Chemostratigraphy of a Mixed Upper Cretaceous Carbonate-Siliciclastic Succession (Southern Pyrenees): Geochemical Proxies for Sedimentological Interpretations

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Abstract

The chemostratigraphy of the growth strata related to the growth of the Sant Corneli-Bóixols anticline, reveals the sedimentary environment evolution of these syn-orogenic sediments. The decrease of Y/Ho ratios throughout the succession from typical open marine values to nearshore values indicates the shallowing upward trend of the growth strata and the progressive input of siliciclastic sediments from emerged areas. The depletion in $\delta^{13}C$ and $\delta^{18}O$, the decrease in the Sr and Mg contents, and the Mg/Ca molar ratios reveal the freshwater input into shallower environments. The results correlate well with the previous sedimentological interpretations of the studied succession. They also support the combination of the elemental and isotopic composition of carbonates to interpret depositional environments in non-continuous subsurface reservoirs and seal rocks.

Keywords

Chemostratigraphy • Mixed carbonate-siliciclastic succession • Southern Pyrenees • Sedimentological interpretations

1 Introduction

Core recoveries are often incomplete, hampering sedimentological descriptions and their interpretations. To solve these limitations, chemostratigraphy is a reliable tool that provides information about the evolution of buried sedimentary systems, which can be applied to both continuous conventional core data and drill cuttings. Furthermore, chemostratigraphy offers additional information for core-scan data, facilitating more robust sedimentological interpretations.

We test whether using Y/Ho ratios, combined with standard geochemistry proxies such as $\delta^{13}C$, $\delta^{18}O$, Sr, Mg contents of calcite shells (innoceramids, rudists, oysters, and other bivalves), and bulk rock samples can be used as geochemical proxies of sedimentary environments.

To validate whether sedimentary geochemistry can shed light on environmental conditions of facies deposition, a 1400 m thick well-exposed middle Campanian to upper Maastrichtian syn-orogenic shallowing an upward succession was studied (Sant Corneli-Bóixols anticline, Southern Pyrenees).

2 Geological Setting

The studied growth strata have 1400 m of thickness, are in the southern Pyrenees (Fig. 1), and record the emplacement of the Sant Corneli-Bóixols anticline from the late Santonian to the latest Maastrichtian.

From older to younger, the studied growth strata succession consists of (1) outer platform to slope deposits; (2) prodelta and offshore siltstones and marls; (3) foreshore calcareous sandstones and delta-front sandstones; and (4) lagoonal and littoral limestones and siltstones.

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A. Çiner et al. (eds.), *Recent Research on Sedimentology, Stratigraphy, Paleontology, Tectonics, Geochemistry, Volcanology and Petroleum Geology*, Advances in Science, Technology & Innovation,
https://doi.org/10.1007/978-3-031-43222-4_13

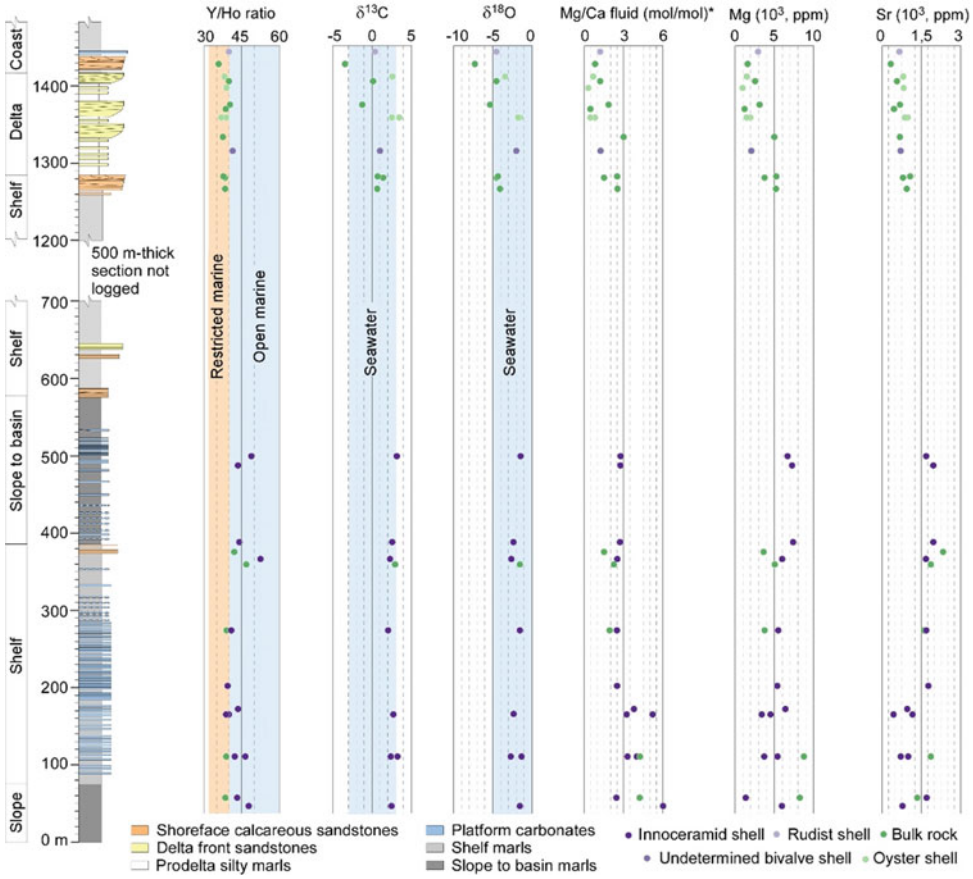

Fig. 1 Stratigraphy, $\delta^{13}C$, $\delta^{18}O$, Y/Ho ratios, Sr and Mg contents, and Mg/Ca molar ratios of the growth strata related to the growth of the Sant Corneli-Bóixols anticline. Mg/Ca molar ratio of parental fluid was calculated using a distribution coefficient of 0.012 for a fluid at 25 °C (Mucci & Morse, 1984)

3 Methodology

Geochemical studies were done in 32 samples of low magnesium calcite shells and bulk rock samples derived from the study of Pascual-Cebrian et al. (2019). For carbon and oxygen isotope analyses of carbonate rocks, an automated Kiel Carbonate Device attached to a Thermal Ionization Mass Spectrometer Thermo Electron (Finnigan) MAT-252 was used. To determine the Sr, Mg, and REE contents, samples were analyzed using High-Resolution Inductively Coupled Plasma Mass spectrometry (HR-ICP-MS), using a Thermo Scientific Model Element XR (Thermo Fisher Scientific, Bremen, Germany).

4 Chemostratigraphy of the Studied Growth Strata

Samples from deeper and older outer platform to slope deposits show $\delta^{13}C$ values between + 2.01 and + 3.19 ‰ VPDB, $\delta^{18}O$ values between −2.72 and −1.25 ‰ VPDB, Y/Ho ratios between 37 and 52.9, Sr contents between 445 and 2278 ppm, Mg contents between 1385 and 8798 ppm and Mg/Ca molar ratios between 1.5 and 5.9. Samples from shallower and younger deposits have lighter $\delta^{13}C$ and $\delta^{18}O$ values between −3.78 and + 3.37 and between −7.27 and −1.72 ‰ VPDB, respectively, lower Y/Ho ratios between 36.46 and 40.8, lower Sr contents between 308 and 1018 ppm, lower Mg contents between 1038 and 5334 ppm and Mg/Ca molar ratios between 0.38 and 3.0.

5 Discussion

Modern seawater contains large positive Y anomaly (calculated as the mass ratio between Y/Ho), with Y anomalies between 40 and 80 in open marine settings decreasing to values between 33 and 40 in nearshore or restricted areas in the studied locality (Nothdurft et al., 2004; Tostevin et al., 2016). Thus, the decrease of Y/Ho ratios throughout the succession, from typical open marine values to lower ratios similar to nearshore settings in shallower deposits, supports the overall upward trend of the growth strata and the progressive input of siliciclastic sediments from emerged areas. The freshwater input into shallower environments could have been responsible for the lighter $\delta^{13}C$ and $\delta^{18}O$ values and the lower Mg/Ca molar ratios and Sr and Mg contents (He & Xu, 2015; Lebrato et al., 2020; Ravelo & Hillaire-Marcel, 2007).

6 Conclusions

The chemostratigraphy of the 1400 m thick Late Santonian to Late Maastrichtian growth strata related to the growth of the Bóixols-Sant Corneli anticline in the Southern Pyrenees reveals a shallowing upward trend that fits with previous sedimentological interpretations. The results support that carbonate's elemental and isotopic composition can be combined as a cost-effective tool for interpreting depositional and environmental conditions in settings where reservoir and seal subsurface data are incomplete.

Acknowledgements Equinor Research Center funded this work, Bergen, Subtetis project (PIECSIC-201830E039), Grup Consolidat de Recerca "Geologia Sedimentària" (2017SGR-824), and DGICYT Spanish Project PGC2018-093903-B-C22. This research is within Grup Consolidat de Recerca "Modelització Geodinàmica de la Litosfera" (2017SGR-847). ICP-MS analyses were done at labGEOTOP of the GEO3BCN. Isotopic analyses were done at CCiTUB of the University of Barcelona. David Cruset acknowledges the Spanish Ministry of Science and Innovation for the "Juan de la Cierva Formación" fellowship FJC2020-043488-I AEI/10.13039/501100011033.

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