High resolution stratigraphy and miocene facies correlation in Lisbon and Setúbal Peninsula (Lower Tagus basin, Portugal)

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ABSTRACT

Key words: Sequential stratigraphy; Miocene; Lower Tagus Basin; Lisbon; Setúbal Peninsula; Portugal.

Correlation between facies associations (marine, estuarine and distal fluvial environments) and disconformities, observed between Foz da Fonte (SW of Setúbal Peninsula) and Santa Iria da Azóia (NE of Lisbon) are presented. The precise definition of the marine-continental facies relationships improved very much the chronology of the depositional sequence boundaries. Tectonic an eustatic controls are discussed on the basis of subsidence rates' variation.

RESUMO

Palavras chave: Estratigrafia sequencial; Miocênico; Bacia do Baixo Tejo; Lisboa; Peninsula de Setúbal; Portugal.

Apresenta-se correlação entre associações de fácies (ambientes marinhas, estuariais e fluviais distais) e descontinuidades sedimentares desde Foz da Fonte (a SW da Península de Setúbal) até Santa Iria da Azôia (a NE de Lisboa). A definição precisa da interdigitação entre fácies marinhas e continentais permitiu precisar a cronologia dos limites das sequências deposicionais. Discute-se a influência dos controlos tectônico e eustático na geração de espaço de acomodação com base na análise das variações da subsidência.

INTRODUCTION

The Lower Tagus basin is situated in the western margin of the Iberian plate. It presents an NE-SW alignment. Its almost siliciclastic neogene infilling shows several sedimentary unconformities. The most important are angular unconformities related to tectonic events associated to the geodynamic evolution of the Iberian plate.

The Lisbon and Setúbal Peninsula areas belong to the distal part of the Lower Tagus basin where the predominant estuarine sedimentation passes westwards to an oceanic one (Antunes et al., 1987; Cunha, 1992a; Cunha 1992b; Pena dos Reis et al., 1992; Barbosa, 1995).

The Miocene (Aquitanian to Early Tortonian) succession is bounded by angular unconformities. It reflects a compressive context related to the Betic collision. Basin's depocenter is placed in the Setúbal Peninsula where thickness attains about 900 m.

Several logs allow high resolution correlations between marine and continental levels dated by planktic forams, mammals, and/or isotopic ages (K/Ar–glaucocites; Sr isotopes). Small and large mammals give precise datation for fluvial/estuarine beds. Palaeontologic wealth — dinoflagellates, palinofossils, nanoplankton, algae, plant macroremains, forams, ostracods and other crustaceans, molluscs, echinoderms, fish, reptiles, mammals — as well
as Oxygen and Carbon isotopic studies provide a huge amount of information on palaeogeographic and palaeobiogeographic reconstructions. Antunes et al. (1973) defined sedimentary cycles in the Lisbon region based on the successive unit's transgressive/regressive character. Antunes & Pais (1993) made correlations with Almada (Setúbal Peninsula) and with the inland part of the basin (Ribatejo); seven transgressive events alternating with six regressive ones were recognized.

Research on the Setúbal Peninsula (Sen et al., 1992; Legoinha, 1993; Antunes et al., 1995; Antunes et al., 1996) improved the biostratigraphic knowledge of some units (presenting correlation difficulties because of facies differences from Lisbon region).

The integration of all lithologic, biostratigraphic (first and last occurrence of significant groups/species of forams and mammals) and isotope (KAr and 87Sr/86Sr) dating allowed the chronostratigraphic framework from Lower Tagus basin Miocene series, as well as the characterization of eight depositional sequences (Antunes et al., 1999).

Analysis and interpretation of outcrops and boreholes (Fig. 1) from the Lisbon-Setúbal Peninsula area (Cotter, 1950; Choffat, 1956; Antunes & Torquato, 1969; Antunes et al., 1996a; 1996b; 1998; 1999; Sen et al., 1992) are presented. Taking into account the previously defined depositional sequences, we present a detailed correlation scheme between facies and discontinuities, as well as a palaeoenvironmental interpretation. Lateral and vertical thickness changes are discussed.

**FACIES ASSOCIATIONS**

Lithology, sedimentary structures, palaeontologic contents and sedimentary discontinuities were used to characterize facies (marine, estuarine and fluviatile). Correlations from Foz da Fonte (SW, in the Setúbal Peninsula) to Santa Iria da Azóia (NE, Lisbon) are shown (Figs 2 and 3).

Vertical and lateral facies' shifts were used to interpret the sea level changes and to characterize transgressive-regressive cycles of different scale order. The eustatic changes could be registered because of the continuous regional subsidence.

The thickness of the Miocene succession increases from Foz da Fonte-Ribeira da Lage sector (about 85m) to Charneca (more than 494m). It diminishes from there to Santa Iria da Azóia (about 162m; Choffat, 1956). In the southwestern and central sectors of the concerned area an alternance between marly limestones and marls predominates. In the NE sector detrital sedimentation predominates in result of the fluviatile influx.
Facies associations and sedimentary environments are as follows:

A1 - infralittoral to circalittoral (conglomerates/glauconite sands and sandy marls with planktic forams);
A2 - littoral to estuarine, infratidal (bioclastics and marls, with molluscs);
A3 - tidal flats (silts, often with abundant organic matter);
A4 - delta/estuary channels and bars (bioclastic, fine to middle sandstones);
A5 - distal fluval (coarse to middle grained sandstones and clays, with plant and mammal remains).

DEPOSITIONAL SEQUENCES AND THE CHRONOLOGY OF DISCONTINUITIES

For each log, sea-level changes were interpreted on sedimentological characteristics and palaeontologic contents. Transgressive/regressive cycles were correlated between all the studied stratigraphic columns. Ten main cycles have been recognized and named by depositional sequences (SD). As the result of better correlation data obtained now, the previous sequence SD-A is divided in SD-A1 and SD-A2 as well as the SD-T in SD-T1 and SD-T2. The last two have not been sufficiently characterized because of the poor exposition and the scarce biostratigraphic markers (Figs 3 and 4).

Integrating all the available data, and their precise stratigraphic position in each sequence, discontinuities between depositional sequences are dated as follows:

SD-A1, D1 - 23 Ma;
SD-A2, D2 - 21 Ma;
SD-B0, D3 - 20 Ma;
SD-B1, D4 - 19 Ma;
SD-B2, D5 - 17.8 Ma;
SD-L1, D6 - 17 Ma;
SD-S1, D7 - 15.3 Ma;
SD-S2, D8 - 12.7 Ma;
SD-T1, D9 - 11.6 Ma;
SD-T2, D10 - 9.5 Ma.

A correspondence with 3rd order eustatic cycles (Haq et al., 1987) is presented (Table 1). Sequences SD-A1, A2, B2, L1, S1 and T1 seem to correspond to 3rd order eustatic cycles. Sequences SD-B0, SD-B1 concern the same eustatic cycle (TB2.1), while SD-S2 corresponds to two (TB2.5 and TB2.6) cycles. In some sequences (SD-L1, SD-S1 and SD-S2) lower order cycles can be recognized.

As Antunes et al. (1996) had referred, discrepancies between the basin’s maximum flooding events and the eustatic maxima (Haq et al., 1987) may be related to local changes on subsidence (and/or inaccurate correlation between different chrono and biostratigraphic scales).

SUBSIDENCE ANALYSIS

A ready approach to the subsidence rate (Table 2) for each depositional sequence was obtained by dividing thickness by the age span between the upper and lower discontinuity boundaries. Backstripping was not calculated; this was regarded as irrelevant due to the succession’s weak burial.

Sedimentation begins in the Lisbon area. This area is the only one where the SD-A1 sequence has been recognized. Subsidence rate increases everywhere till B1 (Fig.4). After a general decrease during SD-B2, subsidence increases between Corroios and Lisbon (SD-L1). Subsidence rate increases again in the Ribeira da Lage-Charneca region (SD-S2).

The thickness of depositional sequences changes laterally very much. Migration of the depocenter also is significant. The A2, B0 and B1 sequences depocenters are in Almada and Charneca. The B2 depocenter is confined to Charneca. In sequences L1 and S1 the depocenter is located at Corroios; in sequence S2 it returns to Charneca.

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Table 1 - 3rd order cycles (Haq et al., 1987) and depositional sequences in the distal part of the Lower Tagus Basin.

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Table 2 – Subsidence rate (m/Ma) for each depositional sequence on studied logs (FF- Foz da Fonte; RL · Ribeira da Lage; CH · Chameca; AC8 · Corroios; AL · Almada; Li · Lisboa; Am · Ameixoeira; SIA · Santa Iria da Azoia). Dark blue colour stresses the greatest subsidence rate for each depositional sequence.

CONCLUSIONS

- Correlation of facies associations and depositional sequences in several Miocene logs (outcrops and boreholes) from Lisbon and Setúbal Peninsula has been achieved.
- Vertical and lateral facies changes of the Aquitanian to Tortonian depositional sequences have been characterized in detail. Redefinition of the previous SD-A and SD-T sequences is proposed.
Fig. 3 - Stratigraphic framework of the Miocene from the distal part of the Lower Tagus Basin (Lisbon and Setúbal Peninsula).
Fig. 4 - Correlation chart between sections and boreholes from Póvoa de Varzim to Lisbon region.
A chronostratigraphic framework of the facies, depositional sequences and corresponding boundaries is presented. Sequence depositional (SD) boundaries (D) are aged (Ma) as follows:

- Aquitanian: D1 - 23 Ma (beginning of Miocene sedimentation);
- Aquitanian: D2 - 21 Ma (SDA1-SDA2);
- Burdigalian: D3 - 20 Ma (SDA2-SDB0);
- Burdigalian: D4 - 19 Ma (SDB0-SDB1);
- Burdigalian: D5 - 17,8 Ma (SDB1-SDB2);
- Burdigalian/Langhian: D6 - 16,4 Ma (SDB2-SD L1);
- Langhian: D7 - 15,3 Ma (SDL1-SDL1);
- Serravallian: D8 - 12,7 Ma (SDL2-SDL2);
- Serravallian: D9 - 11,6 Ma (SDL3-SDL3);
- Tortonian: D10 - 9,5 Ma (SDL4-SDL4).

Local subsidence rates have been quantified in the Foz da Fonte - Ribeira da Lage, Charneca, Corroios, Almada, Lisboa, Ameixeira and Santa Iria da Azoia sectors.

Analysis of the sedimentary and palaeontological contents and isotopic dating provides an improved assessment of the influence of tectonics, eustatism and sedimentary supply in the generation of the accommodation space.

In a regional NW-SE compressive context, the Albufeira syncline had continuous subsidence; that allowed eustatic changes of diverse order to be recognized.

Depocenter migration and facies changes suggest that tectonic blocks subsided at different rates.

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