Journal of African Earth Sciences 110 (2015) 176–187

Contents lists available at ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Integrated stratigraphy of the Ypresian–Lutetian transition in northern Tunisia: Correlation and paleoenvironmental reconstruction

Narjess Karoui-Yaakoub[a,b], Moufida Ben M'Barek-Jemaï[a], Moncef Saïd Mtimet[a], Eustoquio Molina[c,*]

[a] Université de Carthage, Faculté des Sciences de Bizerte, Département des Sciences de la Terre, Jarzouna, Bizerte 7021, Tunisia
[b] Unité de recherche: Pétrologie sédimentaire et cristalline, Université de Tunis El Manar, Tunisia
[c] Departamento de Ciencias de la Tierra & IUCA, Universidad de Zaragoza, E-50009 Zaragoza, Spain

ARTICLE INFO

Article history:
Received 26 March 2015
Received in revised form 30 June 2015
Accepted 1 July 2015
Available online 2 July 2015

Keywords:
Foraminifera
Clay mineralogy
Ypresian/Lutetian boundary
Chronostratigraphy
Paleoenvironment
Tunisia

ABSTRACT

Micropaleontological, mineralogical and geochemical data of the Ypresian–Lutetian transition at the Sejnen section, Tunisia, allowed us to trace a precise correlation with the Global Stratotype Section and Point for the Ypresian/Lutetian boundary recently defined at Gorrondatxe, Spain. The planktic foraminifera assemblages are diversified and enable the biozones of *Acarinina pentacamerata* (E6), *Acarinina cuneicamerata* (E7a), *Turborotalia frontosa* (E7b), *Guembelitrioides nuttalli* (E8) and *Globigerinatheka kugleri/Morozovella aragonensis* (E9) to be identified, revealing a hiatus across the E8/E9 boundary. Comparison with the boundary stratotype indicates that the Ypresian/Lutetian boundary in the Sejnen section is located near the base of the E7b zone, just above the first appearance of the species *T. frontosa*. In the Sejnen section, there are several events identical to those recorded in the boundary stratotype at the Gorrondatxe section. In the middle of this interval, the species diversity of planktic foraminifera is the first to decline, followed by that of the benthic foraminifera in the two sections. Furthermore, taxa with calcareous test peter out while those with agglutinated test reach their peak. There is a marked fall in carbonates in the two sections; while also variations in clay minerals, smectite and kaolinite are very abundant. In the Sejnen section, smectite is the dominant mineral and silica reached its peak. All these data indicate that in northern Tunisia at the Ypresian–Lutetian transition, the marine environment was deep and bathyal, with low energy, oxygenated and characterized by a warm tropical to subtropical climate. Consequently, the Sejnen section may be a suitable section to be defined as auxiliary section (=hypostratotype).

1. Introduction

The International Subcommission on Paleogene Stratigraphy (ISPS) set up a working group to select the Global Stratotype Section and Point (GSSP) for the base of the Lutetian Stage. The stratotype of the Ypresian/Lutetian (Y/L) boundary should be defined at a level stratigraphically close to the base of the classic Lutetian Stage, which is the lowest stage of the middle Eocene (Jenkins and Luterbacher, 1992). Since 1992, the most active members of the working group have visited and sampled several sections in Italy, Israel, Tunisia, Morocco, Mexico, Argentina and several regions in Spain, in order to find a suitable candidate to define the GSSP. Most of the sections found are not suitable as they present stratigraphic hiatuses, facies that are inappropriate for correlation, tectonic complications and other problems (Gonzalvo et al., 2001; Payros et al., 2006), but eventually a suitable candidate was found and the GSSP was defined at the Gorrondatxe section, Spain (Molina et al., 2011).

According to Luterbacher et al. (2004) and Steurbaut (2006), the Ypresian Stage was introduced by Dumont in 1849 to include clay and sandy facies strata located between the continental to margino-littoral Landenian deposits and the marine Brussels Sands, in Belgium. The Ypresian Stage was defined by the associations of calcareous nannofossils (Martini, 1971; Vandenberghe et al., 1998; Steurbaut, 1988, 2006). The Lutetian Stage stratotype, which is about 50 km to the north of Paris, was selected by Blondeau (1981). It contains large foraminifera, palynomorphes and calcareous nannofossils. According to Aubry (1983, 1986), the base of the Lutetian stage is located within the calcareous nannoplankton zone NP14 of Martini (1971), near the boundary of zones CP12a/CP12b of Okada and Bukry (1980); the stage extends to NP15 and the lower part of NP16. Regarding magnetostratigraphy, the basal deposits of the Lutetian stage stratotype have been correlated

* Corresponding author.
E-mail address: emolina@unizar.es (E. Molina).

http://dx.doi.org/10.1016/j.jafrearsci.2015.07.001
1464-343X/

with the Earnley Formation of England, whose base corresponds to the Chron C21r (Ali and Hailwood, 1995).

Regarding planktic foraminiferal biostratigraphy, Hooyberghs (1992) studied two sections of the base of the Brussels Formation in the Brussels-Leuven region, which allowed him to identify planktic foraminifera attributable to the P9 Zone (=*Acarinina aspensis*) of Blow (1979) in one of the sections, and to the P10 Zone (=*Turborotalia frontosa*) in the other section. Micropaleontologists have proposed the first appearance of *Hantkenina nuttalli* to define the Y/L boundary (Toumarkine and Luterbacher, 1985; Berggren et al., 1995); consequently, this event was used to place the Y/L boundary on the Agost section (Gonzalvo and Molina, 1998; Molina et al., 2000; Larrasoaña et al., 2008; Ortiz et al., 2008), the Fortuna section (Molina et al., 2006; Ortiz and Thomas, 2006) and the Gorrondatxe section (Orue-Etxebarria et al., 2006; Bernaola et al., 2006; Payros et al., 2006, 2007, 2009a, 2009b). Nevertheless, the ISPS working group demonstrated that the first appearance of *H. nuttalli* is more recent than the base of the classic Lutetian Basin of Paris (Orue-Etxebarria et al., 2009).

After intensive work, the ISPS working group defined the GSSP for the base of the Lutetian Stage at the Gorrondatxe section, near Bilbao, Spain (Molina et al., 2011). The micropaleontological event that corresponds most closely to the base of the historical Lutetian Stage was chosen as the marker for the GSSP. This seemed to be the lowest occurrence of the calcareous nannofossil *Blackites inflatus* (CP12a/b boundary), just above the lowest occurrence of the planktic foraminifera *T. frontosa*, which is in the middle of polarity Chron C21r. This event coincides with a dark marly level, which has been interpreted as the maximum flooding surface of a depositional sequence that may be global in extent (Bernaola et al., 2006; Payros et al., 2007,2009a,b; Orue-Etxebarria et al., 2009; Rodríguez-Tovar et al., 2010; Ortiz et al., 2011; Molina et al., 2011; Payros et al., 2012).

The aim of this study is to identify the Y/L boundary at the Sejnen section in northern Tunisia, to characterize its environment of deposition and to correlate it with the GSSP of the Y/L defined at the Gorrondatxe section in Spain. Here, we present an integrated stratigraphy of foraminifera, clay minerals and geochemistry, taking into account our previous studies in Spain (Molina et al., 2011), in order to find suitable sections which could serve to propose candidates as auxiliary sections or hypostratotypes.

2. Geographical and geological setting

The section is located in northern Tunisia, in the northern Alpine region with outcrops sediments spanning from the Triassic to the Oligocene, deposited in a normal stratigraphic succession (Fig. 1). Near the Triassic diapiric structure, the outcrops are dislocated by an EW fault system. The Sejnen section is located in the vicinity of the isoclinal folds to the north of the geological map of Hedhil No. 11, scale 1/50,000 at the geographical coordinates: 37°3′55,81″ N, 9°21′31,20″ E. The section is easily accessible by the main road GP7 from the El Aouena village to Sejnen town and it is placed on the eastern side of a narrow track taken approximately 2 km after the intersection of El Aouena.

The Y–L transition sediments are included in the syncline of the Sidi Abdallah Ben Said region toward the south of the Sejnen town, specifically the gray marls of Souar Formation. These marls are well exposed along the road linking the towns of Mateur and Sejnen (Fig. 1). The total thickness of the section is about 125 m. It is composed of hemimetric calcareous beds, gray-beige in color, which are overlain by gray marls rich in iron oxides and sometimes characterized by a crumbly appearance. These marls sometimes become compact and rich in carbonates at the base and the top.

3. Materials and methods

On the field, twenty marl samples were collected across the Y/L boundary to study the planktic and the small benthic foraminifera, the clay minerals and the chemical elements. In the laboratory, the marls samples were previously dried in a stove at a temperature below 50 °C. Of this dry material, 300 g were soaked in the tap water and H_2O_2 for 2–3 days. The washing was conducted on an AFNOR sieves, column whose meshes were successively 315 μm, 100 μm and 63 μm. When necessary the tests were cleaned using an ultrasound device. The residues obtained were dried in an oven at less than 50 °C and then sorted under a binocular microscope in order to study the foraminifera. The photographic images were made using the scanning electron microscope (SEM) at the laboratory of the Tunisian Enterprise of Petroleum Activities (ETAP).

The determination of the $CaCO_3$ content of the clays was performed by the Bernard method. This test measures the volume of CO_2 released during the decomposition of 0.5 g of finely ground clay and dried with 10 ml of hydrochloric acid (10% HCl). Mineralogical analyses were performed by X-ray diffraction on the total rock and on the clay fraction <2 μm. Previously crumbled clay particles, freed from coarse material through a sieve of 63 microns, underwent decarbonation, elimination of organic matter and deflocculation by at least 3 cycles of centrifugation for 10 min at 2500 rev/min until obtaining a pellet. The cloudy supernatant then sedimented freely on smooth glass slides and was analyzed by diffractometry in 3 distinct states: normal, glycolated and baked at 550° (Chamley, 1971).

Chemical analyses of the clays were performed according the method of spectrochemical analysis by X-ray fluorescence, which is based on characteristics of the radiation emitted by the chemical elements of a sample when excited by a suitable source. The direct excitation by electron bombardment is generally used in electron microscopes whereas radioisotope sources and the protons generators are commonly associated with the analysis technique by dispersive energy. This method required the preparation of clay pellets.

4. Results

4.1. Description of the benthic and planktic foraminifera assemblages

Observation under a binocular microscope of residues from different samples from the basal marls, approximately 72 m thick (Sj.1 to Sj.11) revealed an abundant foraminifera association, which was diversified and well preserved. The planktic foraminifera species belong mainly to the genera *Morozovella*, *Acarinina*, *Chiloguembelina*, *Pseudohastigerina*, *Subbotina*, *Turborotalia*, *Globigerinatheka*, *Pseudoglobigerinella* and *Hantkenina* (Fig. 2, Pl. 1). Sometimes tests are filled, apertures obscured and tests abraded at their margins. Benthic foraminifera are represented by the genera *Gyroidinoides*, *Cibicidoides*, *Eponides*, *Anomalinoides*, *Bulimina*, *Dorothia*, *Dentalina*, *Loxostomoides*, *Spiroplectamina*, *Vaginulinopsis*, *Stilostomella*, *Nuttallides*, *Subreophax* and *Nodosaria* (Fig. 3).

These levels are overlain by 10 m of gray marls with abundant microfauna, diversified and well preserved, wherein the species *Guembelitrioides nuttalli* appears near the top at the Sj.12 sample. Above this, there are 30 m of gray marls richer in carbonates where new species of planktic foraminifera are observed from the sample Sj.14, including the marker *Globigerinatheka kugleri*.

4.2. Biodiversity of benthic and planktic foraminifera

The systematic study of the foraminifera shows that they are numerous and diversified (Figs. 2 and 4, Table 1). In sample Sj.3, the planktic foraminifera were numerous: 23 species, 7 belonging