Palaeogeography, Palaeoclimatology, Palaeoecology 461 (2016) 310–327

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

The Pliensbachian-Toarcian paleoclimate transition: New insights from organic geochemistry and C, H, N isotopes in a continental section from Central Asia

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ARTICLE INFO

Article history:
Received 20 April 2016
Received in revised form 19 August 2016
Accepted 21 August 2016
Availabe online 25 August 2016

Keywords:
n-Alkanes
δ^2H
$\delta^{15}N_{org}$
Xenoxylon
brGDGT

ABSTRACT

The Taskomirsay section (South Kazakhstan) is a unique Pliensbachian-Toarcian sequence of lignites, clayey layers and silty-sandstones deposited in a fluvial/lacustrine environment with nearby swampy areas. This period, characterized by a drastic climate change, has been particularly studied in Western Tethyan marine environments, whereas very few studies focused on continental settings. Paleoflora analyses, associated with a multi-isotope approach, based on well-preserved Type-III bulk organic nitrogen isotopes ($\delta^{15}N_{org}$) and hydrogen isotopic composition (δ^2H) of *n*-alkanes, were developed to document paleoclimatic changes in the area. Sporomorph associations and fossil woods revealed a globally warm- to cool-temperate climate – characterized by *Xenoxylon*, a conifer morphogenus biogeographically related to cool/humid settings – apart from slightly less humid and warmer conditions in the early Toarcian. Warmer conditions are supported by reconstructed Mean Annual Air Temperatures (MAATs), based on the first branched glycerol dialkyl glycerol tetraethers (brGDGTs) ever recorded in the Early Jurassic. Nevertheless, no drastic changes were recorded in the $\delta^{15}N_{org}$ values; its signal being attributed to tenuous equilibrium between water- and nutrient-availability *via* intense N-recycling. Based on *n*-alkane distributions, sources of organic matter were separated in two pools: (i) a purely terrestrial (*n*-C_{27}) and (ii) an "aquatic" pool (*n*-C_{23}) constituted of vegetation that thrived under almost permanent water supply. The *n*-alkane δ^2H values (−248 to −151‰) as well as their amounts and average chain lengths (ACL) are in agreement with cool-temperate conditions in the Pliensbachian and less humid/warmer conditions in the early Toarcian. The isotopic difference between δ^2H values of *n*-C_{27} and *n*-C_{23} ($\Delta^2H_{ter\text{-}aq}$) suggests enhanced seasonality during the Pliensbachian-Toarcian transition and low seasonality in the early Toarcian, in agreement with temperate climate-regime. Finally, contrasted response to paleoclimate changes between markers suggests different spatial integration of those proxies. The role of sea-level variations for δ^2H values might also resolve this contrasted response.

1. Introduction

Major paleoenvironmental changes have been documented during the Early Jurassic and particularly in Western Tethyan marine sections during the Pliensbachian-Toarcian transition (Jenkyns, 1988; Bassoullet and Baudin, 1994; Bailey et al., 2003; Morard et al., 2003; Rosales et al., 2004; Hesselbo et al., 2007; Suan et al., 2010; Hermoso et al., 2012; Korte et al., 2015). During the late Pliensbachian, a 5°–6 °C decrease in sea surface temperatures has been evidenced by $\delta^{18}O$ and Mg/Ca of carbonates, possibly related to ice sheet development at high latitudes (Bailey et al., 2003; Rosales et al., 2004; van de Schootbrugge et al., 2005; Suan et al., 2010), and a sea level drop (Hallam, 1967; Hesselbo and Jenkyns, 1998). Then, a period of drastic warming (~8 °C) has been recorded in sea-surface temperatures during the early Toarcian (Bailey et al., 2003; Rosales et al., 2004; Suan et al., 2010), associated with a sea level rise (Hallam, 1967; Hesselbo and Jenkyns, 1998). The global

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http://dx.doi.org/10.1016/j.palaeo.2016.08.020
0031-0182/

scale of paleoenvironmental disturbances during the Pliensbachian-Toarcian transition was confirmed by studies on sites located outside Europe in (i) the Neuquén Basin in Argentina (Al-Suwaidi et al., 2010), (ii) the High Atlas, Morocco (Bodin et al., 2010), (iii) the Qaidam Basin, Northwest China (Wang et al., 2005), (iv) the Clarence-Moreton Basin, Eastern Australia (Jansson et al., 2008) and (v) the Arctic (Suan et al., 2011). However, only few studies have focused on non-marine records (Wang et al., 2005; Jansson et al., 2008), mainly because well-dated terrestrial records for the Early Jurassic are much less common than marine ones (Sobel, 1999).

The Taskomirsay section (South Kazakhstan, Central Asia) is made of non-marine, coal-rich sediments that encompass the Pliensbachian-Toarcian transition (Schnyder et al., accepted for publication). This section is a unique target for paleoclimatic reconstructions prior to and during the Pliensbachian-Toarcian transition in a continental setting. A multi-proxy approach was developed to document paleoclimatic changes in the area based on (i) palynological and paleobotanical records, (ii) bulk geochemistry (Rock-Eval and $\delta^{15}N_{org}$), (iii) *n*-alkane distribution and their hydrogen isotopic composition (δ^2H), and (iv) branched glycerol dialkyl glycerol tetraethers (brGDGTs).

Palynological records (Schnyder et al., accepted for publication), combined with paleobotanical evidences can help to decipher paleoclimatic background as some wood taxa are paleoecologically well constrained (Philippe and Thévenard, 1996; Philippe and Tchoumatchenco, 2008; Philippe et al., 2013; Oh et al., 2015). Recently, $\delta^{15}N_{org}$ measured in lignites and clayey layers was used to indicate wet/dry cycles during the Paleocene-Eocene transition (Storme et al., 2012) and the Eocene-Oligocene transition (Tramoy et al., 2016). Early studies indeed showed that $\delta^{15}N_{org}$ values were positively correlated to temperature and negatively to precipitation in Quaternary and modern plants (Austin and Vitousek, 1998; Handley et al., 1999; Amundson et al., 2003; Swap et al., 2004; Liu and Wang, 2008). Considering the potential of $\delta^{15}N_{org}$ as a paleoclimatic marker for pre-Quaternary sediments (Storme et al., 2012; Tramoy et al., 2016), it will be tested in the Early Jurassic of the Taskomirsay sequence. Similarly, compound-specific δ^2H values are often used as a paleohydrological proxy (Sachse et al., 2012; Sessions, 2016). Major calibration efforts during the last decade allowed improving their use for paleoclimatic reconstructions in the Quaternary (*e.g.*, Hou et al., 2006; Jacob et al., 2007; Mügler et al., 2008; Aichner et al., 2010), but also in the Cenozoic (Andersen et al., 2001; Pagani et al., 2006; Garel et al., 2013), and even in the Paleozoic (Dawson et al., 2004; Izart et al., 2012). However, to the best of our knowledge, compound-specific δ^2H values have only been scarcely used in Mesozoic sediments and not for paleoclimatic purpose (Radke et al., 2005). Yet, the δ^2H of *n*-alkanes preserved in ancient sediments has great potential because *n*-alkanes are much less prone to diagenetic effect than other compounds, because H is strongly bound to C and thus alkanes retain their original hydrogen isotopic composition (Yang and Huang, 2003; Izart et al., 2012; Sessions, 2016). During the last decade, proxies based on branched bacterial membrane lipids (brGDGTs; Schouten et al., 2013), have been developed to reconstruct Mean Annual Air Temperatures in terrestrial settings (MAAT; Weijers et al., 2007; Peterse et al., 2012; Coffinet et al., 2014) and their use for ancient sediments deserves evaluation.

The aim of the present study was to assess the paleoclimatic conditions during the Pliensbachian-Toarcian transition in the sedimentary succession of Taskomirsay using multi-proxy analyses: paleobotany, $\delta^{15}N_{org}$, *n*-alkane distributions and δ^2H values, and, although restricted to a selected set of samples, brGDGTs.

2. Material and methods

2.1. Taskomirsay section

The Taskomirsay section is located in the Karatau (Leontiev Graben), South Kazakhstan, which is one of the numerous continental basins, in central Asia, aligned along the North Tethyan-paleomargin (Fig. 1). These basins were formed by collisions between Eurasia and several blocks (Tarim, Tian Shan and Pamir Kunlun) in a transtensional/transpressional context between the Late Triassic and the Early Jurassic (Sobel, 1999). During the Early Jurassic, the paleolatitudinal position of the Karatau basin was estimated to 36° ± 8° N, based on paleomagnetic reconstructions (B. Vrielynck, pers. com. 2014), in agreement with paleofloral assemblages (40° N; Kirichkova and Doludenko, 1996), which is very close to present latitudes (Fig. 1). Thick piles of terrestrial sediments were deposited thanks to the coexisting high tectonic subsidence.

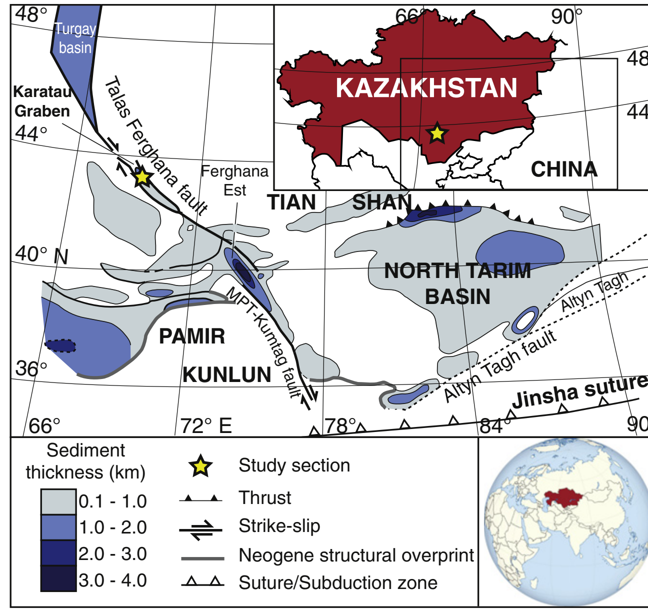

Fig. 1. Geological and geographical situation of the Taskomirsay section. Modified from Schnyder et al. (accepted for publication).

The study section is 53.5 m thick (0 m represents the base of the section) and shows 6 organic-rich sedimentary cycles (Fig. 2; Schnyder et al., accepted for publication). Each cycle exhibits lignite beds (noted LB1 to LB6) overlaid by non-laminated clayey layers and silty-sandstone showing root and trunk surfaces at their top. The succession of lignites, clayey layers and silty-sandstones suggests a meandering river system, in which developed oxbow lakes and peat deposits thanks to the lateral migration of the river system. At the top of the section, a more open and less marginal lacustrine environment under storm influence is deduced from *Botryococcus*, clay/silt alternations and hummocky cross-beddings (HCS) (Schnyder et al., accepted for publication). Wood fragments are frequent along the section and are particularly concentrated in three surfaces labeled TP1, TP2 and TP3 (Fig. 2). Macroscopically, they exhibit an excellent morphological preservation and are found in the tops and insides of silty-sandstones, and always in vertical position, suggesting *in situ* trunks or roots (Schnyder et al., accepted for publication). These sedimentological features are in agreement with peaty/swampy forests in lowland terrains and trees in sandy river banks and/or in upland forests, as might be expected from the paleoclimatic latitudinal patterns during the Early Jurassic, with warm to cool-temperate conditions prevailing from mid to high boreal latitudes (Miao et al., 1989; Rees et al., 2000; Wang et al., 2005).

Despite the common difficulty to date such continental settings, the Pliensbachian-Toarcian transition was identified between ~26 m and ~35 m, based on sporomorph associations and organic carbon isotopes ($\delta^{13}C_{org}$; Schnyder et al., accepted for publication). The section was thus dated no younger than the early Toarcian and no older than the mid-Pliensbachian.