Palaeogeography, Palaeoclimatology, Palaeoecology 467 (2017) 149–165

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

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

Pollen, ostracod and stable isotope records of palaeoenvironment and climate: Upper Miocene and Pliocene of the Çankırı Basin (Central Anatolia, Turkey)

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ARTICLE INFO

Article history:
Received 5 May 2015
Received in revised form 23 February 2016
Accepted 6 April 2016
Available online 13 April 2016

Keywords:
Pollen
Stable isotope
Late Miocene
Pliocene
Central Anatolia
Palaeoclimate

ABSTRACT

An integrated stratigraphic study of Neogene lacustrine succession in the Çankırı Basin (Central Anatolia), combining pollen analysis, biostratigraphy and isotope analysis records variations in vegetation and depositional environment. The palynological analysis of the upper Miocene interval of the studied section reveals the existence of a coniferous forest. This flora reflects warm-temperate, humid climatic conditions. The pollen changes observed at the onset of the Pliocene are related to climatic changes. In the early Pliocene the vegetation changed to a mixed coniferous forest dominated by meso-microthermic trees (*Cedrus* and *Cathaya*) with a widespread herbaceous understory (Poaceae) sparcely interspersed with open areas occupied by Asteraceae whereas *Abies* and deciduous trees (*Quercus*, *Carya*, *Juglans*, *Ulmus*, *Carpinus*, *Acer*, etc.) are represented by lower percentages. This flora reflects a warm-temperate, relatively arid climate, reflecting the global warm climate of the Early Pliocene. The fluctuations in abundance of *Tsuga* may represent fluctuations in temperature. Climate analysis using the Coexistence Approach (CA) shows the presence of precipitation oscillations within the Pliocene. The identified ostracod assemblage indicates a dominance of fresh water conditions during the early late Miocene and of brackish water conditions during the late late Miocene while minor salinity oscillation is present throughout the section. The $\delta^{18}O_{sulfate}$ and $^{87}Sr/^{86}Sr$ isotopic ratios of non-marine gypsum are indistinguishable from the marine evaporites. This suggests recycling of older marine evaporites which is also supported by intense replacement of ostracods by gypsum.

1. Introduction

The Late Miocene and Pliocene are important time periods for climatic studies. During the Miocene the European vegetation changed as the regional climate evolved from subtropical conditions, especially developed during the Langhian, to subtropical-temperate ones which prevailed during the Early Pliocene. Two main factors are responsible for the floristic change during the Miocene which continued during the Pliocene: (1) the global climate variability leading to the late Neogene Cooling, and (2) upheavals in the European palaeogeography (Popescu, 2009).

There are many studies related to climatic changes during these time intervals in the circum-Mediterranean areas (Suc et al., 1995; Pontini and Bertini, 2000; Popescu, 2006; Fauquette et al., 2006; Utescher et al., 2009; Jiménez-Moreno et al., 2007, 2010, 2013; Matson and Fox, 2010; Rey et al., 2013; Hristova and Ivanov, 2014; Bertini and Menichetti, 2014; Combourieu-Nebout et al., 2015). However, there is a limited number of climatic data for the Late Miocene and Pliocene from Anatolia with regard to both marine (Darbaş et al., 2008; Tekin et al., 2010; Darbaş and Nazik, 2010; Karayiğit et al., 2014; Biltekin et al., 2015) and continental deposits (Yavuz-Işık and Toprak, 2010; Yavuz-Işık et al., 2011; Alçiçek et al., 2012; Alçiçek and Jimenez-Moreno, 2013; Alçiçek and Alçiçek, 2014; Biltekin et al., 2015).

The Çankırı Basin is one of the largest basins within central Anatolia with thick Neogene terrestrial sediments suitable for palaeoclimatic studies. There are a few studies in the Çankırı Basin from which palaeoclimatic data are deduced based on sedimentological studies (Varol et al., 2002; Karadenizli, 2011) and, only one multi-proxy study in the basin authored by Mazzini et al. (2013) in which climatic conditions during the late Miocene were discussed. However, the number of palynologically analysed samples in this study (Mazzini et al., 2013) is low. Akgün et al. (2002) palynologically examined 4 samples from Kızılırmak and 6 samples from the Bozkır Formations in the Çankırı Basin and inferred a Middle Miocene age for both formations. However, great caution is needed in making age assignments of nonmarine sediments on the basis of pollen assemblages, especially in

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http://dx.doi.org/10.1016/j.palaeo.2016.04.023
0031-0182/

the Neogene, since most of the plant taxa are practically referable to extant families and there are very few real extinctions (Traverse, 2008 p. 437). Also, the first appearance and/or greatest abundance of various taxa can be diachronous such as in the Gramineae (Batı, 1996 and references therein). The current study presents the first palynological analysis with numerous samples associated with ostracod, micromammals, nannofossils, stable isotopes and strontium isotope analysis to discuss environmental and climatic conditions during the late Miocene and Pliocene in the Çankırı Basin.

2. Study area

The Çankırı Basin is one of the largest Cenozoic basins in Turkey and has possible economical hydrocarbon and industrial evaporitic mineral reserves (Fig. 1). It lies within the İzmir–Ankara–Erzincan suture zone which demarcates the former position of the northern branch of the Neo-Tethyan Ocean (Fig. 2). After subduction of the Neo-Tethyan Ocean, the final collision occurred during the Maastrichtian, along the İzmir–Ankara–Erzincan suture zone during which the Sakarya Continent of the Pontides in the north amalgamated with the Kırşehir Block in the south (Kaymakçı, 2000). The Çankırı fore-arc basin was formed by northward subduction of the Neo-Tethyan Ocean floor beneath the Sakarya Continent. During the early Palaeocene, deposition of terrestrial redbeds and reefal carbonates characterised the basin margins, whereas deep water turbiditic clastics were deposited in the interior parts of the basin (Tüysüz and Dellaloğlu, 1994).

After this collision, the Kırşehir continent started to rotate anticlockwise. This rotation initiated a new tectonic regime dominated by strike slip faults during the late Palaeocene–early Eocene. During this time it was covered by a transgressive sea. As from middle Eocene, mainly south-vergent thrusts developed around the Çankırı Basin (Tüysüz and Dellaloğlu, 1994). Due to the compressional tectonic regime older units surrounding the basin thrusted over younger in-fills, the basin rose, shallowed up and became a continental intermontane basin during the late Eocene–Oligocene in which terrestrial deposits and evaporites were deposited. Today, the Çankırı Basin is a unique area in Central Anatolia, with almost 4 km thick upper Cretaceous to recent deposits (Kaymakçı, 2000).

Early work on the stratigraphy of the Çankırı Basin is concentrated on older units owing to their hydrocarbon potential and the first detailed study on Cenozoic units was carried out by Birgili et al. (1975). They mapped the Cenozoic units and established a number of lithostratigraphic units whereas the ages of those units were based on superposition. Later, studies by Kaymakçı (2000) and Karadenizli et al. (2004) established a higher resolution stratigraphy of the Çankırı Basin using mammal fauna. In the current study the stratigraphic nomenclature of Birgili et al. (1975) is followed as the first formal classification in the basin.

The oldest Neogene unit in the Çankırı Basin is the Kılçak Formation of Aquitanian age and exposed in a very limited area at the southwestern border of the basin near Kılçak village. It is followed in order of younging, by the Altıntaş Formation of Burdigalian age, the Hançılı Formation of Burdigalian to Langhian age and the Çandır Formation of Burdigalian (?) to Serravalian age (Kaymakçı, 2000). Although these units are only partly present in limited areas in the Çankırı Basin but widely exposed in the adjacent Hançılı Basin, they are still shown in Figs. 3 and 4 in order to display their expansion and stratigraphic position.

The Bayındır Formation defined by Birgili et al. (1975) was considered to be of Oligo–Miocene age. Later studies by Kaymakçı (2000) and Karadenizli et al. (2004) showed that its age is younger. The Bayındır Formation is characterised by an alternation of intensely deformed yellowish, white evaporites and clastics. It covers a wide area around Çankırı (Fig. 3). The Bayındır Formation unconformably overlies pre-Neogene units. It is conformably overlain by the Kızılırmak Formation whereas at the basin margins it can be overlain unconformably. The Bayındır Formation is dated as Tortonian (Kaymakçı, 2000) based on identified mammal faunas (Fig. 4). The Bayındır Formation of the current study is correlated with the Tuğlu Formation of Kaymakçı (2000).

The Kızılırmak Formation defined by Birgili et al. (1975) was considered to be late Miocene. The Kızılırmak Formation is characterised by an alternation of red mudstone, gray marl with rich small gastropod fragments, siltstone and claystone. It is dominated by conglomerate and sandstone along the marginal parts of the basin while towards the basin center it becomes finer and more mud-dominated. The Kızılırmak Formation has lateral and vertical gradations into the overlying Bozkır Formation. Based on mammal fossils a Messinian to Pliocene (MN 13) age is assigned to it (Kaymakçı, 2000). The Kızılırmak Formation in the current study is correlated with the Süleymanlı Formation of Kaymakçı (2000).

The Bozkır Formation defined by Birgili et al. (1975) was considered to be late Miocene. The dominant lithology of this formation is white to pale gray gypsum. It is composed mainly of an alternation of gypsum with marls and thin bedded sandstones. The Bozkır Formation is widespread in the Çankırı Basin with its beautiful undeformed stratification. It is dated as early Pliocene (Karadenizli et al., 2004), based on mammal fossils.

Fig. 1. Location map of the study area. The red rectangle shows the position of the Çankırı Basin.