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Orbitally-driven Mid-Burdigalian Coastal Sabkha cycles from the Sivas Basin: Sedimentological, paleontological, and geochemical data

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ABSTRACT

The Early to Middle Miocene period in the Sivas Basin is represented by a thick deposition of mud-dominated marine sediments (Karacaören Formation) in an overall bay-like paleogeographic setting. Previous studies have suggested that halokinesis-induced local tectonics and orbital climatic fluctuations have been the primary controls on depositional evolution. In the present study, we investigated a 60-m–thick Karaman Gypsum Member (KGM), located at the base of the Karacaören Formation, in terms of its sedimentological, paleontological; both palynology and nannofossil biostratigraphy, and geochemical/mineralogical aspects to better characterize climatic controls on its deposition. Nannofossil assemblages indicate that the studied member is confined within the *Sphenolithus belemnos* Zone (NN3; 18.92–17.97 Ma), and is mainly composed of rhythmic alternations of supratidal evaporites and lagoonal/marine mudstones. The palynological data demonstrate a minor, yet consistent, occurrence of megathermic taxa and numerous dinoflagellate cysts in mudstone intervals. The high chemical proxy of alteration (CPA) values and occurrence of kaolinites in the same mudstone intervals further prove deposition under warm and humid subtropical conditions. The perfect match between the environmental cyclicities in the KGM with a benthic $\delta^{18}O$ curve justifies a strong control of obliquity/short eccentricity of a 40–100 kyr duration, and hints at radical precipitation changes throughout the individual orbital cycles. These precipitation changes are explained by extreme latitudinal precipitation gradients during relatively hot periods before the mid-Miocene Climatic Optimum.

1. Introduction

The Late Cretaceous to Early Tertiary period in Anatolia is marked by a progressive convergence between the Pontides and the Tauride-Anatolite platform that converted the İzmir-Ankara Ocean into interconnected epeiric seas (Horstink, 1970; Şengör and Yılmaz, 1981; Görür et al., 1998a). From the Latest Eocene onward, a continental collision gave rise to a number of embayments in the Tuzgölü, Çankırı-Çorum and Sivas basins, where a thick deposition of evaporites occurred (Görür et al., 1998a, 1998b; Rögl, 1999).

The Sivas Basin is located in the easternmost part of Central Anatolia and is considered as a foreland basin related to the İzmir-Ankara-Erzincan and Intra-Tauride sutures developed during the Early Tertiary (Fig. 1A) (Cater et al., 1991; Görür et al., 1998a; Gürer and Aldanmaz, 2002; Yılmaz and Yılmaz, 2006). An extensional geodynamic framework in relation to the exhumation of Central Anatolian Crystalline complex (CACC) to the west was also postulated in the literature (Gökten, 1983; Dirik et al., 1999; Boztuğ, 2008; Poisson et al., 2016).

In the Sivas Basin, a number of evaporitic intervals occurred during 3 distinct periods: the Latest Eocene, Early Oligocene, and Early Miocene (Fig. 1B). A deep marine volcano-sedimentary deposition was gradually replaced by a thin gypsiferous sequence in the west of the basin during the Late Eocene (Atalay, 1999; Tekin, 2001; Gündoğan et al., 2005). The thickest evaporite successions of the basin, also commonly known as the Hafik Formation, were deposited during the Early Oligocene (Poisson et al., 1997; Ocakoğlu, 1997; Çiner et al., 2002). Finally, the colossal Early Miocene marine and coastal sequences include some marine-influenced evaporitic intervals (Ocakoğlu, 1997; Tekin et al., 2001; Çiner et al., 2002; Koşun and Çiner, 2002; Palmer et al., 2004). Recent studies have shown that Holokinetic deformations, mostly rooted from the Early Oligocene Hafik Formation, contributed to the complex deformation of the basin (Ocakoğlu, 1999; Callot et al., 2014; Ribes et al., 2015).

The present study intends to cover a series of problems related to the Early-Middle Miocene marine sediments in the Sivas Basin. First, the

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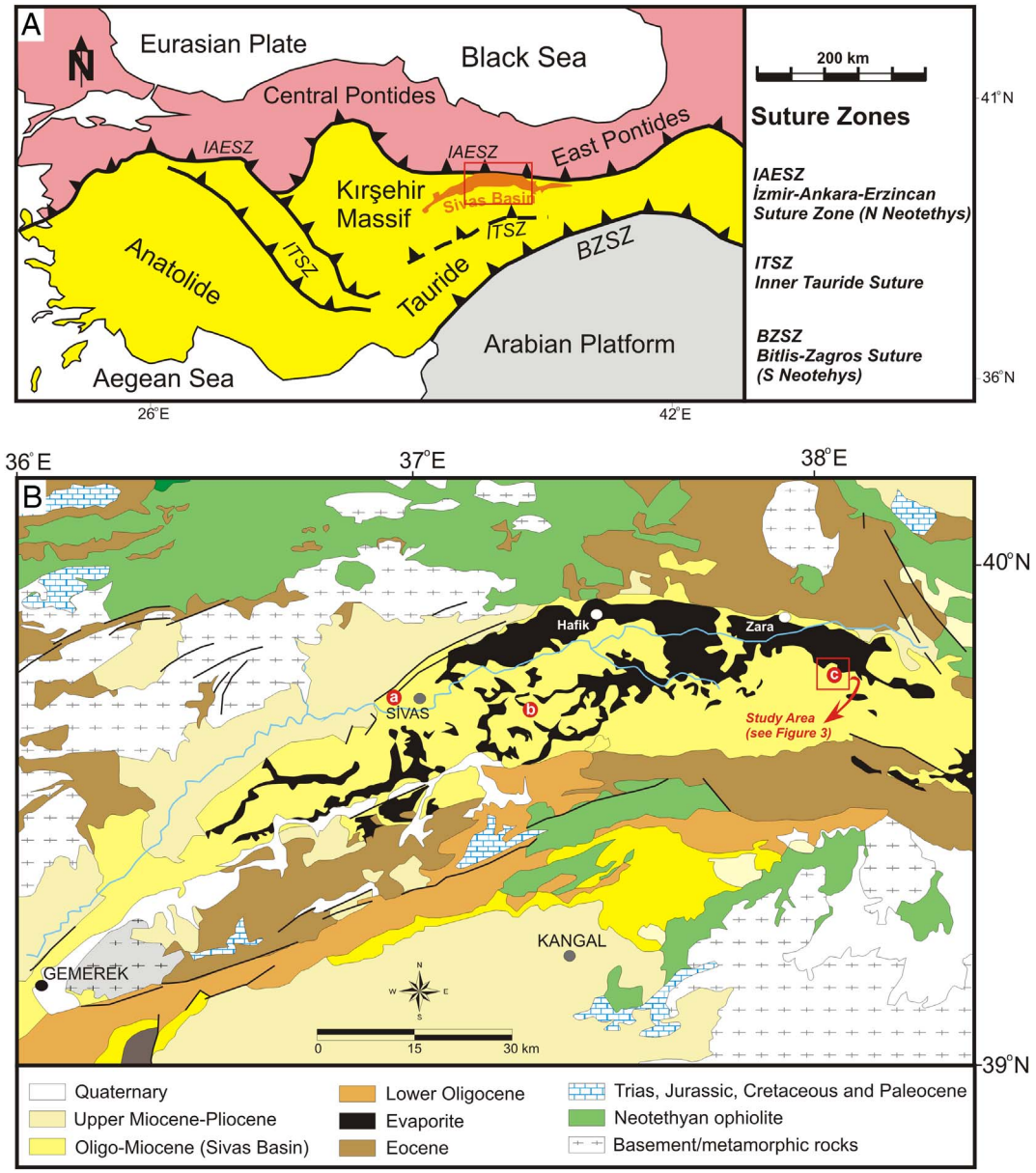

Fig. 1. Suture map of Turkey (A) and Geological map of the Sivas Basin (B) (redrawn from Ribes et al., 2015). Letters a, b, and c in B show the locations of the sections given in Fig. 2.

lithostratigraphic units of the basin have not been linked to relative sea level changes in a genetic frame that would allow regional and global correlations. Data regarding the age of certain stratigraphic intervals, including the gypsiferous interval considered here, in the marine unit, are also scarce (Poisson et al., 2016). Based on the fact that the Eocene and Miocene marine sediments in the Sivas Basin have the capability of producing oil and gas (Özçelik and Altunsoy, 1996; Altunsoy and Özçelik, 1998; Erik et al., 2015), the characterization and correlation of the investigated evaporite package across the basin gains further significance as a potential structural and stratigraphic trap. However, the core of the present study lies in the Early Miocene paleoclimate changes. Many Anatolian pollen studies envisaged an overall warm and humid climate during the Early Miocene, while the same period witnessed episodic evaporite formations, the best of which probably occurred in the Sivas Basin. Rare pioneering studies have documented the gypsum-bearing cyclic sedimentation of different hierarchies (e.g., Çiner et al., 2002), but the age, duration, and magnitude of these cycles need to be further substantiated. To approach these problems, we revisited the basin-fill sequence at the southeastern edge of the town of Zara and focused on a relatively thin (approx. 60 m) coastal sabkha section. Following the construction of an overall sequence stratigraphic framework based on the environmental interpretation of the Miocene basin-fill, we investigated the paleoclimatic signal in the target section. The investigation included a facies analysis, palynology, nannofossil biostratigraphy, and geochemistry/minerology at varying resolutions to capture the different aspects of climate variations, such as changes in vegetation cover, weathering in the source area, and depositional environments. Multi-proxy data showed periodic climatic variations that correlate with other orbital records of the Early Miocene.

2. Materials and methods

Following sedimentological logging and sampling in the field, 119 samples were prepared for palynological and calcareous nannofossil analyses. The palynological analysis involved the treatment of ~20 g of material, using cold hydrochloric acid (35%) and hydrogen fluoride (70%) to remove carbonates and silica. The residue was sieved using a 10-μm nylon mesh, mixed with glycerin, and mounted on microscope