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Characterization of lowest oxygen environments within ancient upwelling environments: Benthic foraminifera assemblages

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ABSTRACT

The Upper Campanian Mishash Formation of southern Israel was deposited within the southern Tethys upwelling belt, with sea floors beneath this system characterized by poorly ventilated sediments approaching anoxia. This study was aimed at tracking the oxygen-poor gradient using benthic foraminiferal assemblages of organic-rich carbonates that are devoid of benthic macro-invertebrates and trace fossils.

Quantitative data were gathered on foraminiferal faunas from four sections, namely Zin/Saraf, Qazra (Ashosh, Omer) and Qilt, from three basins affected by upwelling. Four distinct benthic foraminiferal assemblages characterize the organic-rich carbonate facies (B-assemblages A–D). These assemblages are distinguished by their species richness and composition, relative abundance, and dominance patterns. The low-diversity buliminid-dominated faunas correlate with high (up to 25 wt.%) total organic carbon levels, and inferred pore water oxygen levels range from nearly anaerobic to dysaerobic (up to 0.1 ml O_2/l).

The Zin and Qazra/Ashosh basins in southern Israel have representation of assemblages A and B, indicative of the most oxygen-depleted environments. Assemblages C and D are more common in better ventilated environments, such as the Qazra/Omer basin of southern Israel and the Qilt basin to the northeast. Nonetheless, all these basins have benthic assemblages indicative of low-oxygen pore waters (<0.1 ml O_2/l) beneath the upwelling belt, in comparison with the open Tethyan system indicated by the Shefela basin of central Israel.

1. Introduction

During the Late Cretaceous–Early Tertiary, a wide belt of oceanic upwelling was active along the southern margin of the Tethys. The consequent high flux of organic matter from the upper water column to the sea floor resulted in significant decrease in oxygen concentration in the bottom water, and in some places, anoxia. Open ocean benthic foraminifera assemblages are absent under these conditions, but some species with special morphological and cytological adaptations to these conditions have been described (Bernhard, 1986; Kaiho, 1994; Leutenegger and Hansen, 1979; Sen Gupta and Machain-Castillo, 1993). In particular, genera belonging to the Buliminina are associated with high organic productivity and low levels of oxygen (Bernhard, 1986; Reiss, 1962; Sen Gupta and Machain-Castillo, 1993). Their presence in foraminiferal assemblages can be used to reconstruct the changing low-oxygen paleoenvironments (e.g., Sen Gupta and Machain-Castillo, 1993).

Food flux and oxygen availability are the most important factors controlling benthic foraminiferal assemblage composition (Jorissen et al., 1995; van der Zwaan et al., 1999). Water depth, substrate type, temperature and salinity play a lesser role. Food is plentiful in environments of high productivity, while oxygen concentration becomes the main limiting factor on the sea floor (Almogi-Labin et al., 1990; Jorissen et al., 1995; Kaiho, 1994; van der Zwaan et al., 1999). Foraminiferal assemblages characteristic of the resulting dysaerobic sediment tend to demonstrate low diversity and high dominance, but high numerical abundance (Bernhard and Bowser, 1999; Kaiho, 1994; Sen Gupta and Machain-Castillo, 1993; Sen Gupta et al., 1981).

Dominance of buliminids accompanied by decrease in benthic diversity and low planktonic foraminiferal abundance has been reported in the Upper Campanian Phosphate Member of the Mishash Fm in Israel (Almogi-Labin et al., 1993; Deutch, 1986; Reiss, 1962, 1988). These assemblages occur in organic-rich carbonate facies. Edelman-Furstenberg (2008) identified cycles of organic-rich carbonate, porcelanite, and chert, in sets 1–9 m thick, topped by a shelly horizon, in the Phosphate Member. Molluscan macrofauna in these cycles were used to track the state of oxygenation at the sea floor and the strength of the upwelling system. Analysis of the macrofauna

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showed increasing species richness, large range in body size and decreasing abundance of deposit-feeding bivalves following an increased oxygenation gradient, divided into four zones of oxygenation. The very high numbers and low diversity of this primarily deposit-feeding assemblage indicate high organic loads, low-oxygen levels, and a stressed environment. This interpretation of the molluscan data conforms to the environment implied by the foraminiferal data, as the sterile facies with implied near-anoxia of <0.1 ml O_2/l, as shown by the molluscan data from the organic-rich carbonates, is still populated by a rich foraminiferal fauna.

The present study is aimed at applying this specialized foraminiferal community to track oxygen-stress in bottom- and pore waters at the time the Phosphate Member was deposited.

1.1. The Mishash Formation

The Mishash Fm, of Campanian age, is well exposed in southern Israel. It is composed of chalk and chert rich in phosphate, silica and organic-rich carbonate (Almogi-Labin et al., 1993; Bein et al., 1990; Kolodny and Garrison, 1994; Shaw, 1947). Deposition took place over the NE–SW-trending outer-shelf anticlinal ridges and synclinal basins of the Syrian Arc fold belt. Lateral variation in thickness, lithology and faunal assemblages reflect this paleotopographic setting (Edelman-Furstenberg, 2008, 2009; Gvirtzman et al., 1989).

The phosphatic and organic-rich carbonate lithologies of this part of the section have been well studied because of their economic potential. Litho- and biostratigraphy were included in studies of Reiss et al. (1985), Almogi-Labin et al. (1986), and Gvirtzman et al. (1989). Geochemical studies of biogenic sediments including phosphorites were by Nathan et al. (1979), Shemesh and Kolodny (1988), Bein et al. (1990), and Kolodny and Garrison (1994). Microbial processes in phosphogenesis were described by Soudry and Champetier (1983) and Soudry (1987). Paleoenvironmental studies using microfauna (Almogi-Labin et al., 1990, 1993; Eshet and Almogi-Labin, 1996; Eshet et al., 1994; Moshkovitz et al., 1983; Reiss, 1962, 1988) and macrofauna (Edelman-Furstenberg, 2008; Edelman-Furstenberg, 2009; Soudry and Lewy, 1988) have also been carried out.

Soudry et al. (1985) divided the Mishash Fm into a lower Chert Member and an upper Phosphate Member. The latter is economically important and was divided into three named units; Phosphatic Carbonate at the base, Porcelanite in the middle and Phosphorite forming the top (Fig. 1). The Phosphatic Carbonate unit contains organic-rich carbonate horizons forming 30–54% of its thickness (cf. Edelman-Furstenberg, 2008, 2009). High organic content was reported also in subsurface sequences, up to 25% total organic carbon (TOC) (Bein et al., 1990). The high TOC, high concentration of biogenic phosphate (Soudry and Champetier, 1983) and silica (Moshkovitz et al., 1983), and the common presence of auto- and heterotrophic phytoplankton in these sediments reflect the very high fertility of the water column (Almogi-Labin et al., 1993; Eshet and Almogi-Labin, 1996; Eshet et al., 1994; Hoek et al., 1996).

Almogi-Labin et al. (1993) described abundance, diversity, dominance of buliminids and benthic/plankton foraminifera ratio in the Mishash Fm in the Zin and the Shefela basins (see Fig. 1).

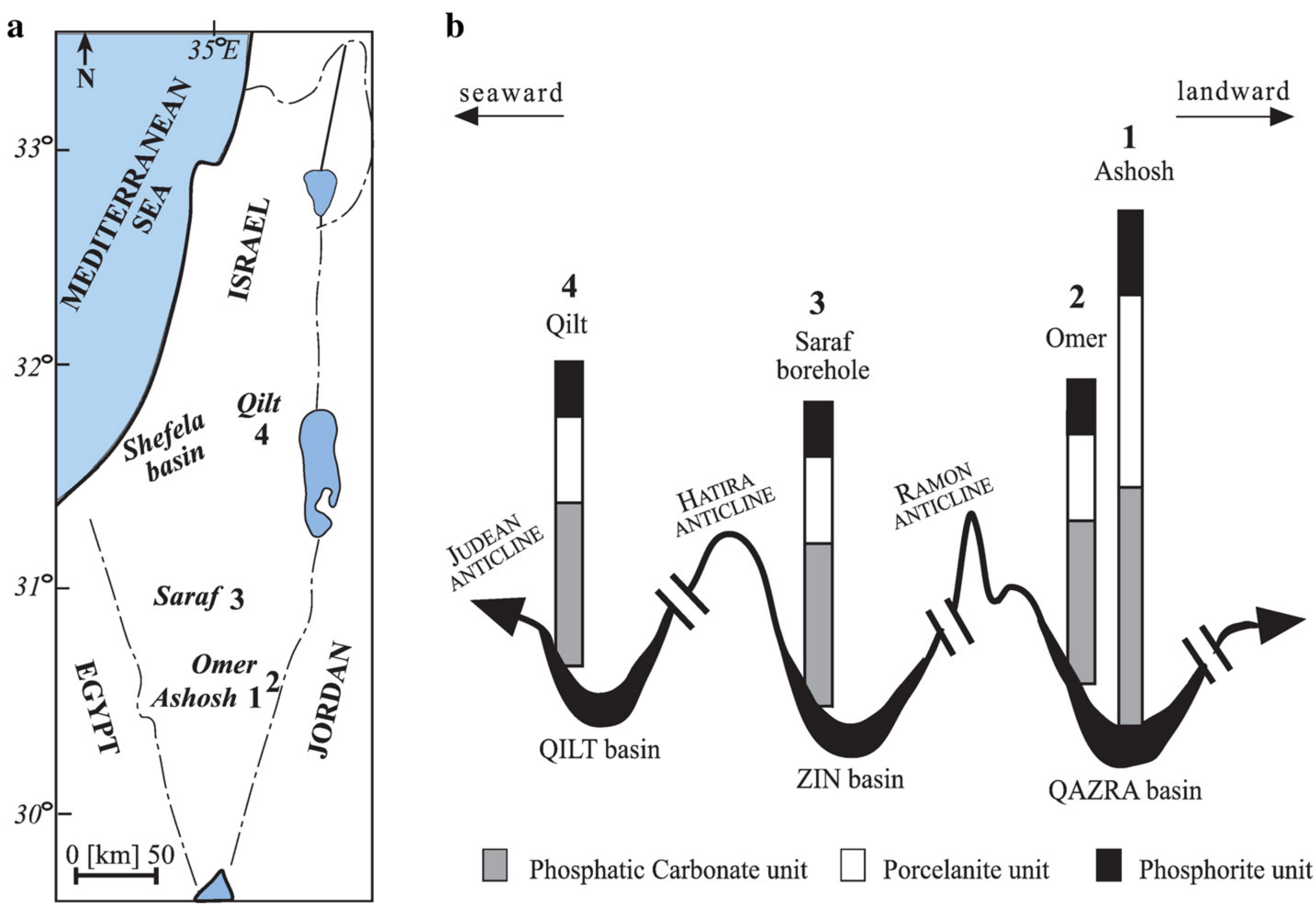

Fig. 1. a. Location map of four sections of the Upper Campanian Phosphate Mbr of the Mishash Fm in Israel; b. schematic NW–SE representation of folds on the shelf, indicating relative paleodepths for the three units of the Phosphate Member. The position of the Shefela basin section is also indicated. c. Correlation of the Phosphatic Carbonate unit in the studied sections. Ashosh, Omer and Qilt sections modified after Edelman-Furstenberg (2009); Saraf borehole after Almogi-Labin et al. (1993).