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Constraining sediment transport to deep marine basins through submarine channels: The Levant margin in the Late Cenozoic

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ABSTRACT

The recent world-class gas discoveries in Early Miocene sand units offshore Israel raises the question of their origin. Apparently, the simplest explanation is to relate them to a fluvial system that arrived from Arabia at that time. This system predated the modern (Pliocene) Nile River supply and existed until captured by the Dead Sea valley. Interestingly, however, very little sedimentation occurred along the Levant continental margin before the Pliocene in spite of its stepped structure that provided much space for accommodation. The only way that sediments could have bypassed the continental margin and arrive at the deep basin without being trapped in the middle is through submarine channels that crossed the continental margin. Here we explore this possibility using 3-D stratigraphic modeling techniques that quantify the sediment load and the water discharge required to fill the basin by pushing enough sediment through submarine channels. We show that such a scenario requires a fluvial system in the order of the largest rivers that exist today on earth in terms of drainage area and water discharge. Alternatively, it requires extreme hydraulic conditions in terms of diffusion coefficients and an elevated drainage basin that could not have existed in the study area. We therefore challenge the traditional view of Arabia as the main source for Oligo-Miocene deposits in the Levant Basin and suggest that the basin was mainly fed by a proto-Nile system that transported clastic material to the North African margin and then farther east by ocean currents. In a wider view we demonstrate how numerical modeling can constrain sediment transport through submarine channels as a function of basin geometry and hydraulic conditions, and how paleogeographic knowledge can be combined with current data on world rivers to evaluate if modeling results are plausible.

1. Introduction

Drilling in the deep Levant Basin offshore Israel finally settled the debate regarding the age of the exceptionally thick sedimentary sequence below the Messinian salt layer. Three wells were drilled since 2009 in the deep Levant Basin: Tamar, Dalit, and Leviathan, located 90, 40, and 135 km offshore Israel, respectively (Fig. 1). All three wells are consistent with the seismic interpretation of an exceptionally thick Late Cenozoic section (Gardosh et al., 2008; Gvirtzman et al., 2008; Gardosh et al., 2010; Steinberg et al., 2011) and challenge other interpretations claiming thick Cretaceous (Peck, 2008) or Paleocene–Eocene (Gardosh and Druckman, 2006; Roberts and Peace, 2007) sequences. Consequently, the Late Cenozoic deep-water sediments of the Levant Basin became a great interest to the industry as well as to the scientific community. To understand the depositional history of these sediments and how sands were transported to the deep basin hundreds of kilometers away from the ancient coastline (the reconstructed Oligocene coastline is shown in Fig. 1), the paleogeography of the circum eastern Mediterranean area at that time must be understood.

Although drilling proved the existence of siliciclastic deposits down to the Late Oligocene (public releases, Noble Energy Inc.), interpretation of seismic data indicates that the significant change in the nature of deposition occurred in the Late Eocene when the sedimentation rate in the deep Levant Basin accelerated by nearly 20 times (Steinberg et al., 2011, Fig. 2). This fundamental observation raises fundamental questions. Why did the sedimentation rate increases? Where did the sediments come from? Where are the ancient sedimentary pathways into and in the deep sea? What was the mode of sedimentary transport and dispersal?

A priori, there are at least two feasible source-to-sink scenarios marked by different arrows in Fig. 1. (1) The large amounts of terrigenous material that began entering the Levant Basin in the Late Eocene originated in Africa and was transported via the Egyptian continental margin that ~25 Ma later (Pliocene) evolved into the Nile River cone; or (2) originated in Arabia (plus the Sinai Peninsula?) and was transported via the Levant continental margin.

The existence of a pre-Pliocene east-to-west transport system, which reached Israel from Arabia across the area that eventually developed into the Dead Sea rift valley and continued farther west to the Levant Basin, has been well established. The earliest indication for such transport is turbidite deposits found within Oligocene outcrops

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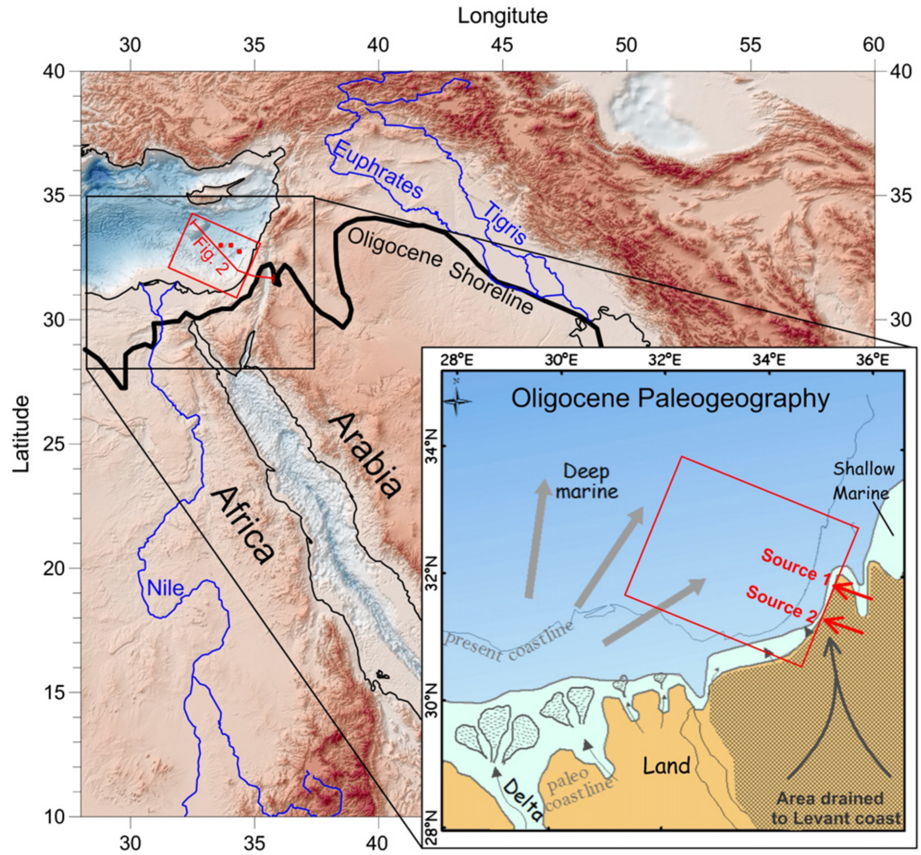

Fig. 1. Location map with present topography and main Middle East rivers. Reconstructed Oligocene shoreline shown by a thick broken line indicates that the extensive deposition in the Levant Basin occurred while the north Arabian Platform was still under water, excluding the possibility of sediment supply from the northeast. Black arrows schematically show expected drainage directions. Estimated area that had drained to the Levant Basin is marked by light gray. Recent gas wells in Oligo-Miocene sand units are marked by red dots. Red rectangle marks the location of the model of Fig. 5. Red line outlines the location of the geological section of Fig. 2. Paleogeography after Steinberg et al. (2011).

of the Lower Saqiye Group in the Judea foothills (Buchbinder et al., 2005) and within Late Eocene deposits of the lowermost part of the Saqiye Group in the subsurface of the coastal plain (Buchbinder et al., 2005). Noteworthy, these turbidites were transported farther to the Levant Basin through deep submarine channels (Druckman et al., 1995; Gardosh and Druckman, 2006; Gardosh et al., 2008; Bar, 2009) that were incised in the Israeli continental margin in the Late Eocene (El-Arish, Afiq, Ashdod, Hanna, and another unnamed canyons marked in Fig. 3).

Ten to fifteen million years later, the nature of the transport from east changed. In the Early Miocene, large amounts of coarse siliciclastic sediments (Hazeva Formation) transported from distances of hundreds of kilometers were trapped in several inland basins (Garfunkel and Horowitz, 1966; Zilberman, 1991; Calvo and Bartov, 2001). The finer

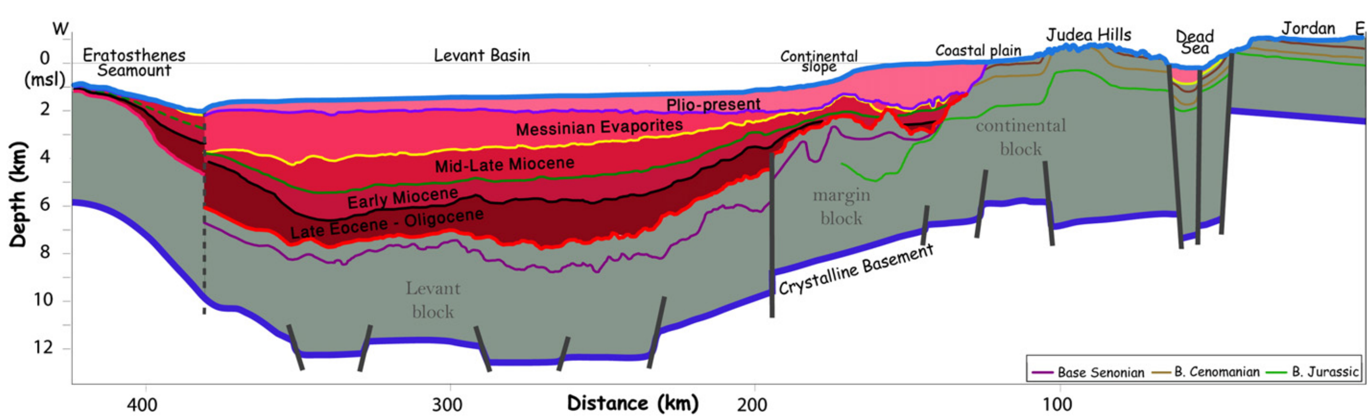

Fig. 2. Geological cross section from the inland Levant region to the Eratosthenes Seamount. Note that the Late Cenozoic section (red colors) representing 35 Ma of deposition is thicker than the deeper part (gray) which was deposited during 250 Ma (Triassic). Also note the Late Eocene–Miocene section (lowest red unit) was deposited mostly in the deep Levant Basin block and very little over the intermediate margin block that was buried only by the topmost unit (Pliocene to recent) after the Messinian Salinity Crisis (spatial details in Figs. 3–4). From Steinberg et al. (2011); location in Figs. 1 and 3.