The Offshore Afiq Canyon and its Messinian Evaporites, and Yafo Sand Apron are Indicators of Young Fluvial Systems Unimpeded by the Levant Rift*

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Abstract

The offshore extension of Afiq Canyon is a deep valley, buried under thick Plio-Quaternary sediments beneath the continental slope off the southern coastal plain of Israel. The valley is filled with Neogene sediments that are capped by Messinian salt. The age of outcropping strata on the canyon walls indicates the likelihood that the canyon was exposed subaerially during the terminal Messinian stage of Mediterranean desiccation because eroded products of Cretaceous, Paleocene, and Eocene age were delivered to an apron of Yafo Sand at the foot of the canyon, interpreted on the basis of its geometry and material from the Or South-1 well as an alluvial/fluvial deposit. Additional valleys of similar dimensions and characteristics to the marine extension of Afiq Canyon occur elsewhere along the continental slope of the entire Levant, suggesting that several rivers of the fluvial system of the Levant, which drained northwestern Arabia to the Mediterranean Sea during the Oligo-Miocene, still prevailed in the Messinian. The Afiq Canyon and its offshore apron as well as equivalents such as the Nahr Menashe fluvial system off Lebanon, imply that the geography of the Levant during late Miocene differed from the present. The Levant Rift could not have been a continuous tectonic depression as it is in the present, but rather a sufficiently disconnected series of grabens that allowed large rivers to still flow in between. The presence of the Afiq apron of substantial volume and with a thickness approaching 200 m along its apex confirms active fluvial systems feeding their bedloads into the Mediterranean as recent as 5 million years ago.

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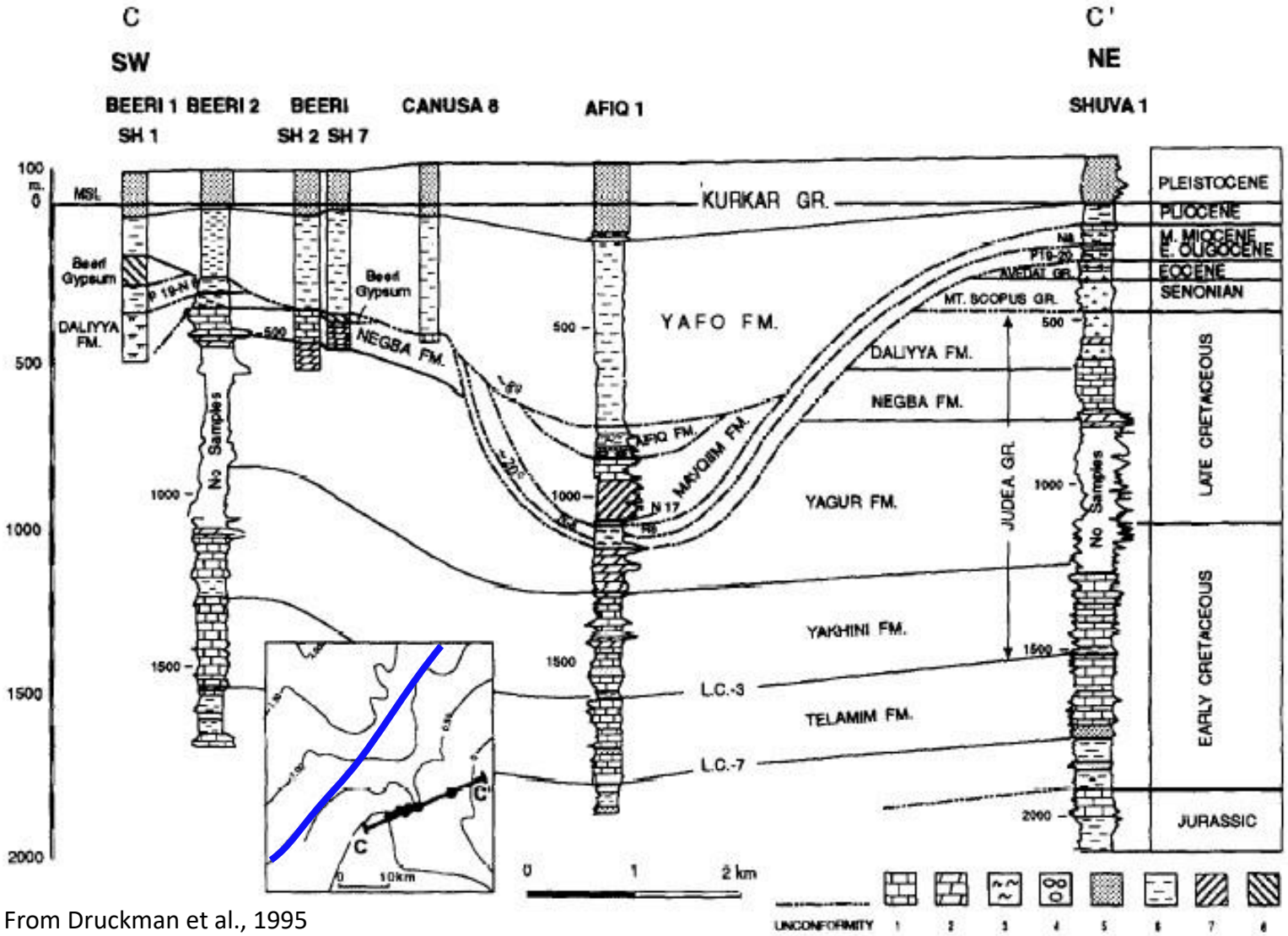


From Druckman et al., 1995

Fig. 1. Afiq Canyon is a deep and wide fluvial channel that entrenched its thalweg into its Cretaceous basement to depth of ca. 500 m and width of ca. 4 km. The abrupt entrenchment of the ancient river in the coastal plain, some 15 km from the present coast (blue line in location chart) suggests an abrupt draw-down of the sealevel, and Messinian anhydrite deposited into the channel, indicates its timing. Another similar fluvial channel was encountered some 15 km to the north of Afiq Canyon. The thick cover of the canyon by sands and shales of Yafo Formation of Plio-Quaternary age reflects the short duration of the draw-down.

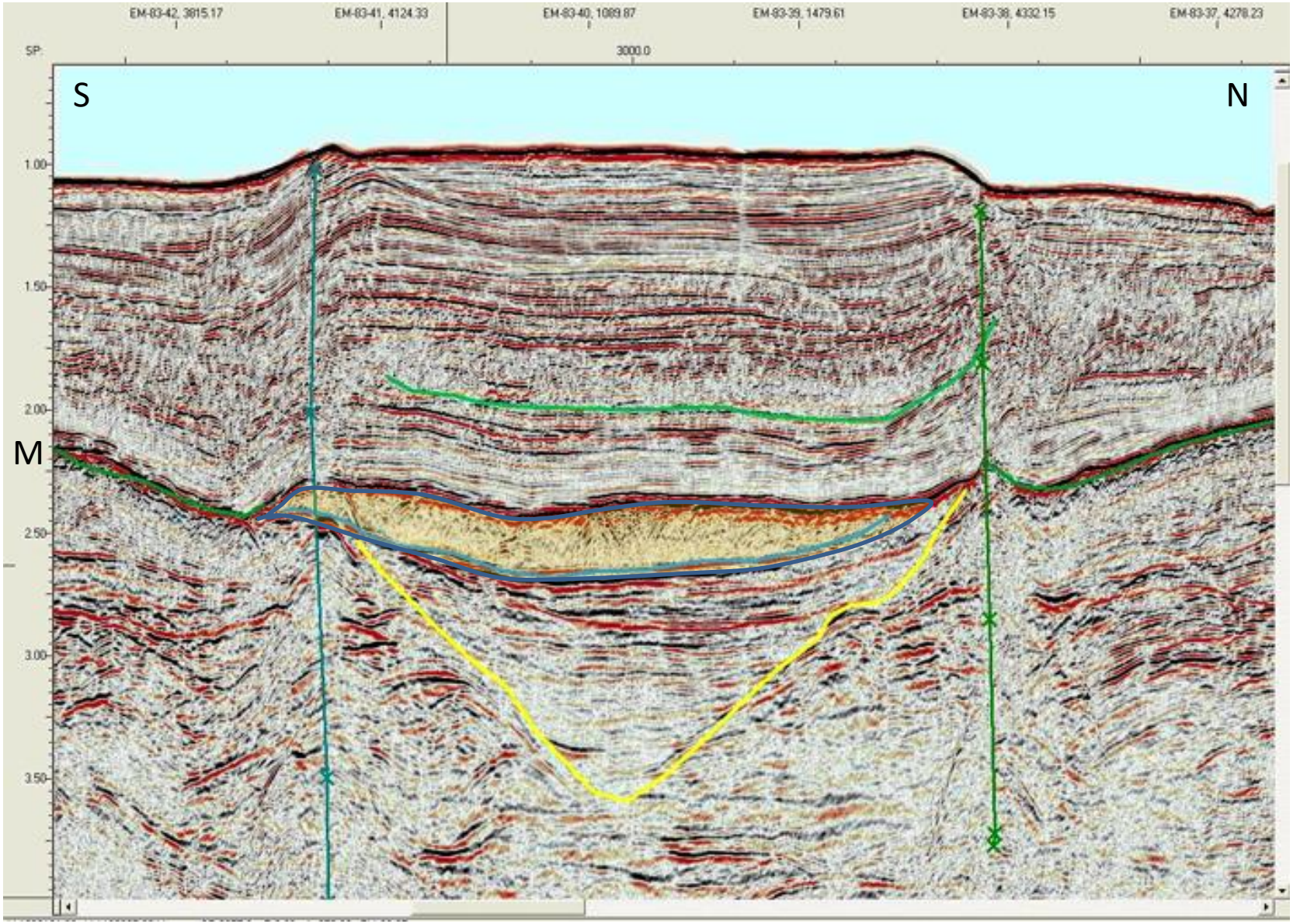
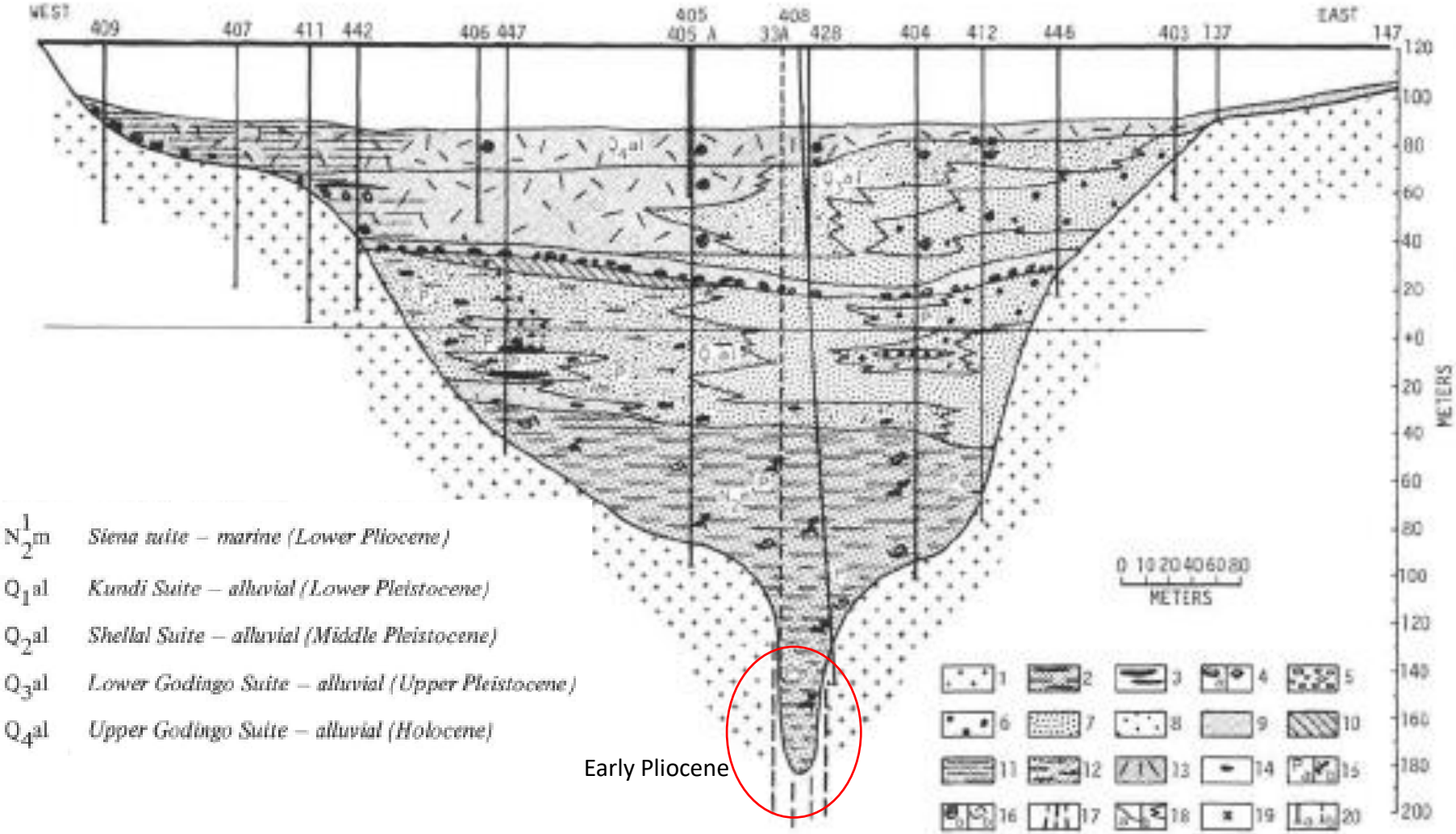


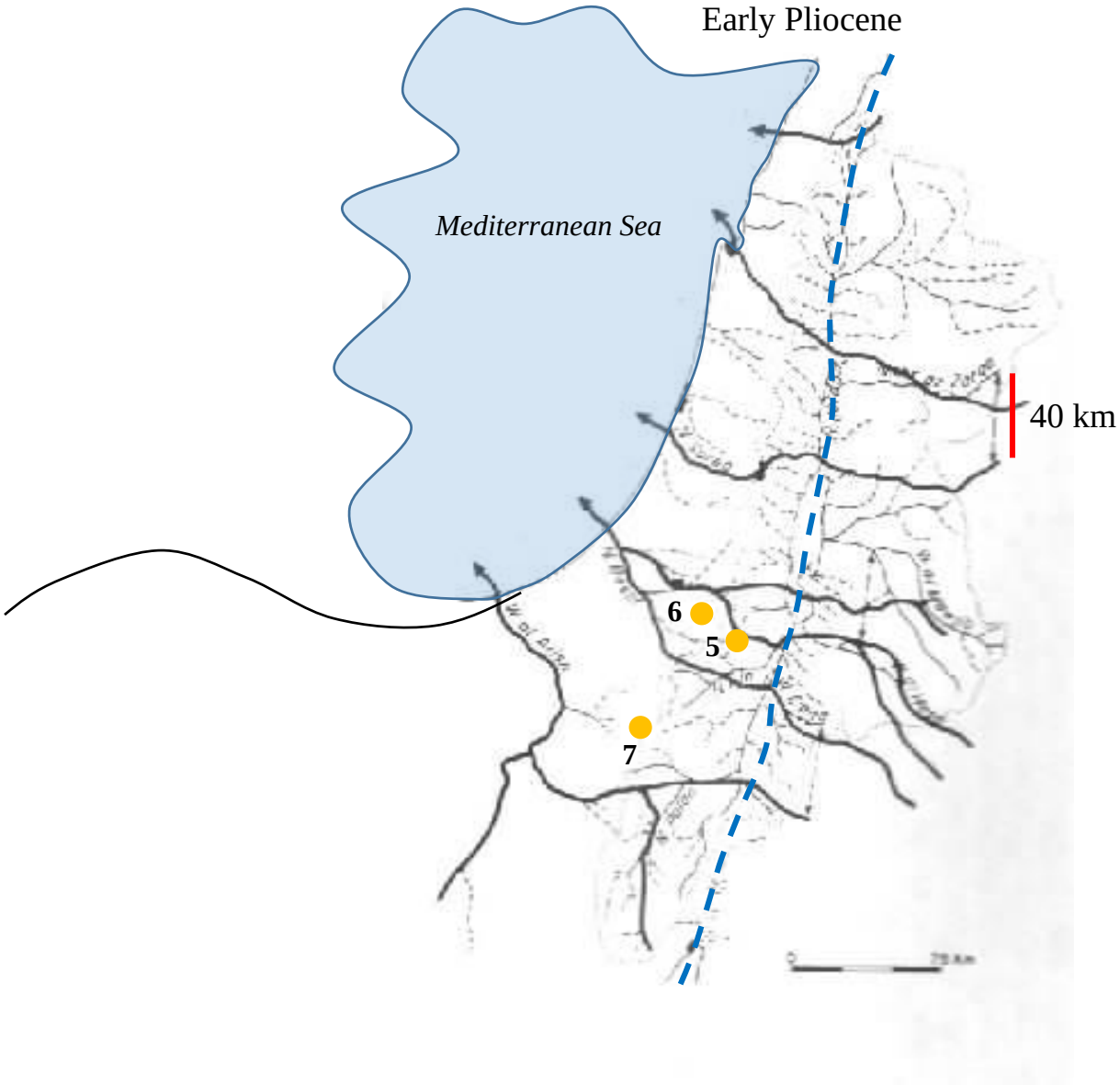
Fig. 2. N-S seismic profile across the marine extension of Afiq Canyon (Fig. 1)). The strong seismic reflector marked M, is covered by a thick layer of the Plio-Quaternary Yafo Formation, is the base of the Yafo Pliocene sequence. The profile shows an erosional unconformity in its flanks, but it is depositional (yellow patch) in the centre, where Messinian evaporites were deposited. Yellow line emphasises the Afiq Canyon, which was entrenched deep into its thalweg. The depositional reflector M is commonly found at isochrone 2.5 sec., suggesting the water depth when during the Messinian desiccation, but the profile indicates a deeper drop of sealevel even before the marine salinity reached salt saturation.



Geological cross-section from boreholes of the Upper Nile Valley south of the Aswan Dam. Legend: (1) rocks of crystalline basement (gneiss and granite); (2) clay with layers of sand and sandy loam; (3) clay lenses in sand; (4a) boulders; (4b) blocks and fragments; (5) pebbles; (6) gravel; (7-13) sands; (7) coarse sand; (8) medium sand; (9) fine sand; (10) sand with thin layers of soil and remains of roots; (11) clayey sand; (12) sand with interbedded clay and loam; (13) micaeous sand; (14) phosphate concretions; (15a) pyrite; (15b) plant remains; (16a) mollusc shells; (16b) ostracode caprices; (17) faults directed along dikes of bostonite; (18a) stratigraphic boundary; (18b) lithologic boundary; (19) archeologic finding; (20a) drillholes; (20b) drillholes projected to the geological profile. Formation identification:

Fig. 3

From Chumakov, 1973



From Zak and Freund, 1981

Fig. 4. Reconstruction of the fluvial system in the Levant in the Early Pliocene. Large rivers were known to have flowed from NW Arabia to the Mediterranean Sea during the Oligocene and the Pliocene, preceding the structural evolution of the Jordan Rift (blue dashed line) and its elevated flanks (Mart et al., 2005). The presented reconstruction, which is corrected for a presumes 40 km of left-lateral faulting offset along the Rift (red line), shows that during the early Pliocene the Jordan Rift did not present any physiographic obstacle to westwards-flowing rivers from Arabia to the Mediterranean, linking the Afiq River (Fig. 1) and its extension in the continental slope (Fig.2) to the Oligo-Miocene fluvial system.

Fig. 5. The Oligo-Miocene fluvial deposits, known as Hazeva (or Husb) Group are distinguished by evidence of variable hydrographic regimes. In places the clastic sediments are coarse boulders, suggesting very strong flow currents and probably steep gradients (compare with Fig. 6). Such flow could have entrenched the deep Pliocene valleys that were discovered in the coastal plain and he continental slope of Israel (Figs 2,1). There is ground to presume therefore, that the erosional basin of the Hazeva rivers extended far into NW Arabia. Site 5 in Fig. 4.

Fig. 6. Mid-Miocene marine oyster reef in central Israel (site 6 in Fig. 4) is evidence for marine transgression from the contemporaneous Mediterranean. The reef suggests gentle land-to-sea morphology.

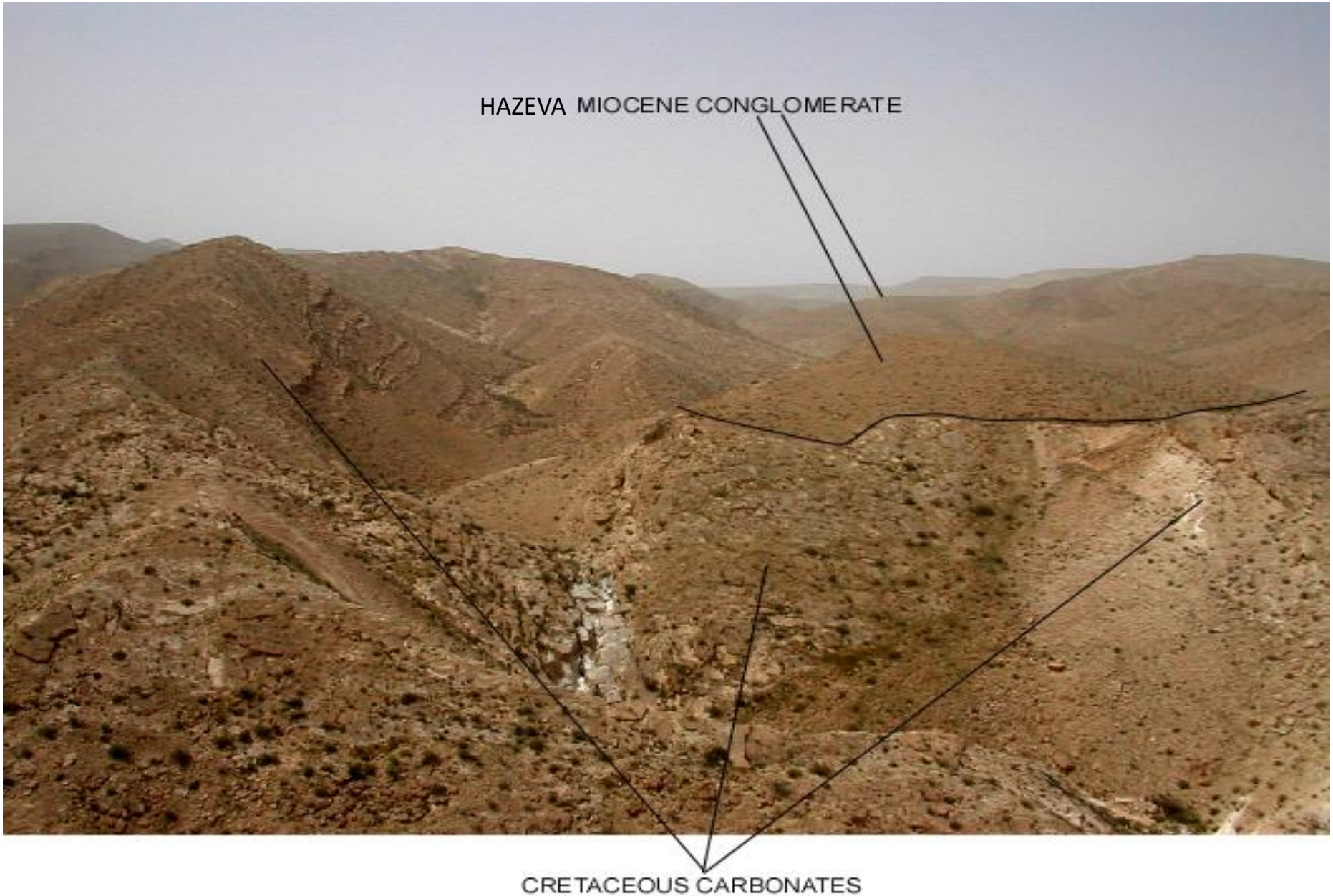


Fig. 7. Fluvial conglomerates of Hazeva Group is deposited in a thalweg that, at present, is located at a mountain top, at elevation of ca. 500 m above sealevel (site 7 in Fig. 4). The valley suggests that the uplift of the displayed mountains, which are part of the uplifted western flank of the Jordan Rift, were uplifted during the Plio-Quaternary. Hazeva Group suggests therefore that the downfaulting of the Jordan Rift and the uplift of its flanks occurred mostly during the Plio-Quaternary and could have started in the late Miocene (Mart et al., 2005).

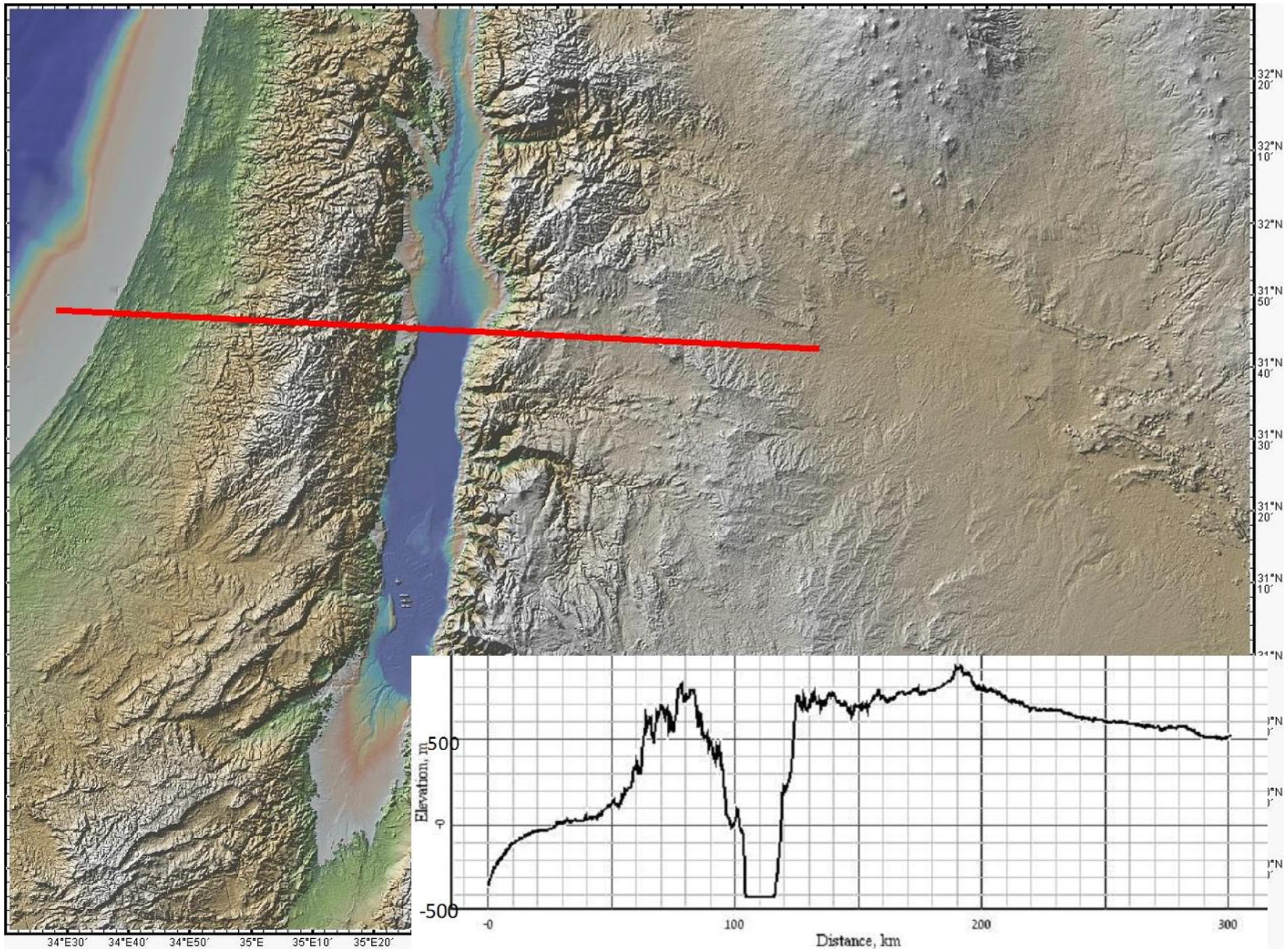
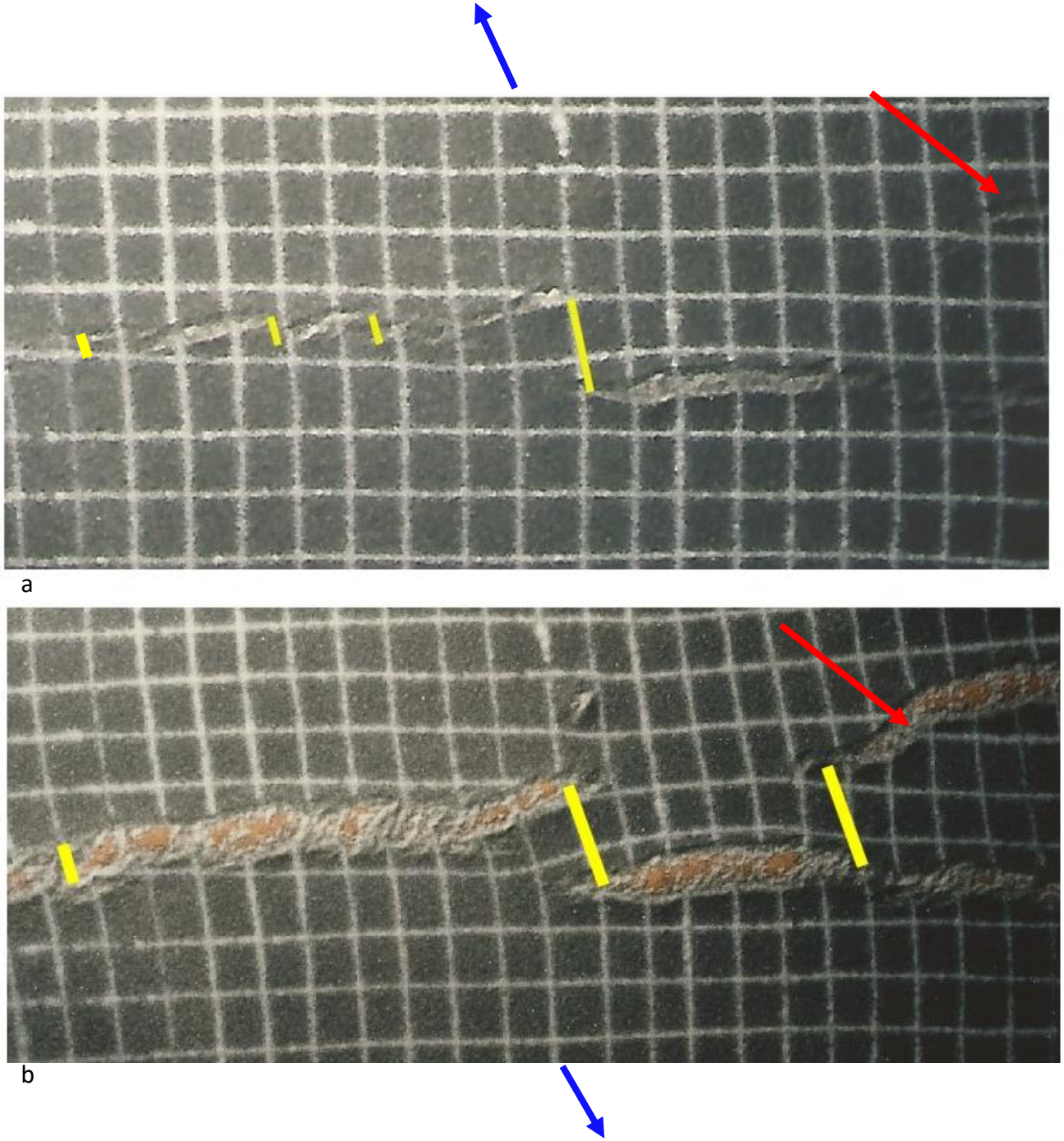


Fig. 8. Geomorphological chart of the southern Levant with the Jordan – Dead Sea rift and its elevated flanks emphasized in the embedded topographic profile (imbedded insert along the red line). The geological traces of the Hazeva fluvial system suggest that (1) the rifting and its elevated flanks developed gradually, truncating the fluvial system in stages, and (2) the demise of the Hazeva rivers took place throughout the late Miocene – early Pliocene. See Figs. 9 and 10 for some supporting evidence. (Source of chart and profile: www.geomapapp.org).

Fig. 9. Experimental oblique extension in a sandbox (Mart and Dauteuil, 2000) show that such extension leads to segmented rifting, where the segments are separated by incipient transform faults (a). Similar incipient transform faults were discerned in the northern Red Sea (yellow lines) and were also attribute to oblique rifting (Baecker et al., 1975). As the deformation continues (b), some of the smaller transform faults were embedded into the developing accretion ridges, but those larger ones that prevailed constrained the offset of the accreting rifts and their length was not affected by the accretion but remained stable. Red arrows marks an accretion rift, that grew in length and with during the deformation. These findings are in agreement with the observations of Bonatti (1985) in the northern Red Sea (Fig. 10). The experiment is set where a layer of red silicone, 1.5 cm thick, is deposited on a reservoir of industrial honey (not shown). The ductile silicone is covered by a 0.5 cm thick layer of brittle gray sand with average grain-size of 0.25 mm, about.



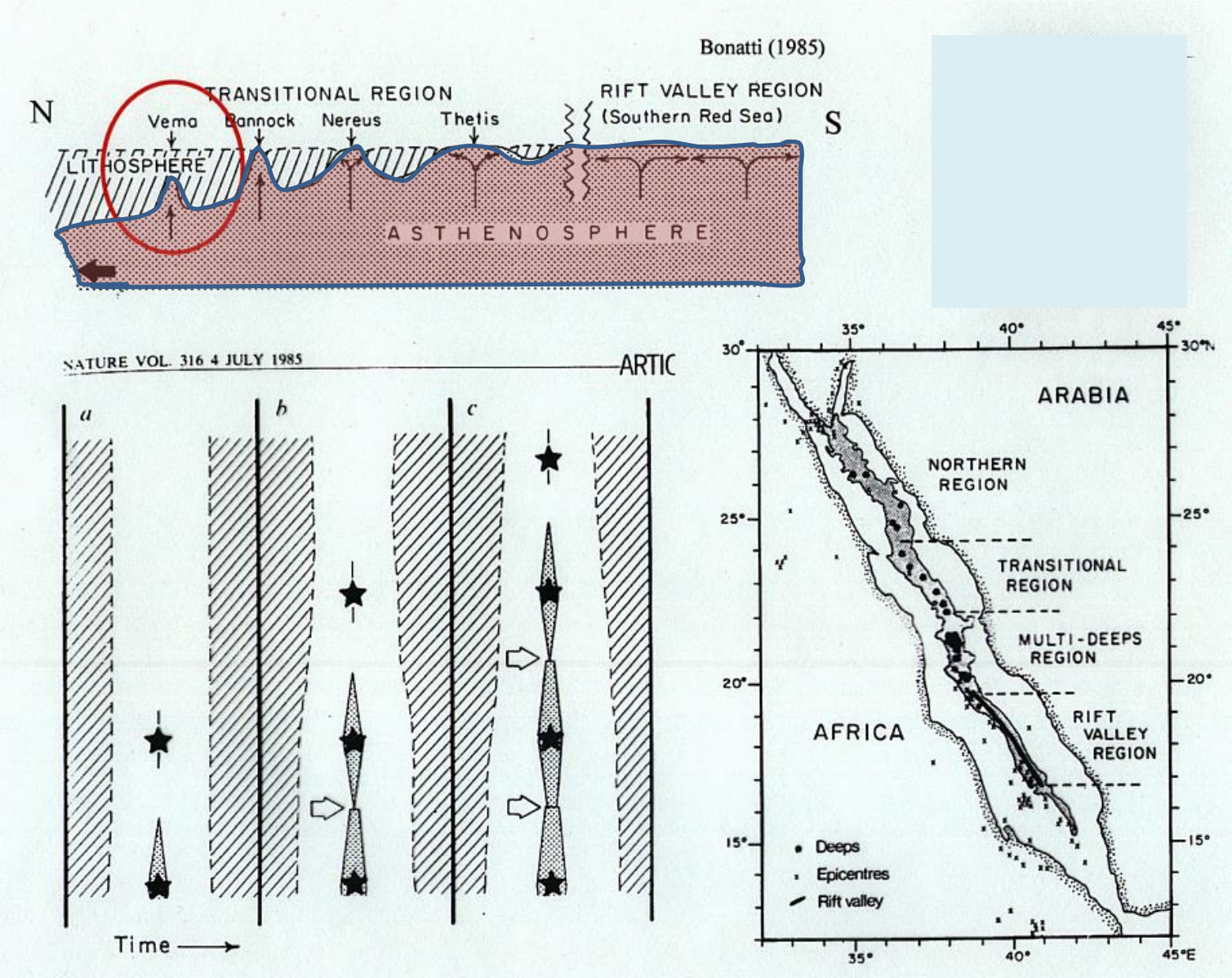
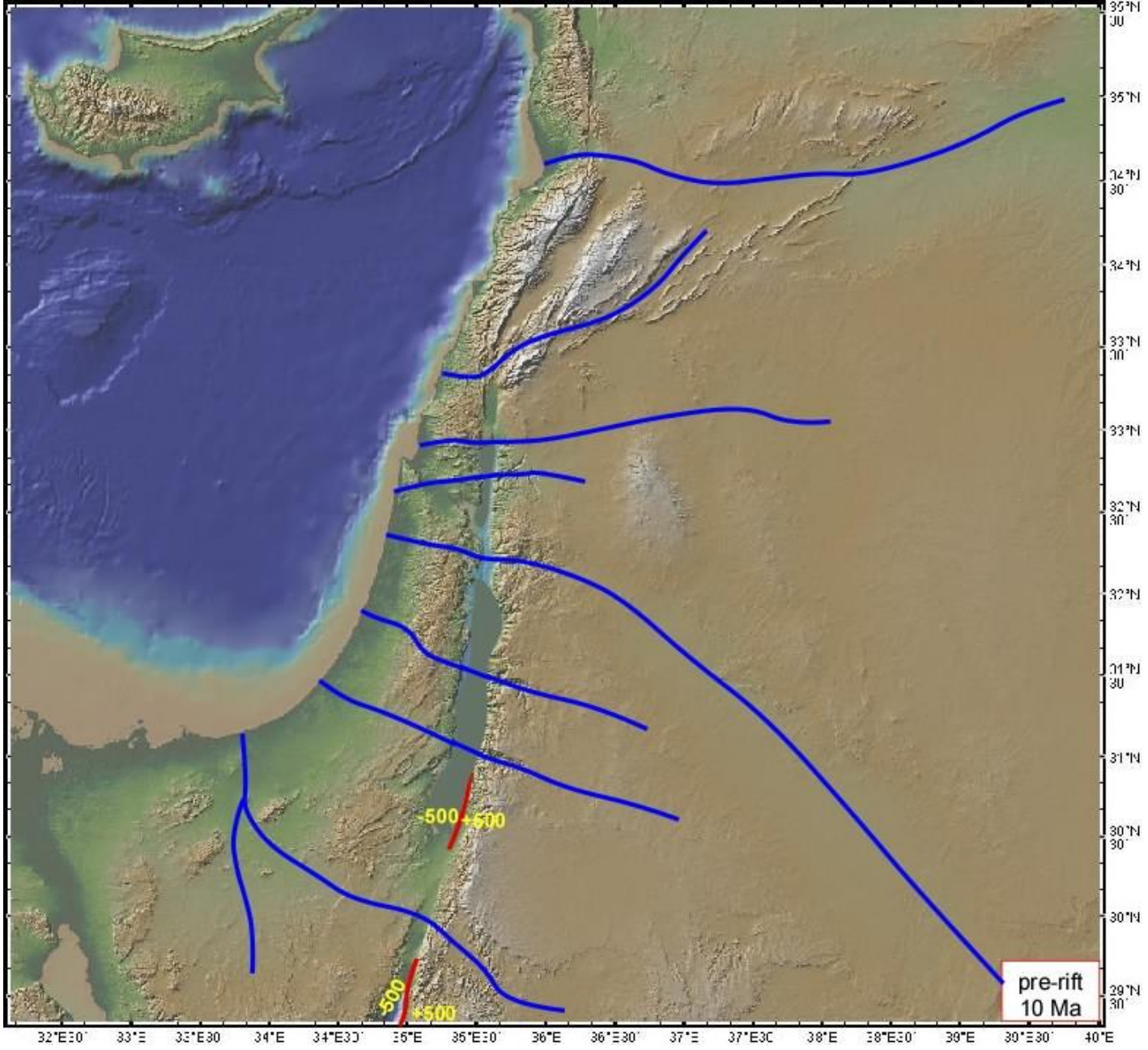


Fig. 10. A tectonic concept for the geodynamics of the norther Red Sea was suggested by Bonatti (1985) who noticed that the asthenospheric basalts outcrops at the floor of the central Red Sea decrease in size northwards. These basaltic occurrences were characterized by magnetic anomalies, by free-air gravimetric anomalies, and by a seafloor depression. However, basalts were not exposed in the Vema depression, and the sub-sea floor occurrence of the basalts was detected only by the gravimeter. Bonatti's model indicates that diapirs asthenospheric develop under the constraints of oblique extension, and some offset in the linearity of the ascending basalts are likely to occur.

Fig. 11. A rough reconstruction of the Hazeva fluvial system in the Levant in the late Miocene, before the Jordan Rift imprinted its physiographic signature on the region, some 10 Ma. We suggest that the formation of the largest structural basins of the Rift started their structural development at that stage, so that rifted basins already existed as the Mediterranean desiccated in the Messinian Stage and the rivers entrenched deep canyons into their thalwegs. As the Mediterranean returned in the early Pliocene, these canyons became fjords where seawater penetrated far inland. Unlike the Nile River, where the retreat of the sea and the sedimentation were gradual , the uplift of the western flank of the Jordan Rift (Fig. 7) entrapped seawater inland and thick deposition of salt took place in the Gulf of Elat (A'qaba), the Dead Sea and the Sea of Galilee (Mart, 2013). We presume that the depicted fluvial system ceased to exist already in the middle Pliocene.



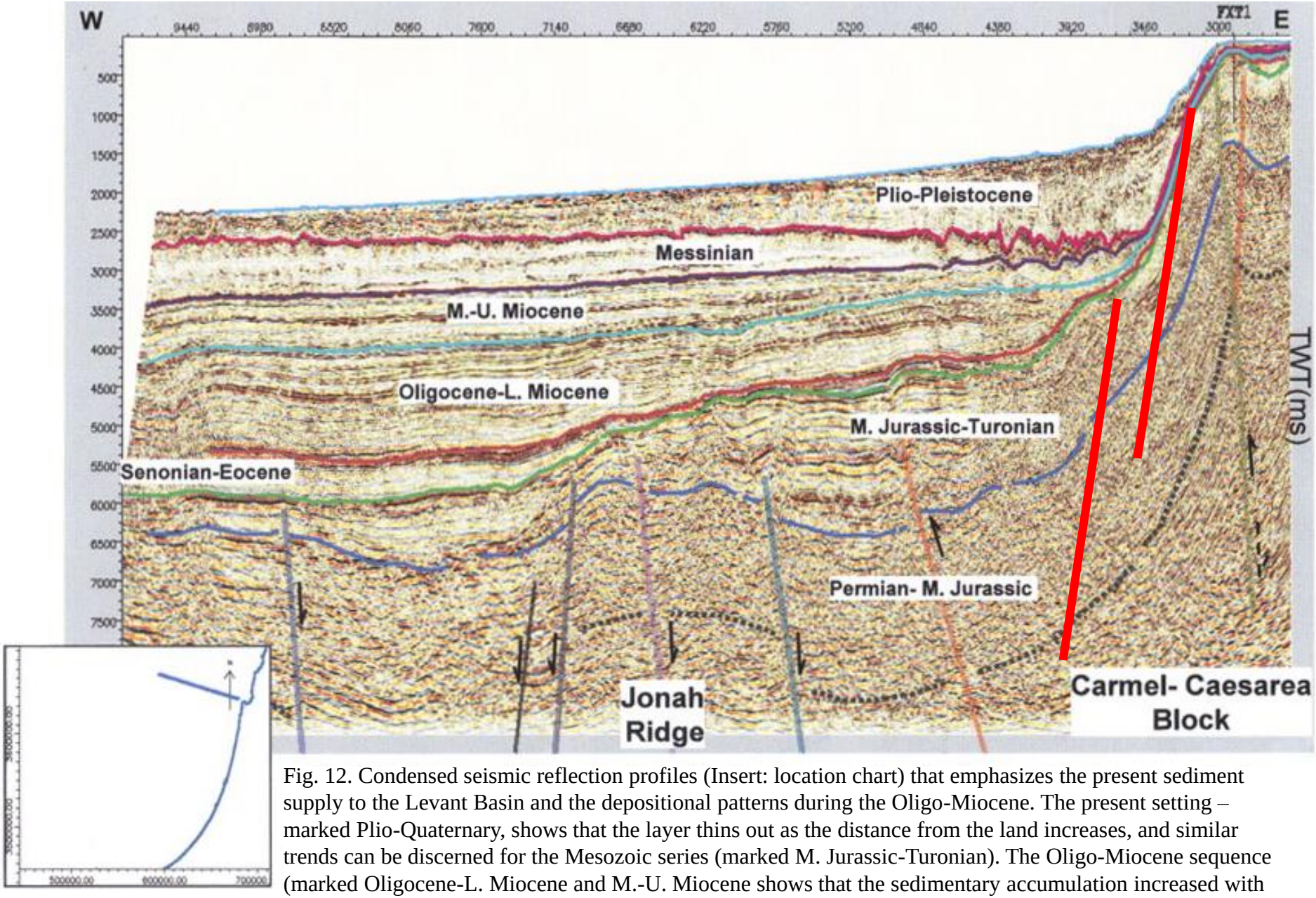


Fig. 12. Condensed seismic reflection profiles (Insert: location chart) that emphasizes the present sediment supply to the Levant Basin and the depositional patterns during the Oligo-Miocene. The present setting – marked Plio-Quaternary, shows that the layer thins out as the distance from the land increases, and similar trends can be discerned for the Mesozoic series (marked M. Jurassic-Turonian). The Oligo-Miocene sequence (marked Oligocene-L. Miocene and M.-U. Miocene shows that the sedimentary accumulation increased with the distance from the continent. The way to account for that observation is to presume that uplift of the continent, mostly during the Oligo-L. Miocene, was accompanied by significant basinal subsidence (Moucha and Forte, 2011; Mart, 2013). The large amount of sediments required to fill the large basin flowed in when the Levant fluvial system was still active (Fig. 13). (Source: Gardosh et al., 2008).

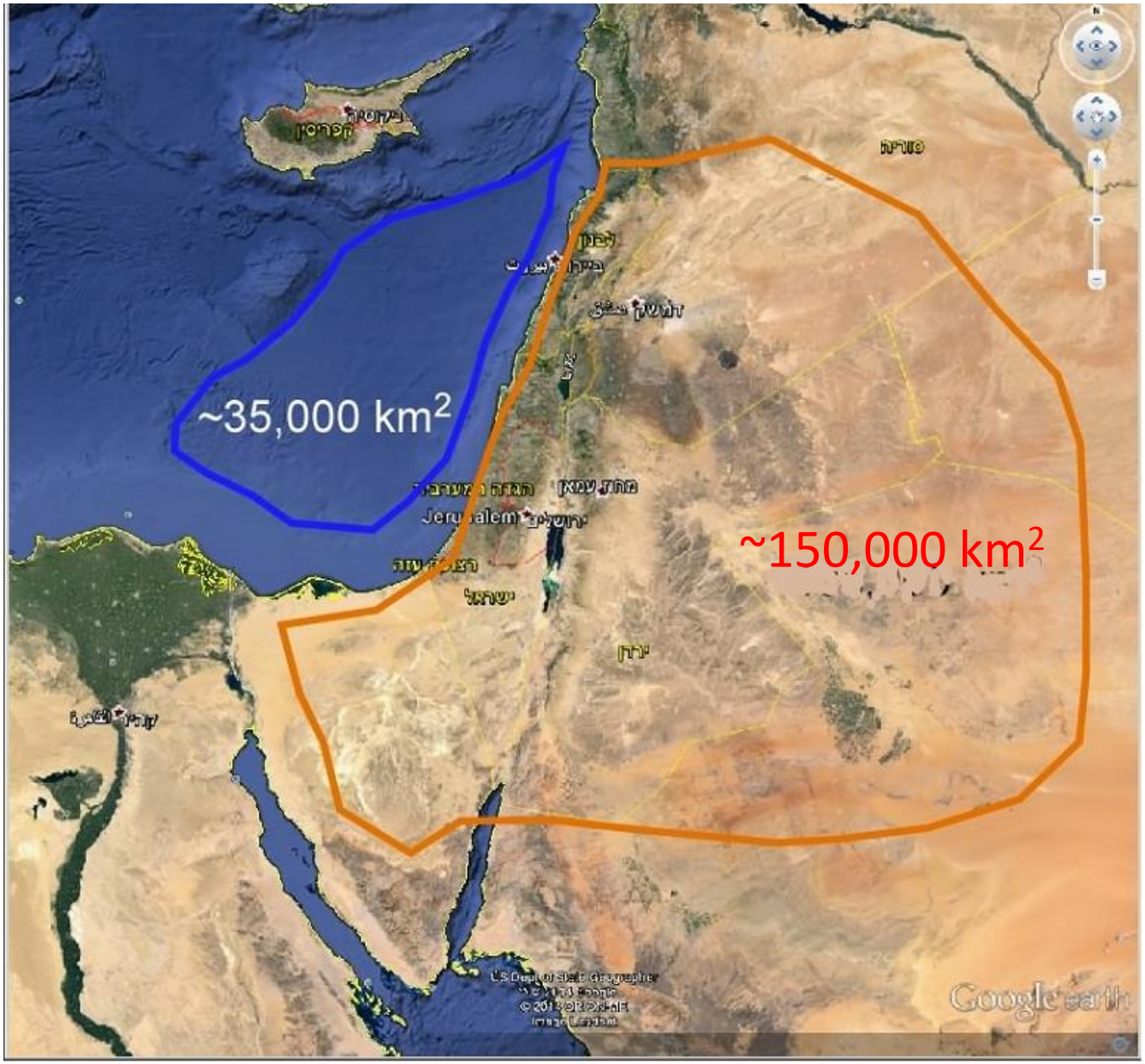


Fig. 13.The geodynamic regime depicted in the presentation suggests that the emergence of the Levant from the Sea, that started in the Oligocene (marked by orange line), when the African plate was located some 1500 km south-southwest of its present location, was accompanied by regional subsidence along its flanks (marked by blue line), and, in places, served as hydrocarbon reservoirs (Moucha and Forte, 2011). The uplifted Levant was accompanied by the subsidence of the Levant Basin. The erosional basin of the Hazeva drainage system of the Levant is approximately 150,000 km^2 large while the area of its terminal basin is ca. 35,000 km^2.