Late Miocene Formations from As Sahabi area, Sirt Basin, Libya in correlation to isochronous SE Europe deposits: A paleoclimatic approach

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As Sahabi area has yielded a rich Neogene vertebrate fauna that aids in understanding evolution and paleoenvironments. Stratigraphically, it consists of three stratigraphical superposed lithological units, from bottom to top; Formation "M", Formation "P" and Sahabi Formation. Formation "M" which forms the base of the exposed section in the As Sahabi area consists of semi-consolidated sandy bioclastic carbonates enriched by warm water organisms such mollusks, bryozans, and corals. The presence of the ostracodes and the foraminifera are strong indicators of shallow warm environments. Formation "P" consists of a lattice of monocrystalline gypsum crystals infilling dessicated cracks of siliclastic clays and sands, with no in-situ fauna reported so far. Formation "P" has been attributed to the Messinian crisis in the Mediterranean. These two formations are followed by the vertebrate fossil-bearing rock unit called the Sahabi Formation, which displays a different depositional setting of continental to semi-continental terrestrial tropical paleoenvironments through fluviatile, lacustrine and deltaic water bodies. Two subsurface boreholes from As Sahabi area (Sirt Basin) have been investigated lithologically and micropaleontologically. The upper siliclastic part of these wells is assigned to Sahabi Formation. The lower thin carbonates are assigned to both Formation “M” and Formation “P”. Two subsurface boreholes (A1-NC214 water well and Sahabi Borehole 1-2) have been lithologically described and investigated for their micropaleontological content. The carbonates at the lower depths belong to Formations “M” and “P” respectively. The microfossil bearing interval of the A1-NC214 water well (interval between 165 and 175m) contains rather well preserved calcareous nannofossil assemblage with common-abundant Helicosphaera stalis and Reticulofenestra pseudoumbilicus, accompanied by Coccolithus pelagicus, Calcidiscus macintyrei, Helicosphaera carteri, Sphenolithus moriformis, Discoaster cf. calcaris, Discoaster cf. challengeri. The increased relative abundance of H. stalis (>10%) implies a biostratigraphic correlation with nannofossil biozone NN8/MNN8b, i.e. the interval of common presence of H. stalis below the First Occurrence of Discoaster bellus group. Therefore the carbonates below the Sahabi Formation, at 165m below the surface, are assigned to early Late Miocene (Early Tortonian), ranging between 10.71-10.40 Ma. Concerning Sahabi Borehole 2 the microfossil bearing interval (interval between 72 and 100m) contains a well preserved nannoflora marked by the presence of Discoaster neoerectus, D. berggrenii, D. bellus, Helicosphaera stalis, Reticulofenestra pseudoumbilicus, Calcidiscus miopelagicus, and therefore is assigned to Late Tortonian nannofossil biozones NN10b-NN11a. The First Occurrence of D. berggrenii recorded within this interval provides a datum event with a fixed age of 8.23 Ma. The presence of common Mediterranean benthic foraminifer Borelis melo along with a few planktonic representatives indicates a shallow marine environment and warm paleoclimatic conditions. The abundance of large specimens of R. pseudoumbilicus is indicative of warm and stratified waters. Several Greek marine sites span the Tortonian-Messinian time interval providing a useful framework for biostratigraphic correlations in the eastern Mediterranean area, e.g. Potamos section/northern part of Gavdos island (NN6 - NN9, 13.28-9.61 Ma), Vassiliki section/E. Crete (NN9, 10.18-9.61 Ma), Skoloudhiana section/W. Crete (NN11, 8.68-7.41 Ma), Kastelli section/central Crete (NN11, 8.68-6.79 Ma), Limin Keri section/southern coast of Zakynthos (NN9, 10.18-9.53 Ma), Ag. Sostis section/southern coast of Zakynthos (7.22-6.52 Ma), Kokkino Rema section/ southern part of Kassos island (NN11, 6.79-5.35 Ma). Although none of these locations bears any terrestrial fauna like the Libyan site, based on their micropaleontological content they confirm the warm climatic conditions prevailing during that time. A particular location that contains vertebrate fauna of equivalent age (including primates) is the Axios Valley in northern Greece.

Nonstationary stress-strain perturbations migrated from mid-ocean ridges and the astenosphere viscosity

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The plot of temporal variation in the seismic activity level of the 40°–80°N segment of the Mid-Atlantic Ridge over the period from 1917 through 1987 is rather similar in shape with an analogous plot for Fennoscandia and, as is shown in the present work, for the eastern part of the North American platform (NAP). However, the characteristic features of the Mid-Atlantic Ridge plot are repeated with an ~3-yr delay in Fennoscandia and with a 4–8-yr delay in the NAP. This positive phase shift is consistent with the hypothesis on significant dynamic control of a mid-ocean ridge (MOR) over seismic activity in adjacent platforms. This control is realized via the MOR push force. Variations in this force induced by the nonstationary process of dike intrusion in the axial zone of the ridge bring about migration of perturbations in the stationary stress–strain state of the lithosphere away from the MOR and induce seismic activity variations in platform regions adjacent to the MOR. The positive time shift in plots of platform seismic activity relative to the corresponding MOR plot is explained in terms of the delay in the arrival of the stress wave at the platform; due to energy dissipation in the asthenosphere, the amplitude of the wave significantly attenuates during its propagation from the MOR. Using the Elsasser model and the observed time shift, an estimate of $\eta = 10^{17}$ Pa s accurate to within ±30% is obtained for the asthenosphere viscosity in the case under consideration. Such values of the viscosity are sufficient to bring about the triggering effect of stress–strain state perturbations on platform seismicity. An increase in the obtained value of η by a few times would lead to overly large travel times of the stress wave, so that seismic activity would remain unaffected by such a wave at distances of the order of 2000 km. The examined numerical model is indirectly supported by the variation amplitude of seismic activity: as compared with Fennoscandia, this amplitude is lower in the central and eastern NAP, located farther from the Mid-Atlantic Ridge. On the other hand, the stationary seismicity level on the NAP is higher than in Fennoscandia, which can explain the difference between stationary values of shear stress intensities τ in the regions considered. The smaller stationary values of τ in Fennoscandia are due to the higher curvature of the Mid-Atlantic Ridge encompassing this region. The results of this work not only confirm the idea previously proposed by the authors according to whom the MOR push force affects the stationary level of seismic activity in adjacent platform regions but also provide new insights into the mechanism of this effect in a nonstationary state.

The exposed base of a collapsing wedge – the Nestos Shear Zone (Rhodope Metamorphic Province, Greece)

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The Nestos Shear Zone (NSZ) in the Rhodope Metamorphic Province is a major high-strain zone between two metamorphic terranes. Microdiamond-bearing ultrahigh-pressure