Multidisciplinary analysis including neotectonic mapping, morphotectonic indices, applied geophysics and remote sensing techniques for studying recently recognized active faults in Northwestern Peloponnese (Greece)

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Abstract

A multidisciplinary analysis comprising neotectonic mapping, morphotectonic indices, applied geophysics and remote sensing techniques was applied in the area affected by the 2008 NW Peloponnese (Western Greece) in order to map the recently-recognized E-W striking Pineios River normal fault zone with a high degree of accuracy, and to better understand its contribution to the evolution of the ancient region of Elis during Holocene time.

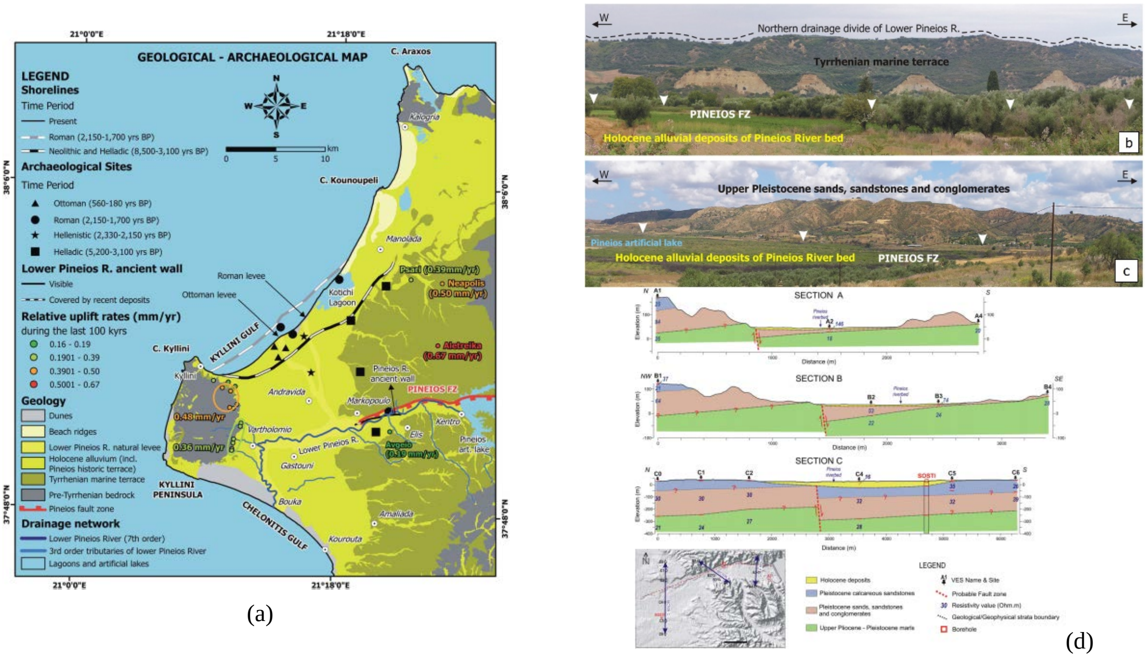
Quantitative constraints on deformation caused by the faulting were applied through the application of morphometric and morphotectonic indices including drainage network asymmetry, longitudinal river profiles and valley floor slope changes, the river sinuosity index (SI) of modern channels as well as mountain front indices including mountain front sinuosity (Smf) and percentage of faceting along mountain front (F%). All of the aforementioned indicated that the Pineios fault zone is a highly active structure.

The study area consists mainly of a succession of Pliocene to Holocene sediments. Already published $^{230}Th/^{238}U$ dating of corals from the upper layers of the sequence indicates a Tyrrhenian age for samples spanning three complete sections from the footwall of the Pineios fault zone. The deposition ages were determined to be 103 ka for the Psari section (at an elevation of 40-45 m above a.s.l.), 118 ka for the Neapolis section (at an elevation of 60–65 m a.s.l.) and 209 ka for the Aletreika section (at an elevation of 140–145 m a.s.l.). The sampling sites that are located north of Pineios fault zone should be located on a single fault block because there is no sign of tectonic disruption between them. The ages of these dated samples correspond to oxygen isotope stages 5.3, 5.5 and 7.3. These stages represent high sea-level stands for the Mediterranean Sea and especially for the western coast of Peloponnese. In particular, at 103 ka sea-level was ~13 m below present sea-level, at 118 ka it was ~1 m below present sea-level and at 209 ka it was ~7 m below present sea-level. From the age of each sample and the sea-level change that has occurred since deposition, uplift rates for the footwall of the Pineios fault zone were calculated as ~0.26 mm/yr for the Psari area, ~0.50 mm/yr for the Neapoli area and ~0.64 mm/yr for the Aletreika area. The maximum uplift rate of 0.64 mm/yr occurs in close proximity to the fault zone. The areas with lower uplift rates are located much further to the north. Because all sample locations are inferred to be within the same fault block, this implies back tilting of the fault block toward north, in full agreement with the rotational block-faulting inferred from structural studies based on fieldwork in the surrounding area.

The rate of uplift for the hangingwall was estimated at ~0.16mm/yr based on a deposition age of 209 ka and a present elevation of 40 m (a.s.l.), which is the lowest elevation that outcrop of Tyrrhenian sediments is found, considering the sea-level change after the deposition. This is much slower even than the slowest measured rate of footwall uplift rate (0.26 mm/yr). The difference between the uplift rate at Aletreika (in the footwall) and the Pineios River plain (in the hanging wall) is ~0.48 mm/yr; this figure corresponds to the slip rate on the Pineios fault zone over the last 209 ka, indicating an overall throw of the fault of ~100 m.

Slip rates were verified by a geophysical survey that measured electrical resistivity along three sections perpendicular to this south-dipping normal fault zone. The geoelectrical data acquisition included 2 “in-situ” resistivity measurements on surface outcrops and 13 Vertical Electrical Soundings. It clearly identifies this tectonic discontinuity at depth where it disrupts depositional layers of different resistivity. Interpretation of the survey results indicates that the fault throw is significantly greater in the westernmost segment of the fault zone, reaching approximately 110 m. This is in good agreement with the fault-slip rate of 0.48 mm/yr that was calculated by the differential uplift rates for blocks on either side of the fault over the past 209 ka.

The continuous activity of Pineios normal fault zone for more than 200 ka has caused relative uplift of the northern block and relative subsidence of the southern block, along with block tilting toward north. The most spectacular landform alteration due to this surface deformation is the N-S migration of the river estuary into completely different open sea areas during the late Quaternary, mainly during the Holocene as well as obvious effects on the shorelines, especially along Kyllini Bay (in the north) where submerged ancient coastlines are known. The sediment transport path has been altered several times due to these changes in river geometry with and the most recent seeming to have occurred almost 200 years ago. The river estuary migrated to its contemporary position along the southern coast, settled on the hanging wall, inducing retrograding of the northern coast, and settled on the foot wall, with rates reaching the order of 0.52 m/yr, as concluded from historical and recently-acquired remote sensing data. Based on the these data, the rate of retrogradation of this shoreline, which is located on the uplifted fault block, is ~ 0.52 m/yr, due to Pineios River estuary migration since a major source of sediment material transportation, which would have contributed to avoid coastal erosion, has been suspended.



(a) (d)

(a) The geological-archeological map of NW Peloponnese. Partial view of the studied area (b) downstream of the artificial dam, looking toward the Pineios fault zone and (c) upstream of the artificial dam.Well-preserved triangular facets are developed on the Upper Pleistocene deposits. White arrowheads point to the fault trace. (d) Geological sections based on the geophysical data.