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Editorial

Tectonics and Sea-Level Fluctuations

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Global sea level has fluctuated significantly over geologic time as a result of changes in the volume of available water in the oceans and changes in the shape and volume of the ocean basins. Fluctuations of the earth's climate (glacial–interglacial cycles) have primarily affected the availability of water masses in the oceans while plate tectonics has influenced the configuration of the continents and the sea floor affecting the capacity of the oceans' basins. Land uplift or subsidence induced by local tectonics has also affected the sea level at local scales.

Quaternary, the most recent geologic period, is characterized by rapid environmental changes during which, climatic alternations of interglacial and glacial stages resulted in eustatic sea-level fluctuations at a global scale. During this era, sea-level highstands are associated with interglacial stages and sea-level lowstands with glacial stages. In tectonically active areas, the interplay between sea-level fluctuations and active tectonics has influenced the recent evolution of coastal landscapes. Coastal areas that have been influenced by intense vertical tectonic movements bear traces of palaeo-shorelines in the form of landforms [1], and changes in the sedimentary facies [2–4]. The study (recognition, mapping, and dating) of uplifted or submerged coastal landforms, which serve as past sea-level indicators, can provide considerable insight into the tectonic and climatic history of coastal areas and can help in the prediction of future sea-level trends.

Tectonically active coastal areas, especially those in close proximity to tectonic plate boundaries and submarine active major faults, are characterized as prone to tsunamis and increase the corresponding risk. Since antiquity, many catastrophic tsunamis have affected coastal areas worldwide. The identification of such past events is based on geomorphological and sedimentological proxies as well as on archaeological and historical evidence. The knowledge of past events is crucial not only in revealing the vulnerability of a coastal area to this particular hazard but also in providing valuable information on its generation mechanisms (activation of a fault, the triggering of a submarine landslide after an earthquake or volcanic activity). Moreover, the evaluation of socio-economic impact of tsunami-related hazards in coastal areas is an essential tool for stakeholders in coastal hazard mitigation.

This Special Issue of the "Journal of Marine Science and Engineering" comprises a selection of six peer-reviewed articles published during 2020–2022. The first three contributions focus on the study of sea-level change geomorphological evidence in the form of erosional landforms (shore platforms, marine terraces, marine notches), while the remaining three, deal with the identification of past tsunami events and the tsunami vulnerability assessment on the coastal zone through modelling. A brief overview of all the contributions, focusing on the main investigation topic and the outcome of the analysis follows.

Karymbalis et al. (2022) [5] investigate the role of tectonic processes in the late Quaternary evolution of the coastal landscape of the broader Neapolis area (Greece) by assessing long-term vertical deformation rates. The authors estimate coastal tectonic uplift deduced by the identification and detailed mapping of marine terraces in conjunction with Optically

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Stimulated Luminescence (OSL) dating and correlation to late Quaternary eustatic sea-level variations. A series of 10 well preserved uplifted marine terraces with inner edges ranging in elevation from 8 ± 2 m to 192 ± 2 m above m.s.l. have been documented, indicating a significant coastal uplift of the study area. Based on the findings of the above approach, a long-term uplift rate of 0.36 ± 0.11 mm a^{-1} over the last 401 ± 10 ka has been suggested for the study area. The spatially uniform uplift of the broader Neapolis area is driven by the active subduction of the African lithosphere beneath the Eurasian plate since the study area is situated very close (~90 km) to the active margin of the Hellenic subduction zone.

Karkani et al. (2021) [6] recalled the shape of tidal notches in order to reconstruct sequences of coseismic subsidence and other relative sea-level changes, which occurred during, at least, the last few millennia in the Aegean Sea, Greece. The authors reanalyzed previously published measurements of submerged tidal notches in several islands and their findings revealed that subsidence trends in many areas of the Aegean Sea are not continuous with gradual movement but are, also, the result of repeated co-seismic vertical subsidence of some decimeters at each time. They concluded that the estimated average return times are of the order of approximately some centuries to one millennium. Although the results cannot be used for short-term predictions of earthquakes, they may provide useful indications on the long-term tectonic trends that are active in the Aegean region.

Evelpidou et al. (2021) [7] performed underwater and coastal geological, geomorphological and biological observations and measurements along the coast of Samos Island (Aegean Sea), in order to reveal the complex character of the uplift deduced by a Mw = 7.0 earthquake, which took place on the 30 October 2020 near the northern coasts of the island. A maximum vertical displacement of +35 ± 5 cm was recorded at the northwestern tip of the island while the southeastern part was known for its subsidence through submerged archaeological remains and former sea level standstills. The 2020 underwater survey unveiled uplifted but still drowned sea level indicators. The vertical displacement at the south and southeastern part ranges between +23 ± 5 and +8 ± 5 cm suggesting a reducing level of uplift towards the east. The authors also point out the crucial value of tidal notches, as markers of co-seismic events and conclude that the co-seismic response of Samos coastal zone to the 30 October earthquake provides a basis for understanding the complex tectonics of this area.

Triantafyllou et al. (2021) [8] investigated the hydrodynamic features and source properties of the tsunami caused by the offshore Samos Island earthquake (Mw = 7.0, 30 October 2020), based on field surveys, video records, eyewitness accounts and far-field mareograms. The authors calculated a tsunami magnitude of Mt~7.0, a tsunami source area of 1960 km^2 and a displacement amplitude of ~1 m in the tsunami source. They concluded that the 15–25 cm co-seismic coastal uplift of Samos decreased the tsunami run-up and that the early warning message perhaps contributed to decrease the tsunami impact.

Batzakis et al. (2021) [9] presented a building vulnerability modelling analysis in order to assess the building vulnerability to tsunami hazard in Kamari (Santorini Island, Greece). The study area is prone to tsunami hazard due to its proximity to the Hellenic subduction zone, which is one of the major tsunamigenic areas. The authors focused on the eastern coast of Santorini, since its morphology and human presence amplify the necessity to assess its building vulnerability. The main objective of the research was to quantify the building stock's vulnerability to tsunami hazard. For this purpose, a "worst-case run-up scenario" was developed. Considering the history of tsunamis in the Aegean Sea, an extreme sea-level rise after a 10 m a.s.l. tsunami run-up, caused by an earthquake with Mw~8.5, was assumed. The relative vulnerability of the buildings in Kamari was calculated via the application of the Papathoma Tsunami Vulnerability Assessment (PTVA-4) analytical model. The results indicate that 423 buildings are within the inundation zone, 58% of which are characterized as highly and very highly vulnerable to tsunamis, revealing the problematic characteristics of the building stock, offering important information to the decision-makers to mitigate a possible future tsunami impact.

Evelpidou et al. (2020) [10] focused on the detailed recording and interpretation of large boulder deposits at Cape Greco (southeastern Cyprus) which has a long history of tsunami events, as observed in archaeological and geological records. Dimensions and spatial distribution of 272 small, medium, and large boulders were documented, while their precise distance from the coastline was recorded by field mapping and remote sensing, using Differential GPS (DGPS), drone, and Geographic Information Systems (GIS) techniques. The authors combined field data with hydrodynamic equations, in order to determine the extreme event(s) that caused their transport inland, and radiocarbon dating was accomplished on three samples of Vermetus sp. to determine the chronological context. Their findings appear to broadly correlate with the 1303 AD tsunami, which has displaced at least part of the studied boulders, and one other undocumented event at AD 1512–1824. The large number of boulders and sizes in at Cape Greco further indicate that their dislocation is most likely owed to multiple events from various sources.

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References

1. Papanastassiou, D.; Cundy, A.; Gaki-Papanastassiou, K.; Frogley, M.; Tsanakas, K.; Maroukian, H. The uplifted terraces of the Arkitsa region, NW Evoikos Gulf, Greece: A result of combined tectonic and volcanic processes? *J. Geol.* **2014**, *122*, 397–410. [CrossRef]
2. Tsanakas, K.; Karymbalis, E.; Cundy, A.; Gaki-Papanastassiou, K.; Papanastassiou, D.; Drinia, H.; Koskeridou, E.; Maroukian, H. Late Holocene geomorphic evolution of the Livadi coastal plain, Gulf of Argostoli, Cephalonia Island, western Greece. *Geog. Fis. Dinam. Quat.* **2019**, *42*, 43–60. [CrossRef]
3. Tsanakas, K.; Karymbalis, E.; Gaki-Papanastassiou, K.; Maroukian, H.; Koskeridou, E.; Cundy, A.; Papanastassiou, D.; Batzakis, D.-V.; Andreou, M. Palaeogeographic evolution of Alykes lagoon, Pydna, Northern Greece during the Holocene, based on geomorphological and sedimentological data. *Zeit. Geomorph.* **2021**, *63*, 2–3. [CrossRef]
4. Karymbalis, E.; Tsanakas, K.; Cundy, A.; Iliopoulos, G.; Papadopoulou, P.; Protopappas, D.; Gaki-Papanastassiou, K.; Papanastassiou, D.; Batzakis, D.-V.; Kotinas, V.; et al. Late Holocene palaeogeographic evolution of the Lihoura coastal plain, Pteleos Gulf, Central Greece. *Quat. Intern.* 2021; *in press*. [CrossRef]
5. Karymbalis, E.; Tsanakas, K.; Tsodoulos, I.; Gaki-Papanastassiou, K.; Papanastassiou, D.; Batzakis, D.; Stamoulis, K. Late Quaternary Marine Terraces and Tectonic Uplift Rates of the Broader Neapolis Area (SE Peloponnese, Greece). *J. Mar. Sci. Eng.* **2022**, *10*, 99. [CrossRef]
6. Karkani, A.; Evelpidou, N. Multiple Submerged Tidal Notches: A Witness of Sequences of Coseismic Subsidence in the Aegean Sea, Greece. *J. Mar. Sci. Eng.* **2021**, *9*, 426. [CrossRef]
7. Evelpidou, N.; Karkani, A.; Kampolis, I. Relative Sea Level Changes and Morphotectonic Implications Triggered by the Samos Earthquake of 30th October 2020. *J. Mar. Sci. Eng.* **2021**, *9*, 40. [CrossRef]
8. Triantafyllou, I.; Gogou, M.; Mavroulis, S.; Lekkas, E.; Papadopoulos, G.; Thravalos, M. The Tsunami Caused by the 30 October 2020 Samos (Aegean Sea) Mw7.0 Earthquake: Hydrodynamic Features, Source Properties and Impact Assessment from Post-Event Field Survey and Video Records. *J. Mar. Sci. Eng.* **2021**, *9*, 68. [CrossRef]
9. Batzakis, D.; Misthos, L.; Voulgaris, G.; Tsanakas, K.; Andreou, M.; Tsodoulos, I.; Karymbalis, E. Assessment of Building Vulnerability to Tsunami Hazard in Kamari (Santorini Island, Greece). *J. Mar. Sci. Eng.* **2020**, *8*, 886. [CrossRef]
10. Evelpidou, N.; Zerefos, C.; Synolakis, C.; Repapis, C.; Karkani, A.; Polidorou, M.; Saitis, G. Coastal Boulders on the SE Coasts of Cyprus as Evidence of Palaeo-Tsunami Events. *J. Mar. Sci. Eng.* **2020**, *8*, 812. [CrossRef]