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Event deposits in the Eastern Thermaikos Gulf and Kassandra Peninsula (Northern Greece) and evidence of the 479 BC Herodotus-tsunami

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Abstract

The world-wide first description of a tsunami and its effects in 479 BC was made by Herodotus. The wave hit the coast of Chalkidiki peninsula Greece where we investigated different areas from Angelochori down to Posidi (Kassandra peninsula) and the ruins of Mende. Ancient Mende was a quite important city in the classic Hellenistic period, already founded in the 12th cent. BC. However, the youngest parts of the city are situated close to the seaside (proasteion of the 6-5th cent. BC). Within the excavation of the cementary, a high-energy layer has been encountered. Besides a vast amount of ceramics, the layer also contains shells of Acanthocardia sp. These have been dated as c. 2900 years BP by 14C, taking into account a reservoir effect of 400 years. Therefore, the layer is considered a suitable candidate to the tsunami reported by Herodotus.

Introduction

The Herodotus Histories (Urania, Book 8, 129) report on a series of ununduation by large waves and sea withdrawals occurring in winter 479 BC during the Persian-Greek war. Large portions of the Persian troops perished by drowning near Potidaea, western Chalkidiki peninsula (Greece), while sieging the Greek town. No earthquake was reported for this event, so a meterological effect or submarine slumping could be possible (Ambraseys 2009). Herodotus's report is interpreted as the first of a historical tsunami (Bolt 1978, Smid 1970).

Modelling of the tsunami source along the western tip of the North Anatolian Fault Zone (NAFZ) in the North Aegean Basin revealed the possibility of high waves induced by seismicity (Reicherter et al. 2010) which may also affect Kassandra peninsula. The westernmost, 55 km long branch of the NAFZ is taken into account for the modelling because it can cause earthquakes with possible magnitudes around 7 or more (Papanikolaou and Papanikolaou 2007). Wave heights dependent from coastal morphology may reach more than 2 meters with considerable run-up in flat coastal areas (Reicherter et al. 2010).

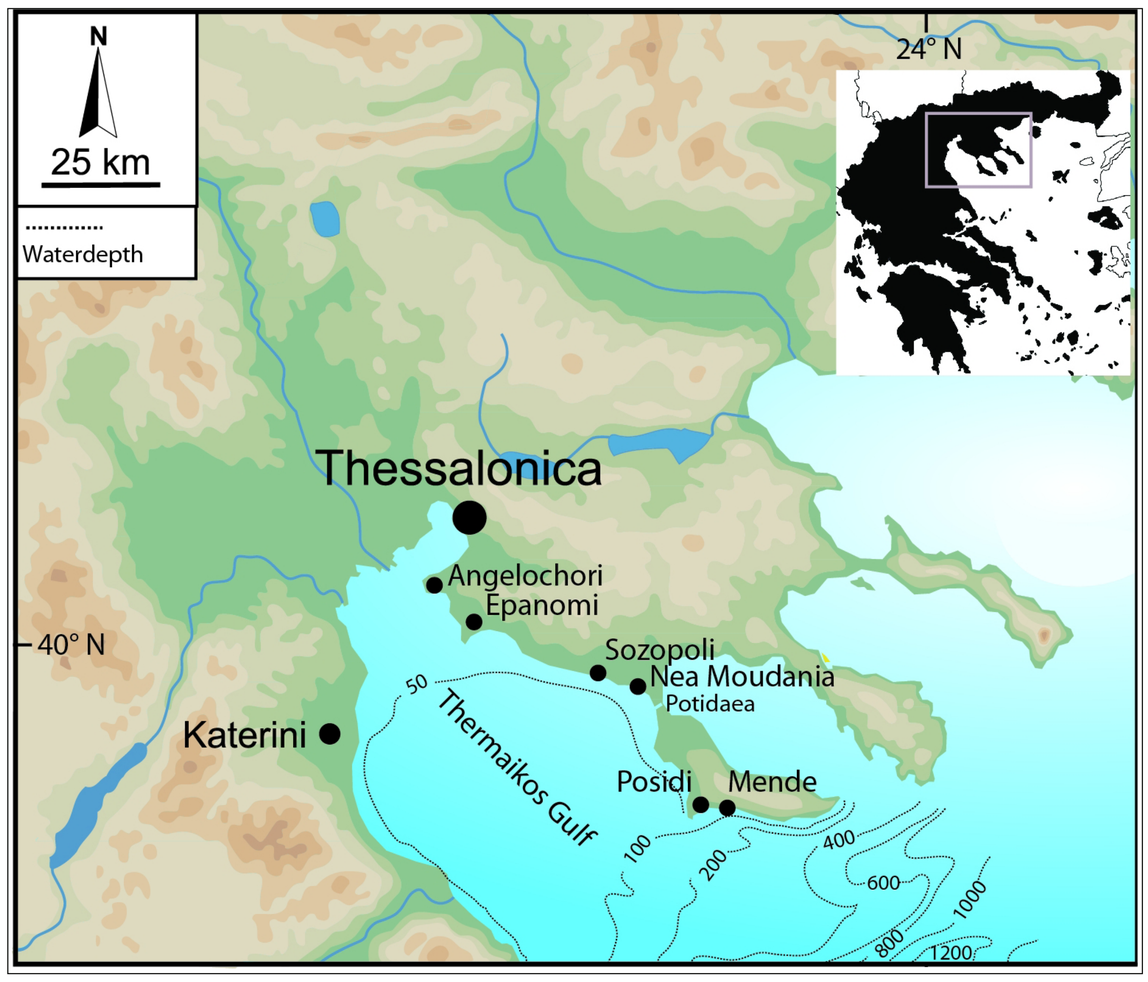

FIGURE 1: Investigation areas along the east coast of the Thermaikos Gulf: Angelochori, Epanomi, Sozopoli, Nea Moudania, Posidi and Mende

Study areas

The investigated areas are situated at the eastern coast of the Thermaikos Gulf (fig.1).). The climate is subtropical with dry and hot summers and mild and wet winters. The main wind directions in summer are from N and NE, so-called Etesians, but in April, May and July winds from S and SE are also common. Beaufort forces lie between 3 and 5, only occasionally rising to gale force. In winter wind stroms reach Beaufort up to 8. The sandy spit of Cap Epanomi marks the transition from the inner to the outer Gulf. Water depths increase from around 25 m in the Thessaloniki Bay to a maximum from c. 200 m in the Thermaikos Gulf and deepen rapidly at the shelf break to around 1200 m in the Sporades Basin (fig.1). Between Thessaloniki and Potidaea the coast has an almost low relief, with flat and narrow beaches with beach ridges mostly not higher than 1 - 2 m and intercalated cliffy sections. Agricultural use and building range until the coast but to some extent low vegetated dunes, more or less silted up lagoons and salines are present (eg Angelochori, Cap Epanomi).

The saline and lagoon of Angelochori are located on a sandy spit bar at the transition of the Thessaloniki Bay to the Thermaikos Gulf. Neogene sands of the Messinian build the main geology. Cap Epanomi is built by a large spit bar with vegetated dunes and a central lagoon. It is situated at the transition from the inner to the outer Thermaikos Gulf. This position leads to substantial seasonal changes in wind and wave action; in particular resulting in a higher amount of coarse sediments in the southern part. The northern part that is orientated to inner gulf shows chevron-like features on aerial images, which may be of aeolian or spillover origin. Aside from the lagoonal area more or less consolidated sandstones of Pliocene age with some intercalations of gravel, clayey and calcareous material crop out. Close to the village of Sozopoli behind a low beach berm a dried out lagoonal area beside a dune field is preserved. Nearby, Neogene sands form a huge cliff. The hinterland geology is built by Miocene to Pliocene sandstones and marls. At all sites Quaternary sand and sandy clays are the youngest sediments.

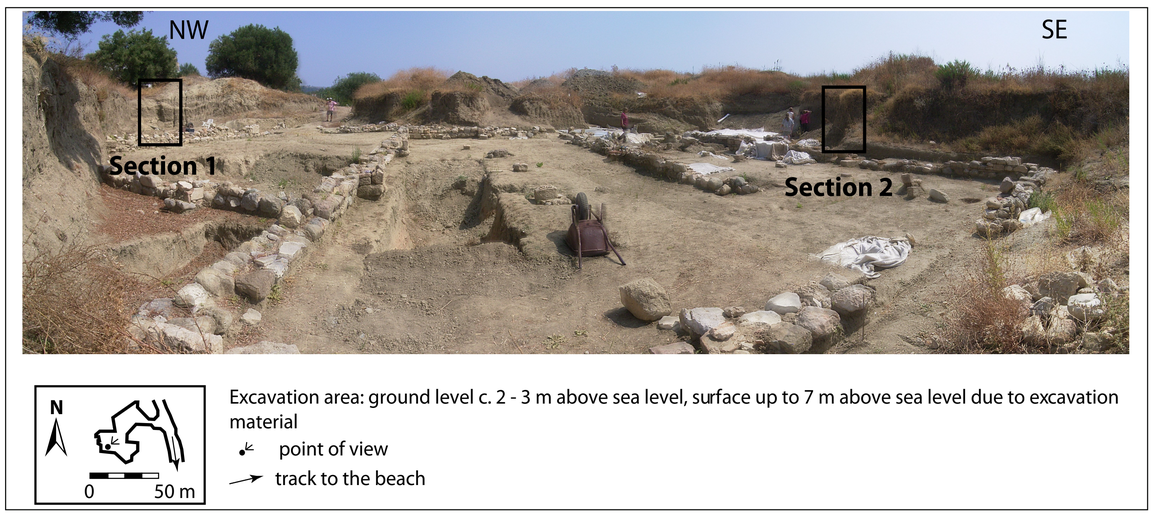

FIGURE 2: Overview of the excavation site of Ancient Mende in 2008 with sections 1 and 2.

Kassandra peninsula (the ancient Pallene) is the westernmost prong of Chalkidiki peninsula and its west coast lies to the outer Thermaikos Gulf. The coastal area comprises mainly Neogene sands, conglomerates and marls of terrestrial and marine origin besides alluvium with sands, boulders and landslide masses.

Methods

During the field work in 2007 and 2008 percussion drilling was undertaken using vibra-coring with an open window sampler between Cap Angelochori, Epanomi, Sozopoli, Nea Moudania and Posidi concentrating on areas sheltered from direct wave action such as lagoonal zones and smooth depressions behind the beach insofar there was no intense human use recognizable.These areas are potential archives for tsunamites.

Field work comprises detailed core description and after a first appraisal additional drilling of overall 93 m of PVC-liners each of 1 m length were undertaken for investigation in the laboratory at the University of Aachen. The sedimentology and magnetic susceptibility of the most cores from Angelochori, Epanomi and Sozopoli were described in 2010 by Reicherter et al.

A set of indicators are taken in account for determination of tsunami deposits as there are finning and thinning up sequences, rip up clasts, mud coated clasts, erosive bases, conservation status of biogens, unusual faunal associations, and the combination of sedimentological compound with magnetic susceptibility.

To get more indications for the 479 BC tsunami of Herodot samples for radiocarbon dating and micropalaeontological investigations were taken from Ancient Mende.

Interpretation and discussion

At Ancient Mende the upper 20 – 30 cm consist of digging material from the excavation underlain by a rooted horizon. Marine sediments are intercalated in terrestrial sand layers. This marine layer consists in section 1 (fig. 2, fig. 3), c. 1.87 m and 2.30 m bgl. of fine sand and contains besides ceramics, charcoal and broken building materials, complete and partly articulated shells of bivalves like *Acanthocardium* sp. The left part of section 1 furthermore shows two fining up sequences. The lower sequence starts with gravel showing an erosional contact in form of a channel. A similar deposit of gravel can be observed on the southwestern side of the excavation in section 2. All micropaleontological samples of the tsunami layer contain unidentified shell fragments, most likely small fragments of gastropods. Some samples show also fragments of agglutinated foraminifera and agglutinated worm tubes. In a sample of the upper part of the tsunami layer fragments of small, thin-shelled gastropods, assumed belonging to the marine species *Cylichna* sp., are found. These snails live as burrowers in the silty and muddy seafloor on the lower shore or deeper.

The top of the marine layer in sect. 1a is dated to 915 +/- 25 years whereas the radiocarbon dating near the base of the marine layers date to +/-2,900 yrs (fig. 3).

Conclusions

The marine layer at the Ancient Mende excavation site is interpreted as an event layer. Fining up sequences, erosive contacts and the occurrence of a channel like bed with an imbricated gravel layer at its base occur inside the settlement and indicate a tsunami. This consideration is confirmed by the occurrence of small gastropods from silty and muddy environments as can be found southward from the spit in deeper parts of the shelf. The small channel like form is interpreted as a backwash channel. Radiocarbon dates from above and from the base of the layer show ages that match the 479 BC tsunami described by Herodotus.

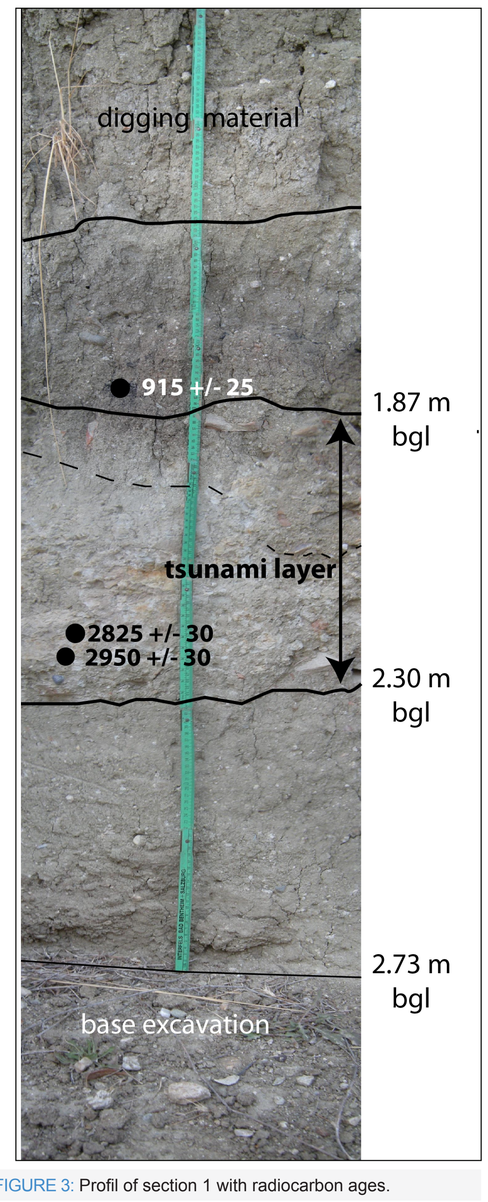

FIGURE 3: Profil of section 1 with radiocarbon ages.

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