Scientific Report on the COST-STSM-ES0701-111

The mission took place, as scheduled, between 6 and 16 October 2009. Under the guide of the Host, various coasts of the North Evvoikos Gulf have been visited. The aim of the STSM was the identification of emerged and submerged sea-level indicators, their measurement and sampling, and sample preparation for radiometric dating. Field observations have been made easier by the use of a car and of a boat provided by the Host.

Hourly tide records between 18/7/2008 and 31/8/2008 at the station of ChalkisN, provided by the Greek Hydrographical Service, have been used, with the help of Alberto Tomasin (University of Venice), to calculate the local approximate tide harmonic constants and the astronomic predictions for the period of survey observations. The "geomorphologically significant" spring tidal range in the area being of the order of 70 cm, heights have been related to the sea level at the time of measurement and subsequently corrected according to the astronomic tide predictions. An uncertainty margin of ±10 cm takes into account the possible influence of meteorological effects on sea level, that have been however limited during the survey. Most field data had been previously carefully investigated, measured and photographed by the Host.

Submerged sea-level indicators

The most interesting discovery made by the Host is the identification of submerged notches corresponding to former shorelines and indicating rapid subsidence movements, probably of coseismic origin. A magnificent recumbent U-shaped underwater notch, apparently unnoticed until now, indicating a former shoreline at about -70±10 cm, is developed on limestone coastal rocks at Atalandi Mines (x=23.17 y=38.65) (Fig. 1).

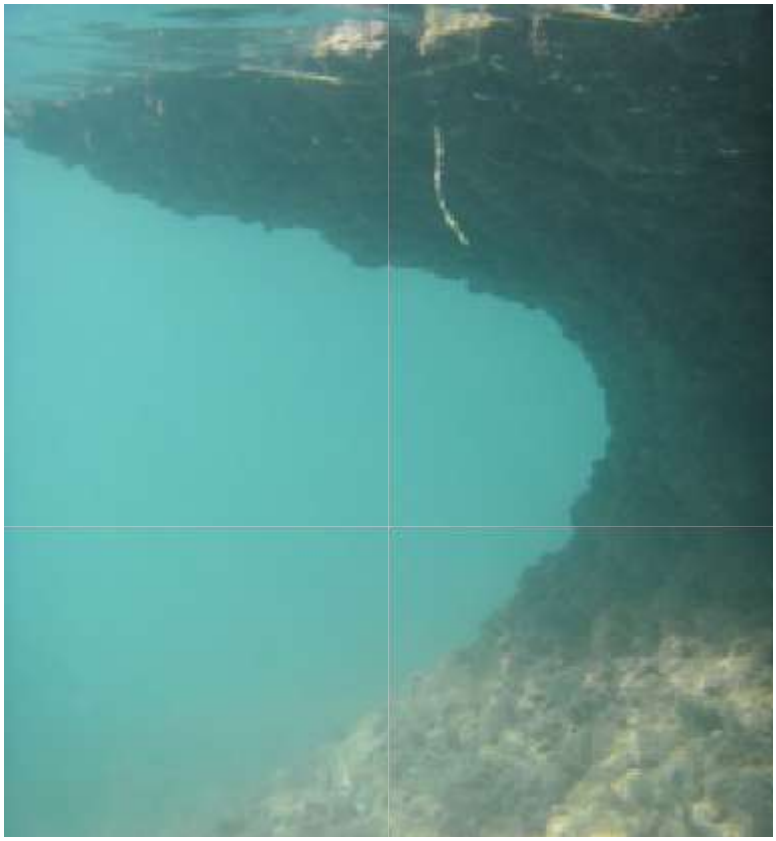

Figure 1. Submerged notch at Atalandi Mines indicating a former shoreline at about 70 cm below the present sea level (Photo N. Evelpidou).

The well-preserved profile of Fig. 1 enables some detailed interpretation. The horizontal depth of the notch at the level of the retreat point is of about 70 cm (though it can exceed 1 m at certain places). Assuming an erosion deepening rate of 0.2 to 0.3 mm/yr, the development of the notch might have needed a period of the order of three thousand years. The height of the notch (often about 120 cm) is greater than the spring tidal range (70 cm), with a notch floor (lower part of the notch profile) higher than the notch roof (upper part of the notch profile), suggesting the occurrence of some relative sea-level rise during its development. The fact that the notch floor is also regular, without any trace of secondary undulation, remnant of a previous notch, suggests that a gradual sea-level rise or subsidence of about 50 cm occurred during the period of notch development. The notch roof is regular and well preserved, suggesting that the submergence of the whole notch was a rapid event. This rapid submergence took place probably during an earthquake of historical times (426 BC, 106 AD, 551 AD, 1894 AD) and possibly provoked a tsunami in the area. The fact that almost no notch marks generally exists at the present sea level suggests that the rapid submergence event was a quite recent phenomenon (1894 AD?). Of course these are only preliminary results that should be confirmed by detailed analysis of well preserved notch profiles at other sites in the same area.
In fact this notch can be followed more or less continuously on limestone rocks westwards, in spite of very frequent water turbidity, between Atalandi Mines and Microvivos (Fig. 2).

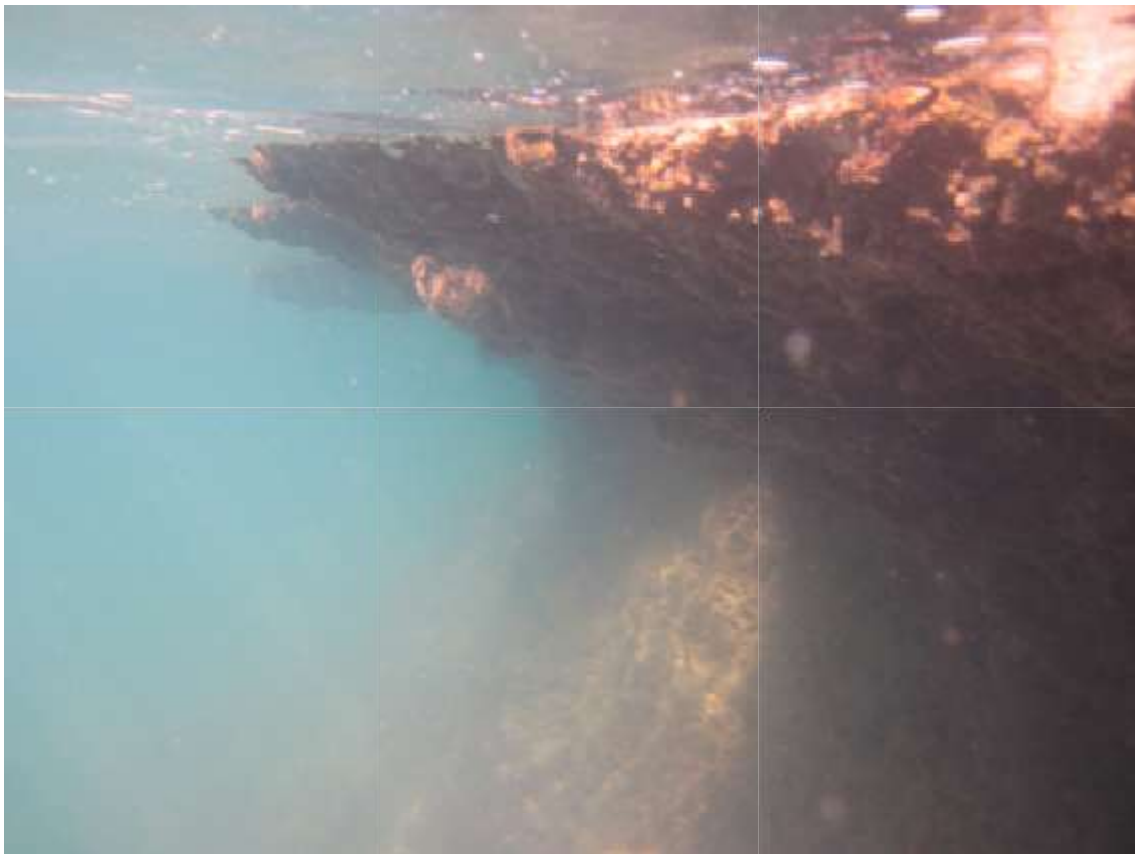

Figure 2. Submerged notch between Vivos and Microvivos (Stop 5) (Photo N. Evelpidou).

At Atalandi Mines, several non *in situ* big rock blocks, containing marine fossils (*Lithophaga*, Vermetids, Serpulids) in growth position, seem to have been projected on the coast by a tsunami wave. An underwater survey in the nearby area showed rapidly that a search for

determining the exact place from where the blocks were coming would have provided only illusory results. Shell samples from these blocks have been collected for possible radiocarbon dating.

Another notch has been observed in the Vougiouklaki area (x=23.17 y=38.67). It is developed between 20 and 50 cm below MSL and its horizontal depth does not generally exceed 20 to 30 cm (Fig. 3). The height of this submerged notch is therefore less than the spring tidal range and there are no marks of another notch developing near the present sea level.

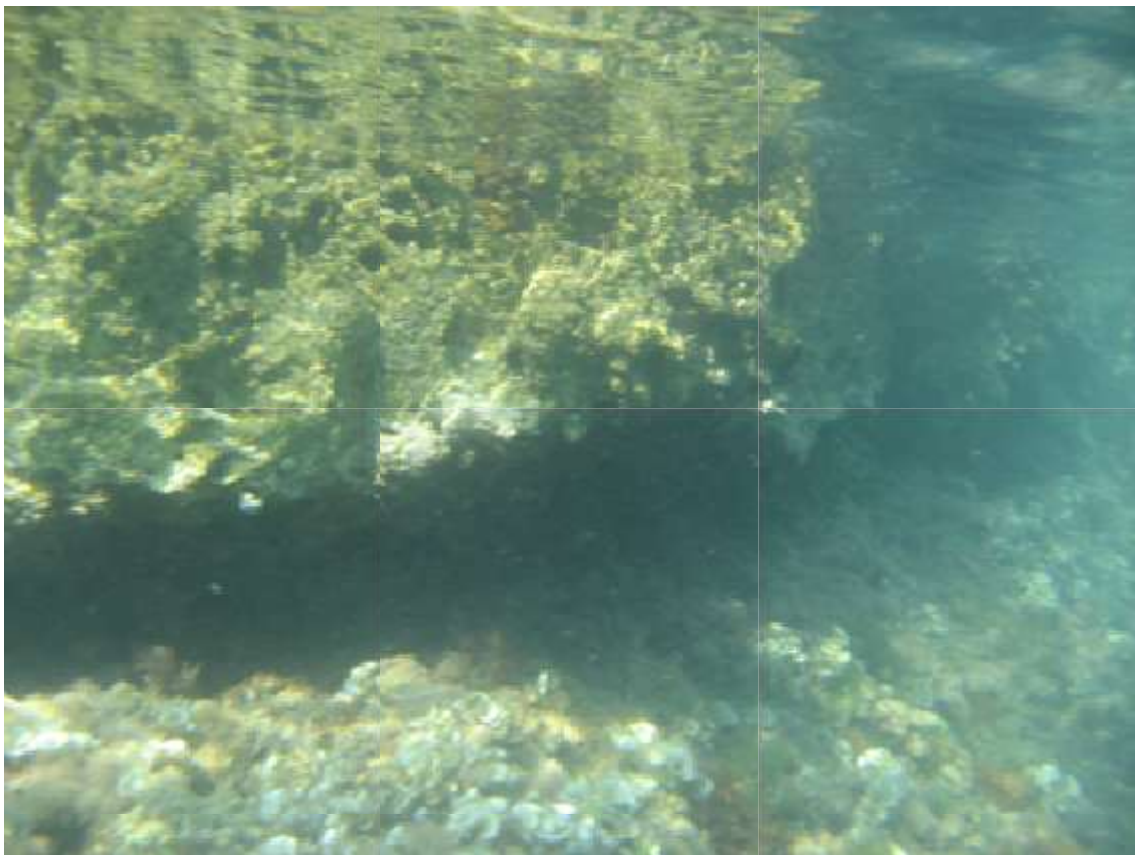

Figure 3. Small notch submerged at about 50 cm below the present MSL at Vougiouklaki (photo N. Evelpidou).

The notch floor, at about -50±10 cm, often extends to a small bench at about the same level. This unusual notch profile might indicate a subsidence of about 50 cm, possibly of coseismic origin, that occurred relatively recently (1894 AD?). Its peculiar shape and the small bench at the same level of the flat notch floor may be related to a zone of particularly strong bioerosion in this area, that is exposed to regular waves action. Nevertheless, interpretation of this notch remains uncertain, especially because, if a coseismic event took place, it is difficult to understand why evidence of submergence is limited to this relatively small area, without extending to the wider region of Theologos.

We could not identify details of submerged remains that could be used as sea-level indicators at the Halai archaeological site. On the other hand the slight submergence of parts of the Theologos Quarry 2 may be due either to a slight change in the relative sea level, or to a particular quarrying technique using wood key wedges, that would have permitted to cut stone blocks also at shallow depth.

Pleistocene marine platforms

In the Limnionas area (x=23.25 y=38.65) a series of stepped marine platforms has been observed. Their elevation varies from +65±10 cm above the present average low tide level for an emerged platform, to depths of about -90±10 cm, -150±10 cm and -200±10 cm underwater. The aerial platform contains some small fossil shells (that we collected for a possible radiometric dating), but seems too hardened to date from the Holocene. There are no signs on it of recent submergence by the sea. The aerial platform, as well as the stepped underwater platforms, may correspond to sea-level changes or to tectonic movements that occurred during the last Interglacial. In some parts on top of this platform a beachrock exists. The height of the beachrock is about 35 cm (Fig. 4). We have collected a sample of the beachrock for an attempt of OSL dating.

Figure 4. Aerial Pleistocene coastal platform in the Limnionas area, capped (left) by remnants of a fossil beachrock.

We have also found in the area some non *in situ* blocks with many *Lithophaga* and Vermetids shells in growth position; in some cases *Cladocora caespitosa* corals were also present. We assume that these blocks were moved on the platform by a tsunami wave and have sampled some shell material for possible radiocarbon dating. The Limnionas area is located in the hangingwall of the Locris fault and can therefore be expected to subside in response of movements of that structure. Assuming that the platforms date from the last Interglacial and that the global sea level at that time was about 7 m higher than at present, a subsidence rate of about 0.05 mm/yr could be deduced for the aerial platform. From the boat we observed in the Arkitsa area a wide flat platform at an elevation of about 20 m (Fig. 5).

Figure 5. Marine terrace observed from a distance in the Arkitsa area.

We could later verify that small marine pebbles and shells can be found in the soil of this platform. It is therefore a marine terrace, that does not seem to have been investigated until now. The Arkitsa area is located in the immediate footwall of the Kamena Vourla fault and can therefore be expected to be uplifted by movement on this structure. Assuming that it dates from the last Interglacial, it would indicate an uplift rate of about 0.10 mm/yr.

Holocene uplift of Evvia Island

A survey of the northwest coast of Evvia enabled us to find in a limestone rock area many emerged *Lithophaga* holes, some of which were containing shells still articulated in a growth position, up to over 4 m above sea level. Marks of a clear shoreline existed at the elevation of about 1.7 m. We could collect for radiocarbon dating two samples, one above and one below the 1.7 m level (Fig. 6).

Figure 6. The Host and the missionary are trying to sample emerged fossil *Lithophaga* shells still in growth position in their holes on the northwester coast of Evvia (photo A. Vassilopoulos).

Conclusion

Thanks to the favorable meteorological conditions and to the careful preparation and excellent organization by the Host, the STSM can be considered as a success, with discovery of several promising new data that will certainly stimulate further collaboration in publishing the results obtained and in new sea-level research.

Paolo Antonio Pirazzoli
Emeritus research director at the CNRS