What have we learned from archaeological and biological sea-level data? The examples of Marseille and Pozzuoli

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INTRODUCTION & METHODS

Tectonic and isostatic movements have prevailed in the Mediterranean since 6000 BP. Using biological and archaeological indicators we are building a high-resolution RSL databank for the Mediterranean area. Our new methodology employs marine molluscs fixed to archaeological remains (e.g. harbour walls, quays etc.) as precise sea-level index points. The aim of the present study is to improve our understanding and interpretation of these biological indicators. In this poster we present results from two case studies: Marseilles, France, subject to a so-called stable tectonic regime, and Pozzuoli located in the Phlaegrean Fields volcanic complex, Italy.

Any fixed marine biological remain, located in growth position, above or below present sea level may be used as a proxy for sea level (Laborel and Laborel-Deguen, 1994).
The precision of the measurements depends upon two factors:
a) the definition of a reliable benchmark;
b) precisely quantifying the relationship between the sea-level indicator and sea surface.

Definition of a biological mean sea-level
Biologists have demonstrated that, on hard substrates (cliffs or quays), the limit between the midlittoral and subtidal zones is generally marked by a sudden change in the qualitative and quantitative composition of algal and animal benthic populations. This biological limit is defined as the biological mean sea level. Seasonal or aperiodic sea-level changes have little influence upon this biological stratification.

We have grouped together biological markers in the Mediterranean on the basis of their bathymetrical relationship to mean sea level:

(1) Sea-level indicators proper: The best suited organisms for RSL studies are those with a very narrow vertical life range, in close proximity to the sea surface. In the western Mediterranean two important species exist: (a) the frondose coralline Rhodophyte *Lithophyllum byssoides*. This species has been used to reconstruct late Holocene sea-level changes on the coasts of southern France (Laborel *et al.*,1994). (b) *Dendropoma petraeum* can build littoral rims of various sizes and shapes. The altitudinal precision, which depends on local topography, surf and tide conditions, varies from ±50 m, on meso- or macro-tidal coasts, to ±5cm in optimal conditions (Laborel and Laborel-Deguen, 1994; Morhange *et al.*, 1998).

(2) Biological indicators of submersion:

(a) Boring species: Boring Mussels include *Lithophaga lithophaga* **(Fig. 1)** and several species of Petricola, Coralliophaga and Hyatella. These taxa are very common on limestone surfaces and may develop anywhere from the water surface down to depths of 50 m and more.

(b) Subtidal builders: These building species have a wide depth life-range. Although they do not show a precise relationship with sea level, they can yield interesting clues about palaeobathymetry. (a) 0-25 m, hard substrates are dominanted by populations of soft algae and fixed or encrusting species. These include Vermetids (*Vermetus triqueter*), and fixed Lamellibranchs (Oysters, Chama and Spondylus). Zibrowius (1995) discusses the Mediterranean's scleractinian corals, and their relationship to depth. (b) In shallow water caves and under littoral overhanging surfaces, where conditions of dim light prevail, stunted formations of "coralligene" can develop. The shade loving Dendrophyllid coral *Astroides calycularis* may locally reach up to the surface, in which case the upper limit of its colonies can be used as a sea-level indicator (Morhange *et al.*, 2006).

Fig. 1: Examples of species used as biological sea-level indicators

RESULTS

Marseilles

(Morhange *et al.*, 2001)

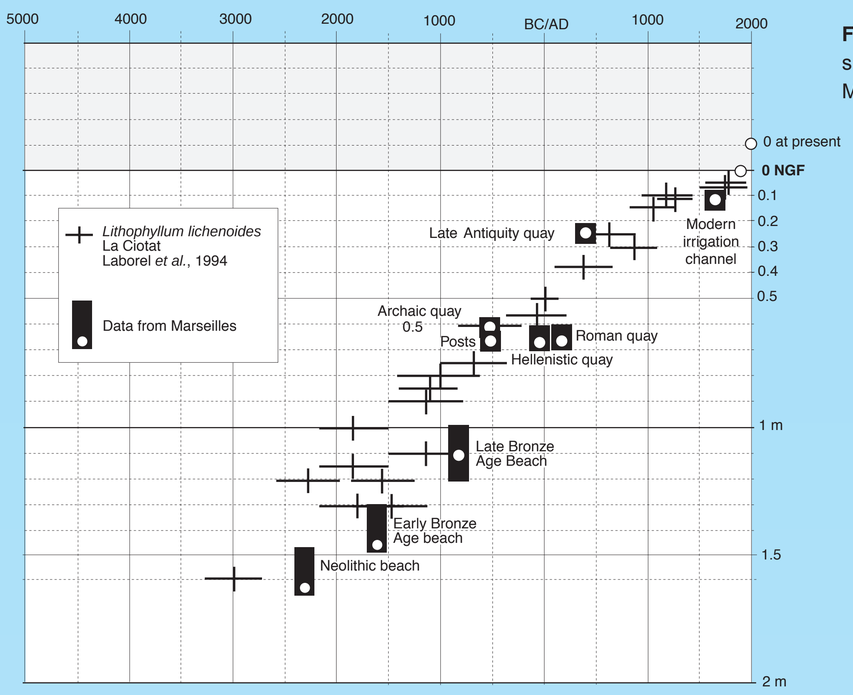

Fig. 2: 5000 years of relative sea-level changes at Marseilles.

In the ancient harbor of Marseille (southern France), marine fauna fixed upon archaeological structures in addition to bio-sedimentary units document a 1.5 m steady rise in relative sea level during the past 5000 years **(Fig. 2)**. A near stable level, at present datum, prevailed from 1500 years AD to the last century. This trend is similar to the one previously documented on the rocky coasts of Provence, southern France. Field observations inside and outside the harbour confirm that no sea-level stand higher than present occurred during the studied period **(Fig. 3)**. Since Roman times, relative sea-level has risen by ~50 cm.

Fig. 3 (A) Jules Verne 3, a Roman dredging boat unearthed in Marseilles' ancient harbour. The vessel dates from the 1st to 2nd centuries AD. **(B)** Upper limit of *Balanus* sp. populations on Marseilles' ancient Greek quay. **(C)** Upper limit of *Balanus* sp. on a Roman stake. **(D)** Roman harbour quay.

Pozzuoli

(Morhange *et al.*, 2006)

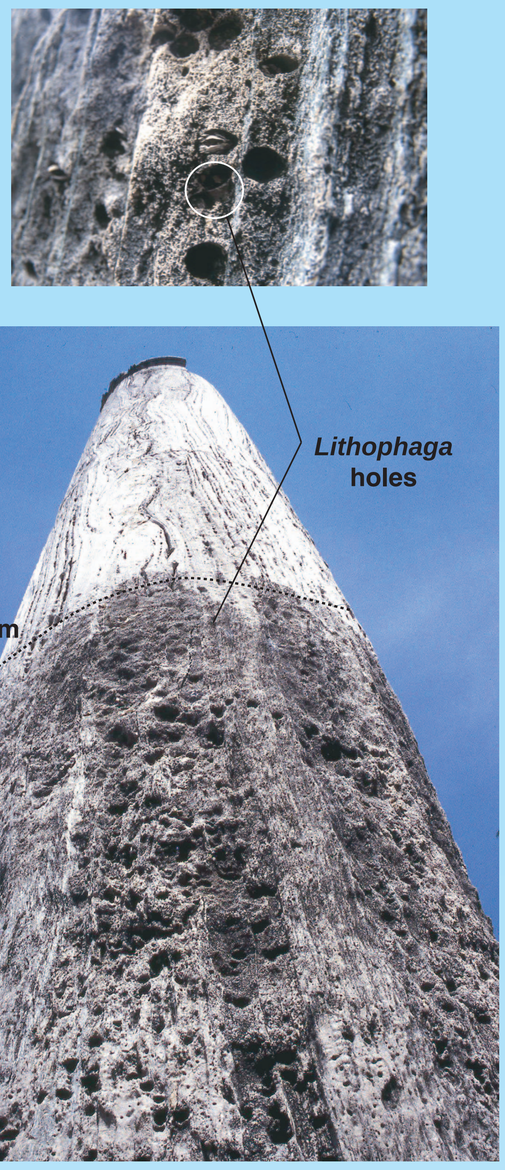

Fig. 5 (A) Remains of Pozzuoli's Roman market, showing biological perforations up to a height of 7 ±0.1 m above present biological sea level. **(B)** Biological perforations with *in situ Lithophaga* shells on a column of the Roman market.

The importance of Pozzuoli's archaeological ruins in linking sea-level change and earth deformation with volcanic activity has been recognized since the 19th century **(Fig. 4)**. Indeed, the pillars of the Roman market were used as a paleotide gauge by pioneer geologists such as Lyell. For the first time, we have radiocarbon dated biological indicators on these remains, showing three 7 m relative sea-level highstands during the 5th century A.D., the early Middle Ages, and before the 1538 eruption of Monte Nuovo **(Fig. 5)**. These repeated uplift and subsidence cycles, not always followed by volcanic activity, have important implications for the evaluation of volcanic hazard.

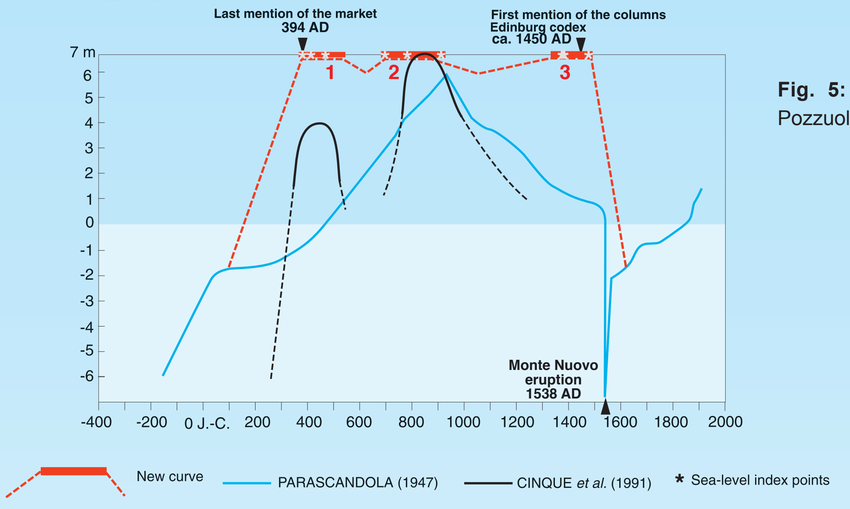

Fig. 5: Relative sea level changes in Pozzuoli during the past 2000 years.

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