

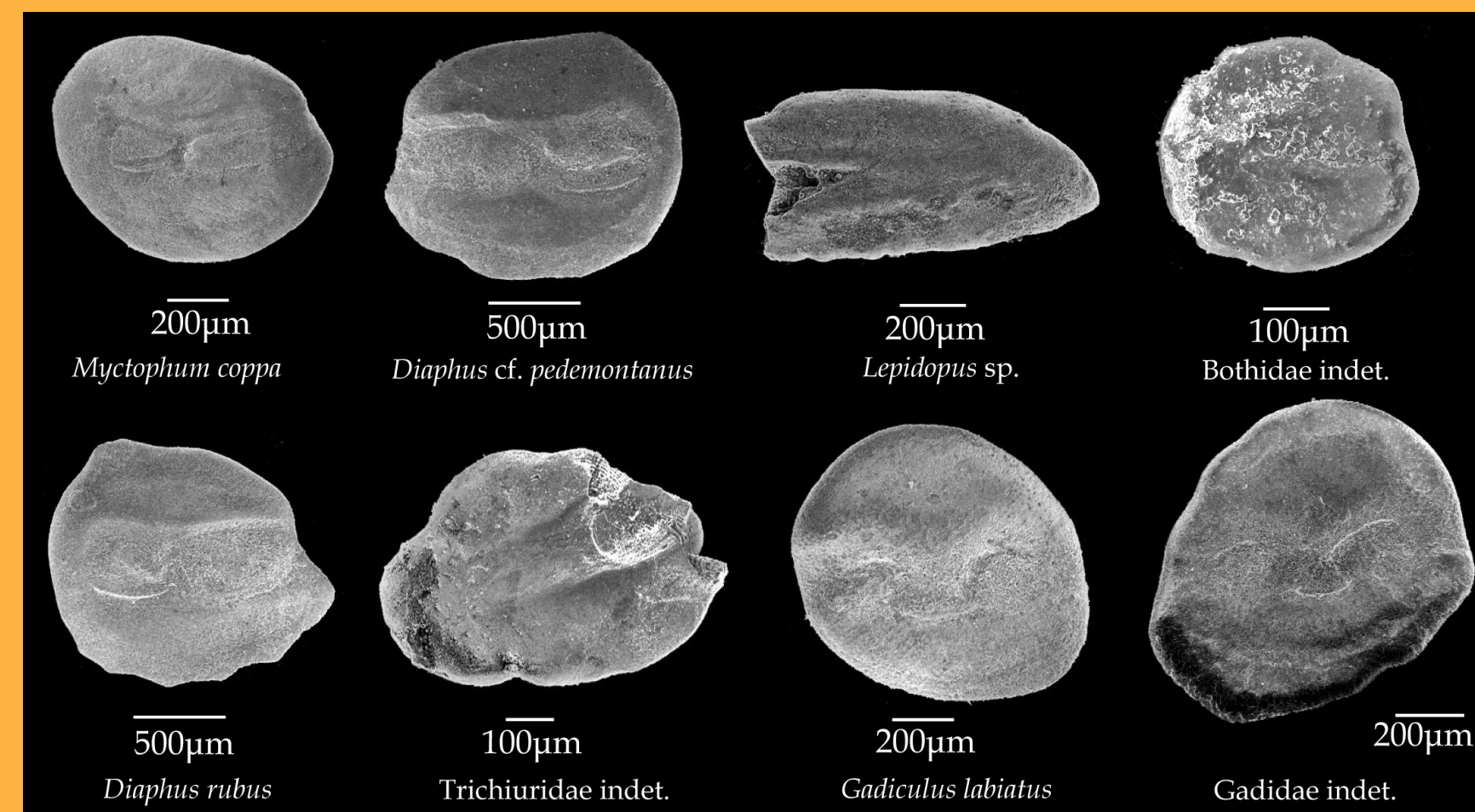
Fish otoliths from the Messinian of Zakynthos Island (Ionian Sea, eastern Mediterranean)

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Systematic Paleontology

Class Actinopterygii Klein, 1885
Division Teleostei Mueller, 1846
Order Clupeiformes Bleeker, 1959
Family Engraulidae Gill, 1861
Genus *Engraulis* Cuvier, 1816
Engraulis encrasicolus (Linnaeus, 1758)
Order Stomiiformes Regan, 1909
Family Sternoptychidae Dumeril, 1806
Genus *Mauroliscus* Cocco, 1838
Mauroliscus muelleri (Gmelin, 1789)
Family Phosichthyidae Weitzman, 1974
Genus *Vinciguerria* Jordan and Williams, 1896
Vinciguerria poweriae (Cocco, 1838)
Order Myctophiformes Regan, 1911
Family Myctophidae Gill, 1892
Genus *Ceratoscopelus* Gunther, 1864
Ceratoscopelus maderensis (Lowe, 1839)
Genus *Diaphus* Eigenmann and Eigenmann, 1890
Diaphus befralati Brzobohaty and Nolf, 2000
Diaphus cavalloni Brzobohaty and Nolf, 2000
Diaphus cf. pedemontanus Robba, 1970
Diaphus rafinesquii (Cocco, 1838)
Diaphus rubus Gironé et al. 2010
Diaphus taaningi Norman, 1930
Genus *Myctophum* Rafinesque, 1810
Myctophum coppa Gironé et al. 2010
Order Gadiformes Goodrich, 1909
Family Moridae Goode and Bean, 1896
Genus *Physiculus* Kaup, 1858
Physiculus aff. huloti Polli, 1953
Family Gadidae Rafinesque, 1810
Genus *Gadiculus* Guichenot, 1850
Gadiculus argenteus Guichenot, 1850
Gadiculus labiatus (Schubert, 1905)
Order Perciformes Bleeker, 1859
Family Gobiidae Bonaparte, 1832
Family Trichiuridae Rafinesque, 1810
Genus *Lepidopus* Gouan, 1770
Order Pleuronectiformes (Regan, 1910)
Family Bothidae Regan, 1910



Paleoecology

The Messinian Kalamaki area presents a well diversified fauna, comprising both abundant pelagic and benthic-benthopelagic fish. The continuous presence of gobiids throughout the basal part of the section and the occurrence of Bothidae suggest rather **shallow water depths before the onset of gypsum deposition**. Furthermore, the occurrence of the tropical benthopelagic species *Physiculus* aff. *huloti* indicates depths less than 320 m. However, the great number of *Diaphus* species and specimens, as well as the presence of gadids (*Gadiculus argenteus* and *Gadiculus labiatus*) in the upper part of the basal sequence (just prior to the gypsum deposits) show that **the area was not secluded**, and depths certainly greater than 50 m may be expected. In addition, *Mauroliscus muelleri* is present in almost all the samples examined and in great abundances. Although this bathypelagic species has a large bathymetric distribution today, between 0-1524 m, it is usually found between 300-400 m depth. Combining the above, a **paleodepth around 300 m** appears more likely for the basal sequence of Kalamaki section.

Very significant may be the record in the Kalamaki samples of *Engraulis encrasicolus*, which is very abundant today in the Black Sea and the Mediterranean, and has been known to tolerate salinities from 5 to 40‰. Silva et al. (2014) suggest that anchovies rapidly track their optimal thermal physiological conditions during extreme climate events, recolonizing the afflicted areas only after preferred conditions have re-established. The presence thus of *E. encrasicolus* at this level may indicate that the major paleoenvironmental perturbation had not yet taken place.



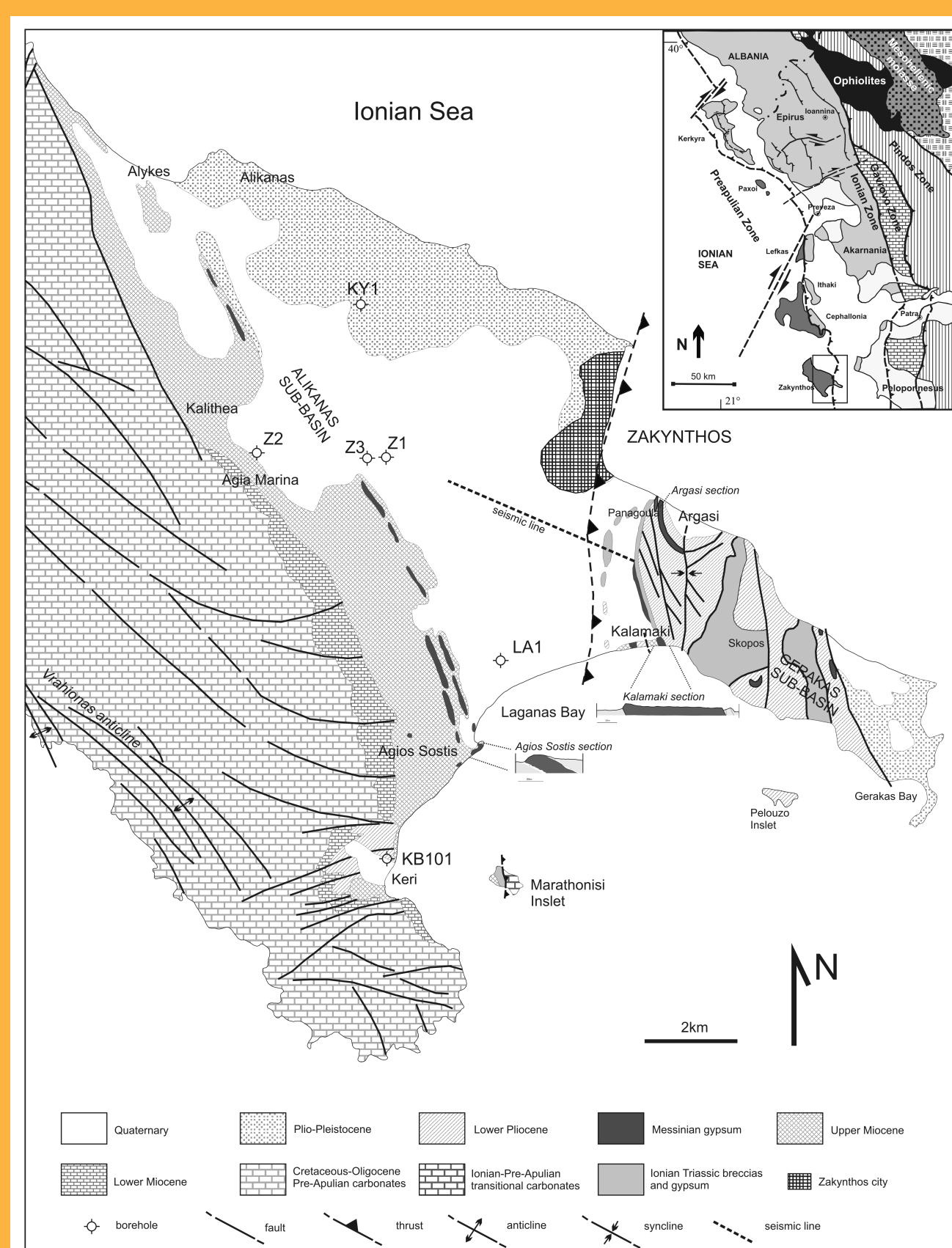
The pre-evaporitic Messinian deposits of Kalamaki section.



The Kalamaki evaporitic sequence. E: evaporites, M: marl beds, Tr: 'trubi' formation.

The study area

Kalamaki section is located in the south-eastern coast of Zakynthos Island, on the eastern edge of Laganas coast. The Neogene sequence of the Kalamaki-Argasi area has been deposited over the Ionian zone basement. Kalamaki section begins with a 15 meter-thick succession of alternating massive and laminated marls with rare calcareous marls and calcarenite intercalations. This succession is followed by 10 meters of slumped and folded sediments of the same lithology, succeeded by a 98 meter-thick evaporitic unit incorporating six evaporitic cycles in alternation with marl deposits (Karakitsios et al., 2013). These deposits have been ascribed to the Primary Lower Gypsum unit of Roveri et al. (2008) deposited during the 1st stage of the Messinian salinity crisis (5.971 – 5.60 Ma). Above the evaporitic sequence, there is a transitional clastic formation of approximately 8 meters thickness. The "trubi" carbonate formation, which overlies through a low-angle angular unconformity, begins with 3 meters of massive marly limestones followed by an alternation of decimetric carbonate and laminated marl beds.



Zakynthos Island geological map.

Methodology

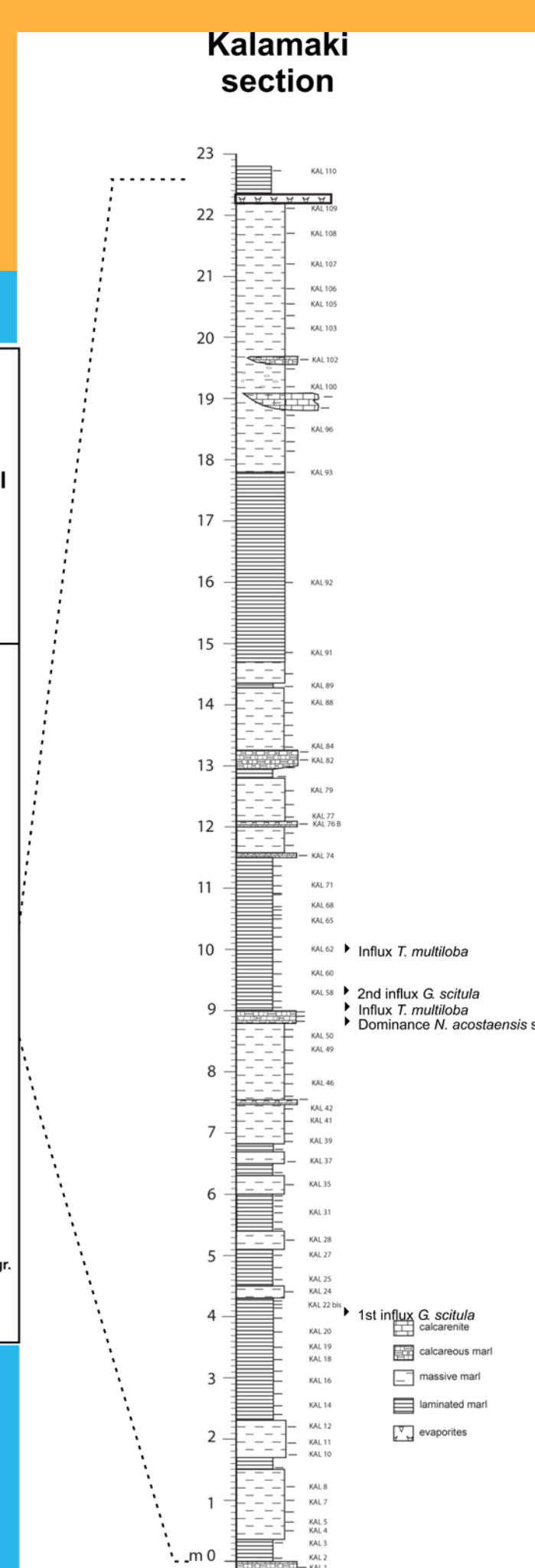
Several bulk samples for otolith analysis were obtained throughout the lower and upper part of Kalamaki section, including the 'trubi' formation, as well as in each of the marl beds in between the evaporite sequence. The lower part of the section yielded the most significant findings, which were then described and systematically identified.

Biostratigraphy

Biostratigraphic analysis of the pre-evaporitic sequence of Kalamaki section indicates that the stratigraphic interval below the gypsum units may be attributed to the late Messinian, based on planktonic foraminifera assemblages and mainly the distribution range of *Turborotalita multiloba* (Karakitsios et al., 2013). The planktonic foraminifera assemblages are characterized mainly by *Turborotalita quinqueloba* and *T. multiloba*, whereas *Globigerinoides obliquus*, rare specimens of *Globigerinoides quadrilobatus*, *Globigerina bulloides*, *Orbulina* spp., *Globigerinita glutinata*, *Neoquobocadrina acostaensis* and rare specimens of *Globoturborotalita decoraperta* are also present. *Turborotalita multiloba* is very abundant and dominates the assemblages from the base of the section, as well as *N. acostaensis* dextral coiling specimens. Sinistral coiled specimens of the latter species are very rare in the Kalamaki assemblages, indicating that the base of the section may be placed within the MMi 13c *Turborotalita multiloba* interval Zone, dated above the age of 6.36 Ma. Several bioevents were recognized, such as the influxes of *G. scitula* gr. and sinistral coiled *N. acostaensis*, indicating that the pre-evaporitic sequence of Kalamaki area ranges up to 6.0 Ma.

Lithology and biostratigraphy of the Kalamaki section.

ATNTS2004 Gradstein et al., (2004)		CHRONO-STRATIGRAPHY		Mediterranean Biostratigraphy		Planktonic Foraminiferal Bioevents	
Age	Polarity	Magneto Zones	Period	Epoch	Stage		
5		C3	NEOGENE	Pliocene	LOWER	Zanclean	Non Distinctive Zone
6		C3A			UPPER	Messinian	
7		C3B		Miocene	Tortonian		



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