

Fish mass mortality in the Upper Miocene laminated gypsum of western Crete (Hania Province, Greece)

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Abstract

The study of the fossil fishes from two outcrops of fossiliferous laminated Messinian gypsum of western Crete has provided new information concerning the deposition conditions of this gypsum. It is shown that the observed mass mortality events did not happen annually, as demonstrated by one slab bearing fossil *Aphanius crassicaudus* (AGASSIZ) belonging to two different year classes. Moreover, the formerly reported occurrence of fossil clupeids in this gypsum indicates that its precipitation did not occur in highly concentrated waters. Consequently, it appears that the gypsum precipitation took place in lagoons filled with sulphate-rich waters having a rather low content of dissolved sodium chloride.

Key words: Crete, Greece, Messinian, gypsum, fishes, cyprinodontids, *Aphanius crassicaudus*, palaeoenvironment.

1. Introduction

The island of Crete is presently well-known for its Neogene fossil fish localities: Tortonian of the Ierapetra Basin (GAUDANT 2004), Messinian of the Messara Basin (GAUDANT et al. 1997) and Pliocene of the Heraklion Basin (GAUDANT et al. 1994; GAUDANT 2001). The purpose of this paper is to shed some light on two Messinian localities in

the Hania Province (western Crete) that have yielded fossil fishes preserved in thinly bedded gypsum (Fig. 1).

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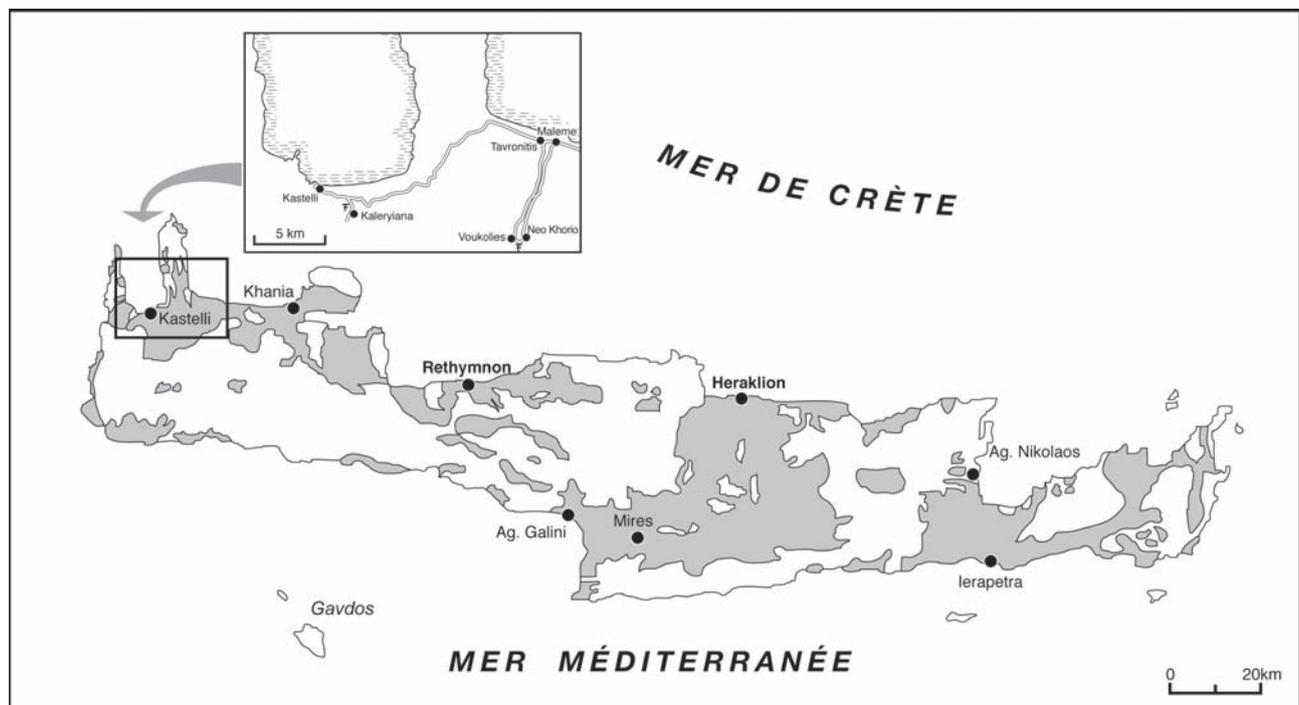


Fig. 1. Map of western Crete showing the two studied outcrops of Messinian gypsum.



Fig. 2. Slab showing many specimens of *Aphanius crassicaudus* (AGASSIZ) belonging to two year classes. Specimen P 287, kept in the Department of Palaeontology of the Natural History Museum, London.

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2. Fishes from the old quarries at Kaleryiana near Kastelli-Kissamos

During the year 1845, the French geologist VICTOR RAULIN travelled through Crete during more than seven months for the French National Museum of Natural History. The results of his observations were published some

time later (RAULIN 1860–1862, 1869). He was the first geologist to report the occurrence of “some holes from which was extracted a yellowish grainy stratified gypsum in which small fossil fishes are preserved”, near the village of Kaleryiana, 2.5 km SE of the city of Kastelli-Kissamos (RAULIN 1869: 110). There he collected several slabs bearing fish specimens and sent them to the French National Museum of Natural History. This material consists of nine specimens having a standard length ranging from 25 to 46 mm. Later, RAULIN noted: “In October [1845] some people were bringing to Khandia small plates on which were preserved skeletons of small fishes that were recognized by Agassiz as being the *Lebias crassicaudus* from Senigallia” (RAULIN 1869: 563). This is confirmed by the fact that the London, Vienna and Geneva museums of Natural History had at that time purchased fossil fishes from Crete preserved in similar yellowish laminated gypsum.

In 1995, it was still possible to collect at Kaleryiana, in the whitish to yellowish gypsum exposed at a few hundred metres to the north of the village (FREUDENTHAL 1969, outcrop 295), several small fossil fishes having a standard length measuring about 20 mm. All belong to *Aphanius crassicaudus* (AGASSIZ).

2.1. Studied material

Geological collections of the French National Natural History Museum: nine slabs collected by RAULIN, bearing articulated skeletons of *Aphanius crassicaudus* (AGASSIZ); catalogue number MNHNF-8.V.601.

Palaeontological collections of the Naturhistorisches Museum in Vienna: four slabs were registered in the catalogue during 1847 (1847-XXVI-1 to 4) and seven other ones seven years later (1854-III-48 to 54). All fish specimens belong to *Aphanius crassicaudus* (AGASSIZ).

Palaeontological collections of the Geneva Museum of Natural History: nine uncatalogued slabs bearing small articulated skeletons of *Aphanius crassicaudus* (AGASSIZ).

As noted by WOODWARD (1901), the British Natural History Museum (London) had also purchased seven slabs of fossil fishes from Crete. Five of them are bearing fishes belonging to *Aphanius crassicaudus* (AGASSIZ): P 1834 (“Crete”, EGERTON’S collection), P 4505 (“Crete”, ENNISKILLEN’S collection), 24555-56 (“Crete”, purchased in 1849 and 1858), and P 287 (“Retimo, Crete” [transferred from the Museum of Practical Geology, 1880]). For these fishes that have been probably collected from the gypsum outcrops in the surroundings of Kastelli-Kissamos, WOODWARD (1901: 295) created the genus *Pachylebias* WOODWARD, “on account of the remarkable hyperostosis of the vertebral axis”. On the two other slabs (P. 1873 and P. 33754) there are preserved an incomplete skeleton and the head of clupeids that have been referred to the species *Alosa crassa* SAUVAGE (GAUDANT 1980). It should be emphasized that the origin of this material is rather imprecise as the only city name (Retimo = Rethymnon) is clearly mistaken, because no Upper Miocene gypsum outcrop is known in the vicinity of this city and even in the whole Rethymnon Province. For this reason, “Retimo” makes probably reference to the probable residence of the fossil trader.

2.2. Discussion

The slab P 287 (Fig. 2) is especially interesting because it bears, on a surface of about 200 square centimetres, two more or less adult specimens showing hyperostosis, that have standard lengths of 46 and 53.5 mm, and about twenty juveniles ranging from 20 to 28 mm in standard length. This density is indicative of a mass mortality episode which suddenly killed all the fishes present in this

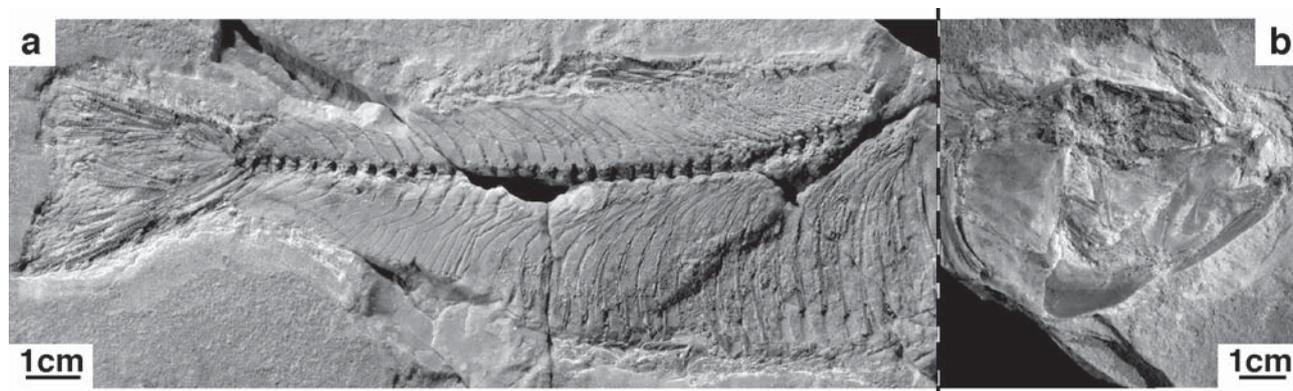


Fig. 3. *Sardina crassa* (SAUVAGE). Two slabs from the Messinian gypsum of western Crete bearing (a) an articulated skeleton (P. 1873) and (b) a head (P. 33754) which is shown here inverted. Both specimens are kept in the Department of Palaeontology of the Natural History Museum, London.

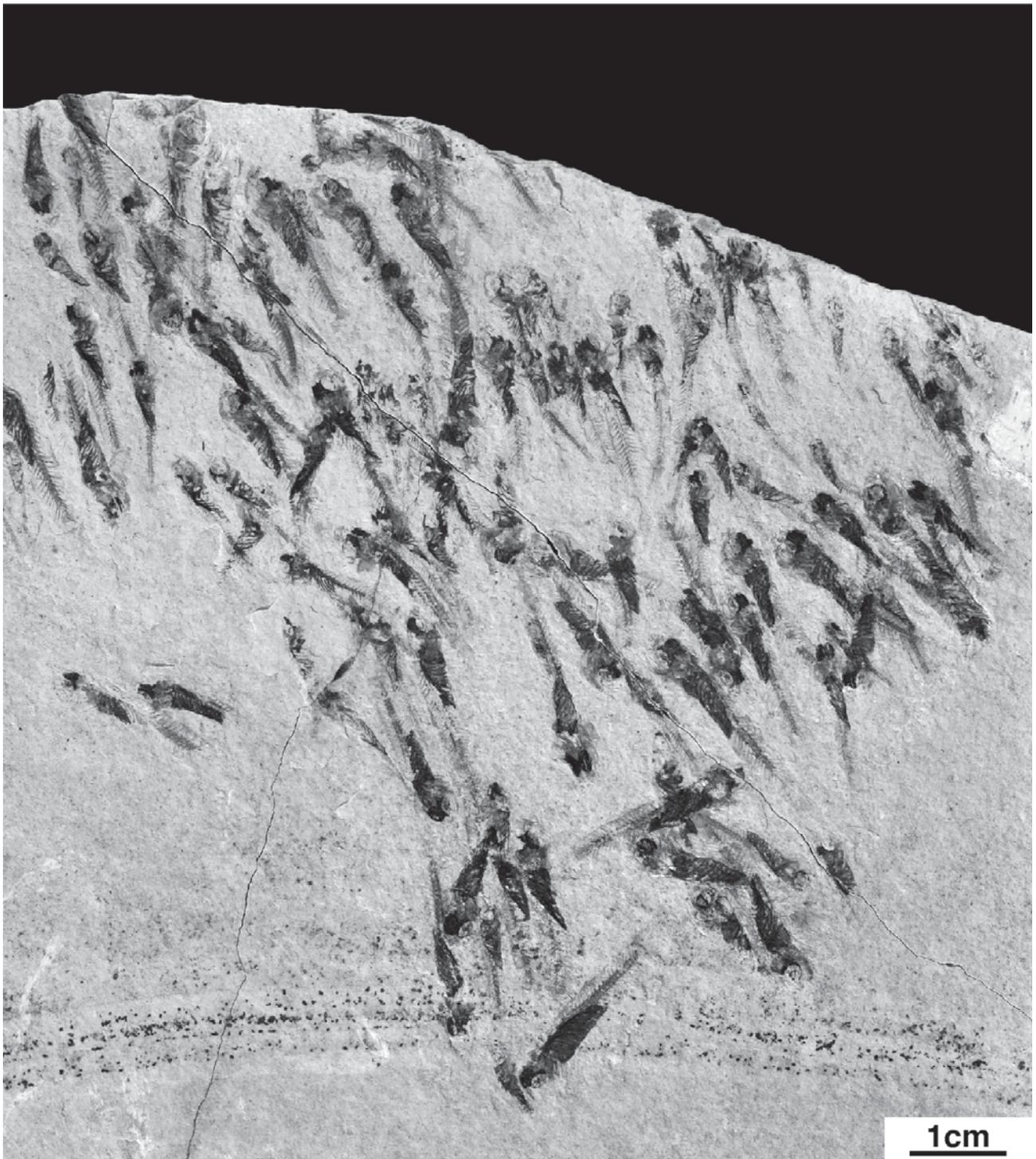


Fig. 4. Slab from the Messinian gypsum of Voukolies showing a shoal of young *Aphanius crassicaudus* (AGASSIZ). Specimen MNHNF-VKL 1, kept in the palaeontological collections of the French National Museum of Natural History.

environment, which was characterized by calm conditions, as shown by the lacking of preferential orientation of the fish skeletons. Two causes may be invoked for explaining the death of these fishes: either a drastic increase of the sulphate concentration of the water, or a brutal decrease of the oxygen content of the water. In the first case, it would imply a very high concentration through evaporation of the original sea water, as suggested by the fact that, according to STURANI (1973), the Recent species *Aphanius fasciatus* NARDO can tolerate saline concentrations of 144 ‰ and support noxious substances such as H₂S (up to 12 mg per litre) and free sulphur (up to 2640 ppm). However, the occurrence in the same laminated gypsum from Crete, of a rather stenohaline marine clupeid, *Sardina crassa* (SAUVAGE), formerly described by GAUDANT (1980) as *Alosa crassa* SAUVAGE (Fig. 3), is not compatible with such a concentration, because clupeids are unable to support highly concentrated saline waters, whereas some can live in hypohaline waters. Consequently, the fossiliferous gypsum from western Crete cannot have been precipitated in normal marine water, because in such conditions gypsum precipitation starts only when the reduction of the initial water volume is over 80%. For this reason, the hectomb of fishes was more probably the result of a sudden decrease of dissolved oxygen in the water of the coastal lagoon in which they were living. Evidently, this process had not an annual periodicity, as shown by the fact that two year classes of fishes having significantly different standard lengths were living together.

3. Fishes from the gypsum of Voukolies

Another fossiliferous locality of Messinian gypsum was found by ADOLF WURM (1886–1968) during the Second World War, between the villages of Voukolies and Neo-Khorio, at about 7 km SSW of Maleme and 14 km

ESE of Kastelli-Kissamos (Fig. 1). He collected there many fossil fishes preserved in a whitish to light bluish laminated gypsum, which was exploited at that time. This material, originally kept in the Department of Geology of the Julius-Maximilians-Universität Würzburg, is currently being transferred to the Bayerische Staatsammlung für Paläontologie in Munich. It consists of juveniles having a standard length of about 20 mm, which are unharmed of hyperostosis, whereas hyperostosis is developed in larger specimens having standard lengths larger than 30 mm. FREUDENTHAL (1969) visited this outcrop of fossiliferous gypsum, which is situated at a short distance southward of Voukolies and Neo-Khorio (his outcrop 316).

3.1. Studied material

The material examined in the Department of Geology of the Julius-Maximilians-Universität Würzburg (WURM collection) consists of about fifty slabs bearing small fishes having a standard length ranging between 15 and 62 mm. All belong to *Aphanius crassicaudus* (AGASSIZ).

The material newly collected by the author at Voukolies includes forty slabs bearing small fishes belonging to *Aphanius crassicaudus* (AGASSIZ). Their standard lengths range from 12 mm to ca. 55 mm.

Additionally, five slabs are bearing shoals of small fishes. This material is kept in the palaeontological collections of the French National Museum of Natural History (MNHNF-VKL 1 to VKL 45).

3.2. Discussion

Among the material collected at Voukolies in 1995, there is a remarkable slab (MNHNF-VKL 1) exhibiting a shoal of very small fishes (Fig. 4). This sample displays



Fig. 5. *Aphanius crassicaudus* (AGASSIZ). Juvenile specimen from Voukolies unharmed of pachyostosis (standard length 22 mm). Specimen MNHNF-VKL 15, kept in the palaeontological collections of the French National Museum of Natural History.

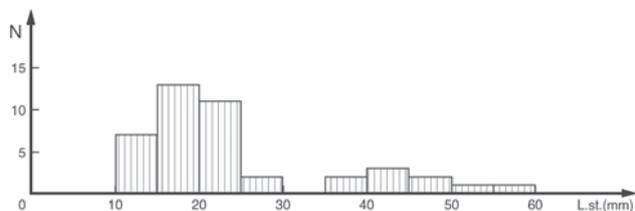


Fig. 6. *Aphanicus crassicaudus* (AGASSIZ). Histogram of measured and estimated standard lengths of the isolated specimens collected at Voukolies in 1995.

about 75 specimens having standard lengths ranging from 15 mm to 20 mm on a surface of about 90 square centimetres. All these small fishes belonging to the same species: *Aphanicus crassicaudus* (AGASSIZ). They are unharmed of hyperostosis, as well as the isolated fishes having the same size (Fig. 5). They were living in an environment characterized both by a low biodiversity and a high productivity, which was from time to time abruptly submitted to lethal conditions, probably produced by a sudden depletion of the dissolved oxygen content of the water.

Taking into consideration the structure of the population sampled at Voukolies in 1995, it clearly appears that it consists of two year classes separated by a small gap (Fig. 6); juveniles having a standard length which is less than 30 mm are by far the most frequent (79%), whereas those having a standard length over 35 mm and are probably the representatives of the second year class, are hyperostosed.

4. Conclusions

The study of samples collected from two different Messinian outcrops in western Crete showing examples

of fish mass mortality has provided new arguments for reconsidering the precipitation conditions of this fossiliferous gypsum. Obviously, it could not have proceeded from the evaporation of normal marine water, but from that of sulphate rich water in which the concentration of dissolved sodium chloride was rather low, so that the gypsum precipitation was compatible with the formerly reported occurrence of living clupeids: *Sardina* [=“*Alosa*”] *crassa* (SAUVAGE) in lagoonal waters (GAUDANT 1980). This may suggest that the fossiliferous laminated gypsarenite proceeds from a resedimentation episode, as already proposed by LO CICERO & CATALANO (1978). Another point of interest is that the mass mortality event shown by the two figured slabs demonstrates that the conditions of life in this lagoon allowed the life of shoals of juvenile *Aphanicus* together with larger fishes belonging to another year class.

A rather similar situation is known from the evaporitic Messinian of the Caltanissetta Basin, in the laminated gypsum that constitutes the basal layer of the upper evaporites (DECIMA & WEZEL 1973; DECIMA et al. 1988; ROVERI et al. 2008). For example, adult specimens of *Aphanicus crassicaudus* (AGASSIZ) (Fig. 7) have been recovered from a thinly bedded gypsarenite at about 3 km SSW of Montedoro, when digging a pipeline trench. Additionally, some surfaces of the same bed exhibit shoals of juvenile fishes, as shown by a poorly preserved specimen kept in the palaeontological collections of the French National Museum of Natural History (MNHNF-PTE 748). However, no clupeid has ever been found in that outcrop.

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Fig. 7. Adult specimen of *Aphanicus crassicaudus* (AGASSIZ) from the thinly-bedded Messinian gypsum of Montedoro (Caltanissetta Province, Sicily). Specimen MNHNF- PTE 747, kept in the palaeontological collections of the French National Museum of Natural History.

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