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# ARAGONITE WHITINGS OF PLIOCENE AND PLEISTOCENE AGE IN THE AREA OF CORINTH

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**ABSTRACT**

White laminae of aragonite needles and stellate clusters up to 10 μm in diameter are interlated within marly sequences of Upper Pliocene/Lower Pleistocene age (W of Corinth) and of Upper Pleistocene age (Saronic Gulf). All aragonites show high Sr contents and heavy carbon and oxygen isotope values. However, values for these layers differ significantly between both localities. At both localities the white varves are intercalated in the transition zone between nonmarine and marine formations. The nonmarine environment is shown by lacrustine times in the Gulf of Corinth and the Saronic Gulf corresponding to glacial periods, when the sea-level was significantly lower than today. With rising sea-level, the lakes (different in water composition due to different drainage area and fresh-water influx) became flooded by the sea. At such times aragonitic whitings are widespread combined with high summer temperatures and with algal blooms extracting $CO_2$ from the sea water. The aragonites differ in composition from lake to lake due to their different initial water composition.

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**INTRODUCTION**

Examples of modern whitings of marine origin have only been described as aragonitic precipitation from the Great Bahama Bank (CLOUD 1962, SHINN et al. 1989) and within the Persian Gulf (WELLS & ILLING 1964). In contrast, carbonate whitings of lacustrine origin have been reported from several localities: aragonitic precipitation in the Dead Sea (BLOCH et al. 1944, NEEV 1963) and in the Pyramide Lake (GALAT & JACOBSEN 1985), or calcitic precipitation in the North-American Great Lakes (STRONG & EADY 1978). PURDY (1963) and FRIEDMAN (1965) discuss four theories for the origin of such carbonates: bacterial origin, derived origin, physico-chemical origin, and skeletal disintegration origin.

Fossil whitings could have been widespread in the past, but until now only the white aragonitic layers within the Pleistocene Lisan Formation of Israel have been identified as true whiting sediments. The sediments of the latter sequence were deposited in an ancient precursor of the Dead Sea, and the aragonitic crystallites are of the same shape as the recent stellate clusters described by BEGIN et al. (1974) and DRUCKMAN (1981).

**LOCATIONS**

White aragonitic layers up to dm thickness are intercalated within the Plio/Pleistocene Corinthian Marl near Corinth (locality 1 in fig. 1) and within the uppermost meters of sediment within the Saronic Gulf (locality 2 in fig. 1).

The older layers are exposed west of Corinth, close to the "km 88" signpost on the road Corinth-Kiato. South of the railway, a cliff shows the uppermost part of the Corinthian Marl (Pliocene according to v. FREYBERG 1973) discordantly overlain by marine-nonmarine sequences of Quarternary age (RICHTER & SEDAT 1983).

The younger aragonites were found in the drillcore SAR 19, east of the Peleponnese (coordinates 37°42.80'and 23°12.20'; 270 m waterdepth; length of core - 290 cm). Within the soft, marly sequence, aragonitic laminae are intercalated from 290 cm up to 50 cm below the sediment/water interface. Radiocarbon analyses of two samples by Beta Analytic Incoporation (Coral Gables, Florida) indicate an Upper Pleistocene age: sample 1 (283 -



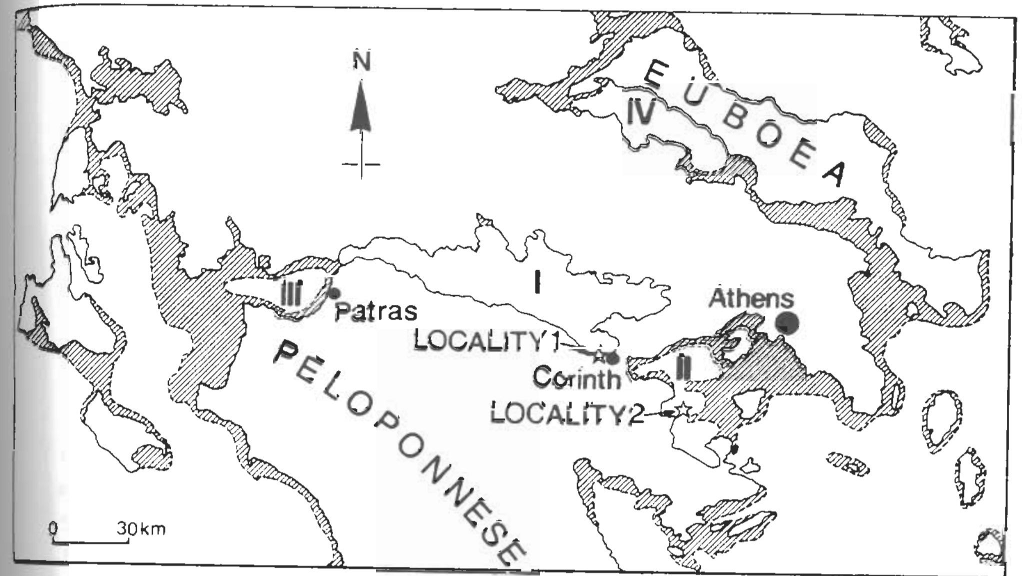


Figure 1

**CAPTIONS**

Figure 1: Scetch map of middle Greece with sample locations in the Corinthian area. The hatched area shows the sea with water depth shallower than 100 m, which will be land during a glacial eustatic lowering of the sea level. At such times there are four large lakes between Peloponnese and Euboea: I. Corinthian Lake, II. Saronic Lake, III. Lake of Patras, IV. Lake of Euboea. The correct boundaries of the (Plio/)Pleistocene lakes should be slightly different due to neotectonic movements. After RICHTER 1984.

290 cm) 18960 ±120 years B.P. (Beta 40238), sample 2 (83 - 90 cm) 18380 ± 130 years B.P. (Beta 40236).

## GELOGICAL SETTING

Both occurrences of aragonitic layers are situated in the lowermost parts of marine sedimentary sequences resulting from a marine ingression due to eustatic sea-level rise. In the course of such ingressions, lacustrine lakes in the Corinthian an Saronic Gulf were flooded (fig. 1). Near Corinth, the sedimentary sequences overlying Neogene lacustrine deposits can be subdivided into two uppermost Pliocene and six Quaternary megacycles (fig. 2). The lower part of each cycle comprises marine sediments which represent interglacial periods with high sea-level. In contrast, lacustrine to terrestrial deposits in the upper part of these cycles reflect glacial periods with low sea-level outside the lakeland in figure 1 (NEUSER et al. 1982). This cyclicity is epressed not only in species variations within the sediments but also in the composition of ooids. Ooids from the lacustrine parts show a radial structure and are composed of $Mg_{4.5-5.5}$ calcite, whereas the marine ooids have a tangential structure of aragonitic rods and nodules like Bahamian ooids (RICHTER & NEUSER 1987).

The uppermost sediments in the Saronic Gulf were deposited as a result of the postglacial marine ingression of the Saronic Lake. Compared to the Plio/Pleistocene megacycles around Corinth, the sediments out of the Saronic Gulf belong to the lower part of a still active ninth megacycle (No. 6 of fig. 2).

## COMPOSITION OF THE ARAGONITIC LAMINAE

Individual aragonitic laminae in both occurrences are generally less then 1 mm thick (often 10 to 100 µm). However, often clusters of laminae appear macroscopically as one homogenous, dm thick, white aragonitic layer. SEM- and XRD-analyses indicate that the fine lamination is a result of interbedded pure and impure aragonitic layers. Impurities amount up to 10 % and are usually detrital carbonate components (calcite, dolomite, shell fragments, etc.), siliciclastic material (quartz, phyllosilicates, etc.), or organic material. The sediments beneath and above the individual aragonitic laminae and clusters of laminae mainly are composed of marly calcisiltites.



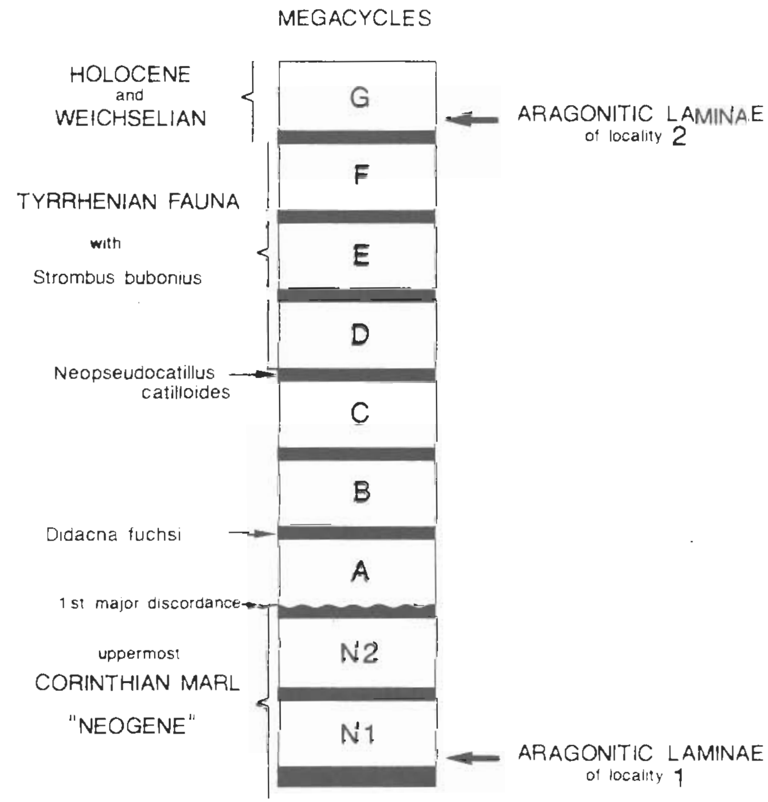


Figure 2

Figure 2: Schematic column of the marine(white)-nonmarine(black) megacycles in the Corinthian area (slightly modified after NEUSER et al. 1982) with the position of the investigated aragonitic laminae.

Pure aragonitic layers are composed of needles and stellate clusters, the size being up to 10 micron in diameter (fig. 3). Both, needles and stellate clusters, show quite a variety of shapes from single aggregates (polysynthetic twinnings, cruciform twins) to perfect spheroids. While aragonites from the Saronic Gulf display clean, fresh crystal faces, the etched surfaces of numerous aragonites from the Corinthian Marl suggest a diagenetic overprint. Particularly the impure aragonitic layers studied in the drillcore from the Saronic Gulf contain up to 10 micron large round aggregates. They have been identified as framboidal pyrite, likely of early diagenetic origin.

Five aragonite samples from the Saronic Gulf and five from the uppermost part of the Corinthian Marl have been measured for their Sr-content using ICP spectroscopy. Both populations show distinctly different Sr-contents of 4200 - 5300 ppm and 7600 - 8400 ppm respectively.

The carbon and oxygen isotopic composition (operator: Dr. H. Strauß, Bochum) of aragonite from the Corinthian Marl suggest a marine origin wheras those from the Saronic Gulf show significantly heavier values (fig. 4).

## INTERPRETATION AND DISCUSSION

Aragonitic needles and stellate clusters are identically to those described from the Dead Sea by DRUCKMAN (1981, fig. 3B). Therefore, white layers of the uppermost part of the Corinthian Marl (locality 1) and of the Upper Pleistocene sediments of the Saronic Gulf (locality 2) are similarly interpreted as results of whitings. Differences in composition (Sr content, C and O isotopes) are due to the different developments of the sedimentary sequences. In both localities, the white varves are intercalated in the transtion zone between nonmarine and marine formations. The nonmarine environment is shown by lacustrine events in the Gulf of Corinth and the Saronic Gulf corresponding to glacial periods, when sea-level was significantly lower than today. With rising sea-level, the lakes became flooded by the sea. Particularly during such times in the eight Plio/Pleistocene megasequences of the Corinthian area, precipitation of aragonitic cements occurred according to RICHTER (1984). Different water composition of the lakes at both localities resulted in different composition of the aragonites.



Figure 3: Scanning electron microscope photographs of aragonitic laminae originating from whitings. A and B: Upper Pleistocene laminae from core SAR 19 (Saronic Gulf); A - spherolitic aggregates of aragonite, B - framboidal pyrite between crystals and clusters of aragonite. C and D: Laminae from the uppermost Corinthian Marl west of Corinth (locality 1); A - spherolitic aggregates of aragonite, B - cruciform twins (center) and spherolitic aggregates (right) of aragonite.

Figure 4: $\delta^{13}C$ and $\delta^{18}O$ values for aragonitic laminae of the Corinthian area. Asterisks - locality 1, dots - locality 2. Hatched area - isotopic composition of normal marine carbonate cements (after SALLER 1984).

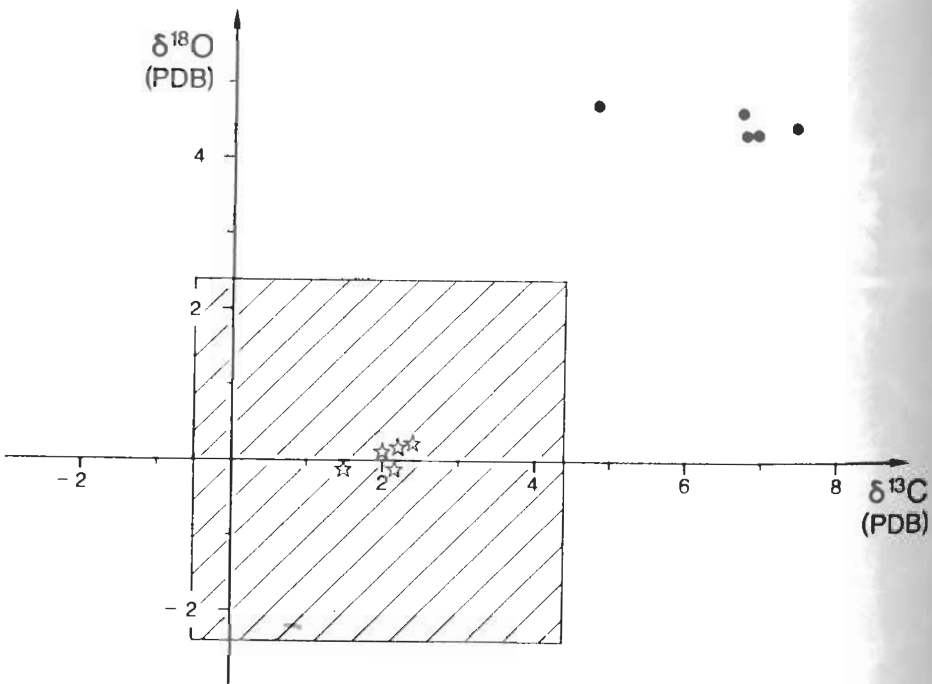


Figure 4



Differences in water composition were caused by different drainage areas of the lakes - high freshwater influx in the Corinthian Lake and low freshwater influx in the Saronic lake, resulting in salinity differences.

For the genesis of the aragonitic whitings we assume high temperatures during summer times combined with algal blooms extracting $CO_2$ from the sea water. This interpretation is in accordance with two experimentally determined facts: a. Aragonite forms under rapid rates of precipitation whereas calcite forms under slow rates (KITANO & HOOD 1965, BUCZYNSKI & CHAFETZ 1991); b. aragonite precipitation in an aquarium is always bacterially mediated and does not occur in a sterile environment (BILLY et al. 1976) - compare similar results of KRUMBEIN (1974) and BUCZYNSKI & CHAFETZ (1991). Due to the specific water composition of the Corinthian Lake and the Saronic Lake, the ingression of the sea resulted in different contents of Sr and in differences in C/O isotopic composition within the aragonitic crystals.

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