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Original article

Discovery of the *Misellina* Zone (latest Kungurian) in the Lentas unit of the Pindos Series (Crete)☆

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ABSTRACT

The origin and significance of the Lentas unit in southern Crete (Greece) is still subject to controversies. New stratigraphical and palaeontological results allow correlations with the classical Pindos-type series in Greece. In particular, new datings from reworked fossiliferous limestone pebbles within the Lentas unit are presented. These data concern especially the carbonate microfacies and carbonate microfossils from the latest Early Permian (i.e., from the late Kungurian Substage or *Misellina* Zone). For the first time in Greece, this period is recognized as being rich in foraminifers and calcareous algae. These fossils are described; especially, two dasycladales *Likanella* (?) *cretae* nov. sp. and *Uragiellopsis bonneauii* nov. sp. are established. The presence of these reworked Palaeotethyan sediments at the base of the Lentas unit suggests a derivation from the Palaeotethyan active margin (arc/fore-arc series).

1. Introduction

From Late Triassic times, the Pindos domain of Greece was a deep-water basin located between the Gavrovo-Tripolitza platform (Greater Apulia) and the Pelagonian units (Stampfli and Kozur, 2006). This domain is well represented in continental Greece, Peloponnese, Crete, and Dodecanese islands. In the Peloponnese, the Pindos-Olonos zone exposes a continuous sedimentary sequence of pelagic facies from the Late Triassic to the Paleocene, overlain by a Palaeocene-Oligocene flysch. Other remnants of the Pindos Ocean, known as the Ethia-Pindos and Mangassa series, are well documented in Crete, but their correlations with the Lentas unit (southern Crete) have never been investigated.

Degnan and Robertson (1998) studied the Pindos sedimentary sequences and defined five main formations in the Peloponnese:

- the Carnian-Norian Priolithos Fm which consists of a flyschoid alternation of litharenites, shales and siltstones and pelagic nodular limestones with *Halobia* spp. Comparable limestones associated with basic volcanic rocks yielded Ladinian-Early Carnian ammonites in the NW Peloponnese (Tsoflias, 1969). Bellini (2002) studied the Priolithos Fm in Kalos Potamos (SE Crete); conodonts indicate a middle Carnian age for the uppermost beds of the latter (Champod and Colliard, 2003). Bonneau and Aubouin (1987) mentioned pelagic Late Devonian conodonts reworked at the base of the Mangassa series, considered as an equivalent of the Pindos series in eastern Crete;
- the Carnian-Liassic Drimos Fm consists of pink to red cherty *Halobia*-bearing limestones alternating with shales and redeposited limestones;
- the Dogger-Malm pelagic Lesteena Fm comprises mudstones, calciturbidites, and abundant radiolarian cherts;
- the Cretaceous Lambia Fm is mostly composed of limestones and redeposited limestones. This formation includes the Klitoria Sandstone Member defined as the Cenomanian-Turonian Pindos first flysch. It is composed of turbiditic sandstones and sandy limestones including ophiolitic debris and volcanic rocks. This flysch episode is transitional to redeposited and pelagic limestones (Senonian-Ypresian), preceding the second Pindos flysch Fm;
- the Palaeocene to Oligocene Pindos Flysch Fm (or second flysch), which is almost completely detrital, including sandstones and siltstones in turbiditic sequences.

The origin and significance of the Lentas unit is still subject to controversy. Davi and Bonneau (1985) first described this unit and proposed a Triassic age for the limestones, but an older age (Permian) cannot be excluded. According to Thorbecke (1987),

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the Lentas unit is an Upper Jurassic-Lower Cretaceous olistolith within the Pindos second flysch unit (Oligocene). In this paper, we focus on the *Misellina* Zone (latest Kungurian) identified in reworked blocks within a conglomerate in the Lentas unit. Until now, only Murgabian-Midian (= Wordian-Capitanian) fusulinids were found in Crete (Bonneau and Lys, 1978; Vachard et al., 1995). In this island, Middle and Upper Permian limestones are generally metamorphosed (anchizone) and/or dolomitized. The discovery of the *Misellina* Zone in Crete permits to test the hypothesis of Vandelli et al. (2009, 2010), who postulated that the Lentas unit could represent the base of the Pindos sequence.

2. Geological setting

In the Tethyan orogenic system, the Aegean external arc, from the Dinarides to the Taurides, dominates the dynamic of the Eastern Mediterranean. The Hellenides are a composite orogenic belt, which underwent two major accretion stages (Papanikolaou, 2009): the Eohellenic phase (Middle Jurassic to Early Cretaceous), and the Alpine phase (Eocene-Miocene). Both have approximately the same vergence towards the South, implying that the palaeogeography is more or less preserved in the current nappe geometry, as well as in the nappe pile. The Hellenides are subdivided into: (1) the Internal Hellenides in the northeast, constituted by the Rhodope massif, the Axios-Vardar zone and the Pelagonian microcontinent, and (2) the External Hellenides to the southwest, including the Pindos domain and the external carbonate platforms, mainly the Ionian zone (non-metamorphic) and the Mani/Talea Ori and Phyllit-Gruppe units (metamorphic).

The island of Crete is almost exclusively constituted by the External Hellenides and exposes a complex nappe structure. Based on their tectonostratigraphic position and their tectono-metamorphic history, these allochthonous units were subdivided into the upper and the lower nappes, separated by a major detachment fault (Kilias et al., 1993). In the studied area (Figs. 1 and 2), only the upper nappes are represented. In a structurally ascending order, they comprise: (**1**) the Tripolitza platform, (**2**) the basinal Pindos domain, (**3**) the Arvi unit whose origin and emplacement is still controversial, (**4**) the Lentas series, (**5**) the Miamou mélange unit, (**6**) the metamorphic Asteroussia nappe, and (**7**) the uppermost ophiolitic nappe. Units (1), (2), and (4) belong to the External Hellenides, whereas units (6) and (7) are part of the Internal Hellenides. The Arvi and Miamou units were grouped together in a tectonic mélange of unknown origin (Fassoulas, 1995).

The Tripolitza platform (1) is a thick sedimentary sequence deposited between the Late Triassic and the Oligocene. In the Lentas area, only the youngest part is exposed. Grey Kimmeridgian limestones and dolomites have been identified during our study. Upper Cretaceous black limestones with rudists overlie the latter. The series evolves towards Palaeocene to latest Lutetian black and dark-grey limestones and an uppermost Eocene to Oligocene flysch series, pelitic at the base and grading into sandstones towards the top.

The Pindos sedimentary sequences (2) consist in a small-scale continuous but dismembered basinal series, ranging from Middle-Upper Triassic to the Tertiary, presenting proximal to distal facies, and concluding with Tertiary flysch deposits.

The Arvi unit (3) was divided by Davi and Bonneau (1985) into four main facies: the Upper Triassic limestones, the flyschoid series (probably Upper Jurassic), the Upper Cretaceous limestones, the pillow basalts with their sedimentary cover represented by red shales and a flysch succession (Senonian?-Maastrichtian). The geochemical analysis of these basalts yielded a within-plate-basalt

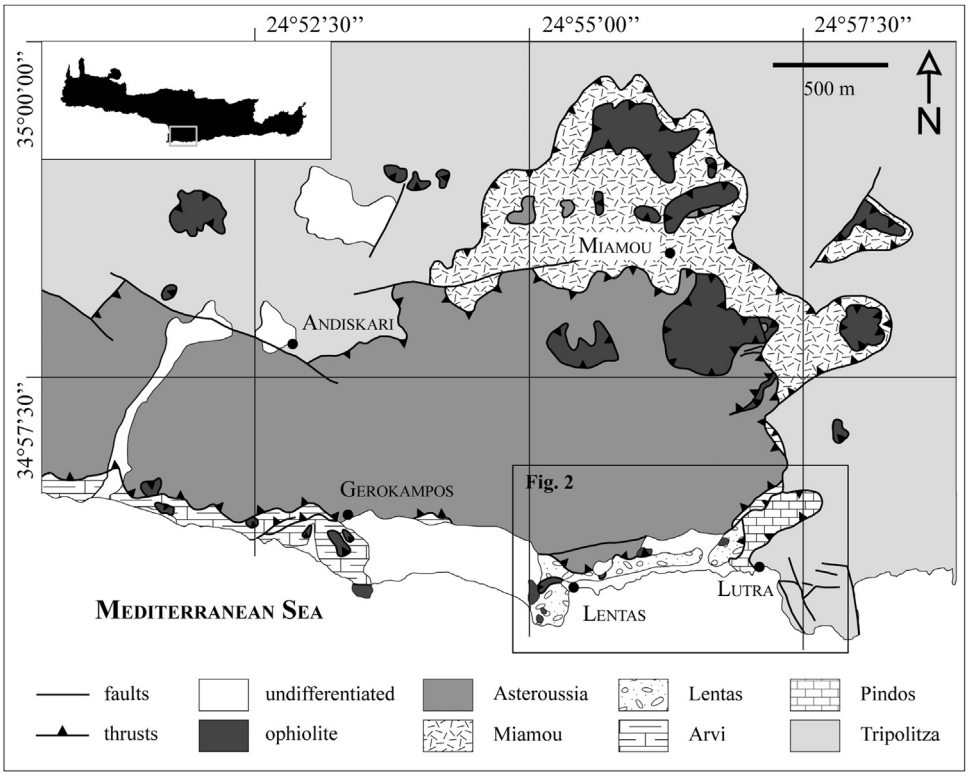

Fig. 1. Simplified geological map of southern Crete.
Modified after Davi and Bonneau (1985).