Journal of Palaeogeography
2013, 2(3): 252−274
DOI: 10.3724/SP.J.1261.2013.00030

Lithofacies palaeogeography and sedimentology

Lithofacies palaeogeography and biostratigraphy of the lowermost horizons of the Middle Triassic Hallstatt Limestones (Argolis Peninsula, Greece)

Fotini A. Pomoni[1, *], Vassilis Tselepidis[2]

1. Department of Geology and Geoenvironment, University of Athens, Panepistimiopolis 157 84, Athens, Greece
2. Institute of Geology and Mineral Exploration, Olympic Village, Acharnae, P.C. 13677 Athens, Greece

Abstract Condensed ammonoid beds of the Hallstatt facies (Anisian−Ladinian) are widespread around the Ancient Theatre of Epidaurus, in the locality Theokafta of the Argolis Peninsula (eastern Peloponnesus). The Hallstatt Formation in Argolis appears, generally, in the form of lensoid bodies of variable sizes, inclination and direction and is always found overlying a formation consisting of keratophyric tuffs. In fact, the contact of the keratophyric tuffs with the overlying limestones, specifically evidenced by an *in situ* brecciated zone, is stratigraphic and constitutes the base of the Hallstatt Limestones. The contact of the Hallstatt Limestones with the overlying radiolarites is stratigraphic as well.

Lithofacies and biostratigraphic research has focused on the lowermost horizons of the Hallstatt Limestones of Anisian age (average thickness about 1.30 m), where a dense sampling has been performed, followed by detailed facies analysis. The lowermost horizons of the Hallstatt Limestones of Theokafta represent typical hiatus beds/concretions *sensu* Wetzel and Allia (2000), characterized by discontinuous sedimentation and erosion. They consist of red ammonoid-bearing hemipelagic limestones with calcium carbonate nodules floating in an enriched Fe-oxides matrix with dispersed lensoid/prismatic calcium carbonate crystals. This part of the section is characterized by condensed sedimentation, due to significant lowering of the rate of sedimentation and includes omission surfaces, firmgrounds and hardgrounds along certain horizons. Nine lithostratigraphic units have been distinguished in the lowermost horizons of the Hallstatt Limestones, including radiolarian packstones, volcaniclastic facies, packstones/floatstones with ammonoids and lag deposits.

Tselepidis (2007) defined nine distinct ammonoid biozones from the Anisian to Ladinian, documenting deposition of the Hallstatt facies during a low depositional rate over nearly 5 million years (using the timescale of Gradstein *et al.*, 2004). The biozones: *Japonites*/*Paracrochordiceras*, *Hollandites*, *Procladiscites*/*Leiophyllites*, *zoldianus*, *trinidosus*, *Reitziites*/*Parakellnerites* and the *Nevadites* (Anisian) and the biozone *curionii* (Lower Ladinian). Although sedimentation was very condensed, it didn't reach the level of mixing fauna.

Synsedimentary and early burrowing processes differentiated the primary texture characteristics of the deposited sediments. Multiphase diagenesis occurred not very deep below the sediment surface and includes boring and/or encrustation, burial and cementation. The deposition of the studied Hallstatt Limestones is considered to be due to anaerobic oxidation of organic matter, which provided excess alkalinity, inducing carbonate precipitation. Sedi-

* Corresponding author. Email: fpomoni@geol.uoa.gr.
Received: 2013−03−30 Accepted: 2013−05−06

mentation took place on differentially-subsided deep swells. After drowning, the swells were covered by pelagic carbonate deposits. Further slight rotation of blocks, along listric faults, may have led to additional differential subsidence of the blocks. Shelf bathymetry and third-order sea-level changes played a significant role in the formation of the Hallstatt beds. In terms of sequence stratigraphy, the studied hiatus concretions and beds are considered genetically linked to rising or high sea-level, formed at the initiation of transgressions, as well as during the time of maximum rate of transgression, in areas where the sediment input was strongly reduced (‘‘condensed section’’) .

Taking into consideration the present location of the Hallstatt Formation, in the context of the Hellenides, an area suitable for the deposition of the Hallstatt Limestones, should be located between the sub-Pelagonian (western part of the Pelagonian zone) and Pindos geotectonic zones, which during the Triassic corresponded to a platform slope and a deep ocean, respectively. The widespread Middle Triassic Han Bulog Limestones (ammonoid-bearing pelagic limestones) from Triassic successions of the Eastern Alps (Dinarides, Hellenides) may have formed partly in similar slope environments.

Key words Middle Triassic, Hallstatt Formation, facies analysis, ammonoid biozonation, condensed pelagic sedimentation, palaeoenvironment, eastern Peloponnesus

1 Introduction

Ammonoid-bearing pelagic carbonate formations on top of platforms, following a significant stratigraphic break, are very common in Middle Triassic sequences of the southern and eastern Alps (Assereto, 1971; Schlager and Schollnberger, 1974; Epting *et al.*, 1976; Brandner, 1984; Angiolini *et al.*, 1992; Brack *et al.*, 2007; Monnet *et al.*, 2008). These formations are condensed, red, micritic, sometimes nodular, rich in cephalopods, conodonts and molluscs, and are known as “Hallstatt-type limestones”. The Hallstatt horizons are of particular stratigraphic and geologic interest, as far as the relationship of the Hallstatt facies with surrounding formations and the determination of the stratigraphic level that coincides with the beginning of Hallstatt facies deposition.

Hallstatt facies correspond to hiatus beds/concretions characterized by discontinuous sedimentation and erosion. Hiatus concretions are hypothesized to form during early diagenesis by reworking of carbonate sediments, after a break in sedimentation or seafloor erosion (Voigt, 1968; Raiswell, 1987, 1988; Spears, 1989; Wetzel and Allia, 2000). A prerequisite for the growth of concretions is that they should remain for a considerable time within the sulfate reduction zone (7000 years; Coleman and Raiswell, 1993). The identification of such horizons has a great stratigraphic and sedimentologic value, as they indicate markers of significant interruption of sedimentation that otherwise would not be noticed (Fursich and Baird, 1975; Baird, 1976). Such discontinuity surfaces are commonly not manifested as biostratigraphic gaps (*e.g.*, Wilson, 1985). The hiatus beds, and specifically the hiatus concretions are characterized by a multiphase diagenetic history that occurs not very deep below the sediment surface and includes exhumation, boring and/or encrustation, burial and cementation (Savrda and Bottjer, 1988).

In terms of sequence stratigraphy, hiatus concretions and beds are genetically linked to rising or high sea-level (*e.g.*, Van Wagoner *et al.*, 1988). They are thought to form during the initiation of transgressions (*e.g.*, Voigt, 1968; Fursich *et al.*, 1991), as well as during the time of maximum rate of transgression in areas where sediment input is strongly reduced (‘‘condensed section’’). Similar deposits, considered to have formed during sea-level highstand, were also reported from drowned carbonate platforms by Kendall and Schlager (1981).

However, this simple sequence-stratigraphic interpretation of hiatus beds and condensed sections, is not always valid, because hiatus beds seem to form more frequently during times of tectonic activity than times of intense sea-level changes (Wetzel and Allia, 2000). Other processes, such as a differential subsidence, may produce sediment starvation or seafloor erosion, providing the necessary conditions for formation of hiatus concretions (*e.g.*, Hesselbo and Palmer, 1992).

The Hallstatt facies occur in the following areas of Greece: in Chios Island (Skythian−Lower Anisian; Bender, 1970; Jacobshagen and Tietze, 1974; Gaetani *et al.*, 1992; Mertmann and Jacobshagen, 2003), in Hydra Island (Anisian−Carnian; Römermann, 1968; Angiolini *et*