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NEW STRATIGRAPHICAL AND SEDIMENTOLOGICAL DATA ON THE LOWER CRETACEOUS ROCKS IN SECTION KALOTINA, WESTERN BULGARIA

Daria Ivanova, Athanas Chatalov*,#

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Abstract

Biostratigraphic, microfacies and C–O isotope data from the lowermost Cretaceous deposits in section Kalotina reveal the development of a shallow carbonate platform (Slivnitsa Formation) in a photozoan mode under moderate to high-energy conditions during the Berriasian. Around the Berriasian/Valanginian boundary the carbonate production switched to a heterozoan-type suggesting a biological crisis. After a subaerial exposure in the earliest Valanginian and subsequent karst formation the platform was drowned during the latest Valanginian. Deposition of carbonate-argillaceous sediments (Salash Formation) occurred in a deeper, open-marine environment under mesotrophic to eutrophic, low-energy conditions with periodical formation of crinoid-rich packstones probably by mass gravity flows. Limestone samples from the Slivnitsa Formation yield higher $\delta^{13}C$ values compared to coeval open-marine deposits which can be explained by an elevated amount of aragonite in the photozoan carbonate production and an enrichment in $\delta^{13}C$ of the shallow platform waters due to high levels of photosynthesis. The most depleted $\delta^{13}C$ value in the uppermost part of the unit most likely reflects a change from oligotrophic to mesotrophic conditions. The C-isotope signatures in limestones of the Salash

#Corresponding author.

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Formation indicate correspondence to the third, smooth decrease phase in the $\delta^{13}C$ record of the global Weissert Event (latest Valanginian and Early Hauterivian) where values tend to recover to pre-excursion values.

Key words: biostratigraphy, microfacies, C–O isotopes, carbonate platform, drowning

Introduction. The earliest Cretaceous was a time of significant climate shifts, eustatic sea-level variations and volcanic activity leading to major paleooceanographic and paleoenvironmental changes [1]. Demise and drowning of many carbonate platforms along the northern Tethys margin and elsewhere occurred in the mid- to Late Valanginian [2–4]. The crisis in marine carbonate production was concomitant with a global perturbation of the carbon cycle [2,3,5], known as the Weissert Episode or Event [1,6]. However, fundamental changes in the carbonate factory, such as switch from photozoan to heterozoan assemblages, have been recorded in the earliest Valanginian, i.e., predating the positive $\delta^{13}C$ excursion [4,7,8].

This study presents new biostratigraphic, micropetrographic and C–O isotope data on the Berriasian–Hauterivian rocks outcropping in section Kalotina, Western Bulgaria. Refined age estimates and microfacies analysis are used to interpret the depositional settings, paleoenvironmental conditions and changes in the mode of carbonate production. Variations in the $\delta^{13}C$ compositions are discussed in terms of their possible controls and correlation is made with coeval Tethyan carbonate deposits.

Geological setting. Lower Cretaceous marine sedimentary rocks are widely exposed in the western part of the Srednogorie Tectonic Zone. The latter belongs to the Balkan orogenic system of the Alpine thrust belt on the territory of Bulgaria. The largest area with outcropping deposits of earliest Cretaceous age is located south of the Zabarde region and east of the border with Serbia. The light-coloured limestones in section Kalotina, which occur in the vicinity of the homonymous village (Fig. 1), are referred to as Slivnitsa Formation. This unit has thickness of > 400 m and its chronostratigraphic range has been determined to span from the Middle Callovian to the Upper Valanginian on the basis of microfossils [10,11]. The Lower Certaceous strata were deposited under dominantly low-energy conditions on a shallow restricted platform (lagoon) [11]. The overlying Salash Formation consists of mainly dark-coloured limestones and marls having total thickness of ~ 75 m. Biostratigraphic data based on pelagic macro- and microfauna indicate Late Valanginian–Early Hauterivian age [10,12], and the lower part corresponds to the uppermost Valanginian *Criosarasinella furcillata* ammonite zone [12]. The carbonate-argillaceous sediments were deposited under open sea conditions [10] in a relatively high-energy slope setting [13]. The boundary between the two formations has been defined as short lithological transition [10], or transgressive surface showing characteristics of hardground [13]. The

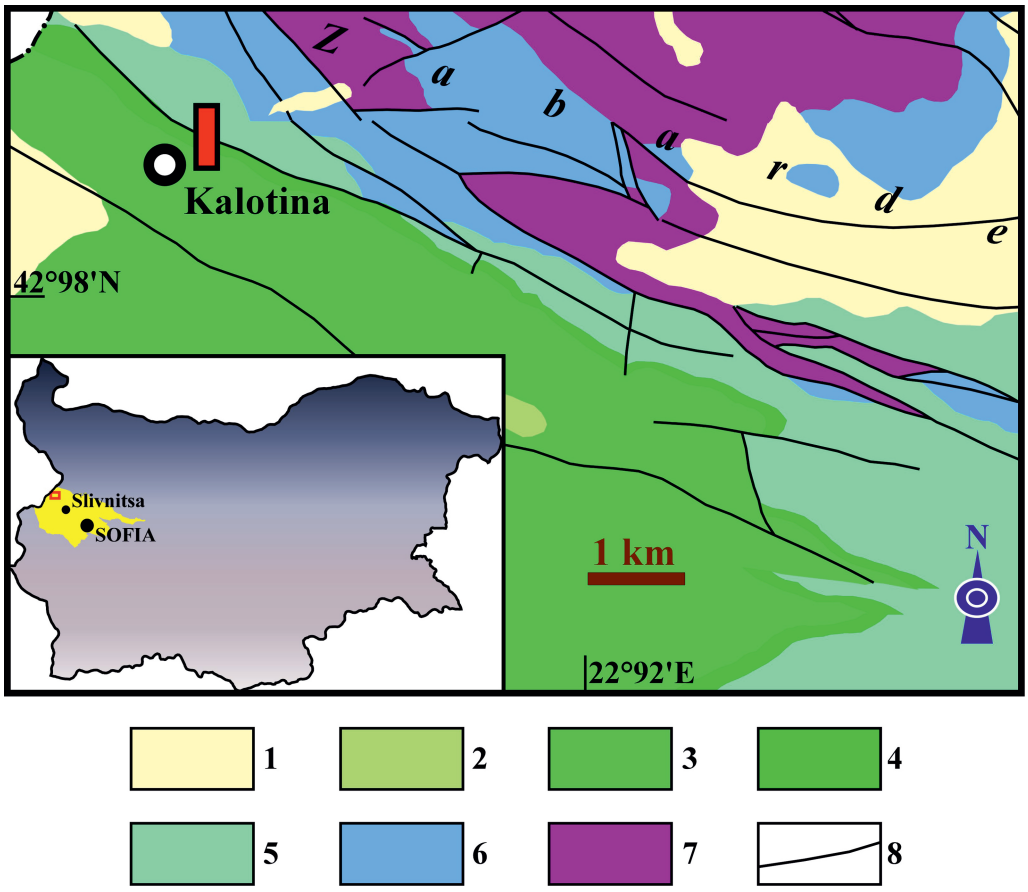


Fig. 1. Geological map of the study area (from Angelov et al. [9]) with location of section Kalotina (42°99′ N, 22°88′ E) shown by rectangle. Legend: 1 – Neogene–Quaternary sediments, 2 – Upper Cretaceous rocks, 3 – Lower Cretaceous rocks, 4 – Salash Fm (Valanginian–Hauterivian), 5 – Slivnitsa Fm (Callovian–Valanginian), 6 – Jurassic rocks, 7 – Triassic rocks, 8 – fault. Inset map: western Srednogorie Zone in yellow

Early Cretaceous sedimentation occurred along the northern margin of the Tethys Ocean adjacent to the European fragment of the Eurasian plate [14].

Material and methods. Limestone samples were collected from the upper part (∼ 100 m thick) of Slivnitsa Formation and the lower/middle levels (∼ 50 m thick) of Salash Formation (Fig. 2) for preparation of forty-six thin-sections. Microfacies types (MF) were distinguished by applying the standard methodology of microfacies analysis. Taxonomic identification and biostratigraphic analysis of some microfossil groups (benthic foraminifera, calcareous dinocysts, calpionellids) were carried out. Thirteen bulk-rock samples were analyzed for carbon and oxygen isotopes on a MAT253 gas isotope ratio mass spectrometer (Thermo Scientific) at the Earth Science Institute of the Slovak Academy of Sciences in Banská Bystrica.

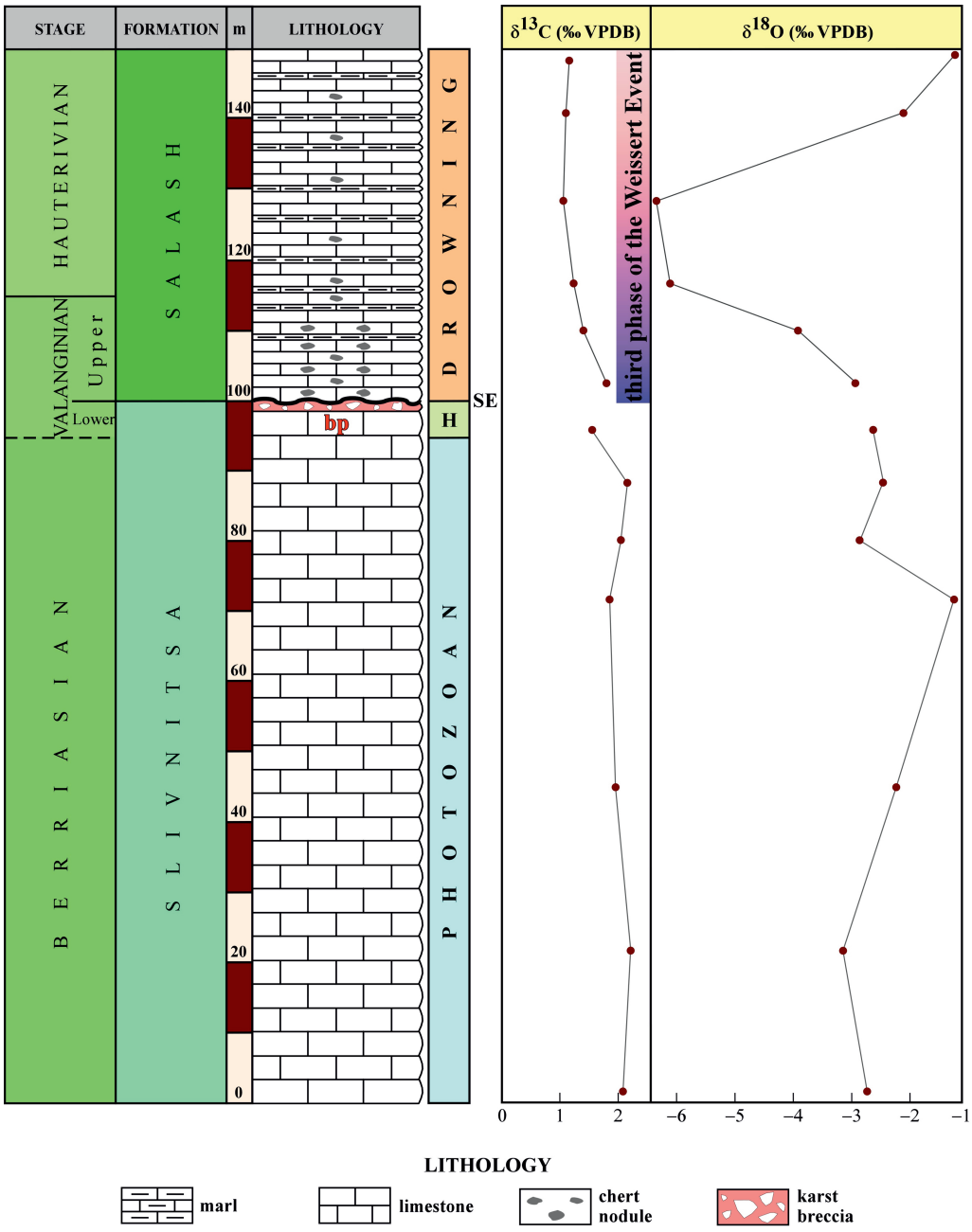


Fig. 2. Stratigraphic-lithologic log, phases of platform development and carbonate production, and C–O isotope curves of the studied Lower Cretaceous deposits in section Kalotina. The age determinations are based on Ivanova et al. [10], Petrova et al. [12] and biostratigraphic data from this study (see text). The C-isotope values in the Salash Formation suggest correspondence to the third, smooth decrease phase in the $\delta^{13}C$ record of the Weissert Event, as described by Martinez et al. [6]. Abbreviations: bp – bioclastic-peloidal grainstones/packstones, H – heterozoan, SE – subaerial exposure

The powdered samples were reacted with H_3PO_4 at 70 °C in a vacuum. The liberated CO_2 was cryogenically purified and introduced to the dual-inlet system of the mass spectrometer. The $\delta^{13}C$ and $\delta^{18}O$ values are reported in per mil units relative to the V-PDB.

Field data, microfacies and biostratigraphy. The thick-bedded limestones of Slivnitsa Formation have grey or light grey colours and dominantly massive structure (Fig. 3a). The top bed is a paleokarst breccia in which pebble- to cobble-sized clasts from the host rock are embedded in reddish carbonate matrix (Fig. 3b). Four limestone MF were distinguished: peloidal-bioclastic-intraclastic grainstone (Fig. 3c), intraclastic-bioclastic grainstone (Fig. 3d), bioclastic-intraclastic packstone with microencrusters (Fig. 3e), and bioclastic-peloidal grainstone/packstone (Fig. 3f) only in the uppermost part of the unit (Fig. 2). The fossil assemblage in the first three MF includes dasyclad algae, large and small benthic foraminifera, thick-shelled bivalves, gastropods and echinoderms. The intraclasts and bioclasts are mainly subrounded and moderately sorted. Other textural components comprise peloids, aggregate grains, radial ooids, micritic oncoids, *Cayeuxia* fragments, bacinellid fabrics and *Lithocodium* crusts. Bladed and fibrous marine cements occur in the grainstones. The fourth MF is characterized by lower relative amount of skeletal grains, disappearance of some organisms (e.g., green algae, microencrusters), reduction in the foraminifera diversity, abundance and test size, occurrence of scarce calpionellids, minor glauconite authigenesis and local presence of clotted-peloidal fabric of the matrix.

The following benthic foraminifera species indicate Berriasian–Early Valanginian age of the studied upper part of Slivnitsa Formation: *Campanellula* cf. *capuensis* De Castro, *Cribellopsis pfenderae* (Canerot & Moullade), *Danubiella gracilima* Neagu, *Everticyclammina cylindrica* Redmond, *Haplophragmoides joukowskyi* (Charollais, Brönnimann & Zaninetti), *Mayncina bulgarica* Laug, Peybernes & Rey, *Meandrospira favrei* (Charollais, Brönnimann & Zaninetti), *Montsalevia elevata* Zaninetti, Salvini-Bonnard, Charollais & Decrouez, *Montsalevia salevensis* (Charollais, Brönnimann & Zaninetti), *Moulladella jourdanensis* (Foury & Moullade), *Pfenderina neocomiensis* (Pfender), *Pseudotextulariella courtionensis* Broennimann, *Valdanchella miliani* (Schroeder), and representatives of the genus *Coscinoconus*. Following Granier [8] and Bucur et al. [15], the Berriasian/Valanginian boundary is tentatively placed at the base of the uppermost interval with bioclastic-peloidal grainstones/packstones which records a significant change in the micropalaeontological communities (i.e., disappearance of calcareous green algae and large benthic foraminifera). The Berriasian limestones were deposited in warm, normal saline, oxygenated waters with very low siliciclastic input under oligotrophic, moderate to high-energy conditions. Diverse skeletal biota flourished in the euphotic zone along with formation of non-skeletal grains and early marine cementation. The shallow platform sedimentation occurred in the tropical carbonate factory. The bioclastic-peloidal grainstones/packstones of

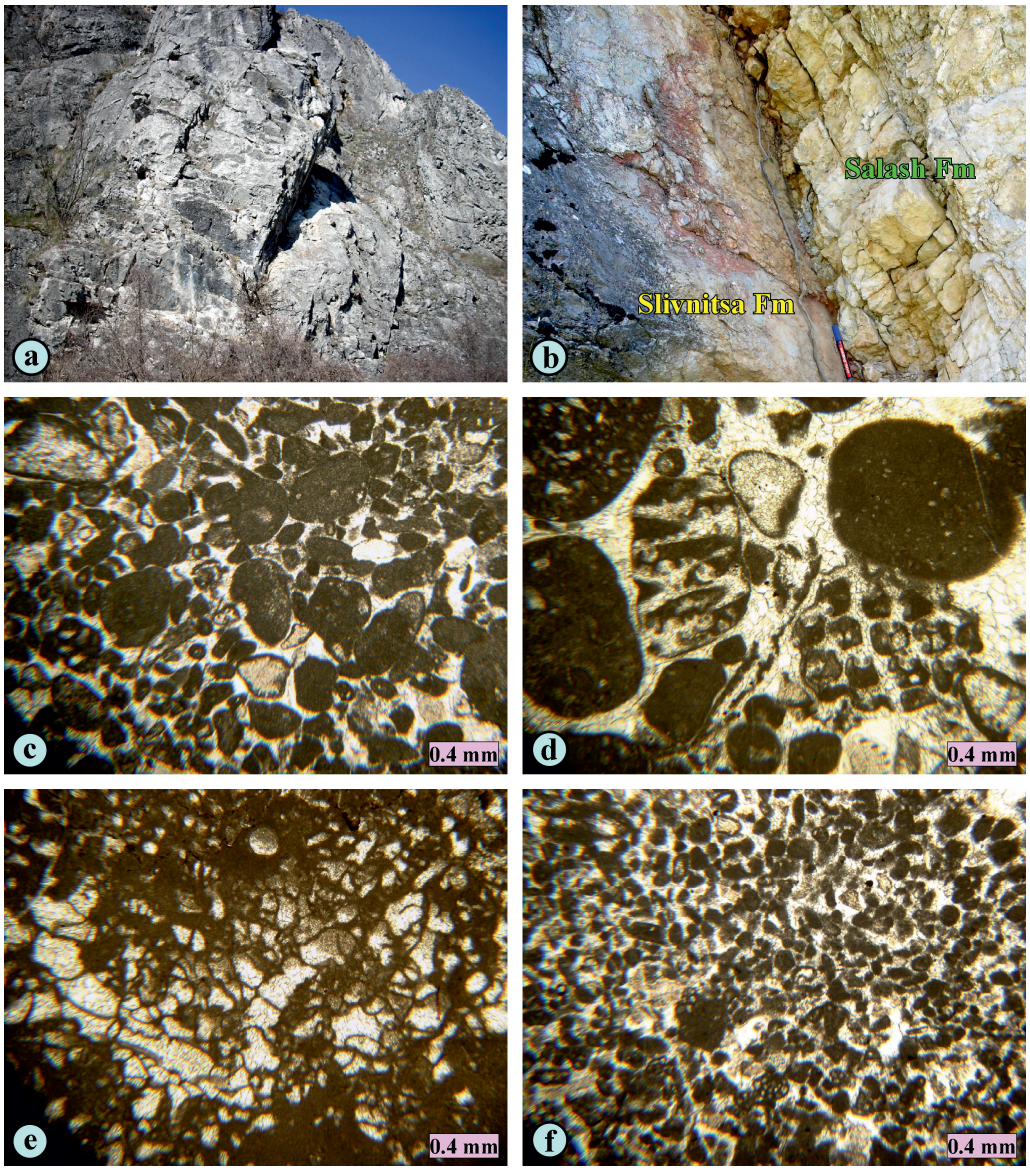


Fig. 3. Macroscopic features and MF types of the Slivnitsa Formation: a – Light grey, thick bedded limestones with massive structure; b – Paleokarst breccia at the top of the unit. Scale: marker pen is 13.5 cm long; c – Peloidal-bioclastic-intraclastic grainstone with subrounded, moderately sorted grains; d – Intraclastic-bioclastic grainstone with large dasyclad fragments; e – Bacinellid fabrics in bioclastic-intraclastic packstone; f – Bioclastic-peloidal grainstone. All photomicrographs are in plane-polarized light

presumed earliest Valanginian age suggest some paleoenvironmental change, i.e., from photozoan to heterozoan mode of carbonate production (Fig. 2), and their microfacies characteristics are indicative for stressful conditions of the platform

ecosystem and probably lower sedimentation rate. The sharp contact with rocks of the Salash Formation is interpreted as a paleoexposure surface recording platform emergence and subsequent karst formation.

The limestones and marls of Salash Formation have various colours (dark grey, grey-beige, ochre, grey-greenish), thin-bedded stratification, massive or laminated structure, and locally chert nodules (Fig. 4a, b). Three limestone MF were distinguished: bioclastic mudstone/wackestone (Fig. 4c–e), spiculite wackestone (Fig. 4f) and peloidal-bioclastic packstone (Fig. 4g). The fossil assemblage in the mudstones and wackestones includes calcareous dinocysts, radiolaria, siliceous sponges, benthic foraminifera (mainly *Lenticulina*) plus scarce calpionellids, thin-shelled bivalves and aptychi. Reworked shallow-water bioclasts, glauconite pellets and silicified patches are locally present. The packstones contain moderately to well sorted crinoid debris and other bioclasts (benthic foraminifera, bivalves, bryozoans, brachiopods). Peloids, intraclasts and detrital grains (quartz, mica) are common additional components.

The lowermost part of Salash Formation corresponds to the Upper Valanginian which is indicated by the calcareous dinocyst species *Stomiosphaera echinata* Nowak (index species of the *St. echinata* zone), accompanied by the species *Colomisphaera heliosphaera* (Vogler), *C. conferta* Rehanek, *C. vogleri* (Borza), *Carpistomiosphaera valanginiana* Borza, *Cadosina fusca cieszynica* Nowak, *C. semiradiata olzae*, and benthic foraminifera typical for this interval. The first occurrence of calcareous nannofossils of the genus *Eprolithus* and the calcareous dinocyst species *Cadosinopsis nowaki* Borza (index species of the *C. nowaki* zone) defines an Early Hauterivian age, as previously noted by Ivanova et al. [10]. Other accompanying species of calcareous dinocysts are *Stomiosphaera echinata* Nowak, *Colomisphaera heliosphaera* (Vogler), *C. lucida* Borza, *Cadosina fusca cieszynica* Nowak and *C. semiradiata olzae* Nowak. The deposition of carbonate-argillaceous sediments began after a long hiatus and was related to a sea-level rise which was rapid enough to outpace the carbonate production and establish a deeper water setting. During this latest Valanginian–Early Hauterivian drowning phase (Fig. 2) the sedimentation occurred in a normal saline, open-marine environment under mesotrophic to eutrophic, dysoxic/suboxic, low-energy conditions. Mudstones/wackestones with carbonate and siliceous pelagic organisms were deposited while scarce bioclasts were transported from shallow-water settings. Fine terrigenous input due to higher runoff during humid periods resulted in marly sedimentation. The crinoid-rich packstones probably represent event deposits in which allochthonous skeletal material and detrital grains were transported from shallower parts of the basin by mass gravity flows.

Carbon and oxygen isotopes. The $\delta^{13}C$ values of all analyzed samples range from 1.10 to 2.21‰, and the $\delta^{18}O$ values are negative ranging from −1.23 to −6.36‰ (Fig. 2). The limestones of Slivnitsa Formation yield relatively uniform $\delta^{13}C$ compositions and a minimum value is recorded in bioclastic-peloidal

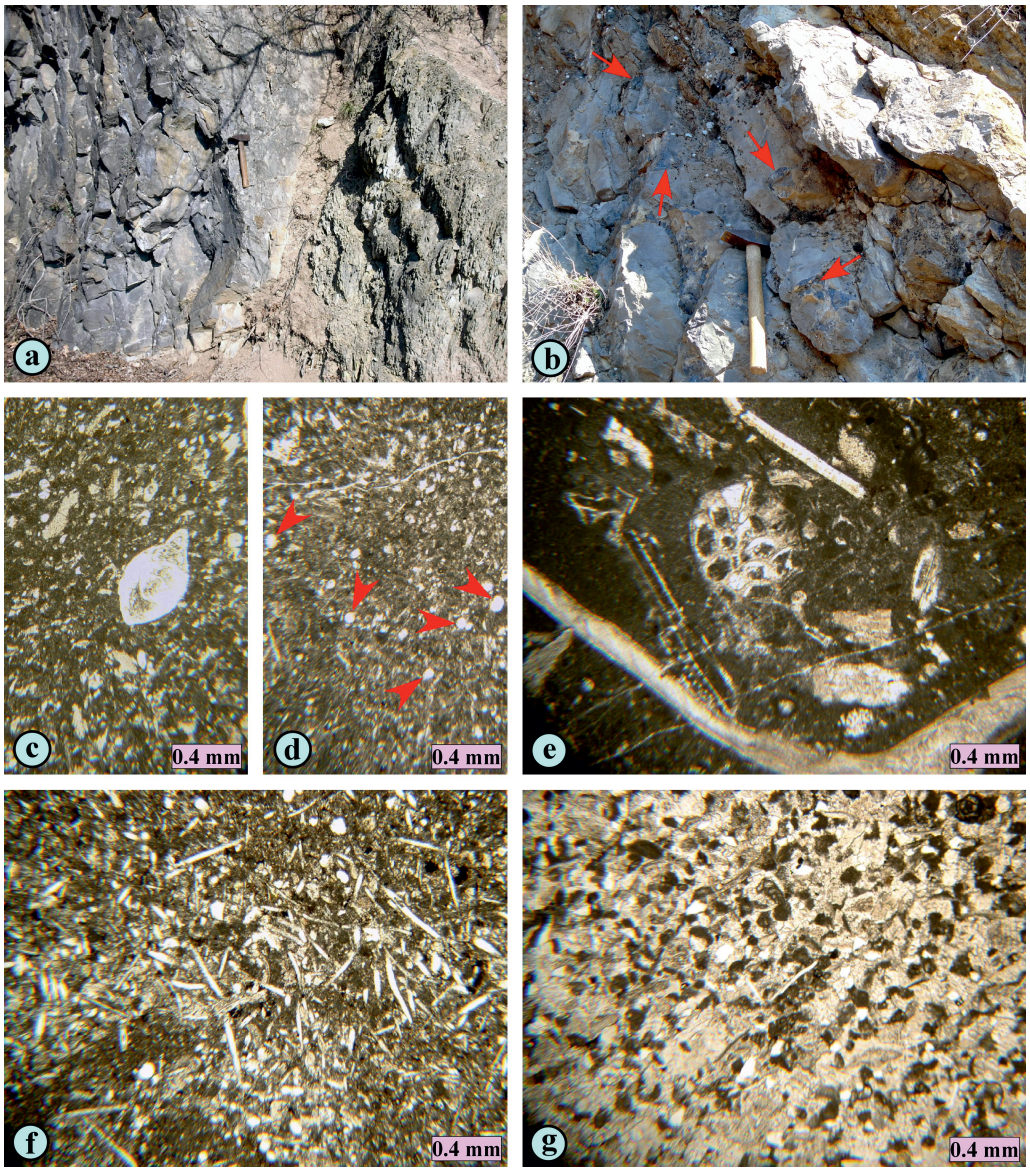


Fig. 4. Macroscopic features and limestone MF types of the Salash Formation: a – Thin-bedded massive limestones (left) and laminated marls (right). Scale: hammer is 33 cm long; b – Limestones with chert nodules (arrows); c – Bioclastic wackestone with *Lenticulina*; d – Bioclastic mudstone with calcified radiolaria (arrows); e – Bioclastic wackestone with resedimented shallow-water skeletal grains; f – Spiculite wackestone; g – Peloidal-bioclastic packstone with dominant crinoid debris. White grains and flakes are detrital quartz and mica. All photomicrographs are in plane-polarized light

packstone from the uppermost part. The samples from Salash Formation have more depleted $\delta^{13}C$ values that outline a decreasing trend and then become stable upward in the section.

The measured C-isotope values are comparable with those recorded in other Berriasian–Hauterivian marine carbonate deposits [2,4–7,16–18], and hence they are considered to reflect a preserved primary signal. Moreover, the lack of covariance between the $\delta^{13}C$ and $\delta^{18}O$ compositions suggests a negligible influence of diagenesis on the isotopic signature [4]. The $\delta^{13}C$ values reported from Berriasian and lowermost Valanginian (hemi)pelagic deposits of the Tethyan realm are generally in the interval 0.5–1.5‰ [4,5,7,16–18], and this is also seen in the global marine carbonate $\delta^{13}C$ stack developed by Price et al. [17]. The samples from Slivnitsa Formation yield more positive $\delta^{13}C$ signatures that are similar to the shallow-water limestones of the Jura platform in France and Switzerland [7]. These higher values compared to coeval open-marine deposits can be explained by an elevated amount of aragonite (e.g., green algae) in the photozoan carbonate sediment production and an enrichment in $\delta^{13}C$ of the shallow platform waters caused by the photosynthesis of carbonate-secreting organisms (e.g., green algae, cyanobacteria) [19]. The lowest measured $\delta^{13}C$ value in the uppermost part of the unit may indicate some diagenetic alteration by meteoric fluids below the karstified top surface. However, another interpretation postulates a change from oligotrophic to mesotrophic conditions which is inferred from the microfacies characteristics of the bioclastic-peloidal limestones. Such decrease in the bulk-rock $\delta^{13}C$ values during the earliest Valanginian (i.e., predating the positive carbon isotope excursion) has been recorded in the Helvetic and Jura platforms, and explained as reflecting a shift from photozoan to heterozoan carbonate production (i.e., dominantly calcite producers in the platform ecosystem) due to increased humidity, higher input of continentally derived DIC (dissolved inorganic carbon) and nutrient enrichment [4,7]. The observed trend of decreasing and then stabilizing $\delta^{13}C$ values in the Salash Formation is similar to studies of (hemi)pelagic and shallow-water carbonate deposits of latest Valanginian (*C. furcillata* zone) and Early Hauterivian age from the Northern, Central and Southern Tethys Ocean [4,5,16,20], as well as to the global marine carbonate $\delta^{13}C$ stack [17]. This isotopic signature seems to correspond to the smooth decrease phase (i.e., after the first rising and second steady phases) in the $\delta^{13}C$ record of the Weissert Event, as described by Martinez et al. [6] for the Vocontian Basin in France (Fig. 2). During this longest third phase the $\delta^{13}C$ compositions became progressively closer to the pre-excursion values [4–6,17].

Conclusions. The Middle Jurassic–earliest Cretaceous carbonate platform (Slivnitsa Formation) developed in a photozoan mode during the Berriasian and switched to a heterozoan mode around the Berriasian/Valanginian boundary. The platform was subaerially exposed in the earliest Valanginian and drowned in the latest Valanginian. The deposition of carbonate-argillaceous sediments (Salash Formation), which continued during the Early Hauterivian, occurred in a deeper, open-marine environment under mesotrophic to eutrophic conditions. The $\delta^{13}C$ signatures of the shallow platform sediments were controlled by the relative arago-

nite contribution and photosynthesis-related fractionation. The $\delta^{13}C$ values of the deeper, open-marine deposits most likely reflect the final smooth decrease phase of the Weissert Event.

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Geological Institute
Bulgarian Academy of Sciences
Akad. G. Bonchev St, Bl. 24
1113 Sofia, Bulgaria
e-mail: dariaiv@yahoo.com

**Faculty of Geology and Geography*
Sofia University "St. Kliment Ohridski"
15 Tsar Osvoboditel Blvd
1504 Sofia, Bulgaria
e-mail: chatalov@gea.uni-sofia.bg