Maastrichtian to Palaeocene and Eocene pelagic carbonates on the island of Svetac (central Adriatic, Croatia)

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Abstract

Maastrichtian to Palaeocene pelagic carbonates on the central Adriatic island of Svetac (Sveti Andrija) are the only outcrops reported to date that document pelagic deposition during the Cretaceous–Palaeogene (K–Pg) transition within the Adriatic Basin. An approximately 3 m thick succession at the Smokvica locality contains a rich and diverse planktonic foraminiferal assemblage which allows dating of the succession and the recognition of some biostratigraphic zones. The lower part of the Smokvica section consists of 1.5 m thick pelagic biomicrite characterized by the abundance of late Maastrichtian planktonic foraminifera that indicate the *Abathomphalus mayaroensis* Zone. An intercalation of intraclastic floatstone <0.5 m in thickness occurring on top of Maastrichtian pelagic biomicrite is characterized by unsorted pelagic intraclasts floating within the pelagic matrix, and both components only contain Maastrichtian planktonic foraminifera. The floatstone is overlain by another <0.5 m thick intraclastic-bioclastic floatstone characterized by rounded pelagic intraclasts (plasticlasts) containing Maastrichtian planktonic foraminifera floating in the pelagic matrix. The matrix of the later floatstone contains Maastrichtian and Palaeocene planktonic foraminifera mixed together. Thus, the transition from the Maastrichtian to the Palaeocene is not continuous but is characterized by amalgamated debrites that are related to at least two separated re-depositional events within the basin. The overlying pure pelagic biomicrite is rich in planktonic foraminifera that indicates the Palaeocene P3 Zone. A few metres apart, after the covered interval, there are also Eocene pelagic biomicrites with planktonic foraminifera which indicate the Eocene E9 Zone, characterized by the co-appearance of benthic foraminifera (*Discocyclina*) floating within the pelagic matrix. It is assumed that a Maastrichtian opening of the deep-water environment connected to the Adriatic Basin within the former Adriatic Carbonate Platform west of the island of Vis could be related to a re-activation of an inherited transverse fault zone.

Keywords: Adriatic Platform and Basin, Cretaceous, Palaeogene, planktonic foraminifera

1. INTRODUCTION

Although tropical Mesozoic carbonate platform successions in the peri-Adriatic region (Figs. 1A, B) are characterized by a hiatus that encompasses the Cretaceous–Palaeogene (K–Pg) boundary (EBERLI et al., 1993; BOSELLINI et al., 1999; VLAHOVIĆ et al., 2005; KORBAR, 2009), there are rare outcrops characterized by a more or less continuous record of the stratigraphic interval of global interest (KORBAR, 2019, and references therein). The Adriatic-Dinaridic Carbonate Platform (ADCP cf. PAMIĆ et al., 1998) that was separated into two major segments: Adriatic Carbonate Platform (ACP) and Dinaridic Carbonate Platform (D'ARGENIO et al., 1971; KORBAR, 2009; Figs. 1A, B), also recognized as a unified Adriatic Carbonate Platform (AdCP cf. VLAHOVIĆ et al., 2005; Fig. 1C), was the largest Mesozoic neritic depositional system in the region. Because of a regional emergence of the platform during the Late Cretaceous into the Palaeogene, and the related hiatus within the succession, only a few exceptional localities from the central part of the Adriatic Carbonate Platform *sensu stricto* (ACP cf. KORBAR, 2009) are characterized by a more or less continuous sedimentary record across the K–Pg boundary. This boundary is marked within the sections by a deposit which is a few centimetres to a few metres thick, interpreted as the K–Pg tsunamite (KORBAR et al., 2015, 2017a).

The contact of the Upper Cretaceous and Palaeogene limestones on the island of Biševo (Fig. 1C) is characterized by approximately 50 million years of non-deposition and erosion (KORBAR et al., 2012) which is typical for the outermost ACP tectonostratigraphic unit i.e., the Istrian Karst (KORBAR, 2009). The K–Pg hiatus within the shallow-water succession is also recognized in the boreholes located to the southeast of the island of Svetac (Sveti Andrija), while to the southwest there is the realm of the Adriatic Basin (GRANDIĆ et al., 1999, 2002; Fig. 1C). The K–Pg transition within the central part of the Adriatic Basin is penetrated by the Koraljka borehole (125 km NW of the island of Svetac; Fig. 1C) is characterized by pelagic chalky limestones with bioclastic (allodapic) platform-derived intercalations (LUČIĆ et al., 1993).

Deeper-water carbonates deposited within the AdCP intra-platform basins were characterized by calcisphere wackestone-packstones with rare planktonic foraminifera, indicating a restricted connection with the open sea (GUŠIĆ & JELASKA, 1990; FUČEK et al., 1991). The openings and durations of the intra-platform basins were diachronous, within the range from the Turonian to the Campanian, while the Maastrichtian was generally characterized by platform emergence, although peritidal deposition occurred within distinct tectonostratigraphic units of the ACP (KORBAR, 2009).

Most of the data on the stratigraphy and palaeoenvironments along the buried ACP margin and the Adriatic Basin in the cen-
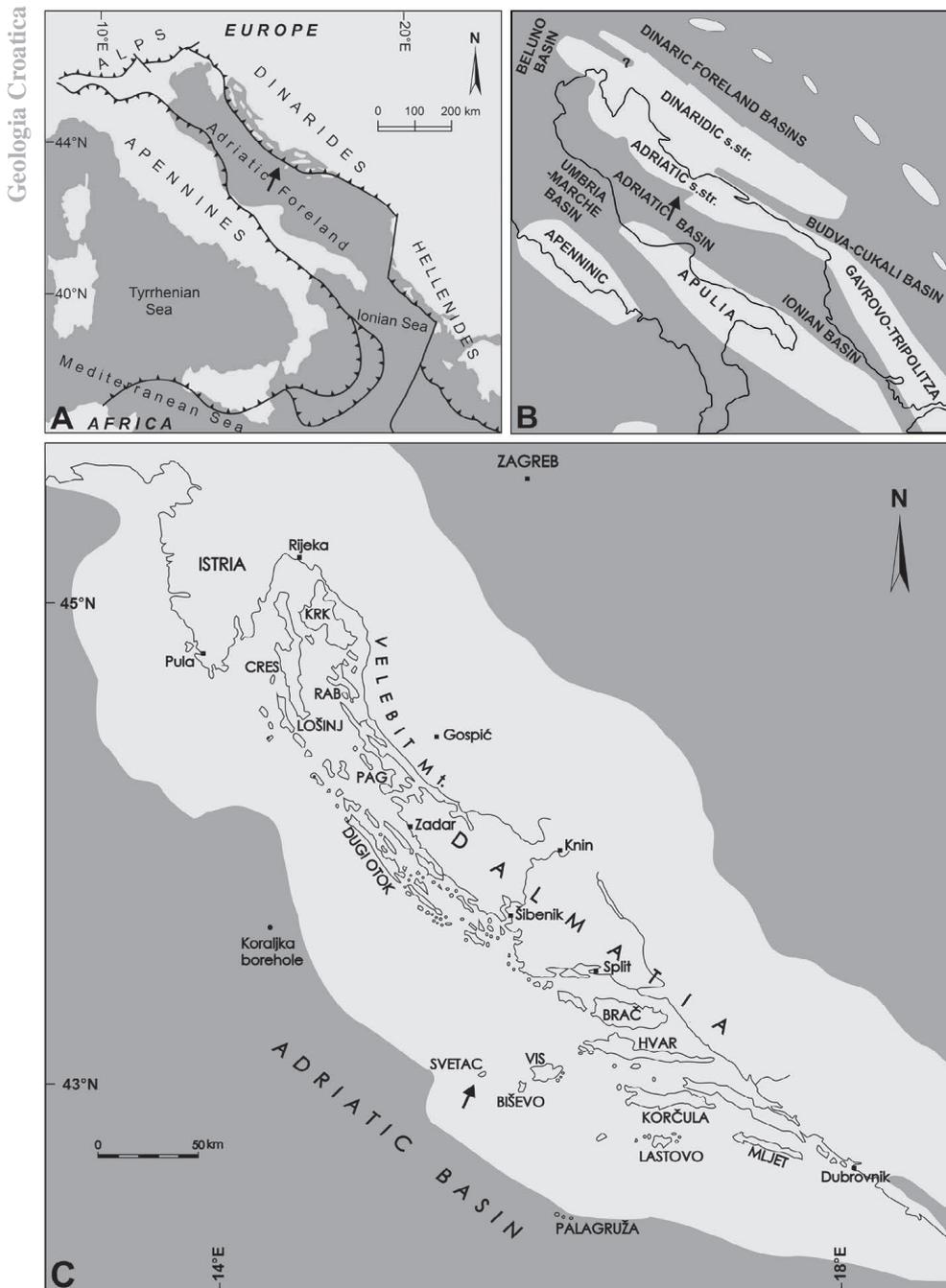
Figure 1. Location map of the island of Svetac (arrows) on: A) a peri-Adriatic geotectonic sketch (after KORBAR, 2009); B) a peri-Adriatic palaeogeographic map sketch showing the existence of two segments of the ADCP domain: the Adriatic and Dinaridic (modified after KORBAR, 2009 and KORBAR, 2019); C) the Adriatic Carbonate Platform (AdCP) domain (light grey, modified after VLAHOVIĆ et al., 2005) along the northeastern Adriatic coast (major Croatian islands and towns are indicated).

tral Adriatic area have been collected for the oil industry, and are synthesised in the published papers (GRANDIĆ et al., 1999; VLAHOVIĆ et al., 2005; KORBAR, 2009). GRANDIĆ et al. (1999) interpreted the ACP margin as lying some 20 km SW of the island of Svetac, along a rather complex tectonic system characterized by salt diapirs (GELETTI et al., 2008). Although KORBAR et al. (2012) show only shallow-water Cretaceous carbonates on the island (Fig. 1C), new more detailed investigations revealed important data on pelagic sedimentation during the latest Cretaceous to Palaeogene period.

The aim of this paper is to document deep-water pelagic facies on the island of Svetac. The facies is important for re-interpretation of the local palaeogeography and for the evolution of depositional environments in this part of the central Adriatic at the end of the Mesozoic (Fig. 1C), as well as for future reconstruction of the western Tethys palaeogeography during the transition from the Late Cretaceous to the Early Palaeogene.

2. GEOLOGICAL SETTING

The central Adriatic area belongs to the central part of the Adriatic microplate (Adria) that has been affected by a very complex Mesozoic to Cenozoic geodynamic evolution characterizing the peri-Adriatic region (CHANNELL et al., 1979; ROSENBAUM et al., 2004; SCHMID et al., 2008). The evolution was recorded within a sedimentary succession several kilometres thick starting from the Triassic rifting phase of Pangea to the latest stage of the Alpine orogeny, when the orogenic belts developed along the circum-Adriatic margins (Fig. 1A). Seismic data and deep wells revealed a thick pile of Mesozoic to Quaternary sediments that are in places tectonically disturbed mostly by salt diapirs that contain incorporated middle to upper Triassic magmatic rocks (GRANDIĆ et al., 1999, 2002; GELETTI et al., 2008; KORBAR, 2009). The diapirs were driven by mobilized middle Triassic salt that in places pierced the sedimentary succession and appears at the surface (BELAK et al., 2005; KORBAR et al., 2012). The di-

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apirs outcropped presumably during the Miocene (PIKELJ et al., 2015), and are still growing (GELETTI et al., 2008; BABIĆ et al., 2012). Thus, salt tectonic related deformations of the overlying Adriatic carbonate platform succession and Quaternary erosion created prominent geological structures and interesting geomorphological features of the central Adriatic islands (KORBAR et al., 2012), that have been recognized recently as UNESCO Global Geopark Vis archipelago.

The island of Svetac is the outermost island of the central Adriatic (Dalmatian) archipelago, located about 50 km south of the mainland, and 22 km west of the island of Vis (Fig. 1C). Palaeogeographically, the island of Svetac is considered to be an integral part of the Adriatic Carbonate Platform (VLAHOVIĆ et al., 2005), and is at the surface built of tectonic blocks derived from a >1500 m thick succession of typical Cretaceous shallow-water (neritic) carbonates (KORBAR et al., 2012).

The wider area of the island belongs to the Adriatic foreland of both the Dinarides and the Apennines (SCISCIANI & CALAMITA, 2009; Fig. 1A). The Cretaceous to Palaeogene Dinaric forebulge stage and the long-lasting subaerial exposure of the platform was followed by deposition during the Oligocene foreland stage at the end of the Dinaric foredeep migration phase (KORBAR, 2009).

The Upper Cretaceous rudist-bearing carbonates outcropping on the island of Svetac is recognized as a typical ACP succession of the Gornji Humac Formation (GUŠIĆ & JELASKA, 1990), although the uppermost part resembles the open-platform and slope carbonates reported from the ACP domain: the Turonian carbonates in the western part of the island of Dugi Otok (FUČEK et al., 1991), the Turonian–Santonian of the islands of Premuda, Ist and Silba (MORO & ĆOSOVIĆ, 2013), or the Middle Campanian facies on the islands of Brač (CVETKO

TEŠOVIĆ et al., 2001; STEUBER et al., 2005) and Hvar (KORBAR et al., 2010). The Gornji Humac formation on the island of Svetac, outcropping on the south-eastern coasts of the island (Slatina locality, Fig. 2), is characterized by recrystallized medium to thick-bedded limestones with typical peritidal rudist lithosomes composed of various radiolitid rudists. In contrast, the northern and western outcrops referred to as the Gornji Humac Formation are built of recrystallized thick-bedded to massive bioclastic limestones rich in rudist fragments and recrystallized biomicrite. The carbonates are in distinct tectonic contacts with the Lower Cretaceous peritidal carbonates of the Goveđari and Babino polje formations (HUSINEC, 2002) from the south and from the north, respectively (KORBAR et al., 2012; Fig. 2 and 2/Supplement – APPENDIX).

3. MATERIALS AND METHODS

The first discovery of the pelagic facies on the island of Svetac was in 2005, documented by the analyses of the sample from the observation point VN-214 (WGS: 15.762892E, 43.026051N; HTRS (E/N): 439927/4765401). In 2014, focused mapping was performed for the purpose of defining the spatial distribution of the pelagic facies. The narrow zone of pelagic carbonates strikes east-west and is bordered by distinct and indistinct faults. The carbonates were partly covered by colluvium in Crna ploča Cove, along a major fault that borders the zone from the north (Figs. 2 and 2/Supplement – APPENDIX). Because of the faults and indistinct bedding (it seems that the bedding within the tectonic block is nearly vertical), it was possible to measure and sample only one section along the narrow pedestrian trail in the Smokvica area (Fig. 2). The section extends from the southwest where it is in tectonic contact with predominantly bioclastic recrystallized carbonates containing radiolitid rudist bioclasts, to the northeast
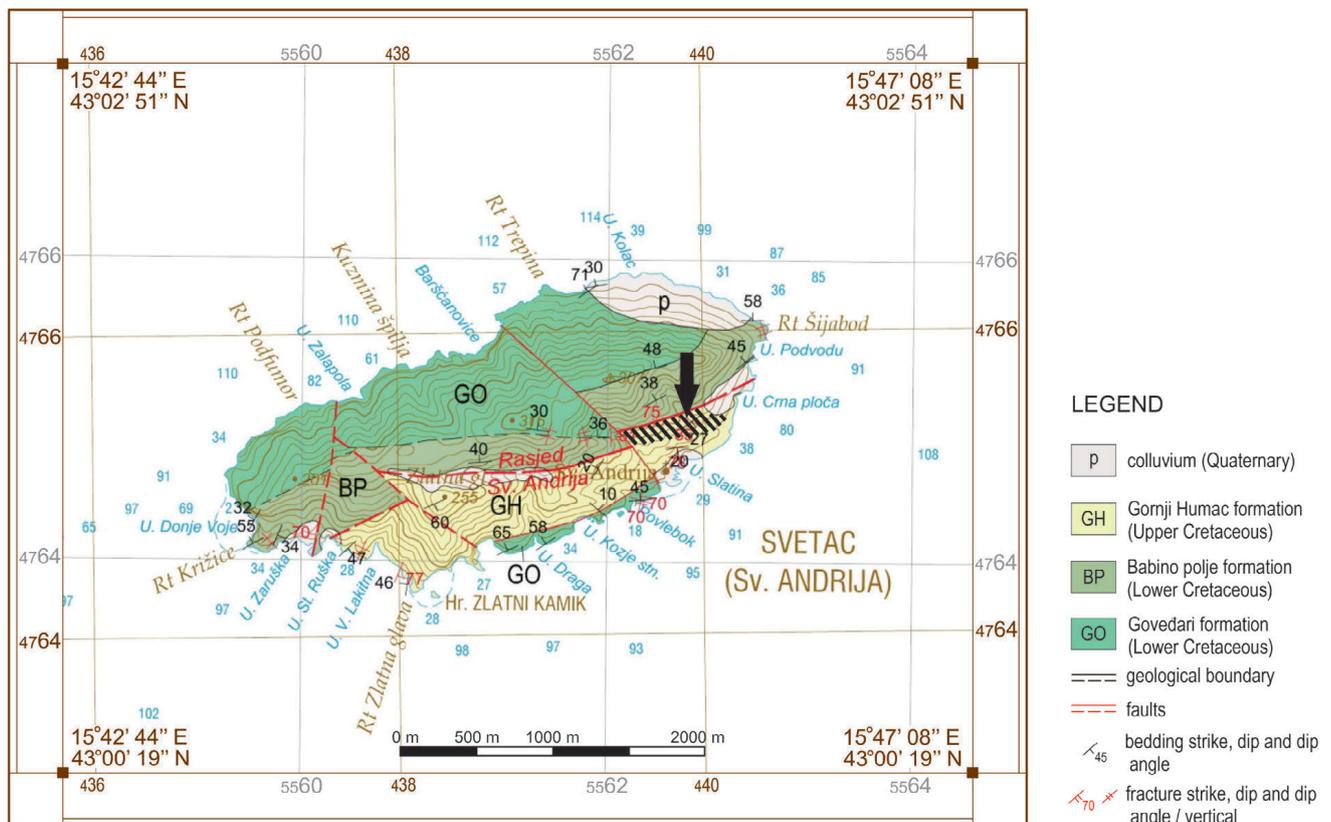
Figure 2. Geological map of the island of Svetac (KORBAR et al., 2012), showing the position of the studied section VSS and sample VN-214 at Smokvica locality (black arrow) within a narrow zone of Maastrichtian to Palaeogene thick-bedded to massive pelagic carbonates (hatched).
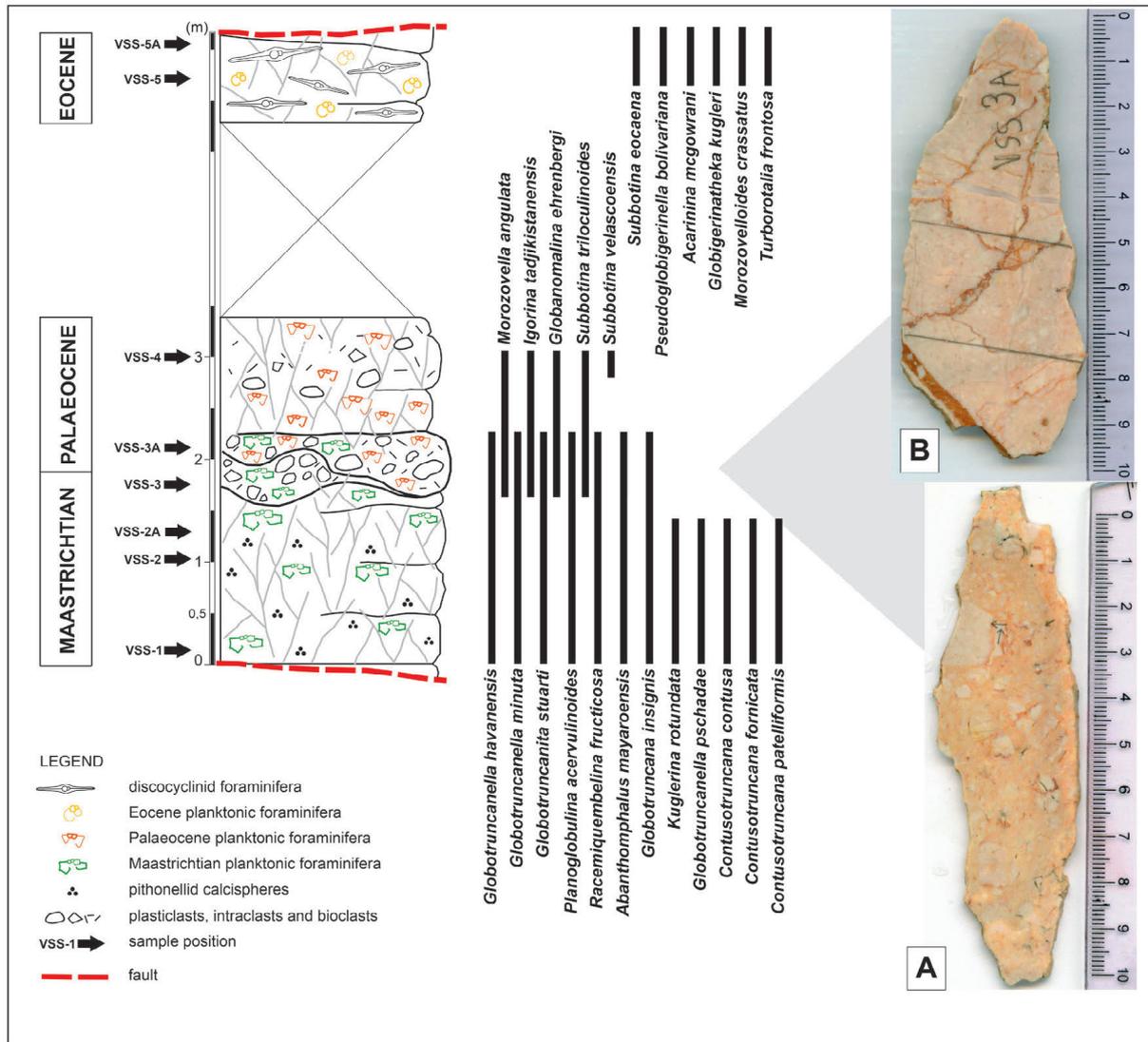
Figure 3. Illustrated stratigraphic column Vis-Svetac-Smokvica (VSS) showing the position of the samples, distribution of the determined fossils, and photographs of polished slabs of intraclastic floatstones (debrites) that mark the contact of Maastrichtian and the Palaeocene: A) sample VSS-3, B) sample VSS-3A.

where it is in tectonic contact with the zone of Maastrichtian pelagic biomicrites (Fig. 2).

The Smokvica section is measured and sampled within the zone of massive pelagic carbonates, starting from sample VSS-1 (WGS: 15.762634E, 43.026043N; HTRS (E/N): 439905/4765400) to sample VSS-4 (WGS: 15.762635E, 43.026076 N; HTRS (E/N): 439905/4765404), and, a few metres north of the covered part (Fig. 3), to sample VSS-5 (WGS: 15.762635E, 43.026106 N; HTRS (E/N): 439906/4765407).

The preliminary palaeontological and facies observations were undertaken in the field by hand lens. Thin-sections were prepared at the Croatian Geological Survey according to the standard procedure for microfacies and micropaleontological analyses (FLÜGEL, 2010). The optical microscopy and photomicrographs of the selected thin-sections were taken by an Olympus SZX12. The taxonomic determinations of planktonic foraminifera were based on un-oriented cross sections of the foraminiferal tests and observations of the morphological characteristics such as the size and the shape of the test, size, shape, number and arrangements of chambers, thickness of the wall, presence or absence, position and number of peripheral thickenings or keels. The species concept for Cretaceous taxa after SLITER (1989) and

PREMOLI SILVA & VERGA (2004) was used, together with the papers of SARI (2006, 2009). Palaeocene and Eocene species were determined after OLSSON et al. (1999), PREMOLI SILVA et al. (2003), and PEARSON et al. (2006). The foraminifera sections of YOUNG et al. (2017) has also been used.

4. RESULTS

The research resulted in discovery of the pelagic thick-bedded to massive carbonates in the Crna ploča cove (Figs. 2, 2/Supplement – APPENDIX, 3, and 4). These are predominantly mudstones to skeletal wackestones (rarely floatstones) with intercalations of recrystallized bioclastic packstone to grainstone. Fine-grained reddish skeletal wackestones in places resemble typical pelagic facies - a biomicrite rich in planktonic foraminifera that lack any benthic fossils.

4.1. Cretaceous to Palaeogene (K–Pg) pelagic carbonates at Smokvica

The Vis-Svetac-Smokvica (VSS) section on the island of Svetac is characterized by a ~3 m thick succession of thick-bedded Cretaceous and Palaeocene pelagic limestones with a few intraclastic and bioclastic intercalations (Fig. 3 and 3/Supplement –

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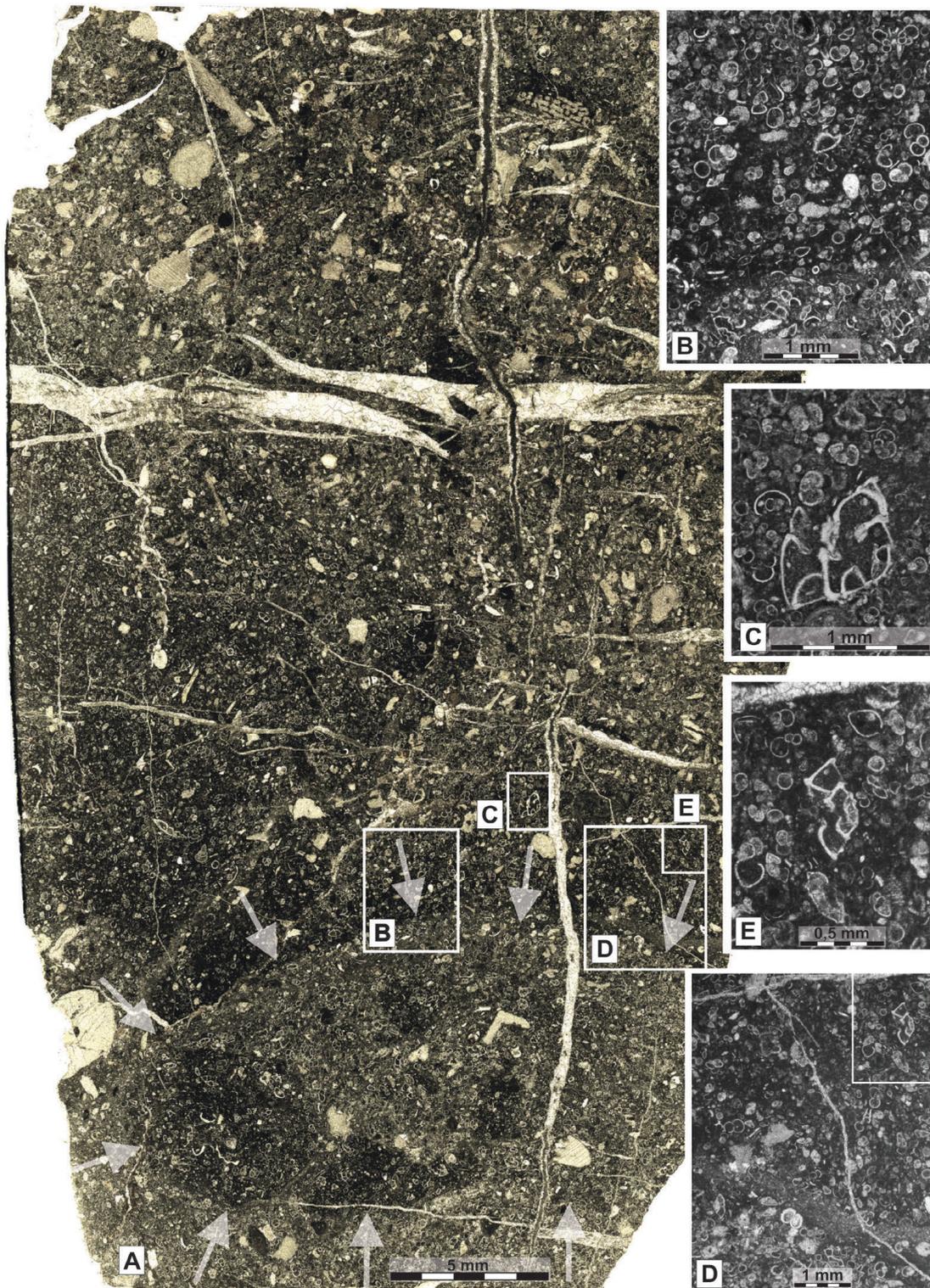
Figure 4. A) Composite photomicrograph of the sample VSS-3A showing the mixture of Palaeocene and Maastrichtian pelagic lime mud and intraclasts/plasticlasts (rim of a Maastrichtian intraclast is indicated by arrows); B and D) magnified parts of the rim; C and E) magnified Maastrichtian planktonic foraminifera from the Palaeocene matrix.

APPENDIX). The lower part of the succession is characterized by a 1.5 metre thick package of pelagic limestones (biomicrite) characterized by the mass occurrence of Maastrichtian planktonic foraminifera (Fig. 5). An intercalation <0.5m thick of intraclastic floatstone is located above the Maastrichtian pelagic biomicrite. The intercalation is characterized by unsorted 2–20 mm long light-grey intraclasts of pelagic wackestone to packstone (biomicrite) that are "floating" within the pinkish-grey pelagic wackestone to packstone (polished slab VSS-3; Figs. 3A and 4). Both lithological components contain exclusively Maastrichtian planktonic foraminifera (Fig. 5).

Directly overlying the intraclastic floatstone (Fig. 3) there is another intraclastic-bioclastic floatstone, (<0.5m thick) characterized by a pelagic matrix and semi-rounded intraclasts (plasticlasts) of similar pelagic facies, along with tiny molluscan bioclasts (polished slab VSS-3A on Fig. 3B). The floatstone is
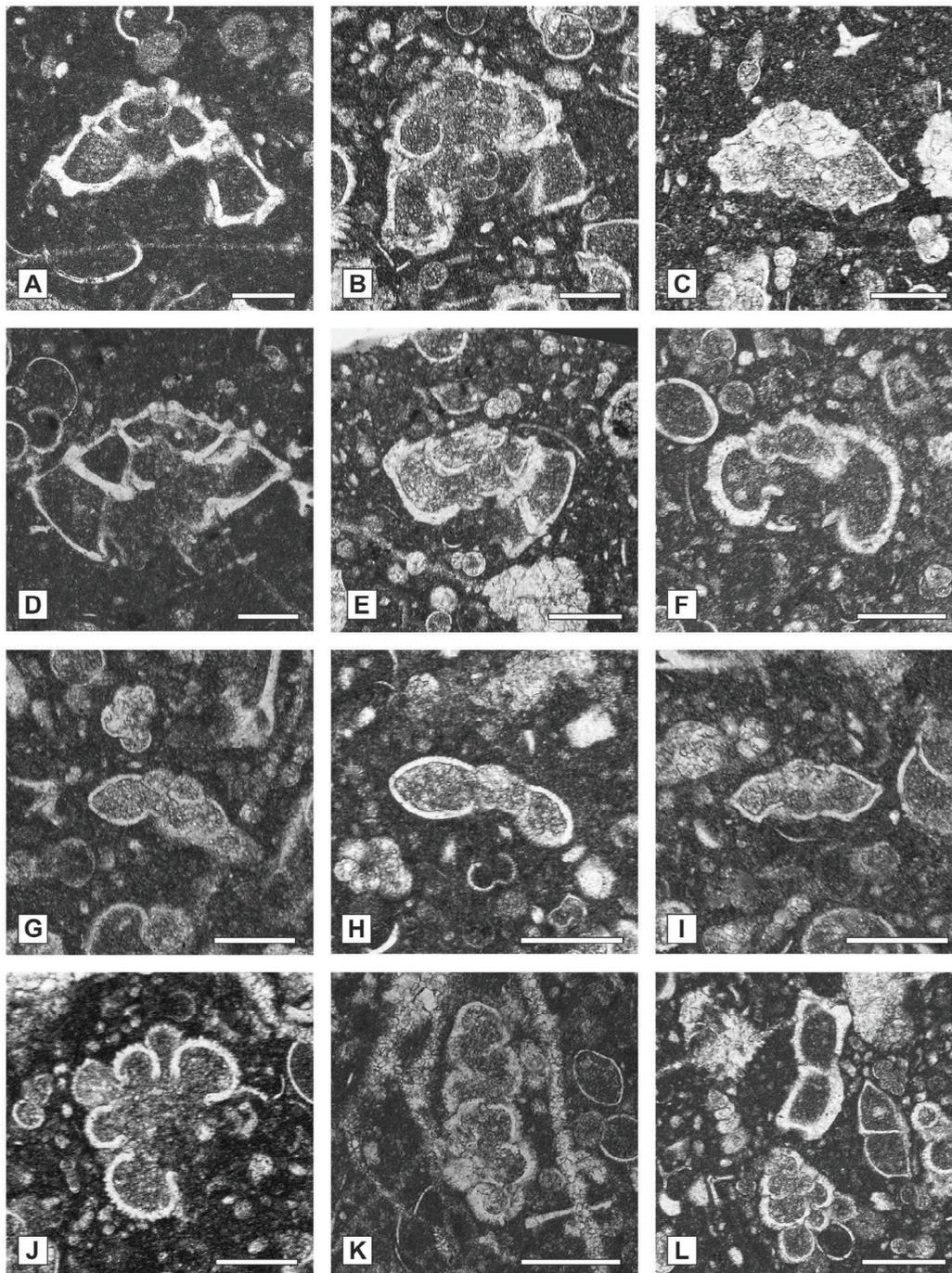
Figure 5. Photomicrographs of selected Maastrichtian planktonic foraminifera from sample VN-214 and samples VSS 1-3. A – *Contusotruncana patelliformis*, sample VSS-2; B – *Contusotruncana contusa,* sample VN-214; C – *Contusotruncana fornicata,* sample VN-214; D – *Globotruncanita stuarti*, sample VSS-3; E – *Globotruncanita insignis*, sample VSS-3A; F – *Kuglerina rotundata*, sample VN-214; G, H – *Globotruncanella havanensis*, sample VSS-3A; I – *Globotruncanella pschadae*, sample VN-214; J – *Racemiquembelina fructicosa*, sample VN-214; K – *Planoglobulina acervulinoides*, sample VSS-3; L - *Planoglobulina acervulinoides* and fragment of *Abathomphalus mayaroensis*, sample VN-214. All scale bars 0.2 mm.

characterized by 2–20 mm long intraclasts and bioclasts floating in a pelagic wackestone to packstone containing Maastrichtian (Figs. 5E, G, and H) and Palaeocene (Fig. 6A–C, and F) planktonic foraminifera in the matrix and in the intraclasts (Fig. 4). Thus, the Palaeocene pelagic floatstone that is characterized by mixed Maastrichtian intraclasts and lime mud containing Maastrichtian and Palaeocene planktonic foraminifera, directly overlies the Maastrichtian pelagic floatstone. It should be noted that the lowermost Palaeocene (Danian) planktonic foraminiferal associations are not observed (Fig. 3). The overlying metre thick pelagic limestone only contains Palaeocene planktonic foraminif-

era (Figs. 3 and 6D). In the middle part of the limestone there is an intercalation of intraclastic-bioclastic floatstone that contains solely Palaeocene pelagic intraclasts.

Two metres north of the Maastrichtian to Palaeocene succession (the walking trail is covered by vegetation, Fig. 3/Supplement – APPENDIX), there is a metre long outcrop of Eocene pelagic limestone (Figs. 3 and 6) that is characterized by the appearance of Palaeogene benthic foraminifera (discocyclinids) floating within the Eocene pelagic mudstone (Fig. 6O). The Eocene pelagic limestone is in tectonic contact with a light-grey Maastrichtian pelagic mudstone outcropping north of the fault.
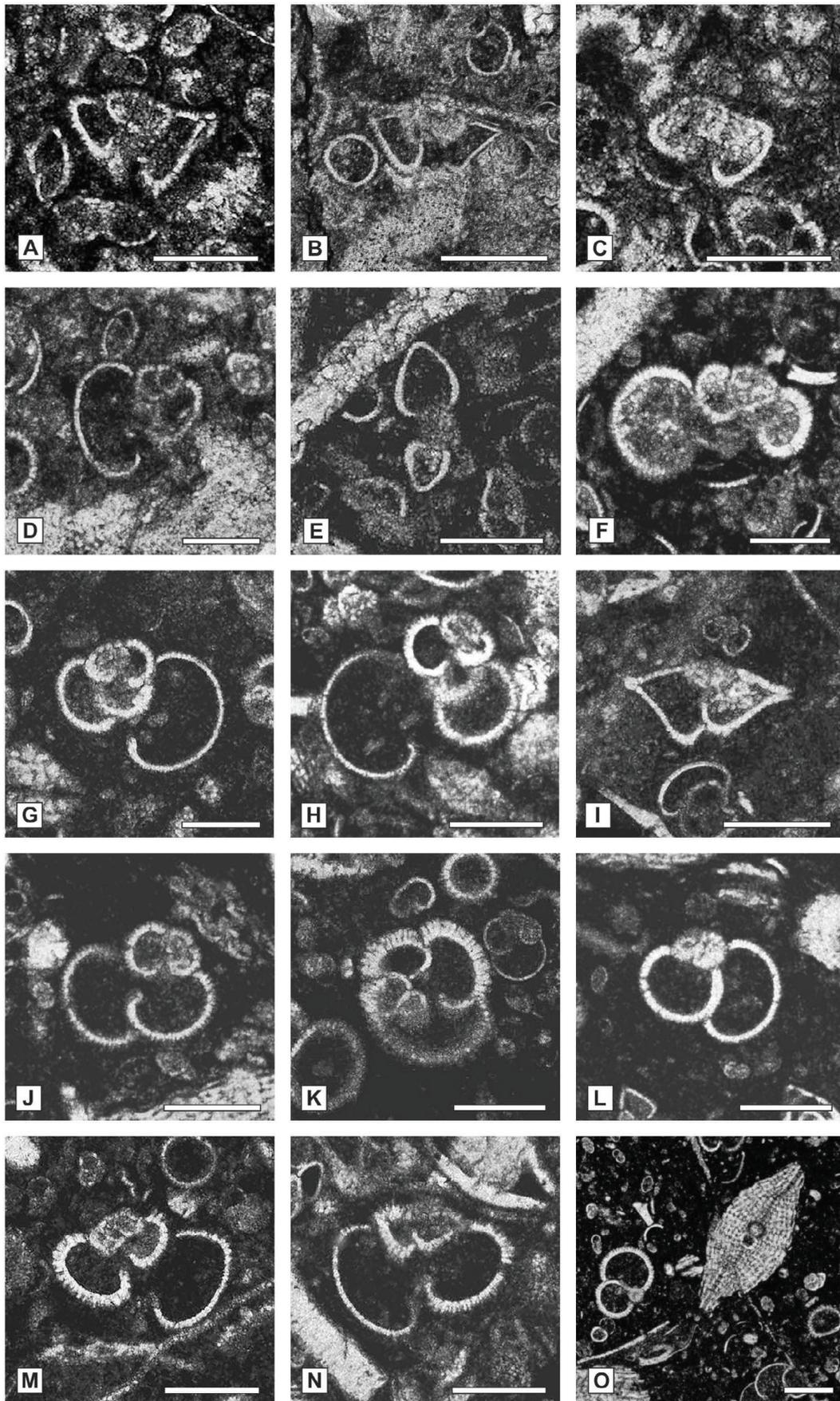
Figure 6. Photomicrographs of selected Palaeogene planktonic foraminifera from samples VSS 3A-5. A,B – *Morozovella angulata,* sample VSS-3A; C – *Igorina tadjik-istanensis*, sample VSS-3A; D – *Subbotina velascoensis*, sample VSS-4A; E – *Globanomalina ehrenbergi*; sample VSS-4; F – *Parasubbotina pseudobulloides*, sample VSS-3A; G, – *Turborotalia frontosa*, sample VSS-5; H – *Subbotina yeguaensis*, sample VSS-5; I – *Morozovelloides crassatus*, sample VSS-5; J – *Subbotina eocaena*, sample VSS-5; K – *Globigerinatheka kugleri*, sample VSS-5; L – *Pseudoglobigerinella bolivariana*, sample VSS-5A; M – *Acarinina mcgowrani*, sample VSS-5; N – *Acarinina bull-brooki*, sample VSS-5; O – discocyclinid benthic foraminifera within the pelagic matrix of sample VSS-5A. All scale bars 0.2 mm.

4.2. Biostratigraphy

The analysed planktonic foraminifera unambiguously indicate the successive appearance of Maastrichtian and Palaeocene species within a ~3 m thick succession in the geological column VSS (Figs. 3 and 3/Supplement– APPENDIX). A few metres north of the succession, after a covered interval, there are also pelagic carbonates that contain Eocene species. The sample from the observation point VN-214 is observed 20 m east of samples VSS-1 and 2, within the same zone of the light-grey pelagic mudstones, and is analyzed here because of the exceptionally well preserved thin-sections of Maastrichtian planktonic foraminifera.

The following Maastrichtian taxa have been determined: *Contusotruncana patelliformis* (Fig. 5A), *Globotruncanella havanensis* (Figs. 5G, H), *Globotruncanella pschadae* (Fig. 5I), *Globotruncanella* cf. *petaloidea*, *Globotruncana arca*, *Globotruncanita insignis* (Fig. 5E), *Globotruncana* cf. *orientalis*, *Globotruncanita stuarti* (Fig. 5D), *Globotruncanita conica*, *Abathomphalus mayaroensis* (Fig. 5L), *Kuglerina rotundata* (Fig. 5F), *Contusotruncana fornicata* (Fig. 5C), *Contusotruncana contusa* (Fig. 5B), *Planoglobulina acervulinoides* (Figs. 5K, L)*, Ventilabrella* sp., *Gublerina* sp., *Racemiguembelina fructicosa* (Fig. 5J), *Macroglobigerinelloides* sp., *Muricohedbergella* sp., *Heterohelix* sp., *Pithonella ovalis, P. innominata* and *P. sphaerica*. The assemblage of planktonic foraminifera indicates the Late Maastrichtian *Abathomphalus mayaroensis* Zone (PREMOLI SILVA & VERGA, 2004).

A mixed assemblage of Maastrichtian and Palaeocene planktonic foraminifera occurs in sample VSS-3A. The following Palaeocene taxa have been determined: *Morozovella angulata* (Figs. 6A, B), *Igorina tadjikistanensis* (Fig. 6C), *I. pusilla*, *Subbotina triloculinoides*, *S. triangularis*, *Parasubbotina pseudobulloides* (Fig. 6F), *Globanomalina ehrenbergi* (Fig. 6E) and *Globanomalina chapmani*. The association is characteristic for the Palaeocene P3 Zone, i.e. the *Morozovella angulata* Lowest Occurrence Zone, defined as the interval between the lowest occurrence (LO) of *Morozovella angulata* and the LO of *Globanomalina pseudomenardii* (WADE et al., 2011). The very rare occurrence of small benthic foraminifera has also been observed. Sample VSS 4 contains the following planktonic foraminiferal species: *Morozovella angulata*, *Igorina tadjikistanensis*, *Subbotina velascoensis* (Fig. 6D), *S. triloculinoides*, *S. triangularis*, *S. cancellata*, *Globanomalina ehrenbergi* and *Globanomalina chapmani*. The planktonic association indicates upper part of the Palaeocene P3 Zone (*Morozovella angulata*).

A rich and highly diverse Eocene planktonic foraminiferal association has been observed in samples VSS-5 and 5A. Species such as *Turborotalia frontosa* (Fig. 6G), *Morozovelloides crassatus* (Fig. 6I), *Subbotina yeguaensis* (Fig. 6H), *S. eocaena* (Fig. 6J), *Globigerinatheka kugleri* (Fig. 6K), *Pseudoglobigerinella bolivariana* (Fig. 6L), *Acarinina mcgowrani* (Fig. 6M) and *A. bullbrooki* (Fig. 6N) are characteristic of the middle Eocene E9 Zone (*Globigerinatheka kugleri/Morozovella aragonensis*) defined as the concurrent range zone of the nominate taxa between the LO of *Globigerinatheka kugleri* and the highest occurrence (HO) of *Morozovella aragonensis* (BERGGREN & PEARSON, 2005; WADE et al., 2011). In addition to the planktonic foraminiferal taxa many specimens of the large benthic foraminifera *Discocyclina* sp. are also present (Fig. 6O).

5. DISCUSSION

The pelagic facies described on the island of Svetac do not resemble intra-platform basinal facies reported from elsewhere on the Adriatic Carbonate Platform (ACP) domain, that are characterized by a paucity of planktonic foraminifera and an abundance of calcispheres (GUŠIĆ & JELASKA, 1990; FUČEK et al., 1991). Instead, the pelagic carbonates on the island of Svetac are rich in various species of planktonic foraminifera, suggesting a direct connection of the depositional environment with the open sea. Thus, it is inferred that during the Maastrichtian a deep embayment developed west of the island Vis (Fig. 7). The embayment did not exist during most of the Cretaceous in the area of the island of Svetac, since the typical peritidal carbonates represented by the well-known shallow-water formations deposited on top of the ACP (AdCP cf. VLAHOVIĆ et al., 2005) are reported from the island (KORBAR et al., 2012; Fig. 2).

Within the 3 m thick Maastrichtian to Palaeocene pelagic succession on the island of Svetac (Fig. 3) there are two types of intraclastic pelagic floatstones at the contact of the Maastrichtian and Palaeocene deposits (Fig. 3). According to the abundance of pelagic mud and the pelagic intraclasts floating in a cohesive matrix, the floatstones are interpreted as muddy debrites (MULDER & ALEXANDER, 2001). Considering a deep-water depositional environment, the debrites have probably been deposited from debris flows within the basin or on the slope. The two debrites are amalgamated and it seems that the upper one eroded the lower one (Fig. 3). Thus, the K–Pg transition is characterized by two amalgamated 0.5m thick debrites deposited at the top of Maastrichtian and at the bottom of Palaeocene, respectively. Re-deposition and mixing of the Maastrichtian and Palaeocene pelagic mud intraclasts imply slope instability and a continuous basinal depositional environment during the Maastrichtian to Palaeocene in the area of the island of Svetac.

The lower (top Maastrichtian) debrite is characterized by intraclasts (plasticlasts) of pelagic carbonates in a pelagic matrix that lack Palaeocene planktonic foraminifera (Fig. 3). The association of late Maastrichtian planktonic foraminifera suggests mixing of a few biozones (Fig. 5), while the latest one is referred to the *Abathomphalus mayaroensis* Zone. Skeletons (bioclasts) of shallow-water benthic foraminifera and rudists are absent in the lower (Maastrichtian) part of the section that points to re-deposition within the basin without the influence from the carbonate platform. It must be highlighted that the carbonate platform margins in the region were characterized by emergence and sediment starvation during the K–Pg transition (MUTTI et al., 1996; VECSEI & MOUSSAVIAN, 1997; BOSELLINI et al., 1999). The
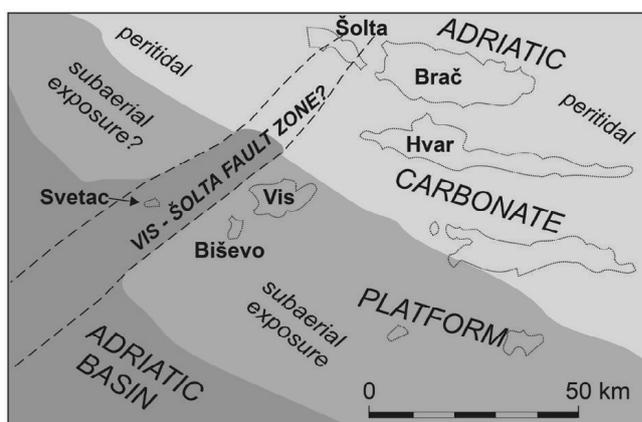
Figure 7. Central-Adriatic palaeogeography and depositional environments (grades of gray and italicised text) during the Cretaceous–Palaeogene (K–Pg) transition. Conservative reconstruction related to the recent arrangement of the central Dalmatian islands (contoured by dotted lines). Inferred transverse faults indicated by broken lines.

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emergence is also recognized on the ACP southern margin (KORBAR, 2009), and the starvation could strongly influence the sedimentation rate within the supposed embayment (Fig. 7).

Considering the unusual event beds reported from the islands of Hvar (KORBAR et al., 2015) and Brač (KORBAR et al., 2017a), both deposited within the peritidal domain of the ACP at the K–Pg boundary (Fig. 7), the Maastrichtian part of the complex debrite on the island of Svetac could be tentatively interpreted as the K–Pg event deposit. If so, it could be related to an extraordinary hydrodynamic event or an earthquake that was able to mobilize pelagic mud and semiconsolidated pelagic sediment from the deep embayment floor, and redeposit the mixture of mud and the intraclasts (plasticlasts) as a sedimentary load within the same pelagic depositional environment (Fig. 7).

The Palaeocene debrite at the K–Pg contact on the island of Svetac contains both Maastrichtian and Palaeocene planktonic foraminifera in the matrix and Maastrichtian pelagic intraclasts (Fig. 3). The content of the debrite implies the existence of a slope along which re-deposition of unconsolidated and semi-consolidated pelagic mud occurred. The content thus implies mixing of fluidized Maastrichtian pelagic mud and pelagic mudstone intraclasts, as well as Palaeocene pelagic mud (cf. BICE et al., 2007).

Considering the fact that the thin-sections of Palaeocene (Danian?) planktonic foraminifera cannot be determined to species level, the age of the upper debrite is related to the Palaeocene *P3* Zone, defined according to the youngest association of planktonic foraminifera in the sample VSS-4 (Fig. 3). Thus, the Palaeocene debrite could be tentatively correlated to one of the Palaeocene regional submarine landslides that are recorded within the pelagic succession of the neighbouring Umbria-Marche basin (MONTANARI et al., 1989; BICE et al., 2007). The Maastrichtian to Palaeocene was a period of intermittent collapses of the northern margin of the Apulian Carbonate Platform into the Adriatic Basin (BOSELLINI et al., 1999) and into the Ionian counterpart on the southwest (RUBERT et al., 2012; Fig. 1B). At least one of the regional Danian events is also probably recorded within the Danian peritidal succession on the neighbouring island of Hvar (KORBAR et al., 2015).

The benthic foraminifera in the separated Eocene part of the presumably discontinuous pelagic succession on the island of Svetac (Fig. 3) imply a possible shallowing upward trend or a development of nearby neritic environments. In case of the later, it could also be interpreted as a skeletal muddy debrite.

Although the typical Upper Cretaceous lithostratigraphic unit of the Gornji Humac Formation is characterized by peritidal limestones, the Upper Cretaceous carbonates referred to the formation on the Basic geological map of the island of Svetac (KORBAR et al., 2012) are characterized by highly diversified facies. Besides, the carbonates are intensively tectonically fractured and recrystallized. Therefore, it is not always possible to distinguish between typical peritidal and deeper-water facies (pelagic limestones with bioclastic intercalations, resembling allodapic limestones). However, the presented results suggest that during the Maastrichtian the area of the island of Svetac became a part of the Adriatic Basin, probably in the form of a deep embayment developed within the former platform domain (Fig. 7). It is possible that the embayment has been opened along a transverse lineament that has been active during the various periods of the Mesozoic, and could be related to the intermittent activity of the deep rooted fault zone striking SW-NE, along which the Vis-Šolta trough/graben formed during the Triassic (GRANDIĆ et al., 2002). Presumably the deep-rooted fault also initiated development of a Cenomanian-Turonian intraplatform basin on the is-

land of Šolta that is characterized by the same strike (KORBAR et al., 2017b). The Šolta intraplatform basin is situated along the northeastern continuation of the supposed transversal lineament (Fig. 7). However, further investigations are necessary to test this hypothesis.

Nevertheless, the discovery of pelagic carbonates on the island of Svetac is important for the reconstruction of the latest Cretaceous to Palaeogene palaeogeography of the central Adriatic area. Considering the hypothetical K–Pg boundary tsunami that possibly originated in the Atlantic Ocean (KORBAR, 2019), the local palaeogeography could also be important for the reconstruction of the western Tethys at the end of the Mesozoic.

6. CONCLUSIONS

According to the micropaleontological and sedimentological analyses of the pelagic carbonates on the island of Svetac it is possible to conclude the following:

1) The unusually thick-bedded to massive pelagic limestones on the island of Svetac are rich in various species of planktonic foraminifera that imply a direct connection of the depositional environment with the open sea of the nearby Adriatic Basin.

2) The 3m thick succession is characterized by the assemblages of planktonic foraminifera that indicate the Late Maastrichtian *Abathomphalus mayaroensis* Zone and the upper part of the Palaeocene P3 Zone (*Morozovella angulata*).

3) The transition from Maastrichtian to Palaeocene pelagic carbonates is not continuous but is characterized by amalgamated debrites that are related to at least two separated re-depositional events within the basin.

4) Although the direct contact of Palaeocene and Eocene pelagic carbonates is not documented, the Eocene pelagic facies, outcropping a few metres from the Maastrichtian to Palaeocene succession, implies a possible continuous Maastrichtian to Eocene pelagic environment on this part of the former Adriatic Carbonate Platform.

5) It is possible to suppose that the Maastrichtian opening of the deep-water pelagic environment of the Adriatic Basin within the former Adriatic Carbonate Platform west of the island of Vis could be related to a re-activation of an inherited transverse fault zone.

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APPENDIX

List of Maastrichtian, Palaeocene and Eocene taxa cited in the text and figure captions (in alphabetical order according to genus):

Maastrichtian planktonic foraminifera

Abathomphalus mayaroensis (BOLLI, 1951)
Contusotruncana contusa (CUSHMAN, 1926)
Contusotruncana fornicata (PLUMMER, 1931)
Contusotruncana patelliformis (GANDOLFI, 1955)
Globotruncana arca (CUSHMAN, 1926)
Globotruncana cf. *orientalis* EL-NAGGAR, 1966
Globotruncanella havanensis (VOORWIJK, 1937)
Globotruncanella cf. *petaloidea* (GANDOLFI, 1955)
Globotruncanella pschadae (KELLER, 1946)
Globotruncanita conica (WHITE, 1928)
Globotruncanita insignis (GANDOLFI, 1955)
Globotruncanita stuarti (de LAPPARENT, 1918)
Gublerina sp.
Heterohelix sp.
Kuglerina rotundata (BROENNIMANN, 1952)
Macroglobigerinelloides sp.
Muricohedbergella sp.
Pithonella innominata (BONET, 1956)
Pithonella ovalis (KAUFMANN, 1865)
Pithonella sphaerica (KAUFMANN, 1865)
Planoglobulina acervulinoides (EGER, 1899)
Racemiguembelina fructicosa (EGGER, 1899)
Ventilabrella sp.

Palaeocene planktonic foraminifera

Globanomalina chapmani (PARR, 1938)
Globanomalina ehrenbergi (BOLLI, 1957)
Igorina pusilla (BOLLI, 1957)
Igorina tadjikistanensis (BYKOVA, 1953)
Morozovella angulata (WHITE, 1928)
Parasubbotina pseudobulloides (BOLLI, 1957)
Subbotina cancellata BLOW, 1979
Subbotina triangularis (WHITE, 1928)
Subbotina triloculinoides (PLUMMER, 1926)
Subbotina velascoensis (CUSHMAN, 1925)

Eocene planktonic foraminifera

Acarinina bullbrooki (BOLLI, 1957)
Acarinina mcgowrani WADE & PEARSON, 2006
Globigerinatheka kugleri (BOLLI, LOEBLICH & TAPPAN, 1957)
Morozovelloides crassatus (CUSHMAN, 1925)
Pseudoglobigerinella bolivariana (PETTERS, 1954)
Subbotina eocaena (GUEMBEL, 1868)
Subbotina yeguaensis (WEINZIERL & APPLIN, 1929)
Turborotalia frontosa (SUBBOTINA, 1953)
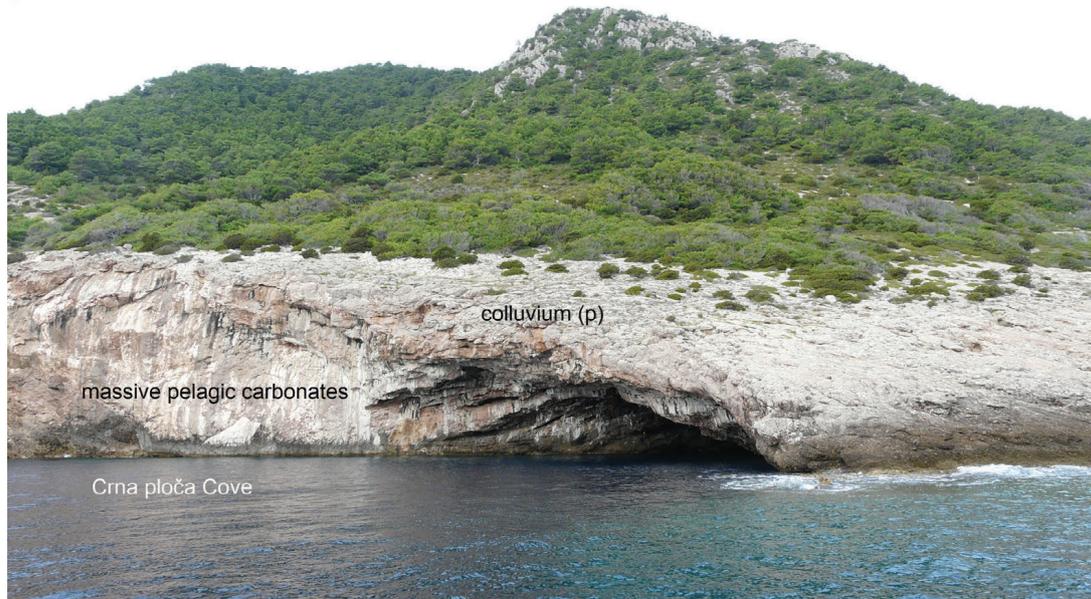
Figure 2/Supplement. Outcrops of massive Maastrichtian pelagic carbonates on the eastern coast of the island of Svetac partly covered by colluvial carbonate breccia (p) deposited along a generally east-west striking Sveti Andrija fault (Fig. 2). Outcrops of Lower Cretaceous carbonates are visible in the background.

Figure 3/Supplement. The main sampling points within the thick-bedded to massive pelagic carbonates on the eastern part of the island of Svetac along the walking trail at Smokvica. Note the heavily vegetated area around the section.