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Ammonites from Mt Kobla (Julian Alps, NW Slovenia) and their significance for precise dating of Pliensbachian tectono-sedimentary event

Amoniti s Koble (Julijske Alpe, SZ Slovenija) in njihov pomen pri natančnem datiranju pliensbachijskega tektonsko-sedimentarnega dogodka

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Abstract

Although ammonites serve as index fossils in the Jurassic, their discovery in the area of present-day Slovenia are rare, with only three locations having been studied in greater detail. Here we presented ammonites from a newly discovered site at Mt Kobla on the eastern Bohinj Range. The site is located at the very top of the Kobla skiing ground, where 250 m of Lower Jurassic limestone of the Julian Carbonate Platform crop out. The succession begins with peloidal/ooidal limestone which upwards passes into bioclastic limestone that alternates in laminas and beds with crinoidal limestone. In the topmost part, limestone breccia is interbedded and neptunian dykes cut the succession. Just below the breccia bed, ammonites were retrieved and genera *Canavaria* and *Neolioceratoides* were identified which indicate an Upper Pliensbachian (?upper Domerian) age. The platform limestones are overlain with basinal strata with internal unconformity. The overall succession records a progressive deepening of the sedimentary environment that culminated in the Upper Pliensbachian and was caused by a regionally recognized, but relatively poorly-dated episode of accelerated subsidence. The Mt Kobla succession correlates well with Mt Mangart and Mt Bohinj successions, which are paleogeographically considered as marginal locations within the Julian Carbonate Platform. Ammonite dating encourages further detailed sedimentary studies of the Mt Kobla succession.

Key words: ammonites, Julian Carbonate Platform, Pliensbachian, Southern Alps, platform drowning, subsidence, tectono-sedimentary event

Izvleček

Čeprav so amoniti vodilni fosili v juri, so njihove najdbe na območju današnje Slovenije zelo redke. Le tri nahajališča so bila natančneje preučena, in sicer spodnjejursko, najverjetneje pliensbachijsko, v Bohinjski dolini, Toarcijsko na Begunjščici in zgornjejursko v Dolini Triglavskih jezer. Med detajlnim geološkim kartiranjem gore Koble, ki se nahaja v vzhodnemu delu Bohinjskega grebena, je bilo odkrito novo najdišče. Nahaja se na samemu vrhu smučišča Kobla, kjer je razgaljeno 250 m debelo zaporedje spodnjejurskih apnencev Julijske karbonatne platforme. Začenja se s peloidno/ooidnim apnencem v skupni debelini 170 m. Lepo je razgaljenih le vrhnjih 60 m zaporedja. Navzgor preide v bioklastični apnenec, ki se v laminah in plasteh menjava s krinoidnim apnencem. V vrhnjem delu celotnega platformskega zaporedja se začnejo pojavljati neptunski dajki in plasti apnenčeve breče. Amoniti so bili najdeni tik pod debelo plastjo breče, ki je interstratificirana v vrhnjem delu zaporedja. Med številno favno smo izbrali najbolje ohranjene primerke in določena sta bila rodova Canavaria in Neolioceratoides, katerih sočasno pojavljanje kaže na zgornji pliensbachij (?zgornji domerij). Platformski apnenci so prekriti z bazenskimi sediment, ki vsebujejo stratigrafsko vrzel. Celotno opisano zaporedje označuje progresivno poglabljanje sedimentacijskega okolja, ki ga je v zgornjem pliensbachiju pospešila regionalno prepoznana, a relativno slabo datirana epizoda ekstenzijske tektonike. Zaporedje na Kobli je primerljivo z lokacijami na območju Julijske karbonatne platforme, ki paleogeografsko spadajo v robne dele Julijske karbonatne platforme. Amonitne datacije spodbujajo nadaljnje detajlne sedimentološke raziskave platformskega zaporedja na Kobli.

Ključne besede: amoniti, Julijska karbonatna platform, pliensbachij, Južne Alpe, potopitev platform, pogrezanje, tektonsko-sedimentarni dogodek

Introduction

The Permian/Triassic boundary extinction events drastically decimated Paleozoic life, leaving few survivors to evolve into the Mesozoic era[1, and references therein]. One of the most interesting and, due to their spiral molds and spectacular suture patterns, attractive groups of fossils that dominated Mesozoic sea life was ammonites. They show rapid speciation, are regularly preserved, and broadly distributed, which promotes them as one of the most valuable index fossils. Although ammonites are common in the Mesozoic of the Tethys Realm, their discovery in the area of present-day Slovenia is sporadic. The first representatives of the Ammonoidea subclassis are known from the Upper Carboniferous and Lower Permian of the Southern Karavanke Mountains[2]. The richest period is the Triassic, with well-known Late Anisian locations at the village of Bučka near Novo Mesto[3] or Hrastenice Quarry near Polhov Gradec[4], as well as the Ladinian and Carnian of the Mežica Mine and Mt. Peca in the Northern Karavanke Mountains, Idrija area and Mt Triglav[5–8] and others[for the review see 9, 10]. Although the Jurassic is the period of prominent ammonite diversification, only three sites have been extensively studied, the first being Pliensbachian Bohinj Valley[11], the second being Toarcian Mt Begunščica[12], and the third the Upper Jurassic Triglav Lakes Valley[13, 14]. Ammonites from the first site were collected from Hierlatz limestone[11, 15], a facies otherwise known from the Northern Calcareous Alps, where it is described as relatively shallow, Sinemurian to the Pliensbachian hemipelagic limestone, deposited on top of morphological highs formed after the drowning of the carbonate platform at the end of the Triassic[16]. Other two sites were excavated from Ammonitico Rosso - type limestone[17– 19], a facies characteristic of the submarine plateaus of the Jurassic Adria passive margin[20–24]. Just a few other Jurassic specimens are reported, mostly from the Julian Alps[10]. Sporadic Upper Cretaceous ammonites are known from Komen and Tomaj limestones from the Karst Plateau[25].

The rare occurrence of Jurassic ammonites is attributed to specific sedimentary environments that persisted in the region during the Jurassic. Shallow water, high energy and flat-topped carbonate platforms were interspaced by deep basins[26, 27], whereas the condensed limestone of the submarine plateaus, i.e., potential ammonite-bearing facies, is mostly eroded and outcrops in just a few places[28, 17]. Consequently, the discovery of new Jurassic ammonites is of special importance for Slovenian paleontology and biostratigraphy. In the present paper, we present such a site from the top of the Kobla skiing-ground found during the detailed geological mapping of the area. The main goals of this paper are to A) describe the geological setting of the site, B) provide a basic sedimentary analysis of the strata with ammonites, and C) define the biostratigraphy of the fossil assemblage.

Previous work and paleogeography

Ammonites were collected from a site located at the top of the Kobla skiing ground in the eastern part of the Bohinj Range, which forms the southern orographic boundary of the Julian Alps (Figure 1). The oldest geological record from Mt Kobla comes from a sketch of the iron mine that was owned by Baron Žiga Zois and made by Polc in years 1788–1790 (Schmidt Goran, pers. comm.). Extensive geological research was made during the construction of the railway tunnel which crosses the Bohinj Range directly below Mt Kobla. Kossmat[29] summarized the data, presented the structure and lithostratigraphic division, and elaborated the geological map (1 : 75 000) of the wider area. The author outlined that the northern slopes of Mt Kobla consist of Late Triassic and Early Jurassic carbonates overlain by Oligocene clastics, whereas the southern slopes consist of thin bedded, often cherty strata. During the work on a Basic Geological Map of Yugoslavia (sheet Tolmin) Buser[15, 28] defined the paleogeographic affinities of these successions: northern, i.e., carbonate succession sedimented on the Julian Carbonate Platform (JCP), whereas southern developments were deposited in the Slovenian Basin (SB)[15, 30]. Both paleogeographic units originated in the Middle Triassic after disintegration of the Slovenian Carbonate Platform[26, 31] which was related to the rifting of

the Meliata Ocean[32]. The JCP disintegrated and drowned in the Middle Jurassic and turned into the pelagic plateau known as Julian High[26], which coincided with the opening of the Alpine Tethys[17, 18]. In recent years, extensive studies of Late Triassic and Jurassic basinal succession were performed on Mt Kobla[33 and references therein]. These studies incorporated the elaboration of a detailed geological map, during which the here-in-described ammonite site was discovered.

Structural setting

Structurally, the area belongs to the Southern Alps, which are characterized by the south-directed Miocene thrusting (Figure 1).

JCP deposits compose the structurally higher Julian Nappe, whereas SB sediments are found in the structurally lower Tolmin Nappe[34]. In the Mt Kobla area, the contact between the JCP and SB successions is exceptionally not a thrust-fault but a steep, northward-deeping fault which eastward separates into two divergent faults (Figure 2). JCP successions are in a sub-vertical to slightly inverse position with steep deeping towards the north, whereas SB successions are repeated several times due to lower-order nappe stacking and deeping normally to the north. Between the JCP and SB successions the small Krevl tectonic block is emplaced[35]. It shows Lower Jurassic JCP- and Middle to Upper Jurassic SB-characteristics. Parallel and north to the main fault runs another fault that separates Triassic and Jurassic JCP successions. A few other faults with minor displacement were recognized in the mapped area (Figure 2a).

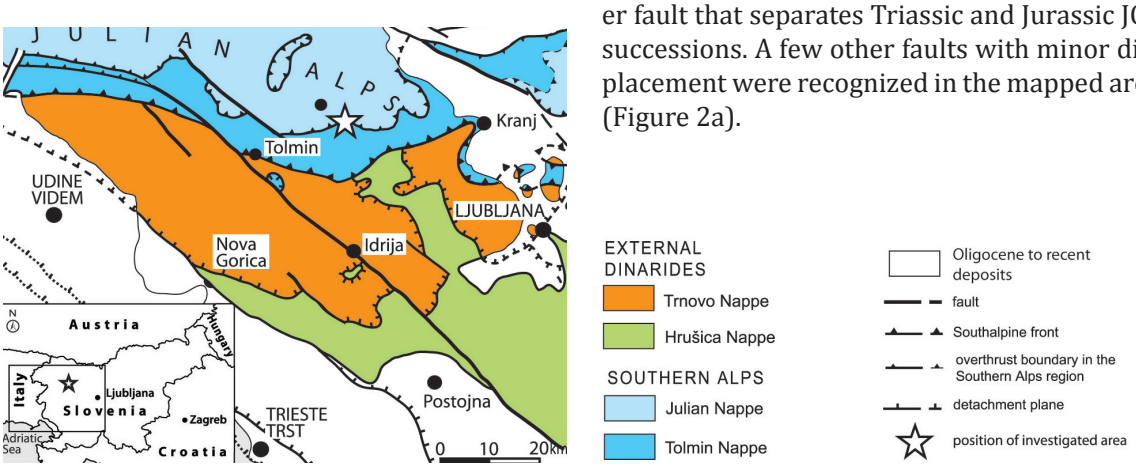

Figure 1: *The location of Mt Kobla and the macrotectonic subdivision of western Slovenia; simplified after[34].*

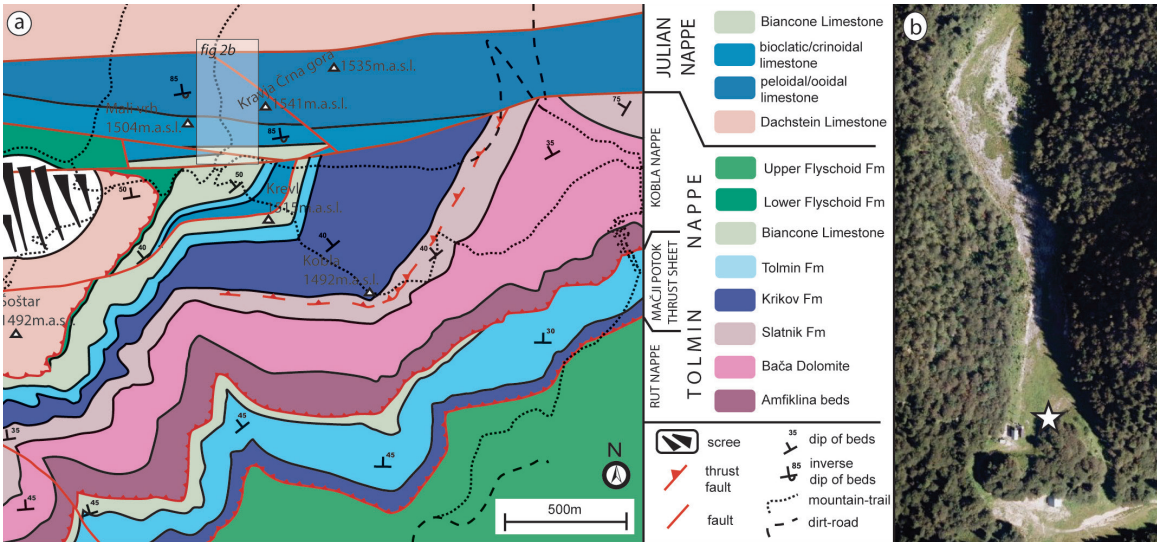

Figure 2: *a) Geological map of the Mt Kobla area, b) orthophoto of the topmost part of the Kobla skiing ground (public data of the Republic of Slovenia, Geodetic Survey RS, DOF 05, 2011) with the location of the ammonite site (marked with a star).*

General description of the Julian Carbonate Platform succession on Mt Kobla

The oldest JCP formation of the mapped area is the Norian-Rhaetian Dachstein reef limestone (Figure 3). The coral *Dictichophyllia norica* and sponge *Cheilosporites tirolensis* were reported on Mt Kobla[36, 37]. The contact with Jurassic deposits is at the previously mentioned fault. It outcrops well on the Kobla skiing-ground where the inner fault zone is up to 0.5 meter wide, partly eroded and surrounded by tectonic mirrors. Kossmat[29] recognized this fault in the railway tunnel and reports clastics from the inner fault zone. Budkovič[38] described a thick marl-bed 2 m between the Triassic and Jurassic JCP successions in the Bohinj area. Taking into concern this data and the fact that the fault plane is parallel to the bedding of the overlying Jurassic strata, this fault could have formed due to the tectonic activation of a marl-dominated formational boundary.

Traditionally, the Triassic/Jurassic boundary on the JCP is placed at the disappearance of stromatolites and the occurrence of ooidal limestone[15]. The overall Jurassic succession in the studied area is 250 m thick. The lower 170 m are characterized by peloidal/ooidal limestone. In the upper 60 m of this interval on the Kobla skiing-ground, where the outcrops are good, they show clear bedding with a bed thickness from 10 cm up to several meters. Cross-lamination occurs in these beds. The package of bioclastic limestone occurs as early as this part of the succession, but is overlain again by peloidal/ooidal limestone. The following 80 m are dominated by bioclastic limestone and will be described in greater detail in the next chapter.

The limestone succession is overlain by a 0.5-meter-thick marl, which presumably correlates with the marl-dominated Toarcian formations known from the surrounding basins[39–42]. The entire succession ends with Biancone-type limestone, i.e., thin-bedded mudstone/wackestone with chert nodules. This facies is characteristic for latest Jurassic and early Cretaceous successions of basins and drowned platforms of the entire Adriatic passive margin[17, 22, 41, 43–45].

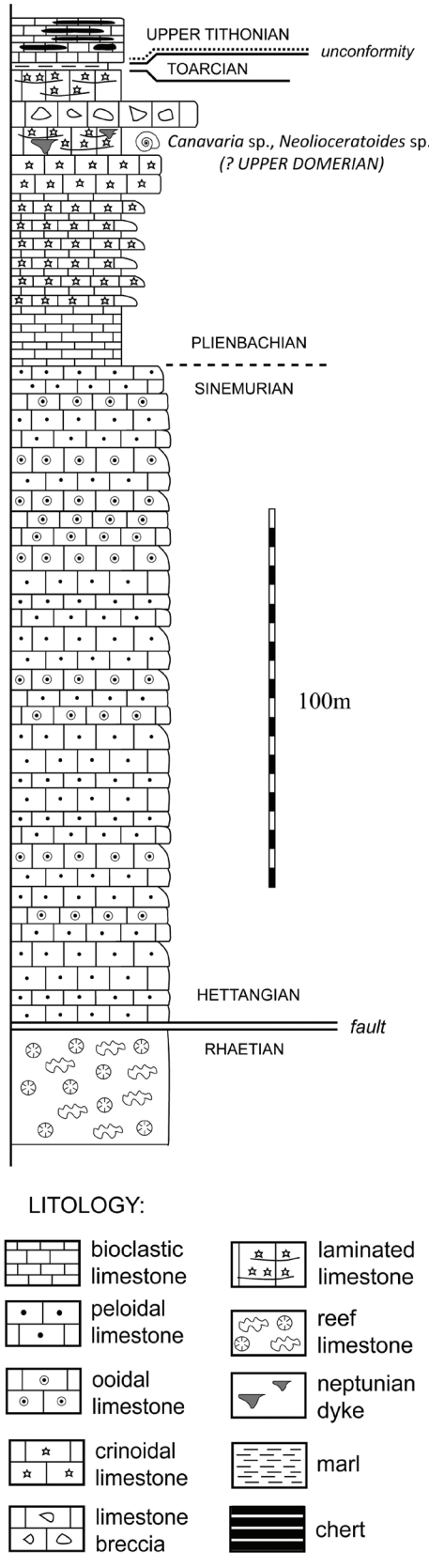

Figure 3: *Schematic stratigraphic column of the Julian Carbonate Platform succession of Mt Kobla.*

Facies of the Ammonite-bearing beds

The entire succession with ammonites is 80 m thick (Figure 4d, e). It is characterized by gray and, in the upper part, also reddish-gray bioclastic limestone. It is wackestone composed of abundant crinoids and sponge spicules, and rarer filaments, ostracods, benthic foraminifera, juvenile ammonites, brachiopods and calcareous sponges (Figure 4b, g). In the lower part, stromataxis structures and sponges in a primary growth-position were observed (Figure 4c).

Bioclastic limestone alternates with laminas and thin beds of crinoidal limestone which is grainstone or packstone composed predominantly of crinoids, and rarer intraclasts and shells (Figure 4b, h). It becomes dominant in the middle part of this interval, where it composes a several-meter-thick package of occasionally graded beds.

The topmost part of the entire interval is characterized again by alternating bioclastic and crinoidal limestones. It additionally contains neptunian dykes (Figure 4h) composed of reddish marly limestone with crinoids as predominant grains, but lithoclasts of surrounding rocks were also detected. They usually fill cavities which are oriented perpendicularly as well as parallel to the bedding. A few-meters-thick limestone breccia bed is interstratified in the upper part of the interval. In the lower part it shows chaotic internal organization (slump) which becomes clearly brecciated towards the top of the bed. Clasts correspond to surrounding bioclastic limestone, but lithoclasts of peloidal/ooidal limestone also occur. The ammonites presented in this paper were found just below this bed.

Ammonites and biostratigraphy

Ammonites were found on the top of the Kobla skiing-ground, close to the uppermost exiting stations of the chair-pull (Figure 2b) and taken from a bedding plane exposed on the rock crevice that occurs at the crossing of two skiing trails (E13°57'29" N46°14'21"). After the exploration of the outcrop, the bedding plane was systematically opened by an additional square meter (Figure 4d, e). The best-preserved specimens were taken to the laboratory together with host-rock, where they were cleaned and photographed. A few selected examples were treated with a pneumatic tool for additional mechanical preparation, but this revealed to be too destructive because of the strong lithification and implementation of fossils in the host-rock (Figure 5h). From the collected material two specimens were determined on the generic level as *Canavaria* sp. (Figure 5a) and *Neolioceratoides* sp. (Figure 5b, c). Although they exhibit poor preservation for qualitative paleontological analysis, they provide precious biostratigraphic dating, because this association is typical of Upper Pliensbachian, more precisely upper Domerian (*spinatum* AZ). Other collected material was too poorly preserved for determination; however it is represented in Figure 5 (d-i). Ammonite data is further constrained by benthic foraminifer *Agerina martana* Farinacci (Figure 4g), which is common in bioclastic limestone. Although it is generally considered as Lower Jurassic, Chiochini et al.[46] narrowed its appearance to the Pliensbachian. Considering these facts, the bioclastic/crinoidal limestone of Mt Kobla is Pliensbachian and the topmost part with limestone breccia and neptunian dykes is (?upper) Domerian in age.

Pliensbachian tectono-sedimentary event based on new ammonite dating

The Late Triassic and Early Jurassic succession of the JCP outcropping on the northern part of Mt Kobla is characterized by a highly productive, shallow-water, high-energy sedimentary environment of barrier reef and ooidal shoal, respectively. In the Pliensbachian, a distinct facies change from peloidal/ooidal to bioclastic limestone records the deepening of the sedimentary environment. Namely, bioclastic limestone indicates the sedimentation on the outer platform to the upper slope. Interstratified crinoidal limestone points to high-energy depositional conditions. The thin laminas of the crinoidal limestone were most probably deposited by bottom currents, whereas thicker

beds could have originated due to high-energy resedimentation events such as tempestites or turbidites. The deepening of the sedimentary environment could have been initially linked to eustatic oscillations of the relative sea-level because in the Tethyan Realm, Pliensbachian is characterized by a second-order transgressive/regressive cycle, (T5/R5 in[47]), whereas the sedimentation documented in the topmost part of the succession was firmly governed by accelerated tectonic subsidence. This prominent Pliensbachian tectonic event is regionally evidenced by the disintegration of the JCP and differential subsidence of separated

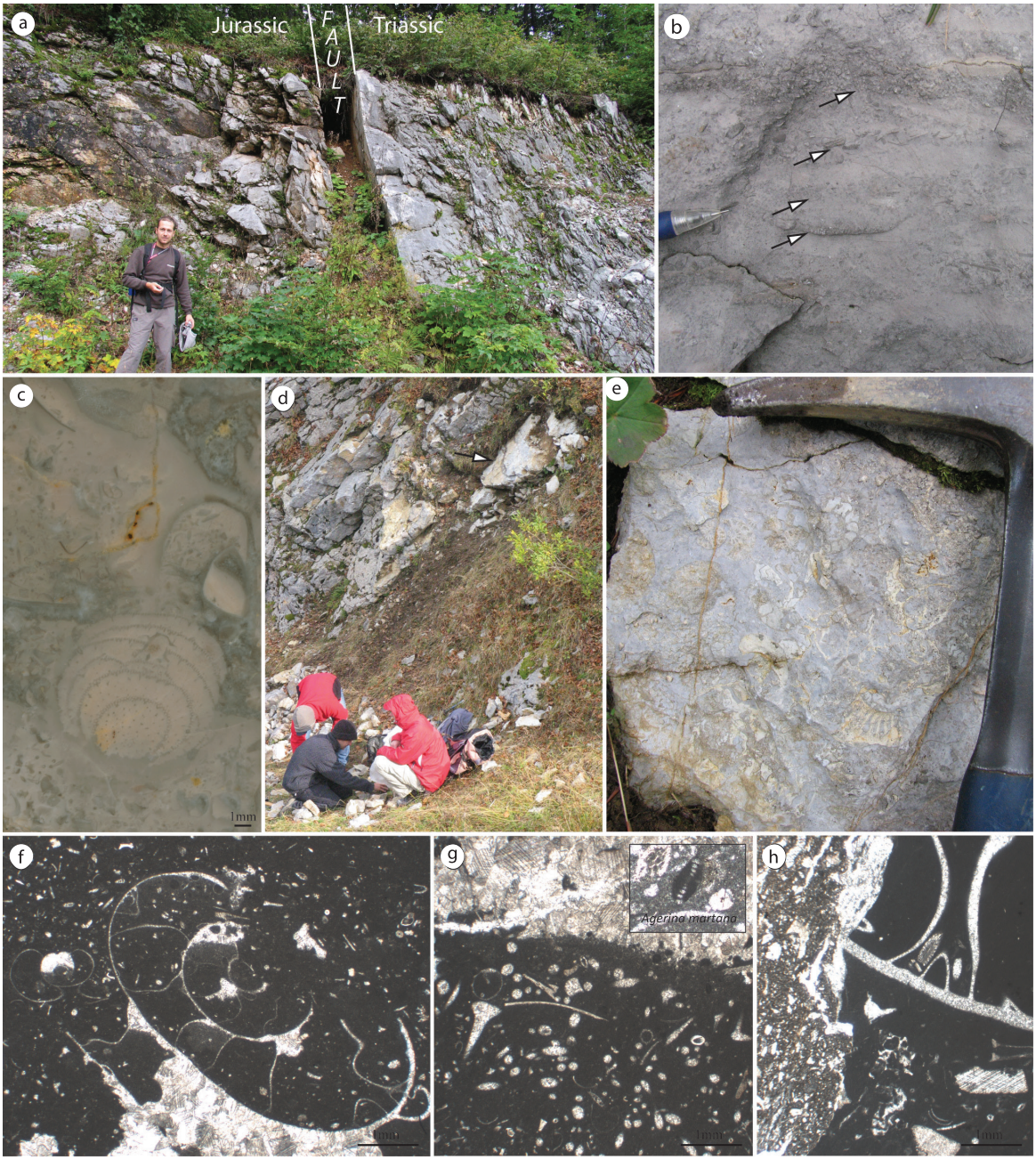

Figure 4: ***a)*** *fault between Dachstein Reef Limestone (left) and peloidal/ooidal limestone (right),* ***b)*** *bioclastic limestone with laminas of crinoidal limestone (arrows),* ***c)*** *sponge* (1.7 cm *in diameter) in the growth-position within bioclastic limestone,* ***d)*** *excavation on the ammonite site with visible ammonite bed-plane (arrow),* ***e)*** *ammonites on the bedding plane,* ***f)*** *juvenile ammonites in wackestone,* ***g)*** *spiculitic wackestone overlain with erosional contact by crinoidal grainstone; in the upper right corner is enlarged foraminifer Agerina martana Farinacci* – 0.2 mm *in length,* ***h)*** *wackestone with ammonite and contact with neptunian dyke (left) filled predominantly with crinoids.*

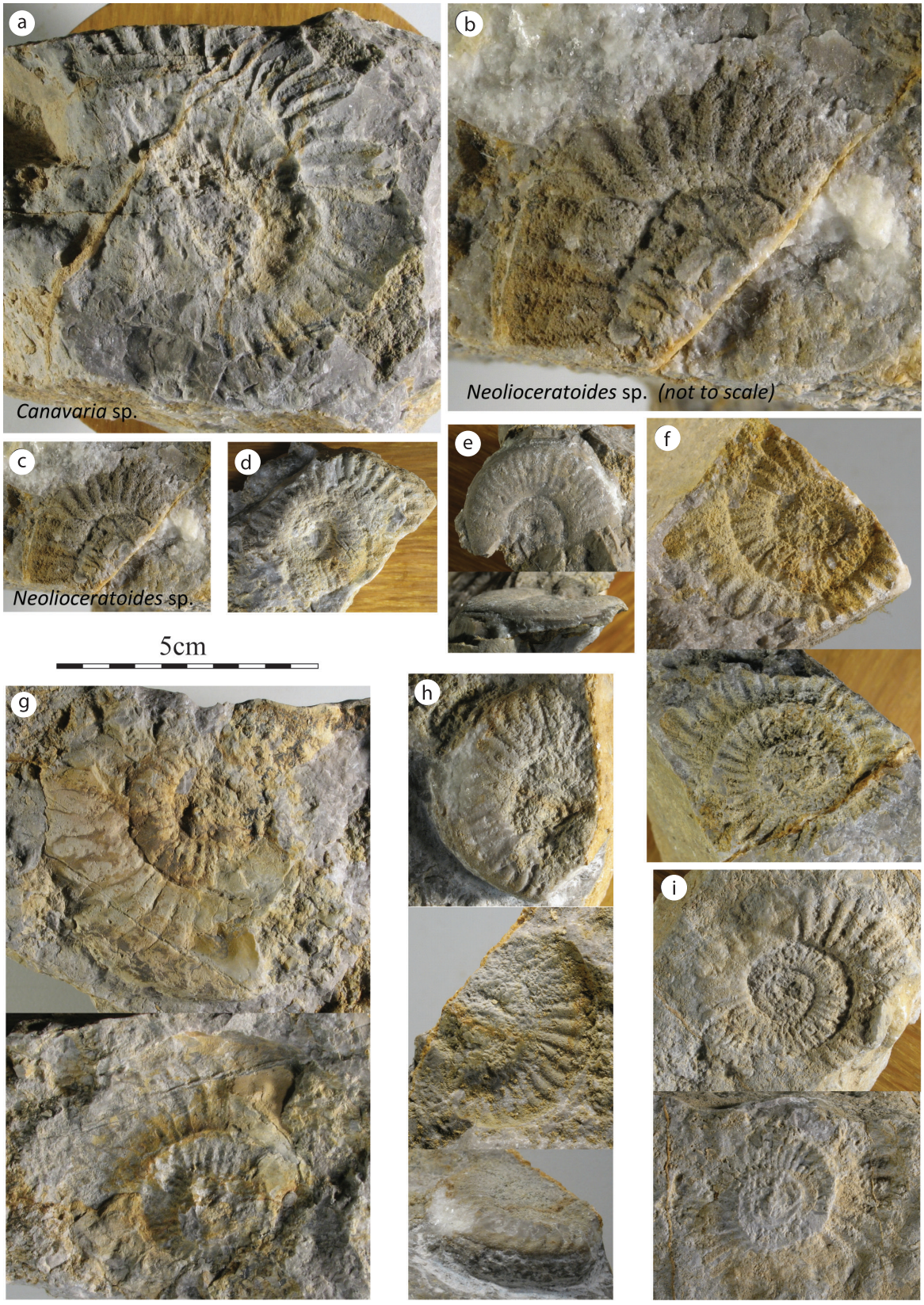

Figure 5: *Ammonites:* ***a)*** *Canavaria sp.,* ***b)*** *Neolioceratoides sp. – not to scale; enlarged Figure 5c,* ***c)*** *Neolioceratoides sp., d-i) undetermined specimens (Figures f, g, h, and i also show casts; Figures e and h show a lateral view).*

blocks[17, 18, 40]. In the adjacent SB, it is recorded by the highly-variable thickness of the Toarcian Perbla Formation[41, 42]. Neptunian dykes characterize the JCP margin[26, 48, 49] and the earliest activation phases are dated as Pliensbachian[50]. In the Bohinj area, Ribnica breccia, which is a debrite composed of limestone and rare chert clasts, covers the basinal Zatrnik Formation and is dated as Lower Jurassic and related to a Pliensbachian tectonic activity[45, 51]. At Mt Kobla, the tectonic event is in accordance with previously-described sedimentary indicators. Namely, it is well-manifested at the top of the carbonate succession with the occurrence of neptunian dykes and limestone breccia. It is this part, from which ammonites were retrieved and dated the main Pliensbachian tectonic intensification to the (?upper) Domerian.

Correlation with other successions of the Julian Carbonate Platform

Ammonite-bearing beds from Mt Kobla are characterized by bioclastic limestone that is the time and facies equivalent of dominant beds in the Sedlo Formation from the Bovec Trough[17, 40]. This trough originated after the Pliensbachian disintegration of the JCP and the Sedlo Formation indicates the initial deepening phases. It is overlain by a Fe-Mn nodular crust which points to unconformity[17]. No such crust was detected on Mt Kobla – however the overlying marls correlate with clay-rich Skrile Formation from the Bovec Trough, which was dated with radiolarians to the Toarcian[39]. The age of the formation was further constrained by chemostratigraphic recognition of the Toarcian OAE[52].

The Mt Kobla JCP succession correlates also with developments from the Bohinj area, where Buser (1986) described Lower Jurassic crinoidal limestone in which Härtel[11] found rich brachiopod, bivalve and ammonite fauna in several locations, mostly active quarries near Bohinjske Češnjice in Bitnje villages. Due to a similar setting and close correlation, a non-revised list of cephalopods is presented herein. Härtel[11] recognized *Phylloceras geyeri* Bonarelli, *P. anonymum* Hass, *P. frondosum* Reynès sp., *Rhacophyllites ex aff. liberti* Gemm., *R. planispira* Reynès, *R. (Meneghiniceras) lariensis* Meneghini, *Lytoceras cf. secernendum* de Stefani, *L. nothum?* Meneghini., *Amaltheus margaritatus* Montfort, *Harpoceras (Arieticeras) retrosicosta* Oppel, *H. bertrandi* Kilian, *H. geyeri* Del Campana, *H. cf. reynèsi* Fucini, *H. (Grammoceras) uequiondulatum* Bettoni, *H. percostatum* Fucini, *H. (Harpoceratoides) serotinum* Bettoni, and *Atractites ex. aff. A. indunensis* Stop. These quarries had already been abandoned and were mostly inaccessible during the geological mapping in eighties[15], which today results in practically unrecognizable sites[53]. Buser[15] outlined that crinoidal limestone laterally and vertically passes to ooidal limestone and in the upper part contains interbeds of micritic (?bioclastic) limestone and, additionally to Mt Kobla, nodular chert. Prominent facies changes of the Jurassic rocks in the Bohinj Valley were also described by Cousin[30], who recognized two distinct facies: a more shallow-water facies to the south and the deeper-water Zatrnik Formation to the north. For the latter, Kukoč et al.[45] proposed on the basis of overlying Cretaceous strata an outermost, ocean-ward paleogeographic location within present-day Slovenia, which is comparable to the developments of the Inner Dinarides. However, exact spatial stratigraphic as well as structural relationships within Jurassic strata in this area remain vastly unresolved[51]. On the contrary, the Mt Kobla succession exhibits a clear upwards deepening trend with well-dated and well-expressed tectonic phase which consolidates its importance in the understanding of the region's Jurassic sedimentary evolution and urges further research.

Conclusions

Jurassic ammonites in the area of present-day Slovenia are only sporadically preserved and just three locations have so-far been studied in detail, which amplifies the importance of newly-discovered sites. At Mt Kobla the overall Jurassic succession begins with peloidal/ooidal limestone. Upwards, it passes into bioclastic and crinoidal limestones which indicate the deepening of the sedimentary environment. At the top of the entire JCP succession limestone

breccia and neptunian dykes additionally occur and point to a regionally-recognized tectonic event. Within these strata ammonites of genera *Canavaria* and *Neolioceratoides* were determined which date to the Upper Pliensbachian (?upper Domerian). The succession correlates with successions which sedimented in environments located on the JCP margins and drowned to basinal depth during the Jurassic. Similarly, on Mt Kobla the platform carbonates are overlain by ?Toarcian marl and latest Jurassic Biancone-type limestone which was deposited after JCP drowning.

Acknowledgments

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