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Lower Jurassic beds with bivalves in south Slovenia

Spodnjejurske plasti s školjkami v južni Sloveniji

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Abstract

The Lower Jurassic beds of south Slovenia outcrop on a surface of several hundred km² with their thickness in places exceeding 300 meters. They were deposited on the Dinaric Carbonate Platform. In them rich accumulations of characteristic bivalves occur that in Pliensbachian and Toarcian inhabited the wide interconnected shallow water regions of the western and southern margins of Tethys and the eastern Pacific. The most interesting are three large bivalve species: *Lithiotis problematica*, *Cochlearites loppianus* and *Lithiopedalion scutatus*. In addition, numerous other genera can be found: *Gervilleioperna*, *Mytilus*, *Opisoma* and *Pachyrisma* (with subgenera *Pachymegalodon* and *Durga*).

The bivalves formed in the region of south Slovenia, in the prevailingly quiet environment of the restricted shelf, sea-bottom mats or biostromes. Their shells can be only rarely found in their growth position. The horizon with bivalves ("lithiotid horizon") in south Slovenia is attributed to Pliensbachian (Domerian). It is up to 75 metres thick and it almost does not pinch out. Within it individual lumachelles of bivalves occur which are from several centimetres to ten metres thick. They are almost exclusively associated with dark, micritic, in places marly limestone and bituminous dolomite. The biodiversity in lumachelles is very low. The intermediate beds that do not contain bivalves mostly consist of oolitic and biosparitic limestone. In this article some localities from various areas of the carbonate platform are described. Considered are paleogeographical and paleoecological conditions that permitted the existence of this typical bivalve fauna.

Kratka vsebina

Spodnjejurske plasti južne Slovenije izdanjajo na površini več 100 km² in ponekod dosežejo debelino več kot 300 metrov. Nastale so na Dinarski karbonatni platformi. V njih so bogata nahajališča značilnih školjk, ki so v pliensbachiju in toarciju množično poselile obsežne, med seboj povezane plitvomorske predele zahodnega in južnega obrobja Tetide ter vzhodnega Pacifika. Najzanimivejše so tri vrste velikih školjk: *Lithiotis problematica*, *Cochlearites loppianus* in *Lithiopedalion scutatus*. Najdemo pa še številne vrste rodov *Gervilleioperna*, *Mytilus*, *Opisoma* in *Pachyrisma* (s podrodovoma *Pachymegalodon* in *Durga*).

Školjke so na področju južne Slovenije, v pretežno mirnem okolju zaprtega šelfa sestavljale podmorske trate ali biostrome. Njihove lupine le malokje najdemo v življenjskem položaju. Horizont s školjkami (»litiotidni horizont«) v južni Sloveniji uvrščamo v pliensbachij (domerij). Debel je do 75 metrov in se skoraj ne izklinja. V njem so posamezne lumakele školjk debele od nekaj centimetrov do 10 metrov in so vezane skoraj le na plasti temnega, mikritnega, ponekod laporнatega apnenca in bituminoznega dolomita. Biodiverziteta v njih je zelo nizka. Vmesne plasti brez školjk najpogosteje sestavljata oolitni in biosparitni apnenec. V našem prispevku so opisana posamezna nahajališča iz različnih predelov karbonatne platforme. Podane so paleogeografske in paleoekološke razmere, ki so pogojevale obstoj značilne školjčne favne.

Introduction

In south Slovenia which is situated in the northwesternmost part of the Dinarides the Jurassic beds exceed the thickness of 1500 metres, and they consist predominantly of limestone. They were deposited on the Dinaric Carbonate Platform, in the Mediterranean part of the ancient Tethys. Since in them no ammonites were found, they cannot be directly subdivided into stages or even zones. For more detailed dating the researcher can use the remains of fossil bivalves, gastropods, brachiopods, hydrozoans, foraminifers and algae.

For subdivision of Liassic beds the fossil bivalves are the most important. Characteristic is *Lithiotis problematica* Gümbel from the Lithiotidae family that is the most famous and geographically the most widespread Lower Jurassic bivalve. Its name is derived from "ear-like" sections that were noticed in north Italy already more than 250 years ago. They were described first as plant remains (Gümbel, 1874, 1890). The species is still "problematic" for paleontologists, since many features connected with the unusual shape of its shell cannot be explained (Reis, 1903; Accorsi Benini & Broglio Loriga, 1977; Chinzei, 1982).

The most abundant bivalves in south Slovenia are *Cochlearites loppianus* (Tausch) and *Lithiopedalion scutatus* (Dubar). *Lithiotis problematica* can be found only in few places. All three species are distinguished by large, unusually shaped and highly variable shells. Justified are question on the mode of life of these bivalves. Their sections are clearly visible in the black Podpeč limestone that is among the most beatiful ornamental stones of Slovenia (Buser, 1987b).

In the Liassic beds of south Slovenia also numerous other bivalves can be found (S. Buser, 1965a; I. Buser, 1989). In preparation is the article with systematic descriptions of individual species announced for the following issue of Geologija (Debeljak & Buser). In the present paper, however, the important localities in south Slovenia are described with the aim of reconstructing the paleoecological conditions during Lower Jurassic on the Dinaric Carbonate Platform that enabled thriving of this characteristic fauna for a relatively short time interval.

The Lower Jurassic bivalves are doubtlessly worth their attention. They are interesting from the biologic, and also from stratigraphic aspects. Further, they permit paleogeographic comparison with other world known localities.

Previous research

In 1890 Tausch von Gloeckelsthurn published his work on the fauna from Liassic limestones in South Alps. It is interesting to note that in his work he represented several beautiful megalodontid specimens from the Podpeč quarry near Ljubljana. In his treatise (1890, 28-29) he correctly established the age of the strata with bivalves that outcrop south of Ljubljana as Jurassic, and not Triassic, as it was considered earlier.

In the years 1959-65 S. Buser geologically mapped the territory of south Slovenia from the Italian-Slovenian border in the west, across Trnovski gozd, Hrušica, Nanos, Logatec and Bloke Plateau with Javorniki, Krim-Mokrec hills and Lower Carniola, to Suha krajina in the east. During this work he collected a rich fossil material, and achieved the subdivision of Jurassic beds (Buser, 1965a,b). As first he determined the species *Lithiotis problematica* and *Cochlearites loppianus* in Slovenia. He established a new bivalve genus with multivincular ligament to which most of specimens from south Slovenia belong. He named it *Lithiopedalion* in his doctoral thesis. He attributed it together with genera *Lithiotis* and *Cochlearites* to the family Lithiotidae.Therefore in Slovenia for these characteristic bivalves the name Lithiotidae became common, although they are nowadays attributed to various families. Buser presented his work at the 42nd annual meeting of the Paleontological Society in Graz in 1972. However, after many years of cooperation, he was overtaken with publication by the Italian paleontologist Accorsi Bennini (1979) who described her genus as *Lithioperna*, although the name *Lithiopedalion* was already used in the international professional literature (Bosellini, 1972).

Localities of Lower Jurassic bivalves elsewhere in the world

The shallow marine Lower Jurassic beds with bivalves are in many places developed lithologically in a similar facies as in Slovenia. Upwards and downwards they are usually not sharply limited. Beside more or less dark grey micritic and biosparitic limestone and dolomite frequently occur marly layers and sheets, and complexes of oolitic limestone.

The most typical faunistic element of the shallow marine Lower Jurassic beds is bivalve *Lithiotis problematica*. It gave its name to the beds and to the facies in which it occurs (e.g. *Lithiotis* limestones, *Lithiotis* facies), although other large, thick-shelled bivalves are usually more abundant (Berti Cavicchi et al., 1971).

The most well known and best studied are localities in the Southern Alps of north Italy (provinces of Verona, Trento and Vicenza). They occur in the upper part of grey Liassic limestones called "Calcari grigi" (Böhm, 1884; Tausch von Gloeckelsthurn, 1890; Bosellini & Broglio Loriga, 1971; Bosellini, 1972).

The Lower Jurassic beds with characteristic bivalves extend across south Slovenia also to neighboring Croatia: Velika Kapela and Velebit (Grubić, 1961), Herzegovina (Katzer, 1904) and Dalmatia (Schubert, 1906). They were found also at Plitvice Lakes. The best preserved specimens of *Lithiotis problematica* and *Cochlearites loppianus* come, however, from the locality Kopilje in Montenegro. Corresponding data unfortunately have not been published.

Similar Lower Jurassic facies with characteristic bivalves appear in south Spain (Turnšek et al., 1975; Geyer, 1977), in south and central Apennines (De Castro,

1962) and in Morocco (Dubar, 1948; Agard & Du Dresnay, 1965; Lee, 1983). Krumbeck (1923) thoroughly studied fauna on the Timor island in Indonesia. Broglio Loriga and Neri (1976), Geyer (1977) and Nauss and Smith (1988) collected data from localities in western France (Sarthe department), Switzerland (Graubünden), Tunisia, Algeria, Albania, Greece, Turkey, Somalia (Mogadiscio), Oman, south Iran, Iraq and in the Himalayas.

Von Hillebrandt (1981) reports genus *Lithiotis* from north Chili and Peru. In North America this genus occurs in California, Nevada and in east and central Oregon (Nauss & Smith, 1988). *Lithiotis* from Oregon was first described under generic name *Plicatostylus* (Lupher & Packard, 1930), which has since been recognized as a junior synonym of *Lithiotis* (Buser, 1965a).

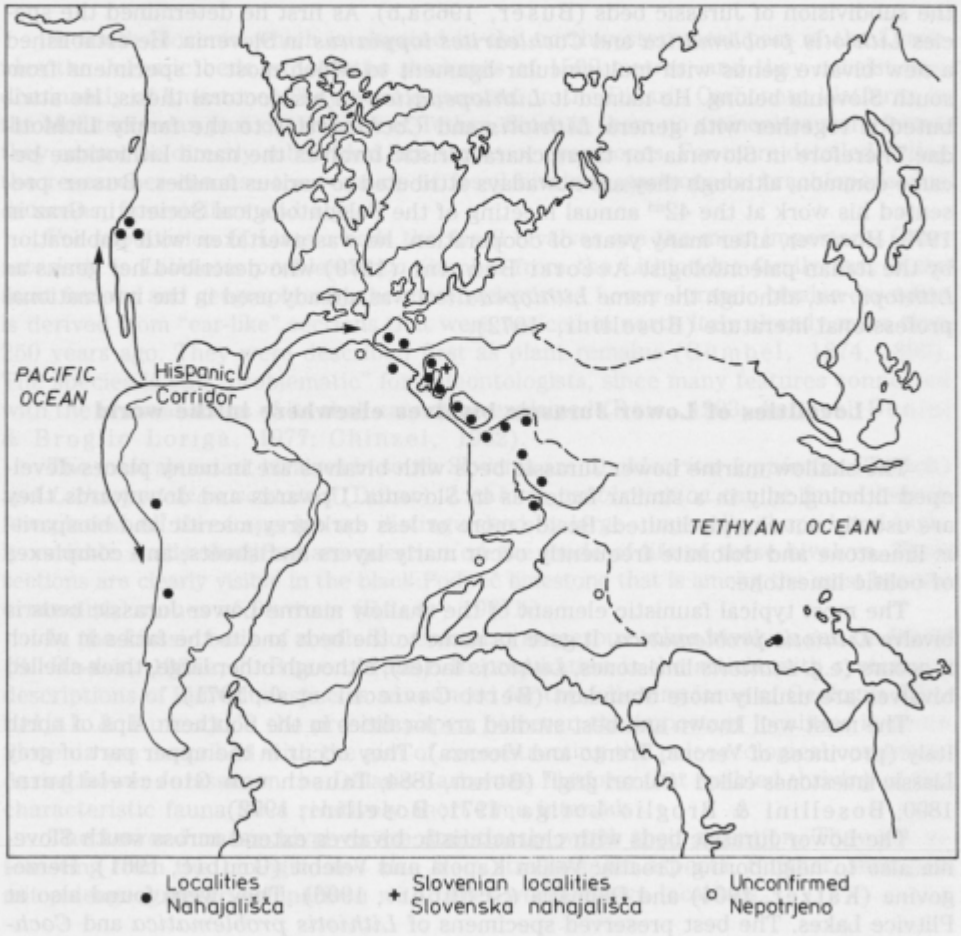


Fig. 1. Paleogeographic distribution of genus *Lithiotis* and presumed migration directions (After Broglio Loriga & Neri, 1976, and Nauss & Smith, 1988)

Sl. 1. Paleogeografska razširjenost rodu *Lithiotis* in predvidene migracijske smeri (Po: Broglio Loriga & Neri, 1976 in Nauss & Smith, 1988)

Such wide extension of localities across the world indicates the existence of wide interconnected shallow marine regions during Lower Jurassic along the western and southern margins of Tethys and the eastern Pacific. Here on carbonate platforms, in the tropic belt or under the influence of warm oceanic currents, very similar paleoecological conditions were established.

The paleogeographic reconstruction of the enumerated localities appears in figure 1. It can be hypothesized that already in Pliensbachian Tethys and the ancestor of the present Pacific were connected by a shallow marine corridor across the present Central America. The connection is called the Hispanic Corridor (Smith, 1983; Smith & Tipper, 1986). It enabled the migration of fauna and flora between the two oceans.

In all enumerated regions, large thick-shelled bivalves abundantly occur. Almost everywhere the most typical species is *Lithiotis problematica* (fig. 1). According to certain authors the bivalves flourished on the sea bottom in the form of mats or biostromes, while others report genuine reefs or bioherms (Agard & Du Dresnay, 1965; Bosellini, 1972; Göhner, 1980; Nauss & Smith, 1988).

In most of enumerated localities besides bivalves the corals, large gastropods, brachiopods and crinoids can be found. Also the microfauna is highly comparable. The most characteristic species among the foraminifers is *Orbitopsella praecursor* (Gümbel). In places also remains of terrestrial plants were found.

Finds of ammonites in shallow marine Lower Jurassic beds are very rare and accidental. Somewhere they occur in under- or overlying beds. On the basis of ammonites the beds with the mentioned fossil assemblage (*Lithiotis* facies) have been attributed to Pliensbachian (mostly to its upper part: Domerian), and somewhere (e.g. in South America) also to the lower part of Toarcian.

Localities of Lower Jurassic bivalves in Slovenia

The Lower Jurassic bivalves occur in the "lithiotid horizon" of southern Slovenia, as it was named in 1965 by Buser (1965a) after the characteristic bivalves that he then attributed owing to evident similarities to the same family: Lithiotidae. Their long, narrow sections serve as a clear identification of the rocks in the field. *Lithiotis problematica* is the most well known, but rather rare. Much more frequent are species *Lithiopedalion scutatus* and *Cochlearites loppianus*. Since nowadays the mentioned three species are attributed to distinct families, the name lithiotides should be abandoned. However, the terms as "lithiotid horizon" or "lithiotid limestone" can be used principally in the sense of facies. Next to enumerated bivalves also the genera *Pachyrisma*, *Gervilleioperna*, *Mytilus* and *Opisoma* are found.

On the basis of field data and comparisons with similar localities in north Italy Buser (1965a, 44–46) attributed the beds with characteristic bivalves to the **upper part of Middle Lias: Domerian**. In Trnovski gozd the characteristic bivalves vanish 10-30 thickness meters below the beds that contain the Upper Liassic brachiopods, and about 50-60 meters below the Lower Dogger beds that were proved by microfossils (Buser, 1979).

The lithiotid horizon in south Slovenia is constant and it almost does not wedge out. It might be less than half a meter thick, but in places it attains even 75 meters. The horizon reaches its maximal thickness at Podpeč, in the Krim-Mokrec hills and in the Krka valley. Here the limestone beds are typically dark grey or even black in color. Northwards the limestone becomes lighter, and the beds with bivalves thinner

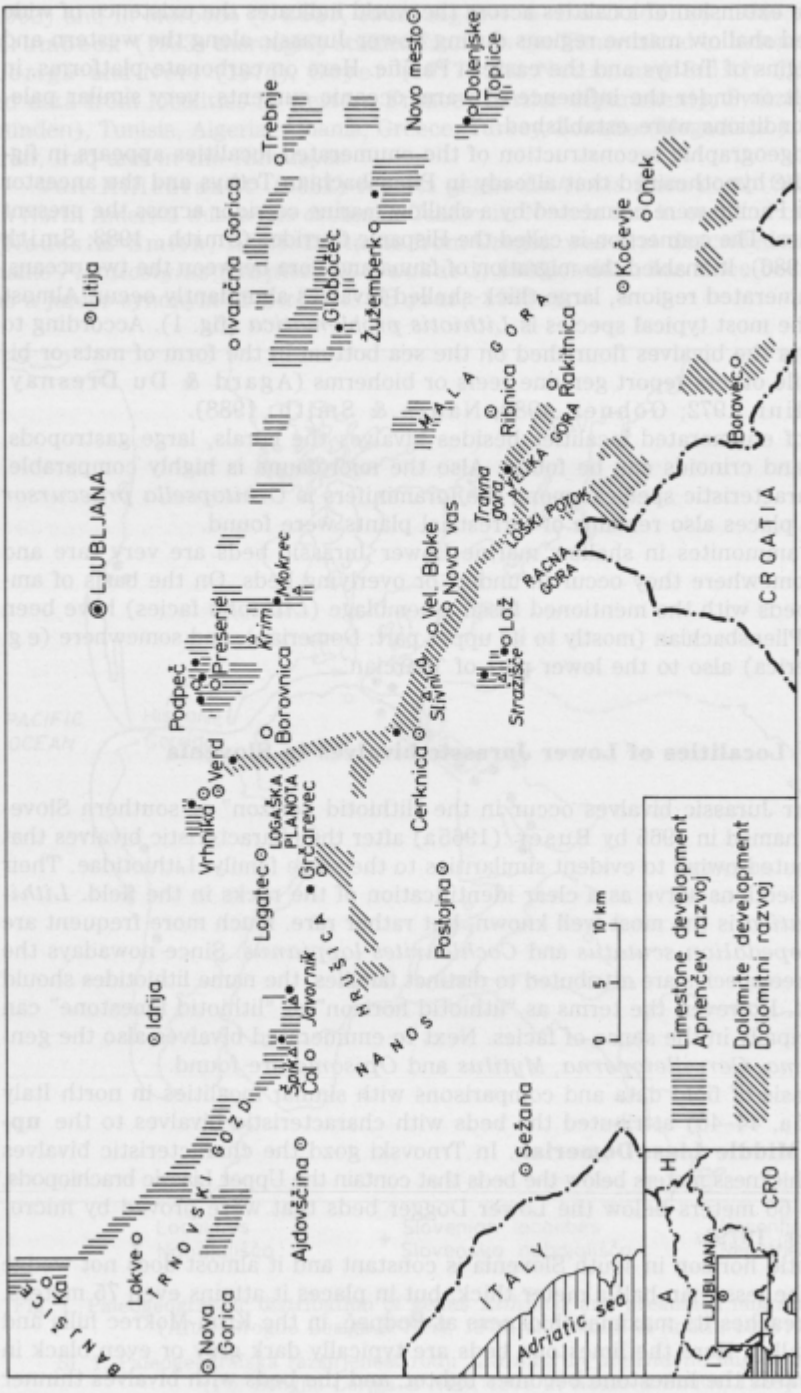


Fig. 2. Distribution of Lower Jurassic beds with bivalves in southern Slovenia with the localities (•) where bivalves can be prepared out of marly layers

Sl. 2. Razprostranjenost spodnejurskih plasti s školjkami v južni Sloveniji z nahajališči (•), kjer je školjke mogoče izluščiti iz lapornatih plasti

and thinner; in Trnovski gozd and Banjišice plateau they in places even pinch out. Also towards the south the lithiotid horizon becomes thinner and it pinches out, especially in places of occurrences of black coal, i.e. at Loški Potok, Bloke, Cerknica and Rakitnica. On most of Logatec plateau, Hrušica, Bloke plateau, Slivnica, Mala and Velika gora and in Kočevje area the bivalves are found in bituminous coarse grained dolomite or in rare thin limestone intercalations within dolomite (Buser, 1965a; Savić & Dozet, 1985).

Figure 2 shows the extension of Lower Jurassic beds that contain bivalves. Specially marked are those localities in which shells can be isolated from the softer marly matrix.

Certain localities discovered by S. Buser during geological mapping more than thirty years ago are unfortunately destroyed or overgrown. This is the case for the abandoned quarry on the right bank of Sušica west of Dolenjske Toplice and for the locality on Javornik (east part of Trnovski gozd). Also the road cuts in Krim-Mokrec hills, southeast of Lož, north of Cerknica and at Grčarevec are almost totally overgrown. Individual specimens can still be found in railroad cuts between Preserje and Verd. Very numerous bivalves are found today in the quarry of Podpeč, in the eastern slope of Špik (north of Col in Trnovski gozd) and at the karst spring Globočec (west of Zagradec). Newly discovered is the locality in the eastern slope of the Stražišče hill east of Gorenje Jezero near Cerknica. The species *Lithiotis problematica*, which is the least abundant, is found east of the village Zafara near Žužemberk.

In the following text are described in detail the localities Špik in Trnovski gozd, the Podpeč quarry, Globočec near Zagradec, Grčarevec south of Logatec, Stražišče at Gorenje Jezero, Ravne at Borovec in the Kočevje area, and Travna gora. These localities are spatially distributed in the manner to represent distinct ancient environments. Besides, at them geological sections could be measured (fig. 3).

Špik in Trnovski gozd

Špik is about 950m high peak in Trnovski gozd about 2km north of Col. Well exposed Upper Triassic and Liassic beds gently dip towards the south. The Upper Triassic dolomite with characteristic stromatolites gradually passes into the Lower Liassic massive coarse grained dolomite of light grey color that is about 100m thick. Upwards follow approximetely 30m of light grey to white micritic limestone which contains in its upper part up to 3m thick intercalations of coarse grained dolomite. Lower Liassic limestone beds form steep rocky steps in the woody slope. At approximately 900 meters altitude their dip is 180/45. The lithologic boundary with the Middle Liassic beds was placed by Buser (1978) at the occurrence of brownish oolitic dolomite which is at that place about 30 meters thick.

Several meters below the Špik summit appears an approximately 70cm thick layer of grey brown marly limestone that contains abundant various bivalves. Prevailing is species *Lithiopedalion scutatus*. Its shells are up to 40cm long and intensely recrystallized. This species is accompanied by *Gervilleioperna buchi* (Zigno), *G. taramellii* (Böhm), *Mytilus lepsii* Tausch and *M. mirabilis* Lepsius. Very frequent are also medium sized megalodontid shells that belong to a new genus and new species. Various bivalve species were probably transported together after death. Their shells are rather well preserved, an indication of short transport. In limestone next to bivalves also numerous small fragments of various fossils occur. The layer from which shells can be separated extends for about 200 meters across the east slope of Špik.

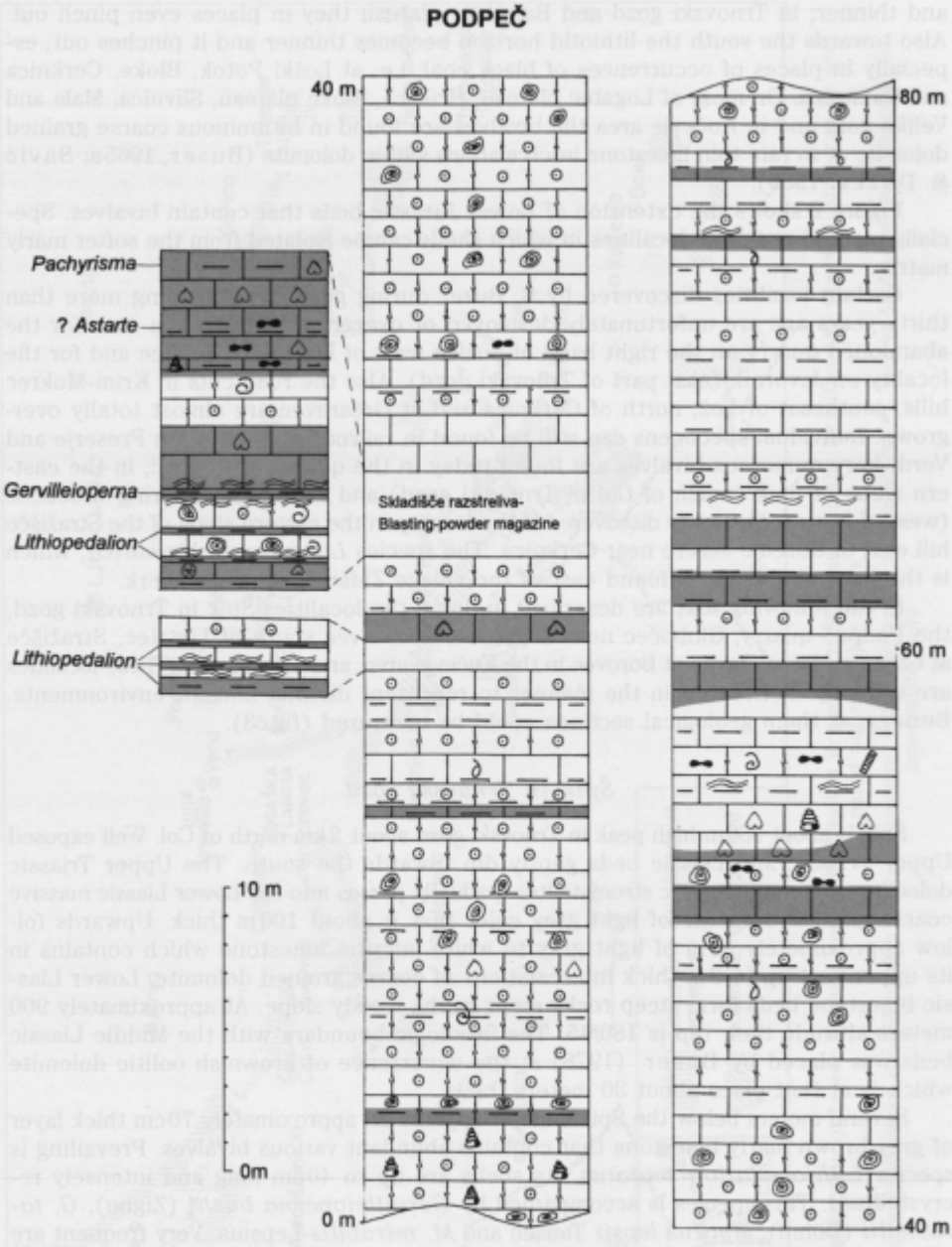
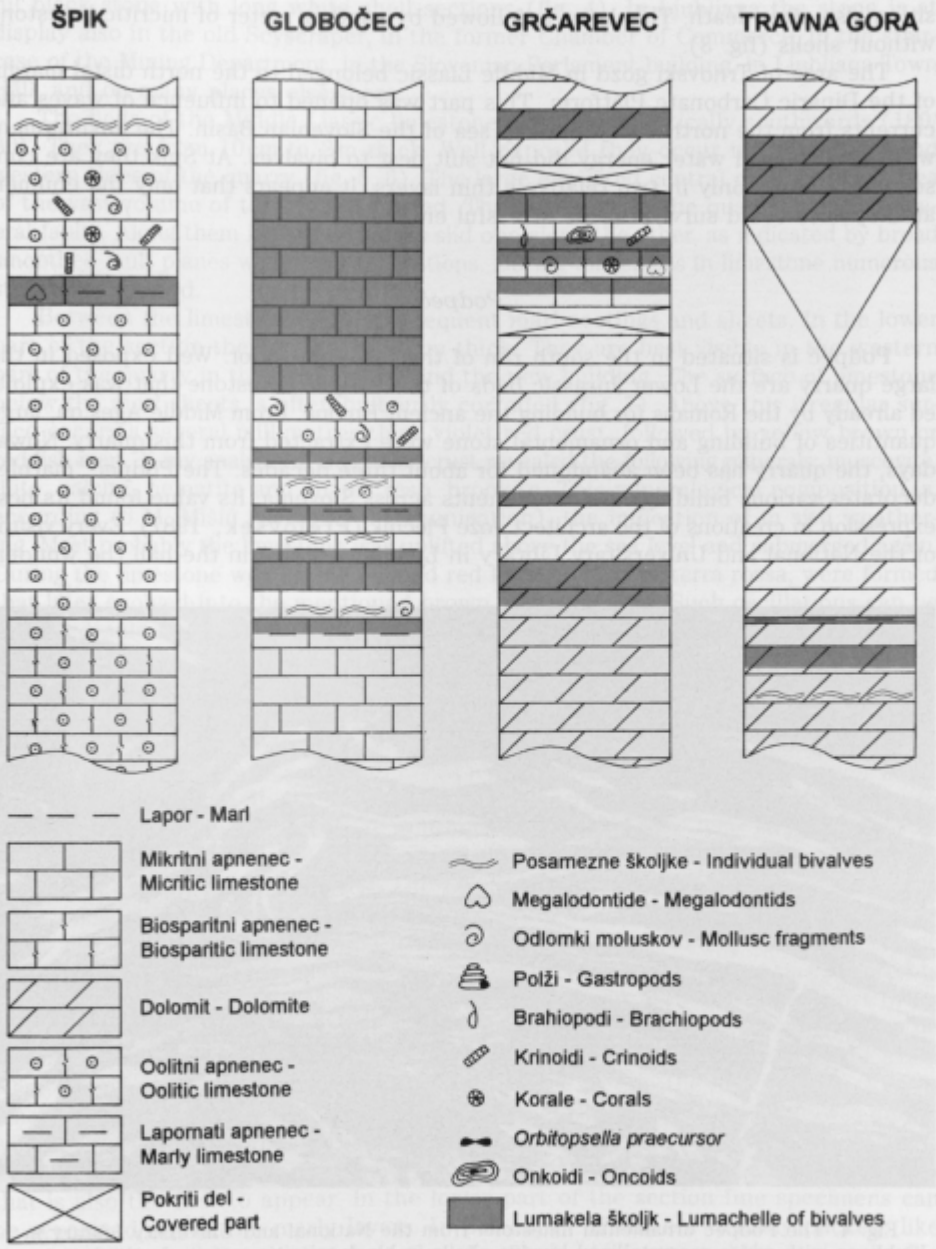


Fig. 3. Stratigraphic columns of Middle Liassic beds in different localities
Sl. 3. Stratigrafski stolpci srednjeliasnih plasti v različnih nahajališčih



Above the layer with shells occur about 5 meters of light oolitic dolomite with numerous fragments of crinoids, echinoids, bryozoans and solitary corals. Higher in the section is an about one meter thick layer of light grey micritic limestone with numerous, however not rock building bivalves of species *L. scutatus*. Some shells lie perpendicularily to the bedding, an indication of the preservation of their living po-

sition also after death. This layer is followed by another meter of micritic limestone without shells (fig. 3).

The area of Trnovski gozd in Middle Liassic belonged to the north distal margin of the Dinaric Carbonate Platform. This part was opened to influence of waves and currents from the northerly lying deep sea of the Slovenian Basin. The environment with an increased water energy did not suit best to bivalves. At Špik they are consequently found only in two relatively thin layers. It appears that only the enumerated species could survive in the stressful environment.

Podpeč

Podpeč is situated in the south rim of the Ljubljana Moor. Well exposed in the large quarry are the Lower Jurassic beds of the Podpeč limestone that was exploited already by the Romans for building the ancient Emona. From Middle Ages on, large quantities of building and ornamental stone were extracted from this quarry. Nowadays, the quarry has been abandoned for about three decades. The Podpeč "marble" decorates various buildings and monuments across Slovenia. Its value found its best expression in creations of the architect Jože Plečnik (Prelovšek, 1987). Every visitor of the National and Universitary Library in Ljubljana notice in the hall the wonder-

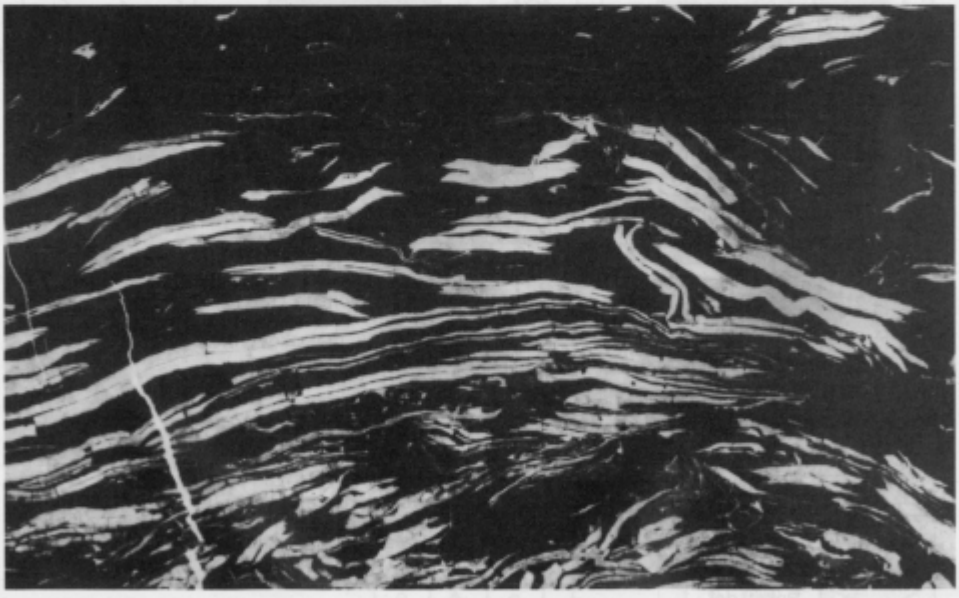


Fig. 4. The Podpeč ornamental limestone from the National and University Library in Ljubljana with white recrystallized bivalve shells in black micritic matrix. In the lower part of slab occur typical sections of genus *Cochlearites*, and in the middle part up to 60cm long sections of genus *Lithiopedalion*

Sl. 4. Okrasni podpeški apnenec iz Narodne in univerzitetne knjižnice v Ljubljani z belimi, prekristaljenimi lupinami školjk v črni mikritni osnovi. V spodnjem delu plošče so značilni preseki rodu *Cochlearites*, v sredini pa do 60cm dolgi preseki rodu *Lithiopedalion*

ful black stone with long white shell sections (fig. 4). In Ljubljana the stone is at display also in the old Scyscraper, in the former Chamber of Commerce, in the staircase of the Mining Department, in the Slovenian Parlament building, in Ljubljana Town Hall, and on many places elsewhere.

The beds of the Middle Liassic limestone dip almost vertically southwards (180/80). They are from 10cm to 2m thick. Well exposed they occur in the eastern and western sides of the quarry (fig. 5, 6). The large exploited central part gives the idea of the vast volume of the stone quarried. The limestone in the quarry is cut by several faults. Along them individual blocks slid one along the other, as indicated by broad smoothed fault planes with vertical striations. During diagenesis in limestone numerous stylolithes formed.

Between the limestone beds are frequent marl coatings and sheets. In the lower part of the section they are up to 15cm thick. They are best visible in the western part of the quarry in the fresh cut behind the new building. The surface of limestone below the marl sheets is often bulbously corroded (fig. 7). Above this irregular surface occurs a several millimetres thick violet red crust, followed by yellow brown or reddish marl. X-ray analysis of the violet crust revealed the following minerals: muscovite, illite, calcite, hematite and anatas resp. brookite. This mineralogical composition is, according to M. Mišič (personal communication), the indication of in situ weathering. Most probably the limestone was uplifted above the sea level and submerged again. During the limestone weathering on land red karstic clays, or terra rossa, were formed that later evolved into the mentioned brown and red marls. Such oscillations can be observed only in the lower part of the section. M. Mišič recognized in the marl the following minerals: muscovite, illite, calcite and goethite. The pollen analysis performed by B. Jelen did not have positive results (personal communication).

The profile (fig. 3) was recorded in the eastern side of the quarry. The lithiotid horizon in the Podpeč quarry is exposed in its entire thickness that amounts to 75 meters. It contains relatively thin beds with shells (0.1–1.5m), and thick intermediate beds without shells. In the section more than 15 isolated lumachelles can be found. Their total thickness is approximately 12 meters. The large number of relatively thin lumachelles suggests the idea of frequent disturbance or even interruption of the growth of bivalves. The bivalves in the Podpeč quarry are found in black micritic limestone, with the exception of the lower part of section where they occur also in marly layers. The lumachelles are most often followed by sparitic limestone with ooids, tiny rounded fragments of various shells (bioclasts) and intraclasts. Currents and waves that delivered various debris and washed out carbonate mud most probably disturbed the growth of bivalves. During periods of unfavorable conditions the animals survived somewhere in the neighborhood, and colonized the old places again when circumstances changed. In the upper part of section the micritic limestone is much more abundant than in the lower part. The environment at that time was quiter, with the resulting thicker and more numerous lumachelles.

The most abundant species among the bivalves is *Lithiopedalion scutatus* (Dubar) that is also the first to appear. In the lower part of the section fine specimens can be separated out of the marly layers. In places the shells are densely packed, like shards, with very little matrix inbetween (fig. 8). As demonstrated by sections in the limestone, certain individuals attained the size of 3/4 meter. In the second part of the section with indications of a quieter depositional environment also species *Cochlearites loppianus* is abundant. Here the shells cannot be separated out from the rock, and the presence of the species is demonstrated by sections in the limestone

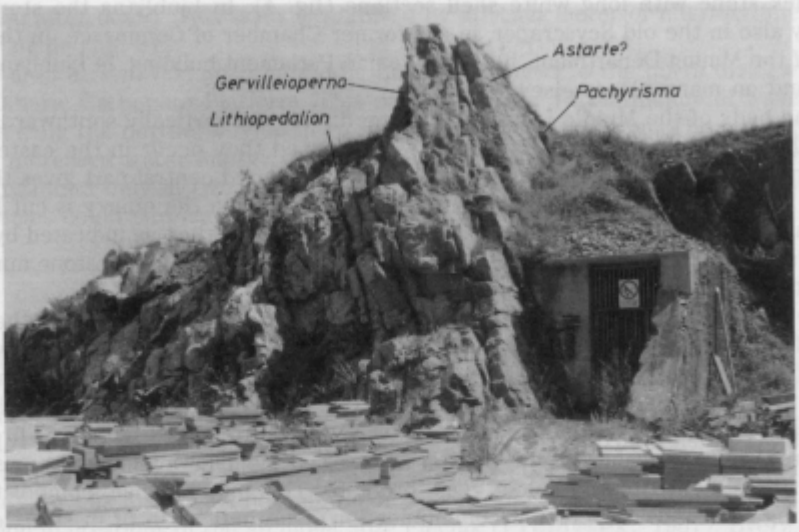


Fig. 5. Eastern part of quarry at Podpeč. Middle Liassic layers at the blasting-powder magazine with lumachelles of various bivalves

Sl. 5. Vzhodni del kamnoloma v Podpeči. Srednjeliasne plasti v bližini skladišča za razstrelivo z lumakelami različnih školjk

Fig. 6. The west part of the Podpeč quarry. The layer with individual bivalve specimens of genus *Opisoma* is marked

Sl. 6. Zahodni del kamnoloma v Podpeči. Označena je plast s posamičnimi primerki školjk iz rodu *Opisoma*

Fig. 7. Bulbously weathered upper surface of limestone, covered by violet crust (fossil soil) and overlain by a marl sheet. Podpeč quarry

Sl. 7. Gomoljasto preperela zgornja površina apnenca. Prevlečena je z vijoličasto skorjo (fosilna tla), sledi pa lapornata pola. Kamnolom v Podpeči

Fig. 8. Extraordinarily numerous shells of genus *Lithiopedalion* that can be separated from marly matrix. Podpeč quarry

Sl. 8. Izredno številne lupine rodu *Lithiopedalion*, ki jih je mogoče izluščiti iz lapornate osnove. Kamnolom v Podpeči

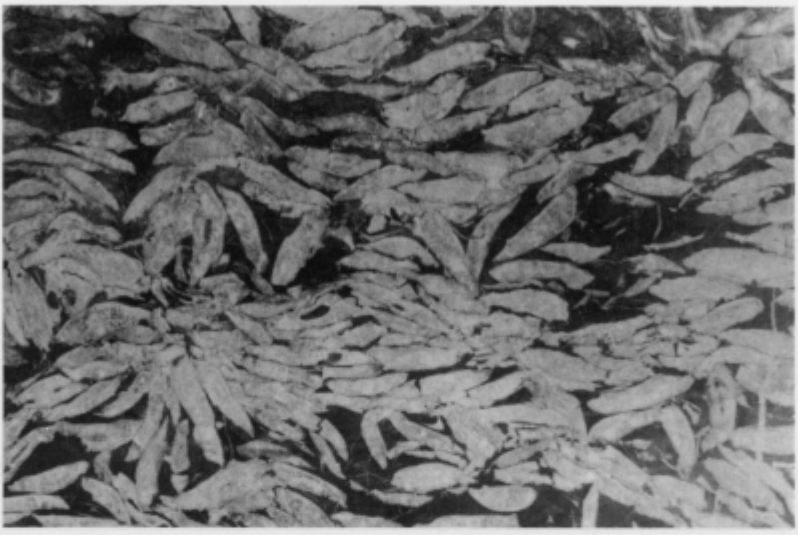


Fig. 9. Ornamental Podpeč limestone from hall of the Ljubljana scyscraper. 5–7 cm wide cross sections of species *Lithiotis problematica* are closely packed together

Sl. 9. Okrasni podpeški apnenec iz veže Ljubljanskega nebotičnika. 5–7 cm široki prečni preseki vrste *Lithiotis problematica* so tesno nagneteni eden ob drugem

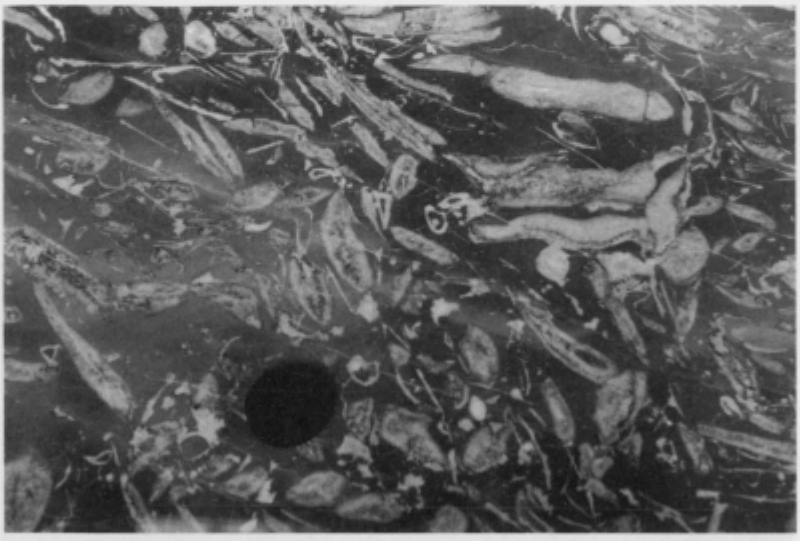


Fig. 10. Ornamental Podpeč limestone from staircase of Mining Department building. "Scattered" remains of various bivalves; among them characteristic remains of genus *Lithiotis* and of megalodontids can be recognized (scale presented by camera cover)

Sl. 10. Okrasni podpeški apnenec s stopnišča Montanistike. »Razmetani« ostanki različnih školjk; med njimi lahko prepoznamo značilne preseke rodu *Lithiotis* in megalodontid. (Merilo je pokrovček fotoaparata)

only. The species *Lithiotis problematica* is very rare at Podpeč; its characteristic sections (fig. 9, 10) can be found only in two or three layers in the upper part of the section.

In the quarry and in the field in general the sections of the mentioned bivalves are not easy to distinguish owing to patina that covered the limestone, or owing to tectonized surface. Fortunately, the orientation of bivalve shells can be studied on polished sheets of ornamental Podpeč limestone. Mainly well preserved shells are chiefly parallel with stratification. In the lumachelles usually a single species prevails. In cases of irregular "scattering" of shells of various species in the limestone, the shells are often damaged (fig. 10). Shells were often broken and in part dissolved also during diagenesis.

In addition to the genera *Lithiopedalion*, *Cochlearites* and *Lithiotis* occur in Podpeč also the following bivalve species: *Gervilleioperna buchi*, *G. taramellii*, *G. timorensis* Krumbeck, *Opisoma* cf. *excavatum* Böhm, *O.* cf. *menchikoffi* Dubar and *Pachyrisma* (*Pachymegalodon*) *chamaeforme* (Schlotheim). Interesting is also the approximately 40 cm thick layer of marly limestone with very small shells that probably belong to genus *Astarte*. This layer is exposed just at the blasting-powder magazine. The sample sites of various bivalves are marked on figures. All of the enumerated bivalves are rock-forming, with the exception of genus *Opisoma* that occurs individually (fig. 11), in biosparitic limestone full of organic detritus that was spherically overgrown by cyanobacteria. It is interesting that in lumachelles with other bivalves no oncoids are present, although they are very frequent elsewhere in the section. Evidently, the cyanobacteria were not able to thrive in association with bivalves.

Buser (1965a) described from the Podpeč quarry two brachiopod species: *Terebratula rotzoana* Schauroth and *T. renieri* Catullo. Gastropods are moderately numerous, but they cannot be prepared out of the tough rock. In thin sections numerous tiny tests may be found, and in the ornamental quality Podpeč limestone gastropods with sections measuring up to 10 cm across (fig. 12). Corals are rather rare. Individual specimens were fixed also on shells of the megalodontid bivalves. It is interesting that nearby, at Gornja Brezovica near Preserje, in the lithiotid horizon also a small coral patch reef can be seen. It is 35 meters long, a few meters wide and 5 meters thick. It laterally passes into dark grey oolitic limestone.

The most characteristic for the Middle Liassic is next to bivalves the large foraminifer *Orbitopsella praecursor* (fig. 13). It is rock-building in some layers of the Podpeč limestone. The microforaminifers are present almost in all beds, therefore they are not specially marked in the lithological column (fig. 3). They are the most abundant in the pelbiomicritic limestone (fig. 14). L. Šribar (manuscript report) determined the following foraminifer families: Ammonidiscidae (*Glomospira sp.*), Lituolidae (genera *Lituosepta*, *Orbitopsella*, *Haurania*, *Pseudocyclammina*), Verneuilinidae, Textularidae and Nubeculariidae (*Opthalmidium* sp.). Present are also dasycladaceans *Thaumatoporella parvovesiculifera* (Raineri) and *Palaeodasycladus mediterraneus* (Pia), codiaceans and problematica *Aeolissacus* sp. The microfossils from Podpeč were determined also by R. Radoičić (manuscript report). In the upper parts of the section R. Radoičić determined also the species *Labyrinthina recoarensis*. According to her opinion, several lowermost beds in the quarry belong to the upper part of Lower Lias. In the uppermost part of section that is rather heavily tectonized the boundary between the Middle and the Upper Lias could be expected.

The most frequent benthic foraminifer is *Glomospira*. It is very abundant in the

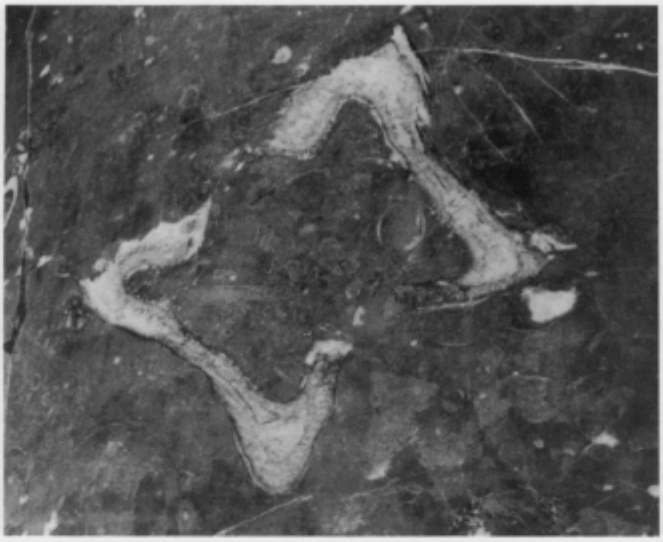


Fig. 11. Ornamental Podpeč limestone in the National and University Library. About 10×10cm large section of bivalve of genus *Opisoma*, most probably species *O. excavatum*. In limestone also characteristic sections of large foraminifers *Orbitopsella praecursor* occur

Sl. 11. Okrasni podpeški apnenec v Narodni in univerzitetni knjižnici. Približno 10×10cm velik presek školjke iz rodu *Opisoma*. Po vsej verjetnosti gre za vrsto *O. excavatum*. V apnencu so tudi značilni preseki velikih foraminifer *Orbitopsella praecursor*

Fig. 12. Ornamental Podpeč limestone from National and University Library. Sections of gastropods are up to 10cm in diameter. Fragments of bivalve shells of genus *Opisoma*

Sl. 12. Okrasni podpeški apnenec v Narodni in univerzitetni knjižnici. Preseki polžev so veliki do 10cm. Nekaj odlomkov školjčnih lupin rodu *Opisoma*

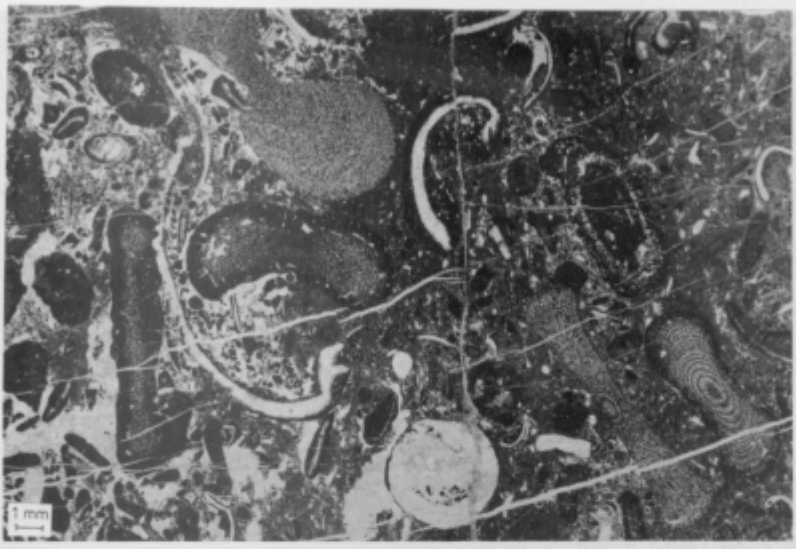


Fig. 13. Dismicritic limestone full of organic detritus, pellets and intraclasts. Above sections of foraminifer *O. praecursor* a section of dasycladacean. Podpeč

Sl. 13. Dismikritni apnenec, poln organskega detritusa, peletov in intraklastov. Nad presekoma foraminifere *O. praecursor* je presek dazikladaceje. Podpeč

Fig. 14. Passage of biomicritic limestone into sparitic limestone full of rounded fragments (bioclasts), ooids and intraclasts. Podpeč

Sl. 14. Prehod biomikritnega apnenca v sparitni apnenec, ki je poln zaobljenih odlomkov (bioklastov), ooidov in intraklastov. Podpeč

entire section, even there where no other microfossil appears. Although the above mentioned calcareous algae are quite frequent in the Podpeč quarry, they were not detected in the bivalve lumachelles. In general is the biodiversity very low in beds where the genera *Lithiopedalion*, *Cochlearites*, *Gervilleioperna* and *Lithiotis* were identified.

The characteristic bivalves in the upper part of section vanish suddenly, without gradual passage. However, according to lithology, the deposition at that did not change considerably. Possible changes in the foraminiferal assemblages have not been investigated.

Globočec near Zagradec

Globočec is a large karst source southwest of Zagradec. In this area the Upper Triassic Main Dolomite with stromatolites passes into light grey micritic Lower Liassic limestone. At the Globočec source layers of dark grey to black Middle Liassic limestone are very well exposed. They are from 10 to 100 cm thick and they dip towards southwest (220/15). In the wooded slope they form rocky steps that may be laterally traced for 50 m. Exposed are only the upper 20 meters of the lithiotid horizon that is in the Krka valley about 50 meters thick.

In the lower part of section (fig. 3) at Globočec appear 5 m of dark grey micritic limestone with rock-forming bivalves of genus *Cochlearites*. Inbetween are only two thin parts that contain just a few sections of shells. Limestone in the lower part is in places marly, therefore shells are easily separated from the rock. Certain specimens are typical representatives of species *Cochlearites loppianus*, whereas others, found about one meter higher, are much larger and of different shape. The latter belong to a new species, but according to the characteristic valve structure the genus is the same. In this part of section also individual specimens of solitary corals were found fixed upon thick bivalve shells.

Higher follow two meters of sparitic limestone with intraclasts, individual ooids, fragments of shells and crinoids. This is the only larger intercalation that does not contain shells. It is overlain by 7 meters of limestone packed with rock-building shells of *Cochlearites*. Sections of genus *Lithiopedalion* are rare. In this part the shells cannot be separated out of the hard rock. After this layer the shells vanish suddenly, without any gradual transition. In black micritic limestone of the last 30 meters of exposed beds not a single specimen can be found.

The type of limestone in the Globočec locality is an indication of quiet sedimentational environment. Bivalves grew almost completely undisturbed. The shells are mostly undamaged, and appear in certain beds even in vertical, i.e. living position. Most of them, however, were overturned on sea bottom after death, so that the fossil shells are oriented parallel to bedding. Very often also wedge-shaped agglomerations consisting of numerous shells can be observed. In such a case after death, or still during life, several shells were tilted together, so that they support each other in the inclined position.

Grčarevec

The small village of Grčarevec lies south of Logatec. About 1 km towards northwest the Middle Liassic beds are well exposed. They dip 300/15. Prevails dark grey

Fig. 15. Characteristic sections of species *Cochlearites loppianus* in limestone northwest of Grčarevec

Sl. 15. Značilni preseki vrste *Cochlearites loppianus* v apnencu severozahodno od Grčarevca

coarse grained dolomite containing individual bivalve lumachelles that are up to 2 meters thick.

In a limestone lens intercalated within dolomite is at the last summer houses northwest of Grčarevec a fresh road cut. In three separated layers that are up to 70 cm thick are well visible sections of rock-building bivalves. Species *Cochlearites loppianus* is here absolutely prevailing (fig. 15). Much less frequent are sections that most probably belong to genus *Lithiopedalion*, and in the middle layer also to genera *Gervilleioperna* and *Mytilus*. Limestone is micritic and dark grey to black in color. It is overlain by dolomite still containing in its lower part characteristic shells that higher up disappear.

At the sharp curve of the old road north of Grčarevec Buser (1978, 396) found in lithiotid horizon well preserved plant remains. This locality is now overgrown. The remains of terrestrial plants indicate the temporary existence of smaller land islands on the carbonate platform.

Stražišče near Gorenje Jezero

Above the Klance village in the Stražišče hill east of Gorenje Jezero near Cerknica, also west of Stari trg, one of the most perfectly exposed sections in the lithiotid horizon can be found.

In more than 20 meters of exposed section about 10 bivalve lumachelles can be numbered. They are from 0.5 to 1 meter, and at most 2.5 meters thick. Genus *Cochlearites* is prevailing. Its characteristically shaped shells appear in places in lens-like dispositions in the rock, the lumachelle pinching out in-between. In certain beds the shells are so numerous that there is practically no cement between them. As a rule they occur in dark grey micritic limestone. Owing to the marly admixture they can be in places isolated out of the rock. The intermediate beds with no shells mainly consist of oolitic and biosparitic limestone.

In the section the sudden massive appearance of bivalves, and also their sudden disappearance can be observed, both without gradual transitions. The lithiotid horizon is followed upwards by sparitic limestone with ooids and bioclasts. It forms the upper part of the hill in the form of an erosion remnant.

Travna gora

A couple of kilometers southeast of Travna gora in the wooded slope a more than 20 meters thick lithiotid horizon can be traced. It is entirely developed in dolomite (fig. 3). The shells can be isolated from the rock in this locality only from one 20 cm thick marl layer in the lower part of section. In dolomite only three real bivalve lumachelles can be found. The intermediate beds also contain individual shells that are more or less frequent and intensely recrystallized. With certainty only the genus *Cochlearites* was identified. In the lower part of the section its shells measure up to 30 cm, and are similar to those in the Globočec locality; they probably belong to a new species. In the uppermost part of the lithiotid horizon the bivalve lumachelle is about three meters thick. In the first half it consists of recrystallized shells that could be attributed to genera *Cochlearites* and *Lithiopedalion*, although the specimens here are much smaller and thinner than usual (valve length 5 cm, thickness not more than 1 cm). In the upper part of the mentioned lumachelle again predominate the typical representatives of genus *Cochlearites*. About 40 meters higher the dolomite is overlain by oolitic dark grey Upper Liassic limestone that alternates with thin sheets of black micritic limestone.

Ravne near Borovec

The Middle Liassic beds in the wider surroundings of Kočevje largely consist of coarse grained bituminous dolomite (fig. 2). This area originally belonged to the southerly, most restricted parts of lagoon, or to the inner part of the Dinaric Carbonate Platform.

The locality Ravne near Borovec is the southernmost in Slovenia. In the lower part of the northern slope of Borovska gora outcrops the black, bituminous thin-bedded limestone. It is overlain by a 1.5 meters thick layer of black micritic limestone that contains relatively small, about 10 cm long shells of genus *Cochlearites*. Upwards layers of bituminous dolomite follow. In the upper part, a 4 meters thick bank of dolomite occurs which is full of unusually thin specimens of genus *Cochlearites*. This bank protrudes from the slope as a steep rocky step which owes its higher resistance to numerous contained bivalve shells.

Living conditions of bivalves on the territory of southern Slovenia during the Lower Jurassic

On the territory of present southern Slovenia the wide Dinaric Carbonate Platform was situated during the Lower Jurassic. This shallow marine environment bordered in the north on the deep sea of the Slovenian Basin (Buser, 1987a), while in the south it continued across the present Croatia. Reconstruction of the ancient relations appears in figure 16.

It is interesting to note that *Lithiotis problematica* occurs also in the surroundings of Bovec (on the Poljanica hill and at the karstic source Glijun), consequently on the territory that with certainty belonged to the Julian Carbonate Platform that was situated north of the Slovenian Basin (fig. 16). It appears almost impossible that the shallow marine fauna could migrate from the Dinaric Carbonate Platform to the northerly lying Julian Carbonate Platform across the deep marine see of the Slovenian Basin. Our opinion is that the Slovenian Basin pinched out in the area of the present central part of the Soča valley, at Trnovo west of Kobarid. It follows that this deep marine

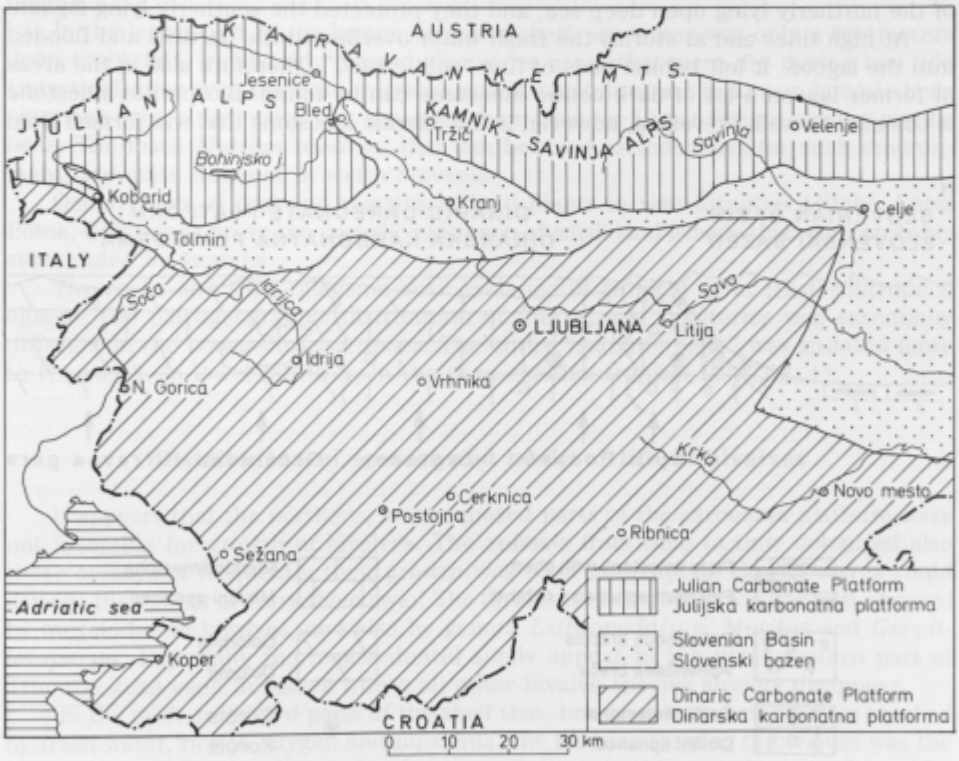


Fig. 16. Present extension of the ancient Julian and Dinaric Carbonate Platforms and the intermediate Slovenian Basin

Sl. 16. Današnja razprostranjenost nekdanje Julijske in Dinarske karbonatne platforme in vmesnega Slovenskega bazena

basin did not continue farther westward into the Belluno Basin of northern Italy. Owing to pinching out of the Slovenian Basin, the Dinaric and the Julian Carbonate Platforms directly bordered on each other in the mentioned area during Liassic.

Let us have a look at the conditions of those times in the region of south Slovenia, on the Dinaric Carbonate Platform (fig. 17):

The northern border of the platform intercepted most of the striking power of waves and currents that arrived from the open deep sea of the Slovenian Basin. Their destructive power is evidenced by limestone breccias on Banjšice and in north Lower Carniola. Otherwise in the northern parts of the Dinaric Carbonate Platform (Trnovski gozd, Banjšice) oolitic and crinoid limestones of light color predominate. They were deposited in wide shoals with warm water only 1-3 meters deep. Cooler waters flowed in from deeper parts of the Slovenian Basin. Owing to increased temperature, part of carbonates precipitated from them around tiny grains that floated in turbulent water. In shallows large amounts of ooids, small tests and fragments of various organisms accumulated that were rounded by wave action. In places, accumulations of this debris reached the sea level. Wide beaches and dunes were formed. Together with small coral and hydrozoan patch reefs (Trnovski gozd) they represented proper dams in front of the northerly lying open deep sea, and they protected the southerly lying lagoon.

At high tides and at storms the fresh water overflowed the barriers and flooded into the lagoon. It left behind beds of fine "oolitic sand". Therefore also in the areas of former lagoon a lot of dark oolitic limestone can be found. Biosparitic limestone is common as well. Prevailing, however, is the micritic limestone that was formed from

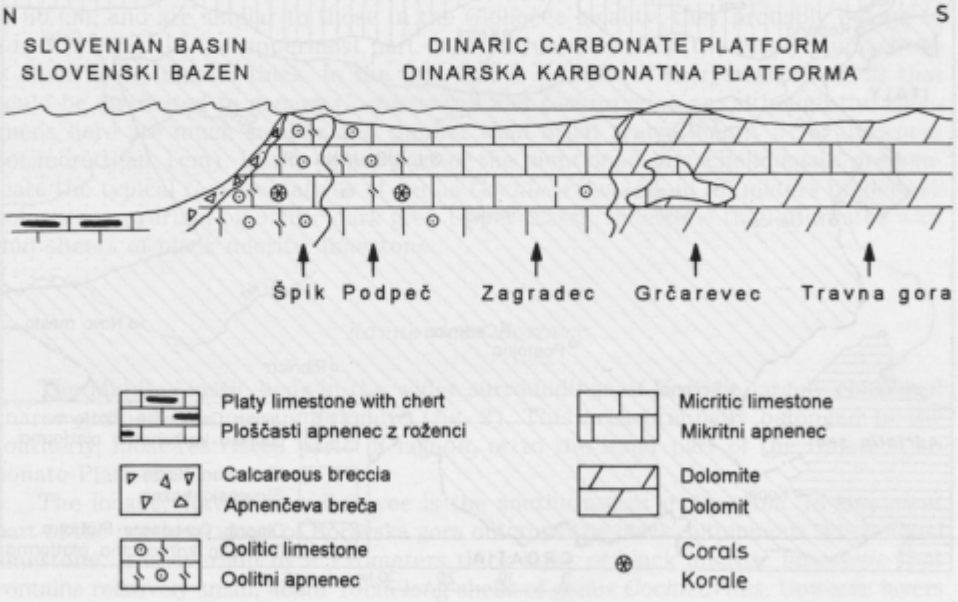


Fig. 17. Schematic representation of various sedimentation environments in lower Jurassic with characteristic types of rocks on the Dinaric Carbonate Platform

Sl. 17. Shematski prikaz različnih sedimentacijskih okolij v spodnji juri z značilnimi tipi kamnin na Dinarski karbonatni platformi

the lagoon carbonate mud. It contains a profusion of tiny tests of foraminifers that used to live at the sea bottom (benthos). In places of steady infolow of fresh water also corals, crinoids and green algae (dasycladaceans) lived. Otherwise in the lagoon most of the living environment on the muddy sea bottom was occupied by bivalves. They formed submarine biostromes with individual lense-like thickenings. In places also gastropods and brachiopods settled. The carbonate deposition was the fastest in this central area, and the lithiotid horizon attained the maximal thickness.

Towards the south the influence of the northerly deep marine region became progressively weaker. Waves and currents reached only to a certain distance. Farther extended the restricted and quiet parts of lagoon. Much oxygen was used for decomposition of organic matter. At the bottom reducing conditions were established. Rocks formed in restricted lagoon are highly bituminous and of characteristic dark grey to black color. Evaporation and with that also salinity of sea water were highest here. The pore water in these sediments contained high magnesium, and consequently they were most likely subjected to dolomitization during diagenesis. It may be conjectured that the alternation of drought periods with prevailing evaporation and rainy periods with heavy rainfall controlled the salinity variation in the restricted lagoon to a high degree.

In the larger part of the lagoon, or inner shelf, see water was only a few meters deep (subtidal). Indubitably existed also wider areas that were dry during low tide (intertidal); however, desiccation cracks and stromatolites are in Lower Jurassic beds extremely rare, a distinction that separates them from the Upper Triassic shallow marine beds. The fossil *Mytilus* bivalves, that can be used as indicators for such environment, are quite frequent in south Slovenia.

Occurrences of coal and remains of land plants in rare localities (Bloke, Loški Potok, Grčarevec) prove the periodic existence of small land islands that were probably surrounded by swamps.

The rocks and the organisms bear evidence of tropical or at least subtropical climate.The paleogeographic distribution of the present territories was essentially different in the Lower Jurassic times. The entire "Adriatic plate" was situated more to the south, in lower latitutes, in the then existing tropical belt (fig. 1).

Distribution of species and mode of life of bivalves

It appears that the northern, most exposed parts of the carbonate platform were not favorable for growth of bivalves. The animals from time to time colonized also these areas, but frequently their growth was soon interrupted. Strong waves could damage their shells or carry them away. The turbulent environment was the best endured by megalodontid bivalves, and also by genera *Lithiopedalion*, *Mytilus* and *Gervilleioperna*. Especially the megalodontid shells appear in the northwestern part of Trnovski gozd even in places where all other bivalve species already disappear.

In the more restricted parts of the shelf that, however, were nevertheless reached by fresh water, rich in oxygen and nutrients, the massive thriving of bivalves was the most frequent. The conditions for their growth were in this part the most favorable, but still rather unstable. Numerous, relatively thin lumachelles indicate that the growth of bivalves was often interrupted. The matrix in lumachelles is as a rule micritic. The sedimentological and paleontological characteristics of the deposits between lumachelles suggest that at times of interruption of bivalve growth, most often increases of wa-

ter energy occurred. Then sediments deposited from which oolitic, oncolitic and biosparitic limestones were formed. Periodically, perhaps during heavier storms, the currents brought so much material to lagoon that the bivalves were literally covered by various debris. On the other hand, strong waves could wash out all sediment that surrounded large shells of the characteristic bivalve species and provided support for them, and scattered them across the sea bottom where they perished. During the times of unfavorable conditions the bivalves survived elsewhere, and later they colonized the previous localities again. The base for the first colonization respectively fixation of juvenile bivalves could have been any firm bottom, various detritus or shells of decayed bivalves. In the central part of lagoon that was under influence of deep marine basin *Lithiopedalion* prevailed. Genus *Cochlearites* was frequent as well. More or less numerously were represented all above enumerated bivalves, also the genus *Lithiotis*.

For the moment, the data show that the quiet, muddy bottom in more southern parts of lagoon was mostly inhabited by genus *Cochlearites*. In the Middle Liassic dolomite often sections of valves are found that could be ascribed to genera *Lithiopedalion* and *Cochlearites*, but they are extraordinarily small. The shell size attains at most 10cm and its thickness at most 1cm, and usually even less. It is possible that the mentioned shells grew under very unfavorable living conditions (increased salinity, decreased influx of fresh water), and they remained small, or that they represent distinct species. Unfortunately, such specimens could not be separated out of the dolomitic rock at any place. We presume that the living conditions in the most restricted parts of the lagoon were in general less favorable than in its central part that used to be under steady, moderate influence of the pelagial. On the other hand, the environment in the most protected parts was much more stable, as proved by the rather thick (up to 4 meters), although not very frequent lumachelles.

At reconstructing various depositional environments on the carbonate platform it must be considered that the area of maximum influences from the deep marine region changed with time. This is the most expressed at the transition from basin to platform. In all parts of the shelf sea, respectively the lagoon, the water energy was subjected to changes, as well as the sea level, the sea bottom and the sediments that were deposited on it.

All enumerated Lower Jurassic bivalves formed submarine biostromes where hundreds of individuals of the same species were crowded together. The bivalves predominantly grew in very shallow water (intertidal-subtidal), since they were able to reach the maximum of nutrients near the sea surface.

The genus *Gervilleioperna* lived in a similar manner as the recent genus *Isognomon*. These bivalves were attached on a firm base with a bunch of byssus fibers. The same is valid for representatives of genus *Mytilus*. This is the same genus that even at present inhabits all shallow seas except for the extreme north. Characteristical for it is the colonization of the tidal environment. At low tide it can survive on the air for hours, so that it hermetically closes the valves. The organism has good resistance to changes of water salinity. It is the best adapted to brackish water in the near shore belt (Cox, 1969, N5-N15). The megalodontid bivalves lived with their apex anchored in the soft sea bottom. The valves and the hinge were very strong, and the round shape enabled the animals to be rolled without damage across the sea bottom in case of stronger waves.

There are still many unsolved questions about life mode of the most characteristic Lower Jurassic bivalves: *Lithiotis*, *Cochlearites* and *Lithiopedalion*. There is

no recent bivalves similar to them and we could hardly compare them also with some other fossil group. Their unusual shape and high degree of variability already for themselves rouse numerous questions concerning their biology (more in: Debeljak & Buser, in prep.). The animals were entirely adapted to the muddy sea bottom, fast sedimentation in the environment and sessile life in densely packed assemblage of specimens of the same species. With regard to relatively small size of their soft bodies they developed enormously large shells. They used to grow throughout their lives, so that the upper part of the shell remained above the level of the surrounding sediment, and that they obtained as much sunlight as possible. Such permanent and uniform growth in height is an extraordinary property, as the growth rate of animals usually exponentially diminishes with age. In deposits where the shells remained in their growth positions after death, we can observe that the individual specimens supported each other, and grew upwards in a tuft-like manner, similar to plants. Frequent are knee-shapedly bent individuals, at which most probably the valve was tilted too dangerously, so that the animal afterwards corrected its position by subsequent vertical growth. Considering such cases it is not surprising that the shape of the shell in the same species can be so variable. The external similarity of the mentioned three genera, which otherwise belong to distinct families, is a result of convergence, of adaptation to similar, very specific living environment. The shells of *Lithiotis*, *Cochlearites* and *Lithiopedalion* might have measured even 0.5 meters. Mussels of such size can be at present found in the equatorial belt or in regions of warm currents where the sea water temperature is constantly above at least 23 °C. Owing to the decrease of CO_2 concentration in water the precipitation of calcium carbonate and skeleton building is facilitated.

It is characteristic that the biodiversity in individual bivalve lumachelles is extraordinarily low. Different species of bivalves evidently did not live together in the same place. In the same manner, next to bivalves practically no other organisms became preserved as fossils. The reason can partly be ascribed to the selective influence of specific environment (muddy substrate, fast sedimentation) that required from organisms special adaptation. Probably also the bivalves themselves rendered impossible the existence of their competitors with fast overgrowth and production of large amounts of organic mud. Photosynthesis in muddy water was practically impossible, what excluded from the environment many organisms, especially the green algae and cyanobacteria. Similar circumstances can be observed nowadays in large oyster farms. Certain species of oysters are able to filter 40 liters of water per hour. In addition, they are genuine accumulators of sediment rich in organic matter that has a putrid smell and that decomposing produces reducing conditions. On the water surface H_2S oxidizes into sulfuric acid. At the top of the sediment the environment is acidic which results into often corroded shells (Stenzel, 1971, N1000-N1003), a phenomenon observed also on fossil remains.

The genera *Lithiotis*, *Cochlearites* and *Lithiopedalion* formed submarine mats or biostromes on the territory of present south Slovenia. In Slovenia there is no evidence of the existence of reef structures. Smaller lense-like thickenings of generally thin bivalve lumachelles are most probably beds of shells after a short transport. Lumachelles laterally do not pinch out, they only thin and thicken. The micritic matrix suggests a low water energy during the time of deposition of sediment. With respect to their shape, the shells are relatively well preserved. The shells of isolated specimens are usually not eroded. The biodiversity in the lumachelles is low. All this suggests generally short transport distances. We believe that the characteristic bivalves

grew on large surfaces, and that after death they were most often only somewhat overturned by the waves.

The blossom time of the characteristic Lower Liassic bivalves (genera *Lithiotis*, *Cochlearites* and *Lithiopedalion*) lasted only around 5–10 million years. On the territory of Slovenia, however, they did not last even that long. In all Slovenian localities at the end of the lithiotid horizon that is attributed to Domerian the mussels suddenly disappeared without gradual diminishing.

During the Upper Liassic in the region of Tethys extensive tectonic movements occurred. In the territory of northern Slovenia, on the former Julian Carbonate Platform, a short land phase took place, and afterwards it rapidly subsided and disintegrated (Buser, 1987a). The influence of these events undoubtedly reached also the Dinaric Carbonate Platform. In the areas of Stična, Šentvid, Radohova vas, in suroundings of Trebnje and Veliki Gaber the Malm beds transgressively overlie the Middle Liassic beds. At Loški Potok in the Upper Liassic coal ocurrences are known. All this may be understood as evidence of uplift of the territory after the deposition of Middle Liassic beds with bivalves. Tectonic activity was reported also from the neighboring Italy. On the Trento Carbonate Platform the shallow marine beds with bivalves are overlain by deep marine limestone of the ammonitico rosso type (Bosellini & Broglio Loriga, 1971).

It can be only conjectured about the causes that led to the sudden extinction of the characteristic Middle Jurassic bivalves. Most probably the reason was in the coincidence of various causes. It is known that these fossils were extremely specialized organisms that could not respond to the environmental change with new adaptations. Of the ancient life, only the interesting fossil record remained.

Acknowledgement

Dr. Stevo Dozet geologically studied the Lower Jurassic beds with bivalves in the wider area of Kočevje. He presented in the field several characteristical localities. Ljudmila Šribar and Dr. Rajka Radoičić determined microfauna in limestone. Msc. Miha Mišič did x-ray determination of marls from Podpeč. Arian Debeljak made graphic parts of the article. The authors are very grateful to them.

Spodnjejurske plasti s školjkami v južni Sloveniji

Uvod

V južni Sloveniji, ki zajema skrajni severozahodni del Dinaridov, so jurske plasti debele prek 1500 metrov; pretežno jih sestavlja apnenec. Usedale so se na Dinarski karbonatni platformi, v mediteranskem delu nekdanje Tetide. V njih ne najdemo amonitov, zato jih ne moremo neposredno razdeliti na stopnje ali celo na cone. Pri natančnejšem določanju starosti si lahko pomagamo s fosilnimi školjkami, polži, brahiopodi, koralami, hidrozoji, foraminiferami in algami.

Za členitev liasnih plasti so najpomembnejše fosilne školjke. Značilna je vrsta *Lithiotis problematica* Gümbel iz družine Lithiotidae, ki je najbolj znamenita in geografsko najbolj razširjena spodnjejurska školjka. Ime je dobila po »ušesastih« presekih, ki so jih v severni Italiji opazili že pred več kot 250 leti. Sprva so jih opisali kot rastlinske ostanke (Gümbel, 1874, 1890). Vrsta je za paleontologe še vedno »problematična«, saj si marsičesa v zvezi z nenavadno obliko lupine še vedno ne znamo razložiti (Reis, 1903; Accorsi Benini & Broglio Loriga, 1977; Chinzei, 1982).

V južni Sloveniji sta najpogostnejši školjčni vrsti *Cochlearites loppianus* (Tausch) in *Lithiopedalion scutatus* (Dubar). Vrsto *Lithiotis problematica* najdemo le na poredkih mestih. Vse tri vrste se odlikujejo po velikih, nenavadno oblikovanih in močno variabilnih lupinah. Najbrž se marsikdo vpraša, kakšen je bil način življenja teh školjk. Njihovi preseki se jasno razločijo v črnem podpeškem apnencu, ki je eden naših najlepših okrasnih kamnov (Buser, 1987b).

V liasnih plasteh južne Slovenije najdemo tudi številne druge školjke (S. Buser, 1965a; I. Buser, 1989). V pripravi je članek s sistematskimi opisi posameznih vrst, ki bo izšel v naslednji številki Geologije (Debeljak & Buser). Tokrat pa so obdelana pomembna nahajališča v južni Sloveniji, s pomočjo katerih lahko sklepamo na paleoekološke razmere, ki so v spodnji juri vladale na Dinarski karbonatni platformi in za razmeroma kratek čas omogočile množično uspevanje značilne favne.

Spodnjejurske školjke vsekakor zaslužijo našo pozornost. Zanimive so v biološkem in nič manj pomembne v stratigrafskem pogledu. Omogočajo pa nam tudi paleogeografsko primerjavo z drugimi svetovnimi nahajališči.

Dosedanje raziskave

Leta 1890 je Tausch von Gloeckelsthurn objavil svoje delo o favni liasnih apnencev v Južnih Alpah. Zanimivo je, da je upodobil in opisal nekaj lepih primerkov megalodontid iz podpeškega kamnoloma pri Ljubljani. V svoji razpravi (1890, 28–29) je pravilno ugotovil, da pripadajo plasti s školjkami, ki izdanjajo južno od Ljubljane, juri in ne triasu, kakor so domnevali pred njim.

V letih 1959–65 je S. Buser geološko kartiral ozemlje južne Slovenije od italijansko-slovenske meje na zahodu prek Trnovskega gozda, Hrušice, Nanosa, Logaške in Bloške planote z Javorniki, Krimsko-Mokrškega hribovja in Dolenjske do Suhe krajine na vzhodu. Pri tem je razčlenil jurske plasti in nabral bogat fosilni material (Buser, 1965a,b). Prvi je pri nas določil vrsti *Lithiotis problematica* in *Cochlearites loppianus*. Ugotovil je, da večina primerkov v južni Sloveniji pripada novemu rodu školjk z večveznim ligamentom. V svoji doktorski disertaciji ga je poimenoval *Lithiopedalion*. Skupaj z rodovoma *Lithiotis* in *Cochlearites* ga je uvrstil v družino Lithiotidae. Tako se je pri nas za te značilne školjke uveljavilo ime litiotide, čeprav jih danes uvrščamo v različne družine. Buser je svoje delo predstavil na 42. letnem srečanju Paleontološkega društva v Gradcu leta 1972. Po dolgoletnem sodelovanju pa ga je z objavo prehitela italijanska paleontologinja Accorsi Benini (1979) in opisala svoj rod *Lithioperna*, čeprav se je ime *Lithiopedalion* že uporabljalo v tuji strokovni literaturi (Bosellini, 1972).

Nahajališča spodnjejurskih školjk drugod po svetu

Plitvomorske spodnjejurske plasti s školjkami so marsikje litološko podobno razvite kot v Sloveniji. Navzgor in navzdol navadno niso ostro omejene. Poleg bolj ali manj temno sivega mikritnega in biosparitnega apnenca in včasih dolomita so pogostne tudi lapornate plasti in pole ter kompleksi oolitnega apnenca.

Najbolj značilen favnistični element plitvomorskih spodnjejurskih plasti je vrsta *Lithiotis problematica*. Po njej so dobile ime plasti in facies, v katerem se pojavlja (npr. *Lithiotis*-Kalke, *Lithiotis* facies), čeprav so druge velike, debelolupinske školjke v teh plasteh ponavadi pogostnejše (Berti Cavicchi et al., 1971).

Najbolj znamenita in najbolje raziskana so nahajališča v Južnih Alpah severne Italije (province Verona, Trento in Vicenza). Nastopajo v zgornjem delu sivih liasnih apnencev, imenovanih »Calcari grigi« (Böhm, 1884; Tausch von Gloeckelsthurn, 1890; Bosellini & Broglio Loriga, 1971; Bosellini, 1972).

Spodnjejurske plasti z značilnimi školjkami se prek južne Slovenije nadaljujejo tudi v sosednjo Hrvaško: Veliko Kapelo in Velebit (Grubić, 1961), Hercegovino (Katzer, 1904) ter Dalmacijo (Schubert, 1906). Našli so jih tudi pri Plitvicah. Najlepše ohranjeni primerki vrste *Lithiotis problematica* in *Cochlearites loppianus* pa so iz nahajališča Kopilje v Črni gori. Podatki o tem najdišču žal še niso bili objavljeni.

Podobni spodnjejurski razvoji z značilnimi školjkami so v južni Španiji (Turnšek et al., 1975; Geyer, 1977), južnih in centralnih Apeninih (De Castro, 1962) in Maroku (Dubar, 1948; Agard & Du Dresnay, 1965; Lee, 1983). Krumbeck (1923) je temeljito obdelal favno na otoku Timor v Indoneziji. Broglio Loriga in Neri (1976), Geyer (1977) ter Nauss in Smith (1988) so zbrali podatke o nahajališčih v zahodni Franciji (dept. Sarthe), Švici (Graubünden), Tuniziji, Alžiriji, Albaniji, Grčiji, Turčiji, Somaliji (Mogadiš), Omanu, južnem Iranu, Iraku in na Himalaji.

Von Hillebrandt (1981) poroča o rodu *Lithiotis* iz severnega Čila in Peruja. V Severni Ameriki pa se ta rod poleg drugih školjk pojavlja v Kaliforniji, Nevadi ter vzhodnem in centralnem Oregonu (Nauss & Smith, 1988). Lupher in Packard (1930) sta rod *Lithiotis* iz Oregona prvič opisala pod rodovnim imenom *Plicatostylus*. Kasneje se je izkazalo, da gre za isti rod (Buser, 1965a).

Takšna razprostranjenost najdišč po svetu priča, da so v spodnji juri na zahodnem in južnem obrobju Tetide in vzhodnega Pacifika obstajala obsežna, med seboj povezana plitvomorska področja. Tu so na karbonatnih platformah, v tropskem pasu ali pod vplivom toplih oceanskih tokov vladale zelo podobne paleoekološke razmere.

Paleogeografska rekonstrukcija naštetih nahajališč je na sliki 1. Domnevamo lahko, da je že v pliensbachiju obstajal neki plitvomorski pas, ki je prek današnje Centralne Amerike povezoval Tetido in prednika današnjega Pacifika. Imenujemo ga Hispanijski koridor (Smith, 1983; Smith & Tipper, 1986). Omogočil je migracijo favne in flore med obema oceanoma.

Na vseh naštetih področjih so pogostne velike, debelolupinske školjke. Skoraj povsod je najznačilnejša vrsta *Lithiotis problematica* (sl. 1). Po mnenju nekaterih avtorjev so školjke množično poseljevale morsko dno v obliki podmorskih trat oziroma biostrom, drugi pa poročajo o pravih grebenih oziroma biohermah (Agard & Du Dresnay, 1965; Bosellini, 1972; Göhner, 1980; Nauss & Smith, 1988).

V večini naštetih nahajališčih so poleg školjk prisotne korale, veliki polži, brahiopodi in krinoidi. Tudi mikrofavna je zelo podobna. Med foraminiferami je najznačilnejša vrsta *Orbitopsella praecursor* (Gümbel). Ponekod najdemo tudi ostanke kopenskih rastlin.

Najdbe amonitov so v plitvomorskih spodnjejurskih plasteh zelo redke in naključne.

Ponekod jih vsebujejo višje- oziroma nižjeležeče plasti. Z njihovo pomočjo plasti z omenjeno fosilno združbo (*Lithiotis* facies) uvrščajo v pliensbachij (večinoma v njegov zgornji del: domerij) in ponekod (npr. v Južni Ameriki) tudi v spodnji del toarcija.

Nahajališča spodnjejurskih školjk v Sloveniji

Spodnjejurske školjke se pri nas množično pojavljajo v »litiotidnem horizontu« južne Slovenije. Tako ga je leta 1965 poimenoval Buser (1965a) po izredno značilnih školjkah, ki jih je takrat zaradi očitnih podobnosti pripisal isti družini: Lithiotidae. Njihovi dolgi, ozki preseki dajejo kamninam na terenu zelo razpoznaven značaj. Vrsta *Lithiotis problematica* je najbolj znana, vendar precej redka. Veliko pogostnejši sta vrsti *Lithiopedalion scutatus* in *Coclearites loppianus*. Omenjene tri vrste danes prištevamo v različne družine, zato bi morali ime litiotide opustiti. Izraze kot so »litiotidni horizont« ali »litiotidni apnenec« pa lahko uporabljamo predvsem v smislu faciesa. Poleg naštetih školjčnih vrst najdemo tudi rodove *Pachyrisma, Gervilleioperna, Mytilus* in *Opisoma*.

Glede na terenske podatke in s pomočjo primerjave s podobnimi nahajališči v severni Italiji je Buser (1965a, 44–46) plasti z značilnimi školjkami uvrstil v **zgornji del srednjega liasa: domerij.** Na Trnovskem gozdu značilne školjke izginejo 10–30 debelinskih metrov pod plastmi, ki vsebujejo zgornjeliasne brahiopode in okoli 50–60 metrov pod spodnjedoggerskimi plastmi, ki so bile dokazane z mikrofosili (Buser, 1979).

Litiotidni horizont je v južni Sloveniji stalen in se skoraj ne izklinja. Debel je lahko manj kot pol metra, ponekod pa znaša celo 75 metrov. Največjo debelino doseže pri Podpeči, na Krimsko-Mokrškem hribovju in v dolini Krke. Tu so plasti apnenca značilno temno sive ali celo črne barve. Proti severu postane apnenec svetlejši, plasti s školjkami pa so vse tanjše; na Trnovskem gozdu in Banjški planoti se ponekod celo izklinjajo. Tudi proti jugu se litiotidni horizont močno stanjša in izklinja predvsem na mestih, kjer so pojavi črnega premoga, to je pri Loškem Potoku, na Blokah, pri Cerknici in Rakitnici. Na večjem delu Logaške planote, v Hrušici, na Bloški planoti, v Slivnici, na Mali in Veliki gori in na Kočevskem najdemo školjke v bituminoznem debelozrnatem dolomitu ali pa v redkih, tankih apnenčevih vložkih med dolomitom. (Buser, 1965a, 39–47; Savić & Dozet, 1985).

Slika 2 kaže razprostranjenost spodnjejurskih plasti s školjkami. Posebej so označena nahajališča, kjer školjke lahko izluščimo iz mehkejše lapornate osnove.

Nekatera izmed nahajališč, ki jih je S. Buser našel pri geološkem kartiranju pred več kot tridesetimi leti, so žal uničena ali zaraščena. To velja predvsem za nekdanji kamnolom na desnem bregu Sušice zahodno od Dolenjskih Toplic in za nahajališče na Javorniku (vzhodni del Trnovskega gozda). Tudi useki cest na Krimsko-Mokrškem hribovju, jugozahodno od Loža, severno od Cerknice in pri Grčarevcu so skorajda povsem zaraščeni. Posamezne primerke še dobimo ob železniški progi med Preserjem in Verdom. Zelo številne školjke danes najdemo v kamnolomu v Podpeči, na vzhodnem pobočju Špika (severno od Cola na Trnovskem gozdu) in ob kraškem izviru Globočec (zahodno od Zagradca). Na novo je odkrito najdišče na vzhodnem pobočju hriba Stražišče vzhodno od Gorenjega Jezera pri Cerknici. Vrsto *Lithiotis problematica*, ki je sicer najredkejša, najdemo vzhodno od vasi Zafara pri Žužemberku.

V nadaljevanju so podrobneje opisana nahajališča Špik na Trnovskem gozdu, kamnolom v Podpeči, Globočec pri Zagradcu, Grčarevec južno od Logatca, Stražišče pri

Gorenjem Jezeru, Ravne pri Borovcu na Kočevskem in Travna gora. Ta nahajališča so razporejena po obravnavanem območju tako, da zastopajo nekdanja različna okolja. Poleg tega je bilo tam možno posneti geološke profile (sl. 3).

Špik na Trnovskem gozdu

Špik je okoli 950 metrov visok vrh na Trnovskem gozdu, ki leži približno 2 km severno od Cola. Lepo odkrite zgornjetriasne in liasne plasti položno vpadajo proti jugu. Zgornjetriasni dolomit z značilnimi stromatoliti postopoma prehaja v spodnjeliasni masivni, debelozrnati dolomit svetlo sive barve, ki je debel približno 100 m. Navzgor sledi približno 30 m svetlo sivega do belega mikritnega apnenca, ki vsebuje v zgornjem delu do 3 m debele vložke debelozrnatega dolomita. Plasti spodnjeliasnega apnenca sestavljajo strme skalne stopnje v gozdnem pobočju. Na približno 900 metrih višine znaša njihov vpad 180/45. Litološko mejo s srednjeliasnimi plastmi postavlja Buser (1978) tam, kjer se pojavi rjavkasti oolitni apnenec. Tega je tu približo 30 metrov.

Nekaj metrov pod vrhom Špika je približno 70 cm debela plast sivo rjavega laporn atega apnenca, ki je poln različnih školjk. Prevladuje vrsta *Lithiopedalion scutatus*. Njene lupine so dolge do 40 cm in močno prekristaljene. Pridružujejo se ji *Gervilleioperna buchi* (Zigno), *G. taramellii* (Böhm), *Mytilus lepsii* Tausch in *M. mirabilis* Lepsius. Zelo veliko je tudi srednje velikih megalodontidnih školjk, ki pripadajo novemu rodu in vrsti. Različne vrste školjk so bile verjetno nanesene skupaj šele po odmrtju. Njihove lupine so precej dobro ohranjene, kar kaže na to, da transport ni bil dolg. V apnencu je poleg školjk vse polno drobnih odlomkov različnih fosilov. Ta plast, iz katere lahko luščimo školjke, se vleče po vzhodnem pobočju Špika približno 200 metrov daleč.

Nad plastjo s školjkami je približno 5 metrov svetlega oolitnega apnenca s številnimi odlomki krinoidov, iglicami morskih ježkov, briozoji in posameznimi koralami. Višje v profilu je približno en meter debela plast svetlo sivega mikritnega apnenca s številnimi, vendar ne kamnotvornimi školjkami vrste *L. scutatus*. Nekatere lupine leže pravokotno na plastnatost, kar kaže, da so školjke po odmrtju ostale v življenjskem položaju. Nad to plastjo sledi še meter mikritnega apnenca brez školjk (sl. 3).

Območje Trnovskega gozda je v srednjem liasu pripadalo severnemu, distalnemu robu Dinarske karbonatne platforme. Ta del je bil na udaru valov in tokov, ki so prihajali iz severno ležečega globokega morja Slovenskega bazena. Okolje s povečano vodno energijo školjkam ni najbolj ustrezalo. Na Špiku jih zato najdemo le v dveh, razmeroma tankih plasteh. Kaže, da so naštete vrste še najbolje prenašale razburkano okolje.

Podpeč

Podpeč leži na južnem obrobju Ljubljanskega barja. V velikem kamnolomu so lepo odkrite spodnjejurske plasti podpeškega apnenca, ki so jih že Rimljani izkoriščali za gradnjo nekdanje Emone. Od srednjega veka naprej so iz tega kamnoloma pridobili velike količine gradbenega in okrasnega kamna. Zdaj že več kot trideset let apnenca ne lomijo več. Podpeški »marmor« po vsej Sloveniji krasi različne stavbe in spomenike. Najlepše je zaživel v stvaritvah arhitekta Jožeta Plečnika (Prelovšek, 1987). Vsakdo, ki obišče Narodno in univerzitetno knjižnico v Ljubljani, opazi v njeni avli čudoviti črni kamen z dolgimi, belimi preseki školjk (sl. 4). V Ljubljani si ga lahko

ogledamo tudi v starem Nebotičniku, v nekdanji Trgovinski zbornici, na stopnišču Montanistike, v zgradbi Slovenskega parlamenta, na Magistratu in še marsikje.

Plasti srednjeliasnega apnenca skoraj navpično vpadajo proti jugu (180/80). Debele so od 10 cm do 2 metra. Lepo so odkrite na vzhodni in zahodni strani kamnoloma (sl. 5, 6). Vmesni odkopani del priča, kako velike količine kamna so tu pridobili. Apnenec v kamnolomu prečka več prelomov. Ob njih so posamezne grude drsele ena ob drugi, tako da so nastale velike zglajene prelomne ploskve z navpičnimi razami. Med diagenezo so v apnencu nastali številni stilolitni šivi.

Med plastmi apnenca so zelo pogostne lapornate prevleke in plasti. V spodnjem delu profila so le-te debele tudi do 15 centimetrov. Najlepše jih vidimo v zahodnem delu kamnoloma, kjer je svež odkop za novo halo. Površina apnenca pod polami laporja je pogosto gomoljasto razjedena (sl. 7). Nad to nepravilno površino je nekaj milimetrov debela, vijoličasto rdeča skorja, sledi pa rumeno rjav ali rdečkast lapor. Rentgenska analiza je pokazala, da vsebuje vijolična skorja naslednje minerale: muskovit, illit, kalcit, hematit in anataz oziroma brookit. Mineraloška sestava po mnenju M. Mišiča (ustno sporočilo) kaže na preperevanje in situ. Verjetno je bil apnenec večkrat dvignjen nad morsko gladino in potem zopet spuščen. Ob preperevanju apnenca na kopnem so nastale rdeče kraške gline oziroma terra rossa, ki je bila kasneje spremenjena v omenjene rjave in rdeče laporje. Takšne oscilacije lahko opazimo le v spodnjem delu profila. M. Mišič je v laporju določil naslednje minerale: muskovit, illit, kalcit in goethit. Analiza na pelod, ki jo je opravil M. Jelen, ni dala pozitivnih rezultatov (ustno sporočilo).

Profil (sl. 3) je bil posnet na vzhodni strani kamnoloma. Litiotidni horizont je v podpeškem kamnolomu odkrit v vsej debelini, ki znaša kar 75 metrov. V njem so plasti s školjkami razmeroma tanke (0,1–1,5 m), vmesne prekinitve brez školjk pa velike. V profilu lahko naštejemo več kot petnajst med seboj ločenih školjčnih lumakel. Njihova skupna debelina je približno 12 metrov. Veliko število razmeroma tankih lumakel kaže na to, da je bila rast školjk velikokrat motena ali celo prekinjena. Školjke v podpeškem kamnolomu najdemo v črnem mikritnem apnencu in v spodnjem delu profila tudi v lapornatih plasteh. Školjčnim lumakelam najpogosteje sledi sparitni apnenec z ooidi, drobnimi zaobljenimi odlomki različnih lupinic (bioklasti) in intraklasti. Tokovi in valovi, ki so v laguno nanašali različen drobir in spirali karbonatno blato, so najbrž motili rast školjk. Školjke so v času neugodnih pogojev preživele nekje v soseščini in se v ugodnejših razmerah spet naselile na prejšnjih mestih. V zgornji polovici profila je precej več mikritnega apnenca kot v spodnji. Okolje je bilo takrat mirnejše, zato so lumakele debelejše in številčnejše.

Med školjkami je daleč najpogostnejša vrsta *Lithiopedalion scutatus* (Dubar), ki se tudi prva pojavi. V spodnjem delu profila lahko iz lapornatih plasti izluščimo lepe primerke. Ponekod so lupine nagnetene ena ob drugi kot črepinje z zelo malo veziva (sl. 8). Po presekih v apnencu sodeč, so nekateri primerki dosegli velikost kar 3/4 metra. V drugi polovici profila, ki kaže na mirnejše sedimentacijsko okolje, je pogostna tudi vrsta *Cochlearites loppianus*. Tu je školjke nemogoče izluščiti iz kamnine, zato prisotnost te vrste dokazujejo le preseki v apnencu. Vrsta *Lithiotis problematica* je v Podpeči zelo redka; njene značilne preseke (sl. 9, 10) najdemo le v dveh ali treh plasteh v zgornjem delu profila.

Preseki omenjenih školjk se v kamnolomu, na terenu zelo slabo razločijo, ker je plasti prekrila patina ali pa je površina tektonizirana. Na srečo lahko orientiranost školjčnih lupin opazujemo na zglajenih ploščah okrasnega podpeškega apnenca. Večinoma lepo ohranjene lupine leže vzporedno s plastnatostjo. V takšnih lumakelah ponavadi

prevladuje le ena vrsta. V primerih, ko so školjke različnih vrst nepravilno »razmetane« v apnencu, so lupine večkrat poškodovane (sl. 10). Lupine so bile velikokrat razlomljene in deloma raztopljene tudi med diagenezo.

Poleg rodov *Lithiopedalion*, *Cochlearites* in *Lithiotis* nastopajo v Podpeči tudi naslednje školjčne vrste: *Gervilleioperna buchi*, *G. taramellii*, *G. timorensis* Krumbeck, *Opisoma* cf. *excavatum* Böhm, *O.* cf. *menchikoffi* Dubar in *Pachyrisma* (*Pachymegalodon*) *chamaeforme* (Schlotheim). Zanimiva je tudi približno 40 cm debela plast lapornatega apnenca z drobnimi školjkami, ki verjetno pripadajo rodu *Astarte*. Ta plast je tik ob skladišču za razstrelivo. Na slikah je označeno, kje so bile najdene različne školjke. Od naštetih vrst so prav vse kamnotvorne, samo primerke rodu *Opisoma* najdemo posamično (sl. 11), in sicer v biosparitnem apnencu, polnem organskega detritusa, ki so ga sferično obraščale modrozelene cepljivke. Zanimivo je, da v lumakelah z drugimi rodovi školjk ni onkoidov, čeprav so sicer v profilu zelo pogostni. Očitno je, da modrozelene cepljivke v družbi s školjkami niso mogle uspevati.

Buser (1965a) je iz podpeškega kamnoloma opisal dve vrsti brahiopodov: *Terebratula rotzoana* Schauroth in *T. renieri* Catullo. Polži so precej številni, vendar jih je iz trdne kamnine nemogoče izluščiti. V zbruskih najdemo številne drobne hišice, v okrasnem podpeškem apnencu pa so preseki polžev veliki tudi do 10 cm (sl. 12). Korale so precej redke. Posamezni primerki so se pritrjali tudi na lupine megalodontidnih školjk. Zanimivo je, da je v bližini, v Gornji Brezovici pri Preserju v litiotidnem horizontu razvit tudi manjši koralni greben (patch reef). Dolg je 35 metrov, širok nekaj metrov in debel 5 metrov. Lateralno prehaja v temno sivi oolitni apnenec.

Za srednji lias je poleg školjk najznačilnejša velika foraminifera *Orbitopsella praecursor* (sl. 13). V podpeškem apnencu je v nekaterih plasteh kamnotvorna. Mikroforaminifere so prisotne skorajda v vseh plasteh, zato na shematskem profilu (sl. 3) niso posebej označene. Najštevilnejše so v pelbiomikritnem apnencu (sl. 14). L. Šribar (rokopisno poročilo) je določila naslednje družine foraminifer: Ammodiscidae (*Glomospira* sp.), Lituolidae (rodovi *Lituosepta*, *Orbitopsella*, *Haurania*, *Pseudocyclammina*), Verneuilinidae, Textularidae in Nubeculariidae (*Opthalmidium* sp.). Prisotne so tudi dazikladaceje *Thaumatoporella parvovesiculifera* (Raineri) in *Palaeodasycladus mediterraneus* (Pia), kodiaceje in problematični fosil *Aeolissacus* sp. Mikrofosile iz Podpeči je določala tudi R. Radoičić (rokopisno poročilo). V višjih delih profila je R. Radoičić določila tudi vrsto *Labyrinthina recoarensis*. Po njenem mnenju pripada nekaj najnižjih plasti v kamnolomu zgornjemu delu spodnjega liasa. V najvišjem delu profila, ki je tektonsko precej prizadet, pa bi lahko pričakovali mejo med srednjim in zgornjim liasom.

Najpogostnejša bentoška foraminifera je *Glomospira*. Zelo številna je v celem profilu, tudi tam, kjer ni drugih mikrofosilov. Čeprav so zgoraj omenjene apnenčeve alge v podpeškem kamnolomu precej pogostne, jih v školjčnih lumakelah nismo zasledili. Nasploh je biodiverziteta v plasteh, kjer so bili ugotovljeni rodovi *Lithiopedalion*, *Cochlearites*, *Gervilleioperna* in *Lithiotis*, zelo nizka.

Značilne školjke v zgornjem delu profila dokončno izginejo nenadoma, brez postopnega prehoda. Po litologiji sodeč, se sedimentacija pri tem ni bistveno spremenila. Preučiti pa bi bilo treba, če je nastala kaka sprememba v združbi foraminifer.

Globočec pri Zagradcu

Globočec je velik kraški izvir jugozahodno od Zagradca. Na tem območju prehaja zgornjetriasni glavni dolomit s stromatoliti v svetlo sivi, mikritni spodnjeliasni apnenec. Ob izviru Globočec so lepo odkrite plasti temno sivega do črnega srednjeliasnega apnenca. Debele so od 10 do 100 cm in vpadajo proti jugozahodu (220/15). V gozdnem pobočju sestavljajo skalne stopnje, ki jim lateralno lahko sledimo na dolžini 50 m. Tu je odkritih le vrhnjih 20 metrov litiotidnega horizonta, ki je sicer v dolini Krke debel okoli 50 metrov.

V spodnjem delu profila (sl. 3) pri Globočcu je več kot 5 m temno sivega mikritnega apnenca s kamnotvornimi školjkami rodu *Cochlearites*. Vmes sta samo dve tanki prekinitvi z le posameznimi preseki lupin. Apnenec je v spodnjem delu ponekod laporнat, zato je školjke mogoče luščiti iz kamnine. Nekateri primerki so tipični predstavniki vrste *Cochlearites loppianus*, drugi, ki smo jih našli kak meter višje, pa so precej večji in drugačne oblike. Pripadajo novi vrsti, po značilni strukturi lupine sodeč pa gre za isti rod. V tem delu profila so bili najdeni tudi posamezni primerki solitarnih koral, ki so bile prirasle na debele lupine školjk.

Višje sledi dva metra debel sparitni apnenec z intraklasti, posameznimi ooidi, odlomki lupin in krinoidov. To je edina večja prekinitev brez školjk. Nad tem je 7 metrov apnenca, ki je poln kamnotvornih školjk iz rodu *Cochlearites*. Preseki rodu *Lithiopedalion* so redki. V tem delu školjk ne moremo izluščiti iz trdne kamnine. Zatem školjke nenadoma, brez postopnega prehoda izginejo. V črnem mikritnem apnencu, v zadnjih 30 metrih odkritih plasti ne najdemo niti enega primerka več.

Tip apnenca v nahajališču Globočec priča o mirnem sedimentacijskem okolju. Rast školjk je bila skorajda nemotena. Njihove lupine so večinoma nepoškodovane in jih v nekaterih plasteh najdemo celo v navpični, to je življenjski legi. Večina pa se jih je po odmrtju prevrnila na morsko dno, tako da so preseki orientirani vzporedno s plastnatostjo. Zelo pogosto lahko opazimo tudi nekakšne zagozde, sestavljene iz številnih lupin. V tem primeru se je po odmrtju ali pa še za življenja več primerkov nagnilo skupaj, tako da se podpirajo v poševni legi.

Grčarevec

Naselje Grčarevec leži južno od Logatca. Približno 1 km proti severozahodu so lepo odkrite srednjeliasne plasti. Njihov vpad znaša 300/15. Prevladuje temno sivi debelozrnati dolomit s posameznimi školjčnimi lumakelami, ki so debele do 2 metra.

V leči apnenca, ki leži med dolomitom, je pri zadnjih počitniških hišah, severozahodno od Grčarevca sveže odkopani usek. V treh ločenih plasteh, debelih približno 70 cm, se lepo vidijo preseki kamnotvornih školjk. Močno prevladuje vrsta *Cochlearites loppianus* (sl. 15). Neprimerno manj je presekov, ki verjetno pripadajo rodu *Lithiopedalion*, v srednji plasti pa tudi rodovoma *Gervilleioperna* in *Mytilus*. Apnenec je mikriten in temno sive do črne barve. Nad apnencem sledi dolomit, ki v spodnjem delu še vsebuje značilne školjke, navzgor pa teh ni več.

V ostrem ovinku stare ceste severno od Grčarevca je Buser (1978, 396) v litiotidnem horizontu našel lepo ohranjene rastlinske ostanke. To nahajališče je danes preraščeno. Ostanki kopenskih rastlin dokazujejo, da so na karbonatni platformi od časa do časa obstajali manjši kopni otoki.

Stražišče pri Gorenjem Jezeru

Iz vasi Klance zavijemo v hrib Stražišče, ki se nahaja vzhodno od Gorenjega Jezera pri Cerknici oziroma zahodno od Starega trga. Tu naletimo na enega najlepše odkritih profilov v litiotidnem horizontu.

V več kot 20 metrih odkritega profila lahko naštejemo okoli 10 školjčnih lumakel, ki so debele okoli 0,5–1 metra in največ 2,5 metra. Prevladuje rod *Cochlearites*. Njegove značilno oblikovane lupine so ponekod lečasto razporejene, vmes pa se lumakela izklinja. V nekaterih plasteh so lupine tako številne, da vmes skorajda ni veziva. Praviloma nastopajo v temno sivem mikritnem apnencu. Zaradi lapornate primesi jih v nekaterih delih lahko izluščimo iz kamnine. Vmesne plasti brez školjk v glavnem sestavljata oolitni in biosparitni apnenec.

Školjke se v profilu nenadoma množično pojavijo in tudi izginejo nenadoma, brez postopnega prehoda. Nad litiotidnim horizontom sledi sparitni apnenec z ooidi in bioklasti, ki kot erozijska krpa sestavlja vrhnji del hriba.

Travna gora

Dobra dva kilometra jugovzhodno od Travne gore lahko v gozdnem pobočju sledimo vsaj 20 metrov debelemu litiotidnemu horizontu, ki je v celoti razvit v dolomitu (sl. 3). Školjke je mogoče izluščiti iz ene same, 20 cm debele lapornate plasti v spodnjem delu profila. V dolomitu najdemo le tri prave školjčne lumakele, vmesne plasti pa vsebujejo tudi posamezne, bolj ali manj pogostne, močno prekristaljene lupine. Zanesljivo gre predvsem za rod *Cochlearites*. V spodnjem delu opazimo najprej do 30 cm velike preseke tega rodu, ki so podobni tistim v nahajališču Globočec in verjetno pripadajo novi vrsti. V najvišjem delu litiotidnega horizonta je lumakela s školjkami debela kar tri metre. V prvi polovici jo sestavljajo prekristaljene lupine, ki bi jih lahko pripisali rodovoma *Cochlearites* in *Lithiopedalion*, vendar so primerki precej manjši in drobnejši kot običajno (dolžina lupine 5 cm, debelina do 1 cm). V zgornji polovici omenjene lumakele pa spet prevladuje tipični predstavniki rodu *Cochlearites*. 40 metrov višje, nad dolomitom, sledi ooliten, temno sivi zgornjeliasni apnenec, ki se menjava s tankimi ploščami črnega mikritnega apnenca.

Ravne pri Borovcu

Srednjeliasne plasti v širši okolici Kočevja sestavlja predvsem debelozrnat, bituminozen dolomit (sl. 2). To je območje, ki je nekdaj pripadalo južnim, najbolj zaprtim delom lagune oziroma notranjega dela Dinarske karbonatne platforme.

Najdišče Ravne pri Borovcu je najjužnejše nahajališčev Sloveniji. Na spodnjem delu severnega pobočja Borovske gore izdanja črni, bituminozni, drobno ploščasti apnenec. Nad njim je 1,5 metra debela plast črnega mikritnega apnenca z razmeroma majhnimi, približno 10 cm dolgimi lupinami rodu *Cochlearites*. Višje sledijo plasti bituminoznega dolomita. V vrhnjem delu je 4 metre debela plast dolomita, ki je polna neobičajno drobnih primerkov rodu *Cochlearites*. Ta plast na pobočju izstopa kot strma skalna stopnja, ker je zaradi številnih školjčnih lupin mehansko bolj odporna.

Življenjske razmere školjk v spodnji juri v južni Sloveniji

V južni Sloveniji se je v spodnji juri razprostirala obsežna Dinarska karbonatna platforma. Ta plitvomorski prostor je proti severu mejil na globoko morje Slovenskega bazena (Buser, 1987a), proti jugu pa se je nadaljeval v današnjo Hrvaško. Rekonstrukcija nekdanjih razmer je na sliki 16.

Zanimivo je, da najdemo školjke vrste *Lithiotis problematica* tudi v okolici Bovca (na hribu Poljanica in pri kraškem izviru Glijun), torej na ozemlju, ki zanesljivo pripada Julijski karbonatni platformi, ki se je razprostirala severno od Slovenskega bazena (sl. 16). Skorajda nemogoče je, da bi plitvomorska favna migrirala z Dinarske karbonatne platforme na severnejšo Julijsko karbonatno platformo kar preko globokomorskega korita Slovenskega bazena. Sklepamo, da se je Slovenski bazen na območju današnjega osrednjega dela doline Soče pri Trnovem, zahodno od Kobarida, izklinil. Ta globokomorski bazen se torej ni nadaljeval proti zahodu v Belunski bazen severne Italije. Zaradi izklinitve Slovenskega bazena na omenjenem področju sta Dinarska in Julijska karbonatna platforma v liasu neposredno mejili ena na drugo.

Poglejmo zdaj, kakšne razmere so nekoč vladale v južni Sloveniji na Dinarski karbonatni platformi (sl. 17):

Severno obrobje platforme je prestreglo največjo udarno moč valov in tokov, ki so prihajali z globljega morja Slovenskega bazena. O njihovi rušilni moči pričajo apnenčeve breče na Banjšicah in severnem Dolenjskem. Sicer pa na severnem delu nekdanje Dinarske karbonatne platforme (Trnovski gozd, Banjšice) prevladuje oolitni in krinoidni apnenec svetle barve. Usedal se je v obsežnih plitvinah s toplo vodo, globoko le 1–3 metre. Iz globljih predelov Slovenskega bazena je sem prihajala bolj mrzla voda. Zaradi zvišanja temperature se je iz nje izločil del karbonatov in se odlagal okoli drobnih zrnc, ki so lebdela v nemirni vodi. V plitvinah so se kopičile velike količine ooidov, drobnih hišic in odlomkov različnih organizmov, ki so jih zaoblili valovi. Ponekod se je nabralo toliko tega drobirja, da je dosegel vodno gladino. Nastajale so obsežne peščene sipine in plaže. Skupaj z majhnimi koralnimi in hidrozojskimi grebenčki (Trnovski gozd) so predstavljale prave pregrade pred globokim morjem na severu in zapirale južneje ležečo laguno.

Ob plimi in neurjih je sveža morska voda prestopila pregrade in po širokih bibavičnih kanalih vdrla v laguno. Za njo so ostajale naplavine drobnega »oolitnega peska«. Tako tudi na področju nekdanje lagune najdemo precej temnega oolitnega apnenca. Pridružuje se mu biosparitni apnenec. Večinoma pa prevladuje mikritni apnenec, ki je nastal iz lagunskega karbonatnega blata. V njem kar mrgoli drobnih hišic foraminifer, ki so včasih živele na morskem dnu (bentos). Na mestih stalnega dotoka sveže vode so uspevale tudi korale, krinoidi in zelene alge (dazikladaceje). Sicer pa so v laguni največ življenjskega prostora na blatnem morskem dnu zasedale prav školjke. Sestavljale so prave podmorske trate (biostrome) s posameznimi lečastimi odebelitvami. Ponekod so se naselili tudi polži in brahiopodi. Karbonatna sedimentacija je bila v tem, osrednjem predelu najhitrejša, zato tudi litiotidni horizont doseže tu največjo debelino.

Proti jugu je bilo čedalje manj vpliva s severnega globokomorskega predela. Valovi in tokovi skorajda niso več dosegali tega področja. To so bili zaprti in mirni deli lagune. Veliko kisika je bilo porabljenega pri razpadanju organske snovi. Na dnu so tako zavladali redukcijski pogoji. Kamnine, ki so nastale v zaprti laguni, so močno bituminozne in značilne temno sive do črne barve. Evaporacija in s tem tudi slanost vode sta bili tu največji. Porna voda v sedimentih je vsebovala veliko magnezija in

so zato le-ti med diagenezo najlažje zapadli dolomitizaciji. Sklepamo lahko, da so menjave sušnih obdobij s prevladujočo evaporacijo in deževnih obdobij z močnimi nalivi precej vplivale na spremembe slanosti v zaprti laguni.

V večjem delu lagune oziroma šelfnega morja je bila voda globoka le nekaj metrov (subtidal). Zagotovo so obstajala tudi večja območja, ki so bila med oseko na suhem (intertidal); vendar so izsušitvene pore in stromatoliti v spodnjejurskih plasteh izredno redki, po čemer se ločijo od zgornjetriasnih plitvomorskih plasti. Školjke rodu *Mytilus* (klapavice), ki so lahko tudi indikatorji za takšno okolje, pa so v južni Sloveniji precej pogostne.

Pojavi premoga in ostanki kopenskih rastlin na redkih mestih (Bloke, Loški Potok, Grčarevec) dokazujejo, da so na platformi od časa do časa obstajali manjši kopni otoki, ki so jih najbrž obrobljala močvirja.

Kamnine in organizmi kažejo, da je bilo podnebje tropsko ali pa vsaj subtropsko. Paleogeografska razporeditev sedanjih ozemelj je bila v spodnji juri bistveno drugačna. Celotna »Jadranska plošča« se je nekdaj nahajala južneje, v nižjih geografskih širinah in tedanjem tropskem pasu (sl. 1).

Razporeditev vrst in način življenja školjk

Kaže, da severni, najbolj izpostavljeni deli karbonatne platforme za rast školjk niso bili ugodni. Školjke so od časa od časa poselile tudi to področje, vendar je bila njihova rast vsakokrat kmalu prekinjena. Močni valovi so lahko njihove lupine odnašali ali poškodovali. Nemirno okolje so še najbolje prenašale megalodontidne školjke, pa tudi rodovi *Lithiopedalion*, *Mytilus* in *Gervilleioperna*. Predvsem megalodontidne školjke se v severozahodnem delu Trnovskega gozda pojavljajo celo tam, kjer vse druge školjčne vrste že izginejo.

V bolj zatišnih delih šelfa, ki pa jih je vseeno dosegla sveža voda, bogata s kisikom in hranilnimi snovmi, so školjke uspevale najbolj množično. Razmere za njihovo rast so bile v tem delu najugodnejše, vendar tudi precej nestabilne. Številne, razmeroma tanke, po vertikali ločene lumakele pričajo, da je bila rast školjk velikokrat prekinjena. Prikamnina je praviloma mikritna; sedimentološka in paleontološka slika med njimi ležečih plasti pa kaže, da je ob prekinitvah rasti školjk največkrat prišlo do povišane vodne energije. Takrat so se usedali sedimenti, iz katerih so nastali oolitni, onkolitni in biosparitni apnenci. Občasno, morda ob večjih neurjih, so tokovi v laguno nanesli toliko materiala, da so školjke dobesedno zasuli z različnim drobirjem. Po drugi strani so lahko močni valovi izprali ves sediment, ki je obdajal velike lupine najbolj značilnih školjčnih vrst in jim dajal oporo, ter jih razmetali po morskem dnu, kjer so propadle. Ob neugodnih razmerah so školjke preživele nekje drugje in se ob priliki spet naselile na prejšnjem mestu. Osnovo za prvo poselitev oziroma pritrditev juvenilnih školjk je lahko predstavljala trdna podlaga, različni detritus ali pa kar lupine odmrlih školjk. V osrednjem predelu lagune, ki je bil pod vplivom globokomorskega bazena, je prevladoval rod *Lithiopedalion*, zelo pogostni pa so tudi primerki rodu *Cochlearites*. Bolj ali manj številčno so bile zastopane vse že prej naštete školjke, med njimi tudi rod *Lithiotis*.

Podatki zaenkrat kažejo, da je mirno, blatno dno v južnejših, najbolj zaprtih delih lagune poseljeval predvsem rod *Cochlearites*. V srednjeliasnem dolomitu pogosto naletimo na preseke lupin, ki bi jih lahko pripisali rodovoma *Lithiopedalion* in *Cochlearites*, vendar so neobičajno majhni. Velikost lupine doseže največ 10 cm in de-

belino do 1 cm, ponavadi pa še manj. Možno je, da so omenjene školjke rastle ob tako slabih pogojih (povečana slanost, zmanjšan dotok sveže vode), da so ostale majhne, lahko pa da gre za posebne vrste. Žal se takšnih primerkov nikjer ne da izluščiti iz dolomitne kamnine, pa tudi lupine so diagenetsko močno spremenjene. Predvidevamo, da so bile razmere v najbolj zaprtih delih lagune za školjke v splošnem manj ugodne kakor v osrednjem delu, ki je bil pod stalnim, zmernim vplivom iz pelagiala. Po drugi strani pa je bilo okolje v najbolj zatišnih delih bolj stabilno, na kar kaže precejšnja debelina sicer redkih školjčnih lumakel (do 4 metre).

Pri ugotavljanju različnih sedimentacijskih okolij na karbonatni platformi se moramo zavedati, da se je težišče vplivov iz globokomorskega predela sčasoma spreminjalo. To je bilo najbolj izrazito na prehodu iz bazena v platformo. Na vseh področjih šelfnega morja oziroma lagune pa so se vsaj deloma spreminjali vodna energija, nivo morske gladine in morsko dno, vključno s sedimenti, ki so se usedali na njem.

Za vse naštete spodnjejurske školjke velja, da so sestavljale prave podmorske trate, tako da se je skupaj nagnetlo na stotine osebkov iste vrste. Večinoma so školjke živele v zelo plitvi vodi (intertidal-subtidal), saj so blizu vodne gladine dosegle največ hranilnih snovi.

Rod *Gervilleioperna* je živel podobno, kot še danes živi rod *Isognomon*. Na trdno podlago so se te školjke pritrjale s šopom lepljivih bisusovih vlaken. Enako velja za predstavnike rodu *Mytilus*. To je edini rod, ki je še danes razširjen v vseh plitvih morjih, razen na skrajnem severu. Značilno zanj je, da poseljuje območje plimovanja. Ob oseki lahko več ur preživi na suhem, tako da hermetično zapre lupini. Dobro prenaša tudi spremembe v slanosti vode. Najbolj mu ustreza brakična voda v priobalnem pasu (Cox, 1969, N5-N15). Megalodontidne školjke so živele z vrhom zasidrane v mehko morsko dno. Lupina in sklep sta bila zelo močna, okrogla oblika pa jim je omogočala, da so se ob močnejših vaiovih in tokovih brez škode kotalile po morskem dnu.

O načinu življenja najznačilnejših spodnjejurskih rodov *Lithiotis*, *Cochlearites* in *Lithiopedalion* je še veliko nejasnosti. Podobne školjke danes ne živijo več, pa tudi s kako fosilno skupino bi jih le težko primerjali. Njihova nenavadna oblika in velika stopnja variabilnosti že sami po sebi zastavljata številna biološka vprašanja (več v: Debeljak & Buser, in prep.). Bile so docela prilagojene na blatno morsko dno, hitro sedimentacijo v okolju in sesilno življenje v gosti združbi istovrstnih primerkov. Glede na majhno velikost mehkega telesa so gradile izjemno velike lupine. Rastle so vse življenje, tako da je školjka ostajala nad nivojem obdajajočega sedimenta, in da si je v gosti družbi sosedov priborila dovolj sončne svetlobe. Takšna nenehna, enakomerna rast v višino je prava posebnost, saj se rast živali običajno eksponentno zmanjšuje s starostjo. V plasteh, kjer so lupine po odmrtju ostale v življenjskem položaju, lahko opazujemo, kako so se posamezni primerki med seboj podpirali in se navzgor šopasto razraščali; podobno kot rastline. Pogostni so »kolenasto« upognjeni primerki, pri katerih se je lupina morda nevarno nagnila in potem spet popravila svoj položaj z navpično rastjo. Pri vsem tem ni čudno, da pri isti vrsti oblika močno variira. Zunanja podobnost omenjenih treh rodov, ki sicer pripadajo različnim družinam, je rezultat konvergence: prilagoditve na podobno, zelo specifično življenjsko okolje. Lupine rodov *Lithiotis*, *Cochlearites* in *Lithiopedalion* so lahko merile kar 0,5 metra. Tako velike školjke danes najdemo predvsem v ekvatorialnem pasu ali pa na območjih s toplimi tokovi, kjer je temperatura vode ves čas najmanj 23 °C. Zaradi zmanjšane vsebnosti CO_2 v vodi je tam olajšano izločanje kalcijevega karbonata oziroma gradnja skeleta.

Značilno je, da je biodiverziteta v posameznih školjčnih lumakelah izredno nizka. Očitno se posamezne vrste školjk med seboj niso mešale. Prav tako med školjkami

skorajda ni drugih organizmov, ki bi se fosilno ohranili. Deloma lahko to pripišemo selektivnemu vplivu specifičnega okolja (blatni substrat, hitra sedimentacija), ki je zahtevalo od organizmov posebno prilagojenost. Najbrž pa so tudi same školjke onemogočale svoje tekmece s hitrim razraščanjem in produkcijo velikih količin organskega blata. V kalni vodi je bila fotosinteza praktično onemogočena, kar je iz tega prostora izključilo veliko organizmov, predvsem pa zelene alge in modrozelene cepljivke. Podobne razmere danes opažamo na velikih ostrižiščih. Nekatere vrste ostrig lahko v eni uri prefiltrirajo 40 litrov vode. Pri tem so pravi akumulatorji sedimenta, bogatega z organsko snovjo, ki zaudarja in ob razpadanju povzroča redukcijske pogoje. Na vodni gladini se H_2S oksidira v žvepleno kislino. Na vrhu sedimenta je kislo okolje, zato so lupine pogosto korodirane (Stenzel, 1971, N1000-N1003), kar lahko opazimo tudi na fosilnih ostankih.

Rodovi *Lithiotis*, *Cochlearites* in *Lithiopedalion* so v južni Sloveniji ustvarjali podmorske trate ali biostrome. Pri nas ni dokazov za obstoj grebenskih tvorb. Manjše lečaste odebelitve sicer razmeroma tankih školjčnih lumakel bolj verjetno predstavljajo nasutine po krajšem transportu prenesenih lupin. Lumakele se lateralno ne izklinjajo; kvečjemu tanjšajo in debelijo. Mikritna prikamnina kaže med usedanjem sedimenta na nizko vodno energijo. Glede na svojo obliko so lupine razmeroma dobro ohranjene. Lupine izoliranih primerkov navadno niso erodirane. Biodiverziteta v lumakelah je nizka. Vse to kaže, da običajno ni prihajalo do daljšega transporta. Menimo, da so značilne školjke uspevale na velikih površinah in da so jih valovi po odmrtju najpogostneje le nekoliko premetali.

Cvetoča doba značilnih spodnjejurskih školjk (rodovi *Lithiotis*, *Cochlearites* in *Lithiopedalion*) je trajala le okoli 5–10 milijonov let; na področju južne Slovenije pa se niso obdržale niti tako dolgo. V vseh naših nahajališčih ob koncu litiotidnega horizonta, ki ga uvrščamo v domerij, školjke izginejo nenadoma, brez postopnega pojemanja.

V zgornjem liasu je na področju Tetide prišlo do obsežnih tektonskih premikov. V severni Sloveniji, na nekdanji Julijski karbonatni platformi, je prišlo do kratke okopnitve, potem pa se je naglo pogreznila in razpadla (Buser, 1987a, 316). Vpliv teh dogajanj je gotovo segel tudi na Dinarsko karbonatno platformo. Na območju Stične, Šentvida, Radohove vasi, v okolici Trebnjega in Velikega Gabra ležijo malmske plasti transgresivno na srednjeliasnih. Pri Loškem Potoku pa so iz zgornjega liasa pojavi premoga. Vse to kaže, da je po odložitvi srednjeliasnih plasti s školjkami prišlo do dvigovanja ozemlja. Tektonske spremembe so se dogajale tudi v sosednji Italiji. Na Trento karbonatni platformi leže nad plitvomorskimi plastmi s školjkami globokomorski apnenci tipa ammonitico rosso (Bosellini & Broglio Loriga, 1971).

O vzrokih, ki so pripeljali do nenadnega izumrtja značilnih spodnjejurskih školjk, lahko samo ugibamo. Po vsej verjetnosti je šlo za splet različnih okoliščin. Vemo, da so bili to skrajno specializirani organizmi, ki se spremembi okolja niso mogli odzvati z novimi prilagoditvami. O nekdanjem življenju, ki nas vedno znova preseneča s svojo raznolikostjo, je ostal le zanimiv fosilni zapis.

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