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THE ROLE OF CORALS IN LADINIAN-CARNIAN REEF COMMUNITIES OF SLOVENIA, YUGOSLAVIA

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ABSTRACT

The first Triassic scleractinian corals in Slovenia are known from the Ladinian-Carnian coral-sponge reef complexes. The Ladinian faunal community is not distinguishable from the Carnian fauna. It leads to the supposition that these complexes may be lateral equivalents. Their beginning should be put into the Cordevolian.

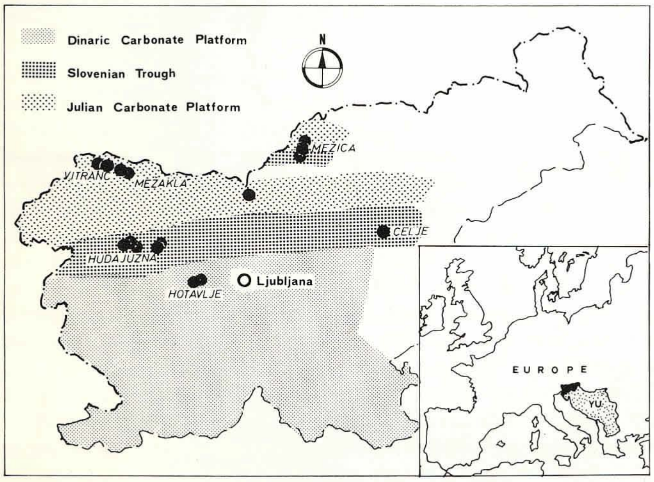
Corals represent 35 to 50 percent of the organic framework. In the entire mass of limestone their proportion varies from 15 to 30 percent of its volume. The starting species of scleractinians are quite heterogenous. They belong to 13 genera and 5 suborders. It supports the supposition that most scleractinians evolved from soft ancestors in several lines at the same time. Among the identified corals, only in the genus *Protoheterastraea* may direct descendants of Rugosa be sought.

The examined buildups are small patch reefs within limestones of the Julian and Dinaric carbonate platforms, and small mud mounds within clastic beds of the deeper Slovenian trough, where corals and sponges played the role of baffling or trapping carbonate mud.

INTRODUCTION

We have started the study of the Triassic reef communities in Slovenia only recently. They appear in two periods, in the Ladinian-Carnian and the Norian-Rhaetian, in several places, and in various reef types (Buser *et al.*, 1982). Only the localities of reef fauna at Jesenica (Čar *et al.*, 1981) and Hudajužna (Senowbari-Daryan, 1981) have been studied in detail. The fossil reef assemblage of Begunjščica was presented by Flügel and Ramovš (1961), and identifications of individual corals from various sites have been made by Kolosváry (1967).

In this paper we present the entire picture of the older, Ladinian-Carnian, reef complex; its distribution, paleogeographic evolution, depositional environment, mode of formation of reef complex, fossil association, and contribution of corals in the reef framework.



Text-figure 1.—Location map of Slovenia with localities of Ladinian–Carnian coral-sponge reef complexes.

ACKNOWLEDGMENTS

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DEVELOPMENT OF TRIASSIC REEFS IN SLOVENIA

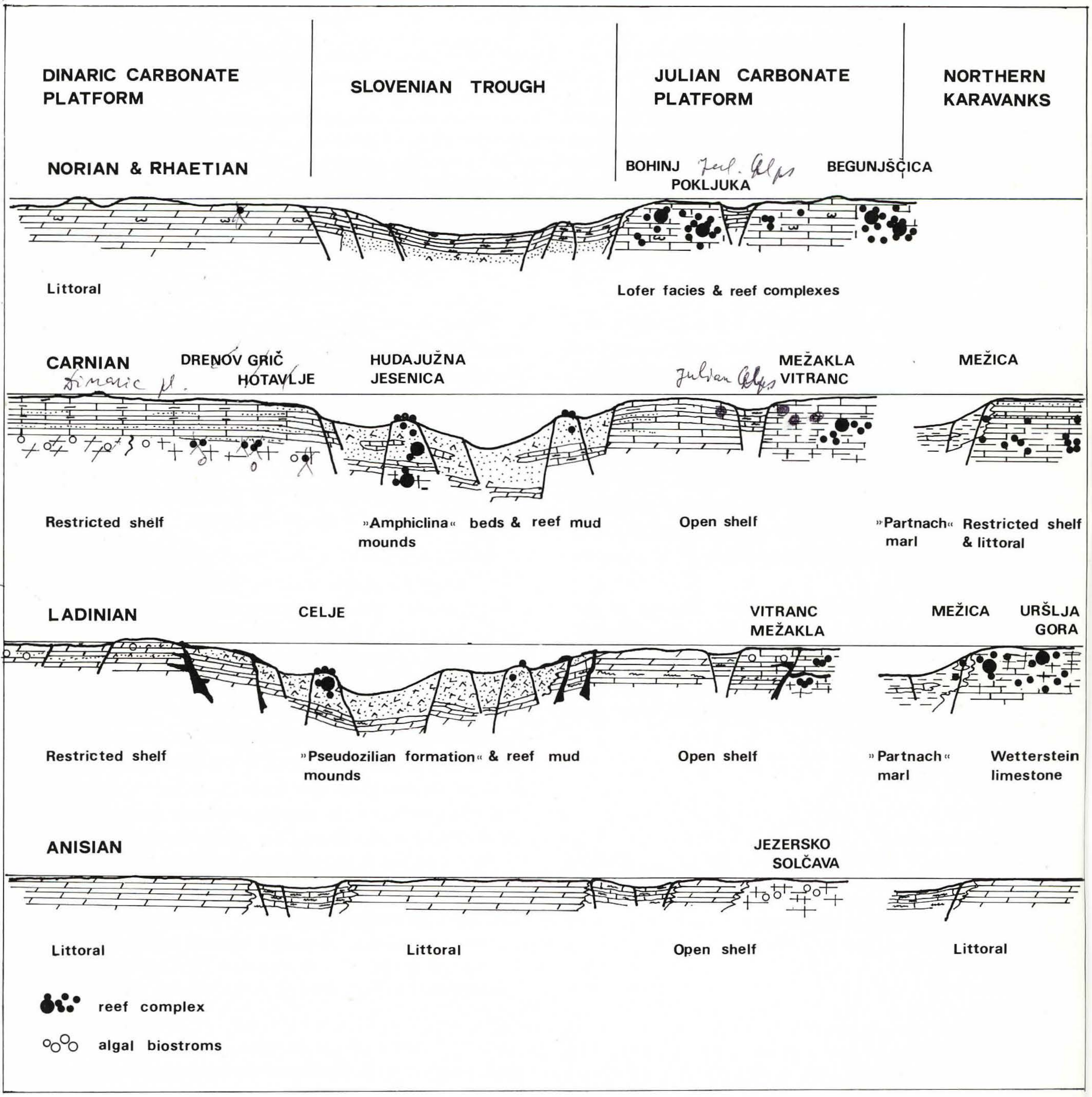
After the Groden clastic beds were deposited during the Upper Permian in the major part of present-day Slovenia, an extended carbonate platform developed. Only the area of northern Karavanke and the extreme part of the southern Slovenia remained land. In rare places on the platform grew smaller coral reefs with the coral *Waagenophyllum indicum.*

The Lower Triassic witnessed the expansion of the carbonate platform to an even greater extent. The carbonate deposition was frequently interrupted by influxes of terrigenous material which made this period completely unfavorable for reef growth.

The Anisian is characterized by the extension of the carbonate platform into the area of the northern Karavanke. Extended algal mats appeared in places during this time which formed several hundred meters of limestone beds. On the major part of the platform, layered dolomite of littoral development was deposited. Coral reef structures are not known from these intervals. Between the Middle and Upper Anisian, long and narrow intraplatform troughs formed and platy limestone with chert was deposited.

Ladinian was, for the major part of the present-day Slovenian territory, one of the most agitated stages of the Triassic. The carbonate platform which was up to then stable, became dissected by long faults forming numerous tectonic blocks. Deep subsidence in central Slovenia started formation of the Slovenian trough. This trough divided the formerly uniform carbonate platform into the Dinaric platform in the south and the Julian platform in the north.

In shallow areas were deposited carbonate sediments, and in deeper troughs various clastic materials. Along fault-lines rose lava and pyroclastic materials of spilitic-keratophyric association. These mixed with clastic and carbonate rocks. Smaller reefs appeared on some relatively uplifted blocks in the trough. Formation of deeper marine areas promoted the growth of organic framework, since water currents became stronger, and aeration of water and supply of nutrients increased. Among the reef structures, one buildup near

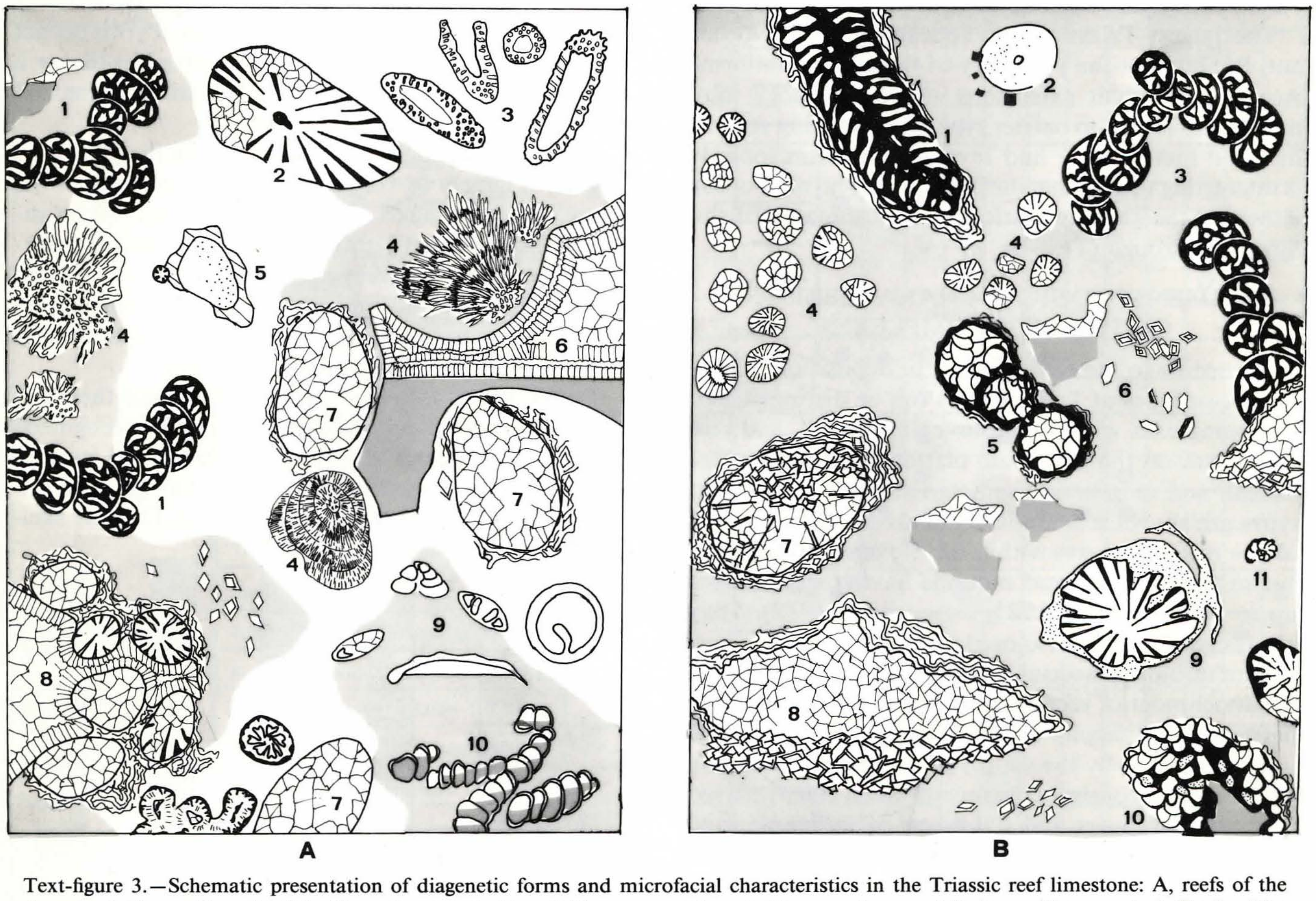


Text-figure 2.—Simplified paleogeographical development in Slovenia from Anisian to the end of the Triassic with positions of coral-sponge reefs.

Celje is almost one hundred meters thick and some hundred meters long and consists of corals and sponges. It is situated among argillites and graywackes cut by keratophyre intrusions (Pseudozilian Formation). According to its position the buildup is assigned to the Ladinian stage, since in its upper part the lamellibrach *Daonella lomelli* was found.

Also in the northern Karavanke, in the wider area of Mezica, a broader trough formed during the Ladinian. Here argillites and marls, as well as platy limestones of the Partnach type were deposited. At the periphery of the carbonate platform on the northern Karavanke and northern Julian Alps, deposition of nonbedded Wetterstein limestones began.

During Carnian (Cordevolian, Julian) the deposition of carbonate sediments continued with coral-sponge buildups in Mezica area and Julian Alps. In the Slovenian trough argillites, sandstones and platy limestones (Amphiclina beds) were deposited. In its southern part on uplifted blocks 10 to 130 m thick and up to 5 km long grew coral-sponge reef structures which outcrop in western Slovenia between the Blegoš Mountain, Hu-



Text-figure 3.—Schematic presentation of diagenetic forms and microfacial characteristics in the Triassic reef limestone: A, reefs of the carbonate platforms; B, reefs of the Slovenian trough. Grey fields represent the micritic groundmass, white is sparitic cement. A. Reefs of the Carbonate Platforms: 1) Various species of calcisponges (Carnian stage). 2) Solitary coral, partly recrystallized. 3) Section of algae *Diplopora* sp. (Ladinian stage). 4) Various species of skeletal algae of Dasycladacea and Solenoporacea. 5) Plate and spicule of echinoderm, coated with syntaxial sparitic cement. 6) Part of a larger solution cavity is filled with micrite and clay, and the upper part with sparitic calcite of several generations. 7) Section of completely recrystallized solitary corals, incrusted with nonskeletal algal envelopes. In places rare dolomitic rhombohedrons occur. 8) Colony of ramose corals incrusted with nonskeletal algae; individual corallites are partly or completely recrystallized; in a part of the colony appears a cavity filled with two generations of cement. 9) Group of molluscs and foraminifers. 10) Sponge *Cheilosporites tyrolensis* (Norian–Rhaetian stage). B. Reefs of the Slovenian trough: 1) Calcisponge *Cystothalamia bavarica,* encrusted with envelopes of nonskeletal algae. 2) Crinoid plate with grains of authigenic pyrite. 3) Calcisponge *Cryptocoelia zitteli,* one of the most abundant reef building organisms. 4) Section of a ramose coral; the septal structure in individual corallites is recrystallized. 5) Calcisponge *Colospongia* sp., encrusted with envelopes of nonskeletal algae; in surroundings, pores with geopetal texture. 6) Isolated crystals of authigenic quartz, albite (twins) and dolomitic rhombohedrons with zonal growth. 7) Entirely recrystallized solitary coral coated with envelopes of nonskeletal algae, partly recrystallized. 8) Stomatactis texture; lower parts of pores filled with late diagenetic dolomite, upper parts of pores filled with coarse sparitic calcite. 9) Solitary coral with a moderately well preserved septal structure; along borders silicified (authigenic microcrystalline quartz). 10) Calcisponge *Uvanella* sp. with rare crystals of authigenic quartz. 11) Foraminifera *Endothyra* sp.

dajužna and Tolmin. Due to strong supplies of clastic materials, growth of the reefs was periodically interrupted. These reefs are assignable to the Upper Cordevolian–Julian stages. In clastic sediments overlying the reefs, conodonts of the Tuvalian age were found (Buser and Krivic, 1979; Turnšek *et al.*, 1982).

On the Dinaric carbonate platform during the Carnian, limestone with *Diplopora annulata* was deposited. Small coral-sponge patch reefs grew only in the surrounding area of Hotavlje. Growth of all Carnian reef structures partially ceased in the Julian and Tuvalian substages (Text-fig. 1).

The largest Triassic reefs appeared during Norian and Rhaetian at the periphery of the Julian platform. According to their extensions and morphology they may be attributed to barrier type of reefs, being several hundred meters thick and several kilometers long. It is interesting to note that during this time no reefs occur either on the Dinaric platform, or in the area of the Slovenian trough (Text-fig. 2).

SEDIMENTOLOGICAL CHARACTERISTICS OF THE REEF COMPLEXES

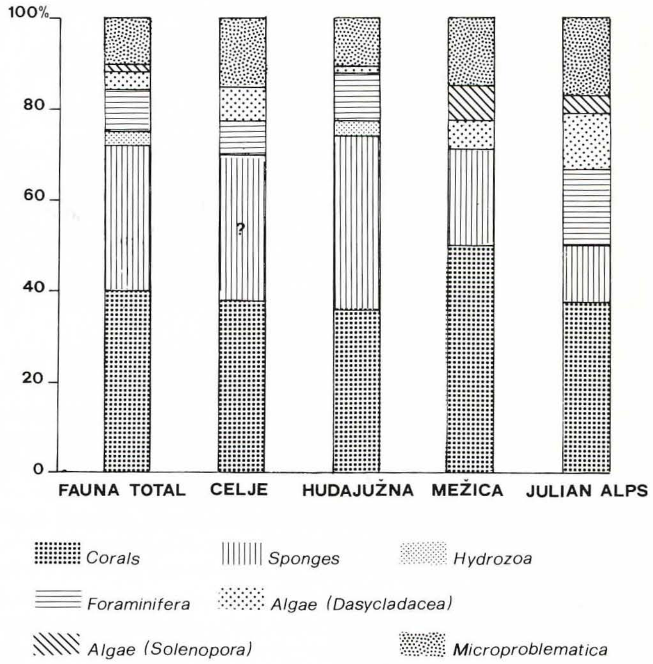
According to the environment of deposition in Slovenia two types of Triassic reefs can be distinguished, reef complexes within the Slovenian trough, and reef complexes on the carbonate platforms. Organic, ecological, and diagenetic characteristics of the two reef types are shown schematically (Text-fig. 3).

The reef complexes within the Slovenian trough occur in the form of mud mounds having steep slopes up to 50° (Čar *et al.*, 1981; Buser *et al.*, 1982). They always grew in rather exposed parts of the basin. Thick beds of turbiditic breccias served usually as solid ground for attachment of reef organisms. Dimensions of bioherms depend largely on the stage in which their life was interrupted by the supply of terrigenous material. The reef cores consist of organisms which chiefly played the role of trappers and stabilizers of carbonate mud (bafflestone-boundstone). Micrite must have been mostly a product of micritization and disintegration of *in situ* skeletons of sponges, since the carbonate content in clastics of the immediate surroundings of the bioherms does not exceed 3 percent.

In the reef, limestone frequently occurs with the texture of the "stromatactis." Cavities up to 15 cm in diameter often display geopetal internal texture in which their lower parts are filled by sparitic ferruginous dolomite, and the upper parts by calcite. Due to admixture of iron the dolomite is brownish on the surface. The ceilings of the "stromatactis" cavities are often coated with envelopes of nonskeletal algae which enabled their preservation, and respectively the collapse of the micritic groundmass. The majority of sponges, corals, and other organisms are encrusted with thinner or thicker coatings of nonskeletal algae. Dolomite, frequent also in the form of isolated dolomitic rhombohedra in the micritic groundmass, is of late diagenetic origin. It crystallized, according to our opinion, in the domain of the mixed marine-freshwater environment at times when the reefs reached closer to the sea surface. Along with dolomitization in the considered reefs, quite often silicification, pyritization, and to a smaller extent albitization occur. Quartz appears in authigenic crystals. The primary source of silica is thought to have been from the surrounding clastic beds. Pyrite occurs as a uniformly dispersed pigment which gives the rock a dark color, an indication of frequent reducing environments within the sediment.

Characteristic of the reef complexes on the platforms is growth largely in very shallow environments of the open carbonate shelf having high energy. Their dimensions are usually much greater than those previously described and they are, in contrast, surrounded by different types of limestones. Their boundaries are therefore not easily determined, and morphologically they are not protruding from the terrain.

Fossils are usually very recrystallized and therefore not easily determined. Mostly they can be recognized only by their shapes which are still preserved because of micritic envelopes and algal incrustations. The micritic groundmass is mostly washed out. Organic skel-



Text-figure 4.—Quantitative analysis of the fossil assemblage in the Ladinian–Carnian reef complexes. Diagram shows percent of fauna in the total and in the four separately studied areas.

SUBORDO	SPECIES		Carnian		Celje	Hudajužna				Mežica		Julian Alps				
		Ladinian	Cordevolian	Julian	Celje	Hudajužna	Jesenica	Zakriž	Leskovica	Hlevnik	Pristava	Vitranc	Prisojnik	Mojstrana	Mežakla	Kamniško sedlo
Archaeocoeniina	Cassianastraea reussi (LAUBE)		—	—									○			
	Koilocoenia decipiens (LAUBE)		—	—										○		
Faviina	Margarophyllia capitata (MÜNSTER)	–	—	—	●	●	●									
	Margarophyllia crenata (MÜNSTER)	–	—	—	●	●	●	●								
	?Margarophyllia michaelis (VOLZ)		—	—			●									
	"Montlivaltia" cipitensis VOLZ	—	—	—	●	●	●				●					
	"Montlivaltia" obliqua MÜNSTER		—	—			○	○						○		
	?"Coryphyllia" sp.	—	—	—	?									○		
	Craspedophyllia cristata VOLZ	–			○											
	Margarosmilia zieteni (KLIPSTEIN)	—	—	—	●	●	●		●	●						
	Margarosmilia septanectens LORETZ		—	—			●		●	●						
	Margarosmilia confluens (KLIPSTEIN)		—	—		●	●		●							
	Volzeia badiotica (VOLZ)		—	—		●	●					●				
	Volzeia sublaevis (MÜNSTER)	—	—	—	?	●				●	●	●				
	Tropidendron rhopalifer CUIF		—	—												●
	Tropidendron sp.	—	—	—	●			●		?		?		●		●
Meandriina	Andrazella labirinthica (KLIPSTEIN)		—	—		●	●						●		●	
Amphiastraeina	Protoheterastraea leonhardi (VOLZ)		—	—		○	●	○								
	Protoheterastraea fritzchi (VOLZ)		—	—			?									
	Protoheterastraea hudajuznensis TURNŠEK		—	—		●										
Fungiina	Myriophyllum badioticum (VOLZ)		—	—		●	●									
	Myriophyllum dichotomum (KLIPSTEIN)		—	—			●	●								
	Myriophyllum gracilis (LAUBE)	—	—	—	○									○		
	Myriophyllum mojsvari (VOLZ)		—	—				○								
	Omphalophyllia boletiformis (MÜNSTER)		—	—		●										
	Omphalophyllia radiciformis (KLIPSTEIN)		—	—		●		●			●					
	Omphalophyllia bittneri VOLZ		—	—							○					
	Sponges	—	—	—	●	●	●	●	?	●	●			●		●
	Foraminifera	—	—	—	●	●	●					●		●	●	
	Algae (Dasycladacea)	—	—	—	○	○					○			●		
	(Solenopora)		—	—						●	●			●		
	Microproblematica	—	—	—	●	●	●	●		●	●	●		●	●	●

○ ONLY ONE SPECIMEN

● TWO OR MORE SPECIMENS

Text-figure 5.—List of coral species in reef localities of Slovenia. Other noncoral fossils are included at bottom.

etons and their debris, mixed with thin intraclasts, are chiefly cemented by fine-grained sparitic calcite.

The reef limestone of the platform type is light in color. It usually does not contain terrigenous admixtures and authigenic quartz. With the exception of the Wetterstein reef complex of Mežica, it shows less intensive dolomitization. The latter is of late diagenetic origin characterized by dolomitic rhombohedrons which are concentrated mostly in micritic nests and in laminae of nonskeletal algae. The textural forms of "stromatactis" are very rare in the platform type of reefs. They contain, however, many solution cavities up to several dm in diameter. These cavities indicate periodical emersions of shelf areas followed by paleokarst development. Solution cavities are filled by several generations of coarse-grained calcite which give them the appearance of cocade texture. In places, mostly those in reefs of the Dachstein Formation, the cavities are filled in part by red carbonate clay of karst origin.

THE ROLE OF CORALS IN REEF COMMUNITIES

The Fossil Assemblages

According to present findings, the oldest finds of Triassic corals in Slovenia can be attributed to the Ladinian–Carnian stages. At that time smaller reef complexes appeared in which corals and sponges are most frequently found. Attached organisms include hydrozoans, *Solenopora* algae, and crinoids. Frequent constituents of reef framework are the microproblematica, and much rarer foraminifers. The algae (Dasycladacea) are found only as individual fragments. Lamellibranchs and gastropods are found along reefs in several places (Text-fig. 4).

The fauna and flora of the Ladinian–Carnian beds can not be extensively subdivided into stratigraphically distinct horizons, therefore, they will be considered as one stratigraphic unit.

Lateral Coral Diversity

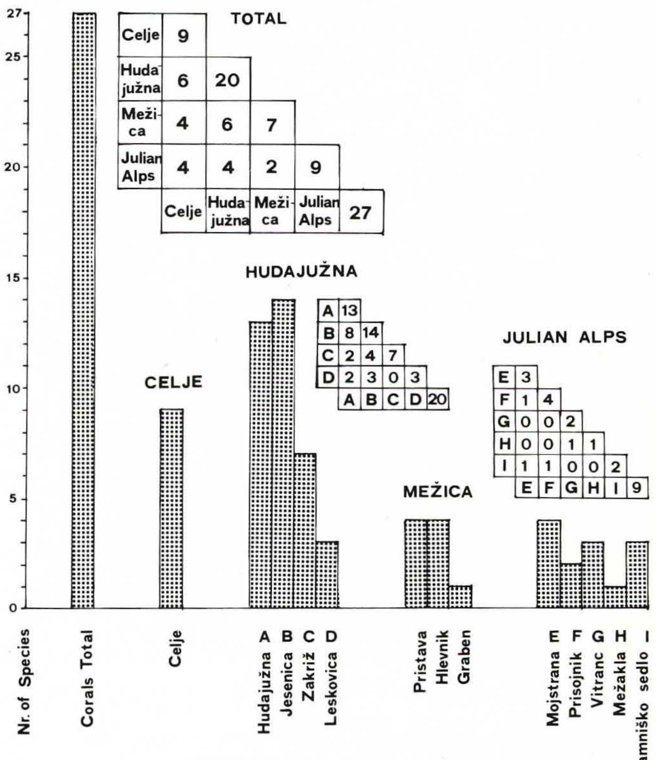
Corals have been found at numerous smaller localities. According to the paleogeographic position and tectonic units these localities have been divided into four areas: (1) Celje, (2) Hudajužna and surroundings, (3) Mežica and surroundings, and (4) Northern Julian Alps. Celje and Hudajužna occur in the Slovenian trough. Also included here are some of the localities at Mežica. Karavanke and the Northern Julian Alps are located on the Julian platform. Corals from the Dinaric platform are so recrystallized that they can not be determined (Text-fig. 5).

Analyses of coral species in various localities have shown great lateral variability. Species from one locality never appear together at the next locality. In the studied areas approximately half of the coral species are common to several areas. Also, within the same area the coral fauna varies greatly between localities. About 60 percent of the species are common to several localities (Text-fig. 6).

Stratigraphic Comparison of Corals

The coral species found in the Ladinian–Carnian beds in Slovenia have been described from the Dolomites in Italy (Volz, 1896; Montanaro-Gallitelli *et al.*, 1973), Hungary and Czechoslovakia (Kolosváry, 1966a, b), and the Pamir Mountains (Melnikova, 1980; Dronov *et al.*, 1982). A similar facies has also been mentioned in several places in the Alps (see review of all investigations in Flügel, 1981, 1982) and in North America (Stanley, 1982).

In all these areas and localities the corals and coral-sponge buildups were generally thought to have developed during the Ladinian–Cordevolian–Julian stages. Where one finds the same facies, the same fossil assemblage occurs (Cassian Formation, Wetterstein beds; Wendt 1982; Turnšek *et al.*, 1982).



Text-figure 6.—Similarity matrix for coral species in the Ladinian–Carnian reef complexes of Slovenia. Diversity and similarity between four studied areas and between localities within individual areas are shown.

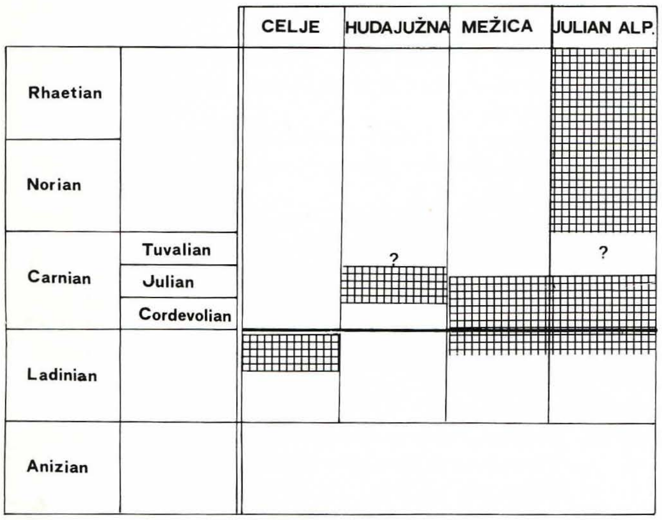
In Slovenia the various coral localities have been described in various ways, according to their geographic position: Celje to Ladinian, Hudajužna to the Upper Cordevolian-Julian, Mežica to the Upper Ladinian and Cordevolian, and the Northern Julian Alps to the Upper Ladinian–Cordevolian, or possibly Julian (Text-fig. 7). If we compare the collections of identified fossils, they are all generally similar in composition. Of the nine coral species at the Celje locality (Ladinian in age), six species are the same as those found at Hudajužna which is Julian. This is the highest similarity of coral fauna between two localities in all of Slovenia. Somewhat similar to Hudajužna are the localities at Mežica and the Julian Alps (Text-fig. 6). According to other workers, abundant Ladinian–Cordevolian sponges occur at Hudajužna (Ott, 1967; Dieci *et al.*, 1968; Senowbari-Daryan, 1981).

The corals and other reef fauna from the Ladinian and Carnian stages are actually identical. Because of this fact it can be inferred that all mentioned reef localities are time equivalent. Their appearance coincides with the beginning of the Cordevolian. Only with such explanation does the former transfer of the Cordevolian from the Ladinian into the Carnian become meaningful, due to the supposition that the Cordevolian fauna is closer to that of the Upper Triassic than to the Middle Triassic. In this case, the position or even the meaning of Ladinian becomes problematical and dubious.

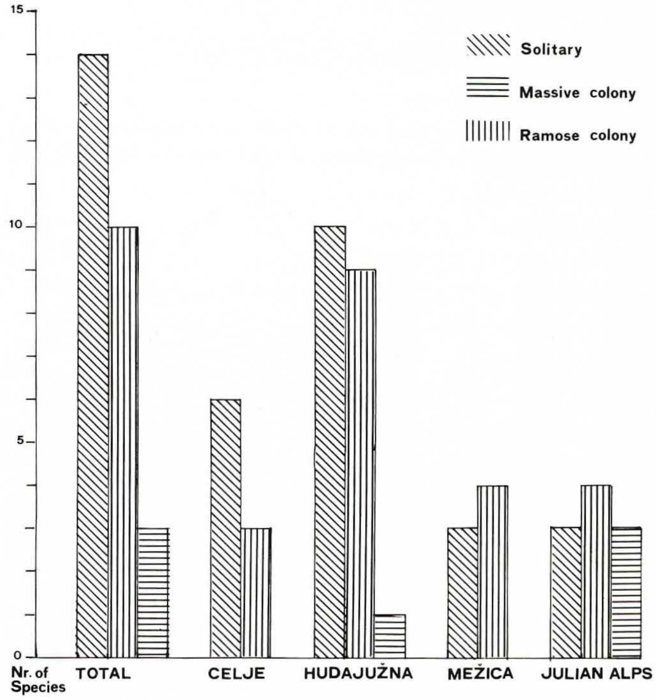
The Share of Corals in Reef Building

In estimating the contributions of corals in the building of reef structures, qualitative and quantitative analysis must be taken into consideration. The latter has shown clear predominance in all localities of sponges and corals which make up 50 to 80 percent of all organisms. In places sponge species prevail, but in the entire mass of organisms the percentage of coral volume is higher, since some colonial corals attain considerable size. However, corals are to a high degree recrystallized and thus not determinable, which gives a false impression in the qualitative analysis. According to the number of species, corals represent 35 to 50 percent of the investigated organisms. By volume corals represent approximately 30 to 60 percent of the organisms. Based on field data on the entire volume of the reef limestone, their proportion varies from 15 to 30 percent.

The coral forms are mostly solitary (14 species) and ramose dendroid-phaceloid colonies (10 species). In the massive colonies, two species are cerioid forms, and one species is meandroid (Text-fig. 8). These corals do not build large reefs. Instead, they build in several depths, small patch reefs and mud mounds within the carbonate and clastic beds. Those in the Slovenian trough could have lived without zooxanthellae as presumed by Stanley (1981). Also Fricke and Hottinger (1983) have found coral bioherms in the Red Sea between depths of 120 and 200 m. They established that the "absence of symbiotic algae below the euphotic zone does not hamper the building of bioherms by stony corals." The growth depends on temperature,



Text-figure 7.—Stratigraphical positions of the four studied areas. In all areas, the fauna are identical and it infers localities to be time equivalent. It is proposed that the first appearance of the coral-sponge reefs should be put into the beginning of the Upper Triassic.



Text-figure 8.—Growth forms of the corals and their quantitative importance in the building of the reef limestone.

currents providing nutrients, and submarine topography. All of these conditions may have been met in the deeper platform basins of the Carnian Tethys Sea.

Evolution of Scleractinia

Identified "Ladinian-Carnian" corals from Slovenia belong to 5 suborders of Scleractinia based on Melnikova (1968) and Roniewicz (1974), rather than Beauvais (1980). The most abundant are representatives of Faviina (14 species) and Fungiina (7 species); two species belong to Archaeocoeniina, 3 species to Amphiastraeina and one species to Meandriina. No species assignable to suborders Stylinina and Caryophyllina were found (Text-fig. 9). The fact that the earliest fauna of Scleractinia in the Middle Triassic is quite heterogenous and diverse adds more credence to Oliver's (1980) opinion that these corals evolved from soft-bodied ancestors along several lines at a time. Such soft-bodied ancestors started secreting calcareous skeletons when favorable conditions arose. In most of these corals the radial symmetry and cyclical septal insertion are characteristic of Scleractinia. The only exception in our collections is the genus *Protoheterastraea* which shows peculiar bilateral symmetry and irregular growth of septa. Similar to this coral is the genus *Zardinophyllum* (Montanaro Gallitelli, 1975) and the Pachythecalidae (Cuif, 1977). Bilateral symmetry occurs in amphiastraeins throughout the Mesozoic. Perhaps only in this suborder should direct descent from rugose corals be postulated.

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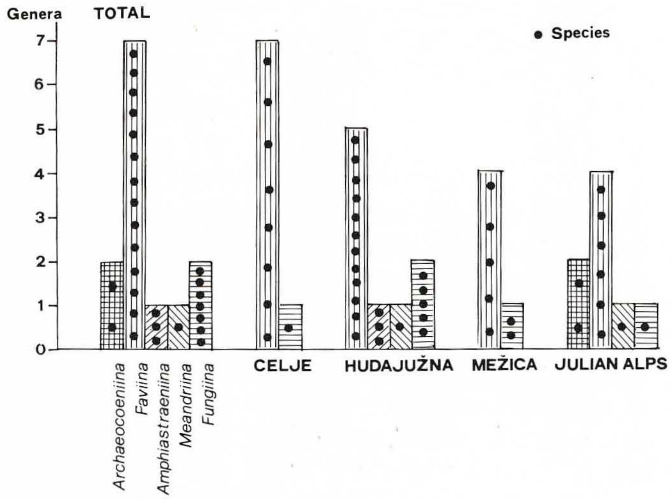

Text-figure 9.—Number of Ladinian–Carnian coral genera and species in the different scleractinian suborders.

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