ARTICLE IN PRESS

Geobios xxx (xxxx) xxx

Contents lists available at ScienceDirect

Geobios

journal homepage: www.elsevier.com/locate/geobio

Research Paper

The palaeobiogeographic significance of the Nötsch area (Austria) during the Middle and Late Mississippian based on rugose corals ☆

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ARTICLE INFO

Article history:
Received 15 January 2024
Accepted 19 September 2024
Available online xxxx

Keywords:
Rugosa
Tabulata
Heterocorallia
Palaeogeography
Palaeotethys
Visean
Serpukhovian

ABSTRACT

The Carboniferous of Nötsch (South Austria) is composed of three formations: the Erlachgraben Formation, the Badstub Breccia, and the Nötsch Formation, that yielded abundant corals, several of them being new for that region. The assemblage is composed of 11 rugose coral species (*Siphonophyllia* sp., *Pseudozaphrentoides juddi*, *Lublinophyllum*? sp., *Dibunophyllum bipartitum*, *Arachnolasma cylindrica*, *Palaeosmilia murchisoni*, *Aulokoninckophyllum carinatum*, *Siphonodendron martini*, *Diphyphyllum furcatum*, *Solenodendron furcatum*, and *Solenodendron horsfieldi*), two tabulate species (*Multithecopora* sp. and *Palaeacis* sp.) and one heterocoral species (*Hexaphyllia mirabilis*). In addition, five rugosans that are not in our collection have been identified by previous authors (*Clisiophyllum* sp., *Pseudozaphrentoides* sp., *Caninia* sp., "*Palaeosmilia isae*", and *Lophophyllidium* sp.). The rugose and tabulate species are described and figured. A palaeobiogeographic analysis comparing the Mississippian assemblages from Nötsch and other Austrian outcrops with other domains in Central Europe has been performed using hierarchical clustering with Simpson and Dice similarity indices. The statistical comparison of the rugose coral assemblages at the genus level allows a better perception of the distribution of the shallow water carbonate platforms in that part of the Western Palaeotethys during the Visean and Serpukhovian. The results are incorporated in a schematic palaeogeographical map of the studied area for the late Visean.

1. Introduction

The Nötsch outcrops are located in South Austria, on the north hillside of the Gail Valley. The name is given by the Nötsch River, which crosses the outcropping area from north to south, and the Nötsch village, located to the south of the Carboniferous outcrops. The Carboniferous outcrops extend as an 8 km long and 2 km wide fault-bounded wedge (Fig. 1). They contain abundant coral fossils and consequently have been studied by palaeontologists since the first half of the twentieth century. However, the detailed stratigraphy was only studied at the end of the twentieth century (Schönlaub, 1985; Flügel and Schönlaub, 1990; Schraut, 1996; Kabon, 1997; Van Amerom and Kabon, 1999, 2000).

The Carboniferous of Nötsch is composed of three formations that are, in stratigraphic ascending order (Fig. 2): the Erlachgraben Fm., composed of greyish blackish shales, micaceous siltstones, sandstones and conglomerates rich in quartz grains; the Badstub Breccia, composed of subrounded and rounded clasts of amphibolites, gneisses, schists, mica-schists, quartz, quartzites, marbles and limestones embedded in a green tholeititic matrix; and the Nötsch Fm. with similar composition to the Erlachgraben Fm. (Hubmann et al., 2003).

The Badstub Breccia has a sedimentary origin (Schönlaub, 1985). Its age, based on plants, is Namurian A (Kabon, 1997), or Serpukhovian based on conodonts (Schönlaub, 1985). The limestone clasts contain abundant fossils that allowed their dating as latest Visean or probably early Serpukhovian (Hubmann et al., 2003), Early Serpukhovian (Vachard et al., 2018) or Late Serpukhovian (Krainer and Vachard, 2002). Megaplant fossils from the upper part of the Nötsch Fm. indicate an Alportian (earliest Bashkirian) age (Van Amerom and Kabon, 2000). Foraminifers and algae from

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https://doi.org/10.1016/j.geobios.2024.09.002
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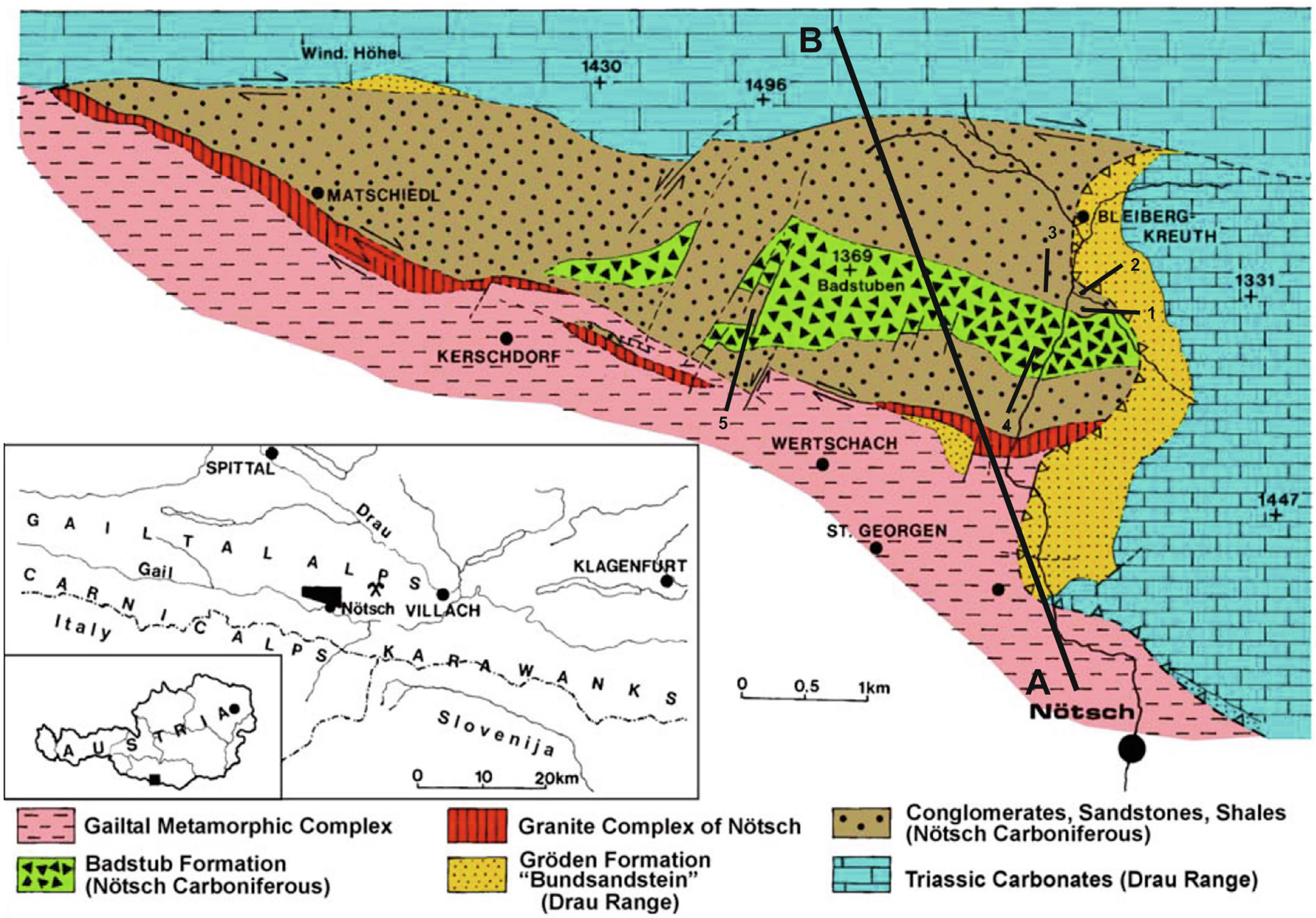

Fig. 1. Location of the outcrops (modified from Hubmann et al., 2003). The corals have been collected in the breccias of the Badstub Formation and in the conglomerates, sandstones and shales of the Erlachgraben and Nötsch formations (both having the same lithologies and represented with the same color). Sampling locality number: 1, Hermsberg (HEK); 2, Lerchgraben (LK); 3, Nötschgraben (EK, EL); 4, Jakomini Quarry (BZ); 5, Nötsch Formation (NÖ21). Section A-B is shown in Fig. 2.

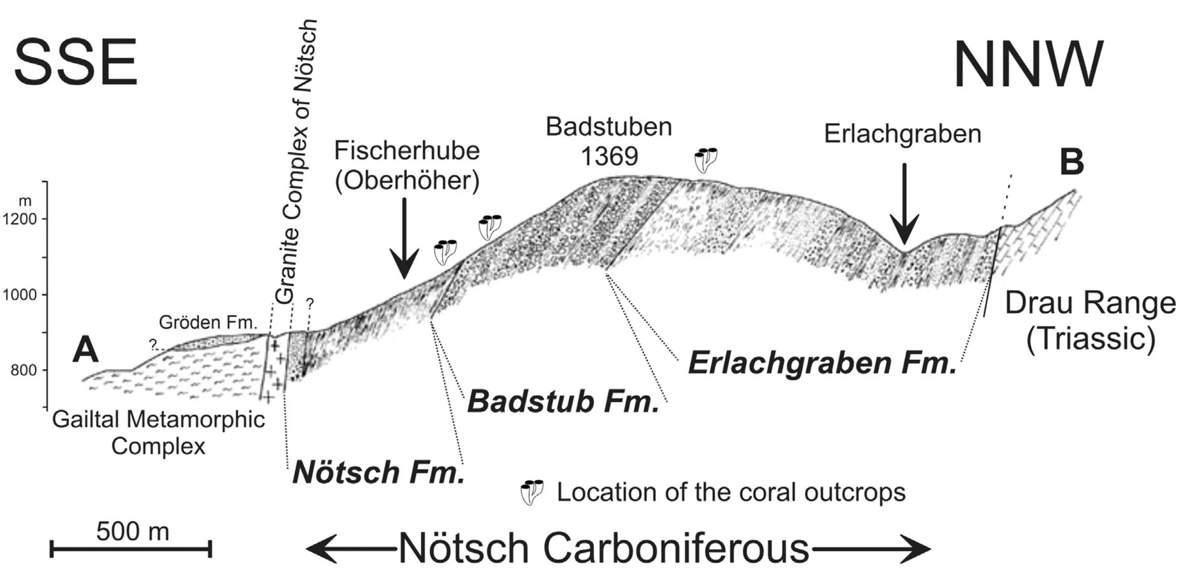

Fig. 2. Section along the A-B line in Fig. 1, showing the stratigraphy of the Nötsch area (Taken from Hubmann et al., 2003).

exotic limestone clasts of the Badstub Fm. indicate a Steshevian (lower Serpukhovian) age (Vachard et al., 2018). These authors suggested that the Erlachgraben, Badstub and Nötsch formations probably constitute a continuous lithostratigraphic group deposited from the latest Visean to the early Bashkirian and probably include a complete Serpukhovian succession.

Flügel and Schönlaub (1990) regarded the limestone clasts as exotic remains reworked from an extensive shallow water carbonate platform located north of the present day Southern Alps and adjacent to a land area. As that platform has been completely reworked in an accretionary wedge or dismantled in an active platform margin, the only relict is represented by the limestone boulders of the Badstub Breccia and the flysch deposits of the Hochwipfel Fm. located southwards in the Carnic Alps (Flügel and Schönlaub, 1990). Other outcrops in Austria that could contain relicts of such a carbonate shelf are the Greywacke zone and the Gurktal Nappe (Hubmann, 2002), but coral assemblages from these areas are poorly and badly preserved.

The abundant marine fauna from the Carboniferous of Nötsch has been described in many papers that have been compiled by Schraut (1999). Rugose and tabulate corals have been described in the papers by De Koninck (1873), Heritsch (1918, 1934), Kuntschnig (1926), Flügel (1965, 1972), and Flügel and Hubmann (1994). The identifications of taxa by these authors as well as those by ourselves are summarized in Table 1.

The corals from the Carboniferous of Nötsch are usually compressed and/or fragmented and a significant part of them cannot be properly identified. However, they are abundant and show a quite high diversity. One of us (H.K.) has sampled them over many years and compiled an excellent collection that allows an important contribution to the knowledge of the assemblage. Eight species of rugose corals and two species of tabulate corals that were not previously known in the area are shortly described hereafter (Table 1). The total assemblage from all localities in Nötsch (Table 2), including species described by previous authors which are accepted here as valid (Table 3), comprises 16 rugosan taxa.

The main interest of the coral assemblage from Nötsch is its location in an area of connection between the western European basins and platforms (Namur-Dinant, British Isles, Montagne Noire, Cantabrian Mountains, etc.) and the eastern European basins and platforms (Donets Basin, Lublin region, Holy Cross Mountains). The main aim of this paper is to compare the coral assemblages of Central Europe to analyse the palaeogeographical relationships of the different domains in that territory during the Visean and Serpukhovian.

2. Material and methods

2.1. Stratigraphy and coral sampling localities

Fossil coral remains are described from five localities of the Carboniferous of Nötsch. Three outcrops are situated in the uppermost part of the Erlachgraben Fm. Number one is located beside the road to Hermsberg (HEK; N46°37.177′, E13°37.039′). The corals of outcrop number two were found in the Lerchgraben (LK; N46°37.244′, E13°37.049′). Sampling locality number three is situated on the northern side of Jakomini Quarry in Nötschgraben (EK, EL; N46°37.214′, E13°36.657′). Megaplant fossils from the uppermost part of the Erlachgraben Fm. indicate an Arnsbergian age (Van Amerom and Kabon, 1999). The Badstub Fm. is most completely exposed in the Jakomini Quarry. The corals of the Badstub Fm. were collected in the year 1992 in a several metres thick dark shale ("Zwischenschiefer"), intercalated within the upper third of the Badstub Fm. (Outcrop number four: BZ; N46°37.112', E13°36.611'). Outcrop four no longer exists today because of the growth of the quarry. Coral outcrop number five (NÖ21; N46°37.092', E13°35.148') is located in the basal part of the Nötsch Fm. on the southern slope of mountain Badstuben (1,369 m).

2.2. Methodology

The corals have been sampled during many years of fieldwork in the Nötsch area by one of us (H.K.). This collection largely increases the known assemblage of rugose corals in that area. It comprises more than 100 fragments of solitary and colonial corals;

Table 1
Historical identifications of corals in Nötsch.

De Koninck (1873)	Frech (1894)	Heritsch (1918)	Kuntschnig (1926)	Heritsch (1934)	Flügel (1972)	**This paper**
Zaphrentis intermedia	*Zaphrentis intermedia*					
	Lonsdaleia rugosa			*Axophyllum expansum*	*Clisiophyllum?*	
	Syringopora	*Syringopora*				
		Caninia murchisoni	*Caninia murchisoni*	*Caninia juddi*	*Pseudozaphrentoides juddi*	*Pseudozaphrentoides juddi*
		Caninia compressum		*Caninia compressum*	*Pseudozaphrentoides* sp.	
				Caninia sp.	*Caninia* sp.	
		Cyathophyllum sp.	*Cyathophyllum carinthiaca*	*Palaeosmilia carinthiaca*	*Palaeosmilia murchisoni*	*Palaeosmilia murchisoni*
				Palaeosmilia isae	"*Palaeosmilia*" *isae*	
		Cyathaxonia rushiana			*Lophophyllidium* sp.	
				Koninckophyllum interruptum	*Arachnolasma cylindrica*	*Arachnolasma cylindrica*
						Dibunophyllum bipartitum
					Hexaphyllia mirabilis	*Hexaphyllia mirabilis*
						Aulokoninckophyllum sp.
						Diphyphyllum furcatum
						Siphonodendron martini
						Siphonophyllia sp.
						Solenodendron horsfieldi
						Solenodendron furcatum
						Multithecopora sp.
						Palaeacis sp.

Table 2
Distribution of identified taxa in the different outcrops.

Identified species \ localities	HEK	LK	EK, EL	BZ	NÖ
Arachnolasma cylindricum	1				1
Aulokoninckophyllum carinatum				1	
Dibunophyllum bipartitum	11		7	5	
Diphyphyllum furcatum	1				
Lublinophyllum? sp.	1				
Palaeosmilia murchisoni	2			4	
Pseudozaphrentoides juddi	2				
Siphonodendron martini	3				
Siphonophyllia sp.	2				
Solenodendron furcatum	1				1
Solenodendron horsfieldi	5	1			
Multithecopora sp.		1	1		
Palaeacis sp.				1	
Hexaphyllia sp.	1			1	

Table 3
Generic distribution of corals in the selected areas.

Genus	Austria	Poland	Moravia	Balkans	Donets	Germany	Belgium	S. France
Actinocyathus		x			x		x	x
Amygdalophyllum		x		x			x	
Arachnolasma	x	x			x		x	
Auloclisia				x				
Aulokoninckophyllum	x	x					x	x
Aulophyllum		x		x	x	x	x	
Axoclisia						x	x	
Axophyllum	x	x	x	x	x	x	x	x
Biphyllum		x						
Bothrophyllum		x		x		x	x	
Caninia	x	x	x	x	x	x	x	x
Caninophyllum							x	
Clisiophyllum	x	x		x	x	x	x	x
Corwenia		x			x			
Dibunophyllum	x	x	x	x	x	x	x	x
Diphyphyllum	x	x	x		x	x	x	x
Dorlodotia					x		x	
Gangamophyllum		x	x	x	x			x
Haplolasma		x				x	x	
Kizilia		x					x	x
Koninckonaotum		x						
Koninckophyllum	x	x	x	x	x	x	x	x
Lithostrotion		x		x	x	x	x	x
Lonsdaleia	x	x	x		x	x	x	
Lophophyllidium	x							x
Lublinophyllum	x?	x						
Melanophyllidium								x
Mirka		x						
Nervophyllum		x			x			
Orionastraea		x						
Palaeosmilia	x	x	x	x	x	x	x	x
Palastraea		x				x	x	
Pareynia							x	x
Pseudozaphrentoides	x	x	x	x	x	x	x	x
Rozkowskia		x						
Schoenophyllum					x			
Siphonodendron	x	x	x	x	x	x	x	x
Siphonophyllia	x	x		x		x	x	
Solenodendron	x				x	x	x	
Spirophyllum		x						
Heterophyllia		x	x		x	x		
Hexaphyllia	x	x			x	x		x
Aulopora		x						
Michelinia		x			x	x		
Multithecopora	x	x			x	x		
Palaeacis	x	x		x		x	x	
Syringopora	x	x	x	x	x	x	x	x

66 specimens were identified at generic level and 44 were identified at specific level. The best-preserved specimens have been sectioned; 70 thin sections 2.8 × 4.8 cm, 10 thin sections 5 × 5 cm and 2 thin sections 5 × 8 cm have been prepared and studied with an Olympus SZ61 binocular and a LEICA DLMP microscope. The pictures of the specimens were taken with an Olympus SP 500 UZ photo camera and a LEICA DFC420C camera. They were cleaned and handled with Photoshop and Photopaint software.

All palaeobiogeographic analyses have been performed using PAST 4 (Hammer et al., 2001). The study uses a paired group (UPGMA) Hierarchical Clustering. Hierarchical Clustering requires the use of a similarity index, for which many authors proposed different ones (Raup and Crick, 1979; Hubálek, 1982; Rodríguez, 1986; McCoy and Heck, 1987; Shi, 1993; Schmachtenberg, 2008). Several indices were used to analyse the biogeographical relationships of the selected domains. To test the stability of the resulting clusters, 1000 bootstrap resamplings have been performed on them. The branches with bootstrap values lower than 50% are not stable and should not be considered conclusive. In most cases the bootstrap supports were low and most indices were discarded for this reason. Finally, Simpson similarity index was selected because it is not strongly affected by differences in sample size or heterogeneous sampling effort (Hammer and Harper, 2006), because the bootstrap support is higher than all other indexes, and to better reflect the spatial turnover over the nestedness (Baselga, 2010). The Dice index has been also considered for comparison.

Any palaeobiogeographic analysis should take into account the plate tectonics, and the blocks to be compared should be consistent with structural units. We tried to follow this axiom in our palaeobiogeographic analysis, but in some cases the record itself or the studies in some areas are scarce. Three palaeogeographic domains are recognised in Germany for the Mississippian: the Rhenohercynian, the Saxothuringian, and the Moldanubian, from north to south (Weyer, 2000). However, records there are scarce and in the second and third domains, the corals always occur in allochthonous facies (olistostromes or Culm), probably coming from the first domain (Weyer, 2000). Thus, for this study, these three domains have been amalgamated as one single area (Germany). The same was done with the three main Austrian outcrops yielding Mississippian corals (Carnic Alps, Nötsch, and the Greywacke Zone; Hubmann, 2002) and several palaeogeographic units in Poland (Sudetes, Upper Silesian Basin, Lublin Basin and its southeastward prolongation in Ukraine, the Lviv-Volynsk Basin and Moravia in the Czech Republic have been grouped under the "Poland" name). The same problem exists in the Balkans, where there are some key studies (Kolosvary, 1954a; Kostic-Podgorska 1955, 1964), but the knowledge is scarce and incomplete. Thus, single localities were grouped in larger regions, mostly coinciding with countries to avoid different levels of knowledge of the palaeontological record.

As in the outcrops of Nötsch, and also in many other outcrops from central Europe, the corals occur in reworked sediments (breccias, conglomerates, olistoliths and flysch) and species are not identifiable in many cases. Since families are not detailed enough, the taxonomical level used for this comparison is the genus. When all or most regions contain well-preserved and well-known assemblages, the use of species is preferable (Rodríguez Castro and Rodríguez, 2022), but this is not the case for this study because even the best studied area (Belgium) has a high percentage of taxa left in open nomenclature (45%; Denayer et al., 2011). In an attempt at lowering the environmental influence over the analyses, our analyses exclude the undissepimented corals since they are typical of deep water or turbid water facies (Hill, 1938–41; Kullmann, 1997).

The main interest of the Nötsch outcrops from the point of view of the corals is the identification of an assemblage that lived on a carbonate platform that is not preserved. Similar cases are common in the Mississippian from Europe. The Variscan Orogeny destroyed several Visean and Serpukhovian carbonate platforms whose relicts are preserved in olistostromes and olistoliths or whose inhabitants were reworked into turbiditic sediments, usually Serpukhovian and Bashkirian in age. That is the case of the "Eder Gebiet" in Germany (Weyer, 2000), of the "Montagne Noire" in France (Aretz and Herbig, 2003), of the Malaguides (Herbig, 1986) and partly of the Guadiato Area in Spain (Rodríguez et al., 2016). The Asbian transgression favoured the development of wide carbonate platforms around the emerged regions, where corals flourished and diversified (Herbig, 1998). The succeeding Brigantian and Serpukhovian regression caused the erosion of the late Asbian shallow-water carbonates and their redeposition as debris-flows and conglomerates within the flysch succession. In some of these cases, the reworking processes produced fragmentation, compression and recrystallization of the corals. Consequently, in many cases the identification at species level is not possible and even in some instances, the corals are not identifiable at all.

As many taxa have been identified only at the generic level in Nötsch, but also in other countries in Central Europe, comparisons with assemblages of other regions were done at this level. The genus *Lublinophyllum*, which has been identified with doubts, has been included in the comparison as well as all the undetermined species of different genera. The palaeogeographical interest of the Austrian assemblages lies in their intermediate position between the well-known platforms from Western and Eastern Europe. The comparison of assemblages will be reduced to the current closest areas. A wider comparison of the Western Palaeotethys Mississippian corals is in preparation by one of us (I.R.-C.).

The comparison tries to find the palaeobiogeographic relation between shallow carbonate platforms during the late Visean and early Serpukhovian. Consequently, only corals regarded as living in shallow-water environments have been considered here in order to avoid interferences from ecologic relationships. The use of a broad stratigraphic range is due to the occurrence of many of the coral records in Serpukhovian and Bashkirian reworked facies (debris, olistoliths, olistostromes, flysch) in which there is a mixture of material from the Visean and the Serpukhovian. That problem was already pointed out by Schönlaub (1997) in his analysis of the Carboniferous biogeography of Austria. Theoretically, the biogeographic comparison should be made between assemblages of the same age. But the special situation of the outcrops in Central Europe, which suffered strongly from the Variscan Orogeny, means that in some areas only Serpukhovian assemblages have been preserved, in other areas only upper Visean assemblages have been preserved and, finally, some areas contain both. Because of that, both Visean and Serpukhovian assemblages have been taken into account here. It surely produces a reduction of the precision of the results, but we should keep in mind that presence of a genus in two areas in different times also indicates that there was a communication between those areas (the corals migrated earlier or later between them). So, the biostratigraphic value of the comparison is lower, but the global analysis of the geographic relationships remains valid.

An extensive bibliography has been consulted for analysing the assemblages from Central Europe. In some cases, synthetic papers have simplified the task. Excellent syntheses such as Weyer (2000) for Germany, Denayer et al. (2011) for Belgium, Fedorowski (1968, 1975, 1981) for Poland have been useful for our purposes. On the contrary, other areas needed the revision of a large number of papers. The information from Balkans was mainly obtained from Kolosvary (1954a, 1954b), Kostic-Podgorska (1954, 1955, 1960, 1964); the information from Moravia was obtained from Zukalová (1961, 1965); the information from Ukraine was extracted from Vassiljuk (1960, 1964); the information from Southern France was obtained from Semenoff-Tian-Chansky and Ovracht (1965), Perret and Semenoff-Tian-Chansky (1971), Aretz (2002), and Aretz and Herbig (2003). The results of the bibliographic analysis plus our own identifications of the corals are shown in Table 3.

There are some methodological problems to solve because of the different level of study in different regions. Some regions have been studied for a long time because of the presence of good outcrops and scientific tradition, like Belgium, Germany or Poland. Some other areas present few coral studies because the outcrops are not appropriate or because the corals are not well preserved, like in Balkans or Austria. In addition, the late Visean is a time of high temperatures, with an important transgression (Herbig, 1998), when migrations were easy for the coral planulae because most marine connections between different regions were open. In that contex, a high diversification took place, but also many of the genera reached a cosmopolitan distribution, or almost.

3. Results

The specimens from Nötsch are mostly fragmented (lacking the apexes or the calices), eroded (lacking partly or totally the dissepimentarium) and/or compressed, with their inner structures broken (Fig. 3). So, only 60% of the sectioned specimens have been identified at the generic level and only 50% of them have been identified at the species level, despite most of them belonging to well-known genera. Nevertheless, the assemblage is quite diverse, composed of 11 rugose coral species, two tabulate species and one heterocoral species. Three taxa of rugose corals (*Clisiophyllum*? sp., *Caninia*? sp. and *Lophophyllidium* sp.), not present in our collection but previously identified by Flügel (1972), and a tabulate (*Syringopora* sp.) identified by Heritsch (1918) have been also recorded in Nötsch. The species *Lonsdaleia carnica*, recorded in a boulder in the Hochpwipfel Fm. from the close Carnic Alps (Rodríguez et al., 2018), and the genus *Axophyllum*, recorded in the Greywacke zone in flysch facies, have been included in the Austrian assemblage for comparison with other areas. Only the rugose species have been included in the palaeobiogeographic analysis because, in some areas selected for comparison, the studies on tabulate corals and heterocorals are scarce or totally absent.

This paper is not a taxonomic review. The descriptions are given for the illustration of the coral identifications. Consequently, the descriptions of the identified species are complete but they do not contain detailed synonymies; references to papers where they can be found are included in the species remarks and the diagnosis are not included, but referred to well-known previous papers. The morphological terminology is based on Hill (1981) with some additions by Poty (1981) and Rodríguez (1984). The microstructural descriptions are based on the terminology proposed by Semenoff-Tian-Chansky (1974) and some refinements by Rodríguez (1984). The taxonomic classification follows Hill (1981) with some variations following later papers (Denayer et al., 2011; Rodríguez et al., 2016).

3.1. Systematic palaeontology

Phylum Cnidaria Hatschek, 1888
Class Anthozoa Ehrenberg, 1834.
Subclass Rugosa Milne-Edwards and Haime, 1850.
Order Stauriida Verrill, 1865.
Family Cyathopsidae Dybowski, 1873.
Genus ***Siphonophyllia*** Scouler in McCoy, 1844.
Siphonophyllia sp.
Fig. 3(A)

Material: Two incomplete and partly compressed specimens: HEK12C, HEK51, Hermsberg road, upper part of the Erchlachgraben Fm.

Description: Two cylindrical fragments of solitary corals, 15 mm in diameter. 30 major septa, not extending to the axis. The minors are irregular, sometimes short, sometimes reaching the border of the dissepimentarium, and thinner than the major septa. Some majors and minors are interrupted by lonsdaleoid dissepiments in the external part of the dissepimentarium. The major septa are thickened in the tabularium. A slightly shortened cardinal septum is visible in an inconspicuous fossula (Fig. 3(A), lower-central part) and other protosepta are not prominent. The dissepimentarium is wide, composed of 5 to 6 rows of intercepted and lonsdaleoid dissepiments irregularly distributed. Outer wall is simple and thick.

Remarks: The specimens show all diagnostic features of the genus *Siphonophyllia* (see Rodríguez et al., 2016), solitary corals having thickened septa in the tabularium, cardinal septum shortened in fossula, dissepimentarium wide, made of several rows of interseptal and lonsdaleoid dissepiments, and complete tabulae. The poor and incomplete preservation and the partly eroded external portion of the specimens impede a specific identification and the features do not fit with the most common Mississippian species of the genus. This genus has not been previously identified in Nötsch.

Genus ***Pseudozaphrentoides*** Stuckenberg, 1904.
Pseudozaphrentoides juddi Thomson, 1893.
Fig. 3(B, C)

Material: Two incomplete and compressed specimens: HEK31 and HEK40J, Hermsberg road, upper part of the Erchlachgraben Fm.

Diagnosis: See Semenoff-Tian-Chansky (1974: p. 193).

Description: Cylindrical fragments of solitary, strongly compressed coral. The reconstructed diameter is ca. 29 mm and the number of major septa is 40. The wall and dissepimentarium are partly eroded, but the wall is moderately thick and smooth and dissepiments are both regular and angular (Fig. 3(B)). The septa are short, leaving a large free zone in the central part of the tabularium. They are thin in the dissepimentarium and strongly thickened in the tabularium. The protosepta are not identifiable due to the strong compression. Features of the tabulae could not be identified in the two studied specimens.

Remarks: Preservation is very poor, but most features (septa and dissepiments) and dimensions (diameter and number of septa) fit well with the diagnostic characters given by Semenoff-Tian-Chansky (1974) and Poty (1981). This species has been previously cited and described in Nötsch by Heritsch (1934) and Flügel (1972).

Genus ***Lublinophyllum*** Khoa, 1977.
Lublinophyllum? sp.
Fig. 3(D)

Material: One fragment of corallite: HEK40L, Hermsberg road, upper part of the Erchlachgraben Fm.

Description: Fragment of a corallite, 15 mm in alar diameter, 9 mm in tabularium diameter and 34 septa. The wall is thick and festooned. The septa are short, thin and they are interrupted in the dissepimentarium by lonsdaleoid (transeptal) dissepiments of first and second order. None of the protosepta is conspicuous. The lonsdaleoid dissepiments are locally very large, leaving empty spaces in the dissepimentarium. The preserved portion is located at the calice, where three offsets are observed. That located at the right side (Fig. 3(D)), shows the cardinal septum already developed. They show a new wall covering a portion of the calice.

Remarks: The specimen from Nötsch is included in *Lublinophyllum* with question mark, because it shares most features with the specimens described by Khoa (1977), including the local large lonsdaleoid dissepiments but that genus shows lateral increase whereas our specimen shows an axial increase. The features are similar to those in *Siphonopyllia*, but the absence of thickened septa in the tabularium and the large lonsdaleoids leaving empty spaces in the dissepimentarium in that genus, plus the solitary habit are

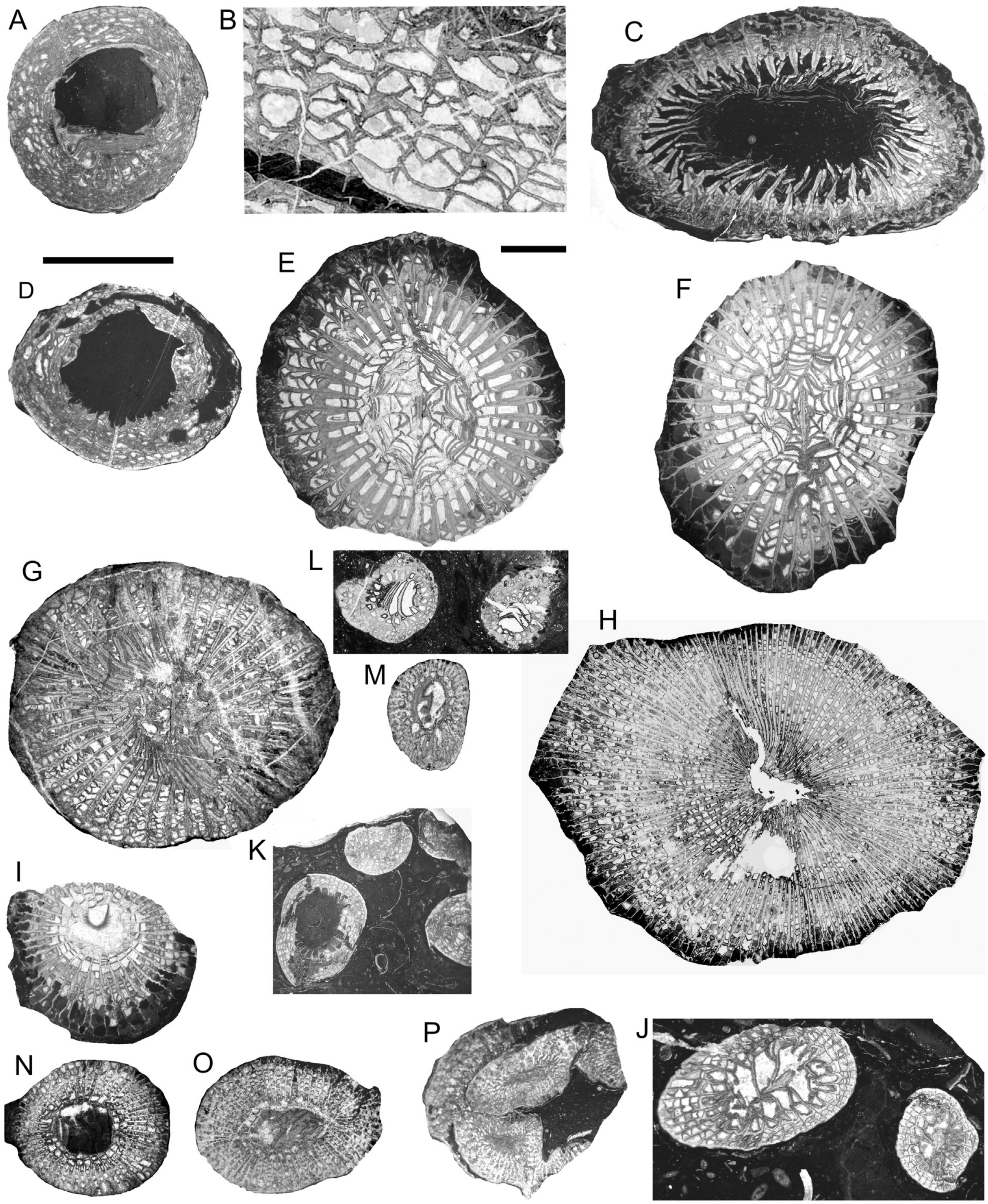

Fig. 3. Rugose corals from Nötsch. **A.** *Siphonophyllia* sp., specimen HEK51, transverse compressed and fragmented section. Note the lonsdaleoid dissepiments in the upper left side of the corallite. **B, C.** *Pseudozaphrentoides juddi*. B: specimen HEK 40 J, detail of the dissepimentarium; C: specimen HEK 31, transverse compressed section. **D.** *Lublinophyllum?* sp., specimen HEK 40L, transverse section showing calicular buddings. **E, F.** *Dibunophyllum bipartitum*. E: specimen BZ3A, transverse section; F: specimen HEK0, transverse section. **G.** *Arachnolasma cylindrical*, specimen HEK 7B, transverse section. **H.** *Palaeosmilia murchisoni*, specimen BZ4A, transverse section. **I.** *Aulokoninckophyllum carinatum*, specimen BZ25, transverse section. **J.** *Siphonodendron martini*, specimen HEK 30D, fragment of colony. **K.** *Diphyphyllum furcatum*, specimen HEK 12B, fragment of colony. **L, M.** *Solenodendron furcatum*. L: specimen NÖ 21-1B, transverse section of a part of the colony; M: specimen HEK 40 M, transverse section of corallite. **N-P.** *Solenodendron horsfieldi*. N: specimen HEK 20 M, transverse section of corallite; O: specimen HEK 40H, transverse section of corallite; P: specimen LK2A, transverse section showing offsetting. Scale bars: 10 mm (A, C-P), 2 mm (B).

too important differences. *Lublinophyllum* has not been cited previously in Nötsch.

Family Aulophyllidae Dybowski, 1873.
Subfamily Dibunophyllinae Wang, 1950.
Genus ***Dibunophyllum*** Thomson and Nicholson, 1876.
Dibunophyllum bipartitum (McCoy, 1849)
Fig. 3(E, F)

Material: 23 specimens in different stages of preservation: BZ1C, BZ3A, BZ7, BZ10, BZ20, Jakomini Quarry, upper Badstub Fm.; EK4, EL1, EL2, EL3A, EL4, EL6, EL10A, Nötschgraben, upper part of the Erchlachgraben Fm.; HEK0, HEK2, HEK8a, HEK9, HEK10, HEK11, HEK12, HEK14a, HEK15, HEK30D'and HEK45D, Hermsberg road, upper part of the Erchlachgraben Fm.

Diagnosis: See Poty (1981: p. 41).

Description: Eroded solitary corals that show commonly the wall and part of the dissepimentarium eroded. Some of them are also compressed. The best preserved specimens show an alar diameter comprised between 18 and 27 mm, a tabularium diameter comprised between 12 and 16 mm and an axial structure comprised between 5 and 7 mm. The number of septa varies between 41 and 54. The wall is thin and smooth. The dissepimentarium is composed of 3 to 5 rows of angulate to inosculate dissepiments, with the inner row thickened. The septa are long, reaching the axial structure. They are thin in the dissepimentarium, but thick in the tabularium. The axial structure is variable. It reaches 1/3 of the diameter and is composed of a median lamella, a small number of radial lamellae and tabulae inclined to the periphery. The lamellae are usually anastomosed or winding. The tabulae are incomplete, tent-shaped and divided in two series: axial and periaxial.

Remarks: This species is well known and very abundant in the upper Mississippian of the whole Palaeotethys. The specimens from Nötsch show similar features to the specimens described in other areas of the Western Palaeotethys, such as Belgium (Poty, 1981; Denayer et al., 2011), Spain (Rodríguez et al., 2001, 2016) and Morocco (Semenoff-Tian-Chansky, 1974; Said and Rodríguez, 2008; Aretz, 2012). Some specimens are very compressed and their structures are not well preserved. As the genus *Arachnolasma* is close to *Dibunophyllum* and it has been described previously in Nötsch (Flügel, 1972), two or three of the specimens assigned to *Dibunophyllum* whose structures are not well preserved could belong to *Arachnolasma*.

Genus ***Arachnolasma*** Grabau, 1922.
Arachnolasma cylindrica Grabau, 1922.
Fig. 3(G)

Material: two compressed specimens: HEK7B, Hermsberg road, upper part of the Erchlachgraben Fm.; NÖ21-1, Basal part of the Nötsch Fm.

Diagnosis: See Said and Rodríguez (2008: p. 29).

Description: Solitary corals partly compressed. The reconstructed alar diameter varies between 22 and 24 mm. 44–45 thick, long major septa that reach a small axial structure (ca. 1/5 of the alar diameter) without well-defined boundaries and having a thick axial lamella and a low number of radial lamellae. The dissepimentarium is partly eroded, composed of 6–8 rows of angular dissepiments. The septa show two phases of secretion. Minor septa are very short and discontinuous.

Remarks: The key differences between *Arachnolasma* and *Dibunophyllum* are a thick axial plate and a smaller axial structure without well-defined boundaries in *Arachnolasma*. As most dibunophylloid specimens from Nötsch are compressed, the details of the axial structure are not well preserved. However, most specimens that are quite well preserved show a well-defined axial structure and mostly thin axial plate. Therefore, most specimens have been included in *Dibunophyllum* although this genus was not previously cited in Nötsch. On the contrary, the only two specimens included in *Arachnolasma* show a thick axial plate, diffuse boundaries in their small axial structures and measurable features identical to *A. cylindrica*. This species has been previously cited in Nötsch by Flügel (1972).

Family Palaeosmiliidae Hill, 1940
Genus ***Palaeosmilia*** Milne-Edwards and Haime, 1848.
Palaeosmilia murchisoni Milne-Edwards and Haime, 1848.
Fig. 3(H)

Material: Six fragmented and variously compressed specimens: BZ4A, BZ6B, BZ8, BZ24, Jakomini Quarry, upper part of the Badstub Fm.; HEK8b, HEK38, Hermsberg road, upper part of the Erchlachgraben Fm.

Diagnosis: See Denayer et al. (2011: p. 161).

Description: Large fragments of trochoid solitary corals. The alar diameter varies from 25 to 50 mm; the tabularium diameter varies from 12 to 28 mm. The external wall, as well as considerable parts of the dissepimentarium, are eroded. The dissepimentarium is composed of 10 to 20 rows of dissepiments. The inner rows are made of interseptal, mainly regular, but sometimes angulose dissepiments. The innermost row may be slightly thickened. Major septa are very long, all reaching the axial zone. They are fibrous and straight in the tabularium, but trabecular and slightly to strongly sinuous in the dissepimentarium. Their number varies from 93 to 110. The cardinal septum is shortened in a long and narrow fossula, slightly expanded in the axial zone. The minor septa are also long, approximately reaching 1/2 length of the major septa.

Remarks: All specimens from Nötsch show the typical features of the species which is highly variable (Semenoff-Tian-Chansky, 1974: p. 160). The fragmentary stage of the specimens and erosion of their wall and external parts of the dissepimentarium impede a more detailed description.

Genus ***Aulokoninckophyllum*** Sando, 1976.
Aulokoninckophyllum carinatum Carruthers, 1909.
Fig. 3(I)

Material: One single portion of a solitary specimen: BZ25, Jakomini Quarry, upper part of the Badstub Fm.

Diagnosis: See Sando (1976: p. 432).

Description: Solitary aulate fragment of coral. The alar diameter is 15 mm, the tabularium diameter is 9 mm and the aulos diameter is 4 mm. The number of major septa is 25. The wall is mostly eroded, but some relicts preserved in the counter quadrants are thin and smooth. The septa are long, most of them reach an incomplete and irregular aulos, which occupies 1/4 of the corallite diameter. The septa are thin in the dissepimentarium, and strongly carinate. The carinae are formed of trabeculae. The major septa are thickened in the outer tabularium, slightly tapering and thinning axially and with fibrous microstructure. In the dissepimentarium, the septa are undulating and sinuous and in the tabularium only slightly undulating. In the dissepimentarium, the minor septa are of the same thickness as majors and may penetrate slightly into the tabularium. The dissepimentarium is partly eroded, composed of 6 to 7 rows of regular and angulate dissepiments. The inner rows are slightly thickened and closely spaced.

Remarks: The specimen from Nötsch shows all typical features of the species *A. carinatum*, (strong carinae and undulate septa in the dissepimentarium, irregular aulos and thickening of septa at the transition dissepimentarium/tabularium). *A. carinatum* has a large range of variability in size and number of septa; the specimen from Nötsch fits well with the lowest range of diameter and number of septa of the species.

Family Lithostrotionidae d'Orbigny, 1852.

Genus ***Siphonodendron*** McCoy, 1849.

Siphonodendron martini (Milne-Edwards and Haime, 1850)

Fig. 3(J)

Material: Three fragments of colonies: HEK20D, HEK30D and HEK30E, Hermsberg road, upper part of the Erchlachgraben Fm.

Diagnosis: See Poty (1981: p. 27).

Description: Fragments of fasciculate corals. The corallites are 6 to 9 mm in diameter, 4 to 6 mm in tabularium diameter and have a styliform columella. 22 to 27 major septa that are variable in length and may reach the columella. Minors length is ca. one half of that of the majors. The dissepimentarium is well developed, composed of two rows of regular dissepiments. Complete, conical tabulae.

Remarks. The specimens identified as *S. martini* from Nötsch show identical size and number of septa to those typical for the species, but only small fragments of colonies having 2 to 6 corallites have been recorded. It was not previously cited in Nötsch.

Subfamily Diphyphyllinae Dybowski, 1873.

Genus ***Diphyphyllum*** Lonsdale, 1845.

Diphyphyllum furcatum Hill, 1940

Fig. 3(K)

Material: One single fragment of a phaceloid colony with corallites compressed and broken: HEK12B, Hermsberg road, upper part of the Erchlachgraben Fm.

Diagnosis: See Poty (1981: p. 34).

Description: Fragment of a fasciculate coral with corallites lacking a columella. Corallites 6–7 mm in diameter and having 25–27 major septa that are quite short, leaving a wide axial zone. Minor septa are very short, reduced to the dissepimentarium and being absent in some loculi. The dissepimentarium is composed of 2–4 rows of interseptal dissepiments.

Remarks: The specimen from Nötsch shows a diameter and number of septa located in the higher part of the variability of the species, but the diameter is clearly smaller than *Diphyphyllum fasciculatum*. All the features are typical of the genus, except that its typical peripheral increase is not recorded in the small portion of the preserved colony. The absence of columella in all the preserved corallites discards the possibility of being a diphyphylloid *Siphonodendron*. The genus *Diphyphyllum* has not been previously recorded in Nötsch.

Genus ***Solenodendron*** Sando, 1976.

Solenodendron furcatum (Smith, 1925)

Fig. 3(L, M)

Material: Two fragments of colonies: HEK40M Hermsberg road, upper part of the Erchlachgraben Fm.; NÖ21-1B, Basal part of the Nötsch Fm.

Diagnosis: See Denayer et al. (2011: p. 172).

Description: Fragmentary fasciculate aulate corals in which the aulos is formed by union of deflected axial ends of majors. The alar diameter reaches 4.5 to 5 mm, the tabularium diameter 2.5 to 3.5 mm, and the aulos diameter 1.8 to 2.2 mm. 23 to 24 major septa. The major and minor septa are carinate. The dissepimentarium is regular.

Remarks: The recorded specimens are included in masses of broken solitary and colonial corals. In both cases, the corallites show all features typical of the identified genus and species. The alar diameter and number of septa fit well with the diagnostic features. The aulos is typically composed of the deflected axial ends of the septa and these are carinate. This species is first described in Nötsch.

Solenodendron horsfieldi Smith and Yü, 1943.

Fig. 3(N–P)

Material: 6 fragments of colonies and isolated corallites: HEK14A, HEK20D', HEK20M, HEK20N, HEK40H, Hermsberg road,

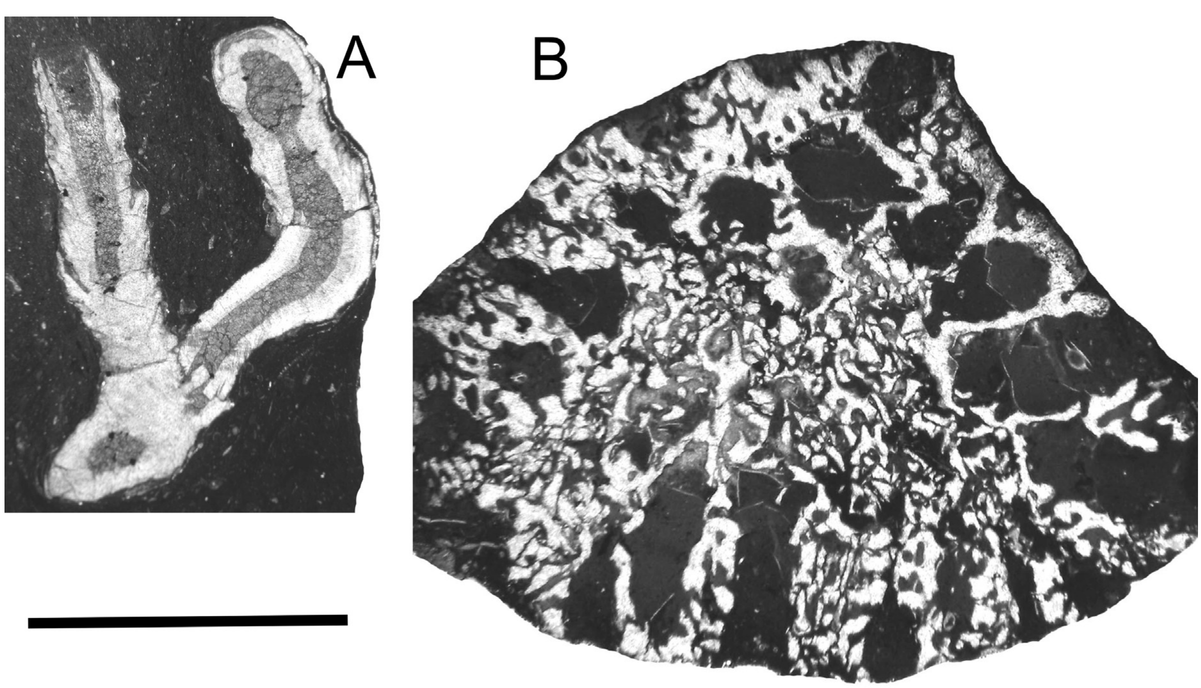

Fig. 4. Tabulate corals from Nötsch. **A.** *Multithecopora* sp., specimen LK2B, longitudinal section. **B.** *Palaeacis* sp., specimen BZ21, transverse section of the colony. Scale bar: 5 mm.

upper part of the Erchlachgraben Fm.; LK2A, Lerchgraben, upper part of the Erchlachgraben Fm.

Diagnosis: See Sando (1976: p. 426).

Description: Phaceloid *Solenodendron* with corallites 9–10 mm in alar diameter, 6–7 mm in tabularium diameter, 3.5–4 mm in aulos diameter, and 27–32 strongly carinate major septa. The aulos is composed of the deflected ends of the major septa. The minor septa are also carinate and penetrating slightly in the tabularium. The dissepimentarium is composed of 4 to 6 rows of interseptal, regular dissepiments. Increase calicular in the studied specimens (Fig. 3(P)).

Remarks: All the specimens fit well with the features (carinate septa, aulos composed of deflected ends of the major septa) and dimensions of the species. As well as most species described in this paper, it has not been previously described in Nötsch.

Order Tabulata Milne-Edwards and Haime, 1850.
Family Syringoporidae Fromentel, 1861.
Genus ***Multithecopora*** Yoh, 1927.
Multithecopora sp.
Fig. 4(A)

Material: two fragments of colonies: EL3B, Nötschgraben, upper part of the Erchlachgraben Fm.; LK2B, Lerchgraben, upper part of the Erchlachgraben Fm.

Description: Fasciculate colonies, formed of cylindrical corallites with well-defined wrinkled epitheca. Thick wall composed of layers of lamellar and fibrous microstructure. The lumen of the corallites is reduced to 2/5–1/3 of the diameter. Corallite diameter ca. 1.5 mm. Lumen diameter 0.5–0.6 mm. Connecting tubules have not been recorded. Tabulae thin, complete, horizontal to concave, in places absent. Lateral increase.

Remarks: The corallite and lumen diameters fit well with *Multithecopora* sp. C of Coronado and Rodríguez (2014) (Visean, SW Spain), but the fragments are too small for further comparison.

Family Palaeacidae Roemer, 1883.
Genus ***Palaeacis*** Haime in Milne-Edwards, 1860.
Palaeacis sp.
Fig. 4(B)

Material: One single specimen: BZ21, Jakomini Quarry, upper part of the Badstub Fm.

Description: fragment of colony, 16 mm in diameter. Corallite walls 0.5–1 mm thick. More than 20 corallites generally subcircular, but may be polygonal, and reach a maximum diameter of 3 mm. Corallite lumen ca. 1.5 mm. Calices deep, without tabulae. The corallite walls are penetrated by tubes 0.1–0.2 mm in diameter, which connect adjacent corallites. Absence of tabulae.

Remarks: Few species of *Palaeacis* have been nominally described. The specimen from Nötsch has smaller corallites than *P. axinoides*, *P. smythi* and *P. cuneiformis*, and a higher number of corallites than *P. smythi*. The existence of only a single, fragmentary specimen impedes further identification. This genus is first mentioned in Nötsch.

3.2. Quantitative palaeobiogeographic analysis

A brief previous palaeoecological analysis of the coral assemblage must be done. All the specimens are transported, broken and compressed. Consequently, they do not constitute a biocoenosis, but a taphocoenosis, coming from different locations and ages. The solitary dissepimented corals are by far the most abundant, with the species *Dibunophyllum bipartitum* being the most abundant. If we include the tabulate corals, the solitary specimens constitute 70.6% of the identified specimens. This percentage is probably lower if we consider all the unidentified fragments. In addition, no massive rugosans have been recorded. The assemblage is a mixture of the associations 1, 2 and 3 (Somerville and Rodríguez, 2007), which represent different areas of a shallow carbonate platform.

In order to check the direct relationships of the Austrian assemblages with the other regions, we built a paired table (Table 4) with the values of the Simpson similarity index. Some areas may have a low number of genera for reasons other than the original diversity of the assemblage. The lack of studies in some regions, or a poor fossil record with only reworked facies could introduce inaccuracies in the analyses. The effects of nestedness (Baselga, 2010, 2012), which could be caused by geographical barriers, and the effects of insufficient sampling are not distinguishable just looking at the numbers.

Fig. 5 represents the clustering produced by the analysis of the dataset that includes the rugose coral genera without inclusion of the tabulate corals and heterocorals, and also excluding the undissepimented corals. Results from both Simpson and Dice indices are shown. The Dice index is more affected by influences such as nestedness (Baselga, 2010), and by heterogeneous sample size (Hammer and Harper, 2006). The results were similar topographies, with only the Balkans occupying a different position. Since we want to focus on the spatial turnover (Baselga, 2010) over the nestedness, we only discuss here the results of the Simpson index-based clustering. Moreover, the Dice cluster shows lower bootstraps, with only one stable node.

The Simpson index-based clustering shows a close relationship between Germany and Belgium, in a very stable branch (90% bootstrap support). The proximity between these regions is easy to understand, because the Belgian platforms were prolonged eastwards. Most occurrences of dissepimented corals in Germany occur in reworked rocks and in calciturbidites, transported into deep settings, because the original platforms are mostly not preserved. Despite that, the coral assemblages show a close similarity with Belgium. The analysis also shows a close relationship between Poland and the Balkans. A bootstrap support of 56% (Fig. 5) indicates also the reliability of this relation. The aforementioned groups (Germany-Belgium and Poland-Balkans) seem to be more similar between them than to the Donets region, even though those branches of the cluster are not stable (31% bootstrap support; Fig. 5).

The differences between the Donets and Poland, despite the geographical proximity, might be associated with the existence

Table 4
Pairwise comparison of the selected regions based on the Simpson Similarity index.

	Austria	Poland	Balkans	Donets	Germany	Belgium	S. France
Austria	–	0.875	0.600	0.750	0.750	0.875	0.685
Poland	0.875	–	0.933	0.850	0.889	0.807	0.777
Balkans	0.600	0.933	–	0.733	0.800	0.866	0.666
Donetz	0.750	0.850	0.733	–	0.722	0.800	0.666
Germany	0.750	0.889	0.800	0.722	–	1.000	0.555
Belgium	0.875	0.807	0.866	0.800	1.000	–	0.777
S. France	0.687	0.777	0.666	0.666	0.555	0.777	–

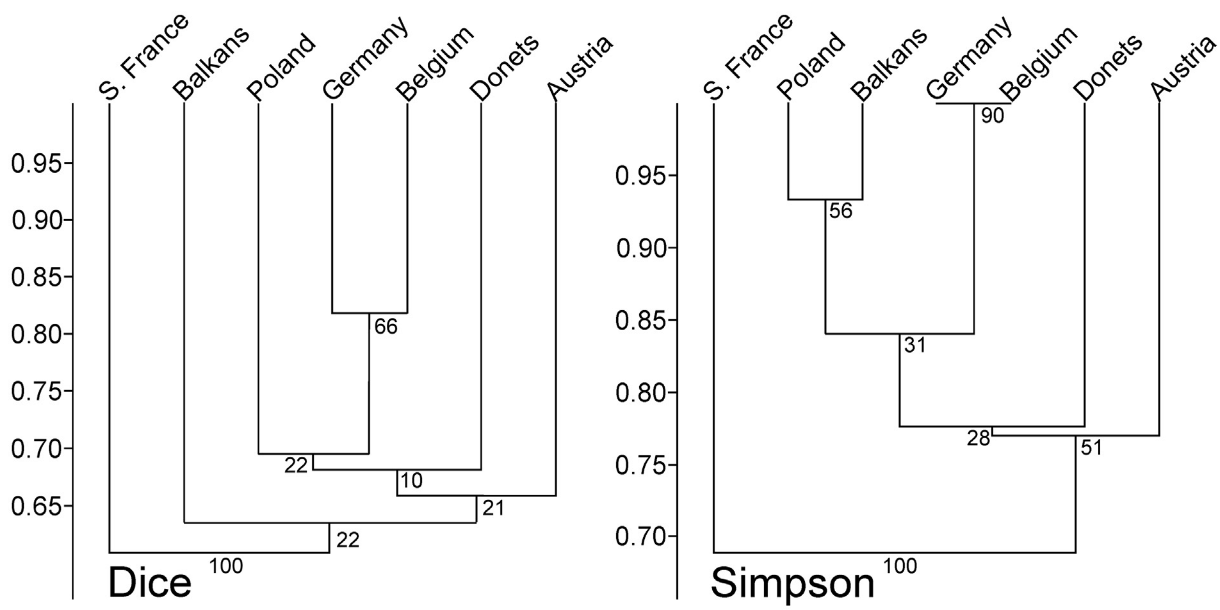

Fig. 5. Paired Group (UPGMA) Hierarchical Cluster analyses using the Dice similarity index (left) and the Simpson similarity index (right).

of the Ukrainian Shield between them (Nikishin et al., 1996), which represented an important barrier. On the contrary, the close relationship of Poland with the Balkans could be related to a free sea connection without any continental barrier between them.

The Austrian outcrops seem to be quite distant from all previously mentioned regions, but again that branch of the cluster is not stable (28% bootstrap support; Fig. 5). It could be due to the fact that the platforms from which the corals were removed were located far away southwards in the Palaeotethys, before they were displaced northwards, first during the Variscan Orogeny and much later during the Alpine Orogeny. However, when comparing by pairs, Austrian assemblages have a high similarity index with Poland and Belgium (0.875 using Simpson index), Donets and Germany (0.75), and somewhat lower with Southern France (0.6875) and the Balkans (0.6). It shows that the Palaeotethyan platforms of Central Europe had a high level of connection during the Visean and Serpukhovian.

The last branch of the clustering, with a 51% bootstrap support, shows that the most isolated region was Southern France, separated from the northern areas of Belgium and Germany by the Armorican and Central Massifs in France, and from the eastern platforms by a longer distance. Finally, the palaeogeography of the studied region during the late Visean based on coral data and in previous papers by different authors (Franke, 2000; Webb, 2002; Cocks and Torsvik, 2006) is shown in Fig. 6.

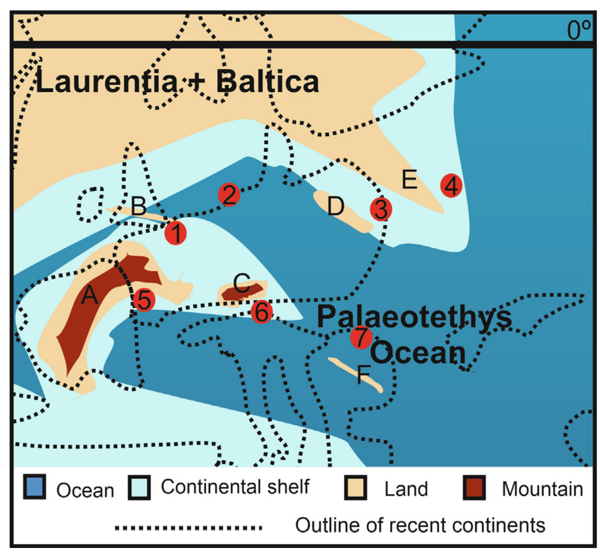

Fig. 6. Palaeogeographic map of the central part of Europe during the late Visean. 1: Belgium; 2: Germany; 3: Poland; 4: Donets; 5: South France; 6: Austria; 7: Balkans. A: Ibero-Armorican Massif; B: London-Brabant Massif; C: Krystalline High; D: Moravo-Silesian massif; E: Ukrainian shield; F: Moesian Platform. Based from Rodríguez-Castro et al. (2023), modified with the data from the present paper.

4. Discussion

4.1. Taxonomic level

The study of the coral assemblage from the Nötsch area and its comparison with other areas from Central Europe (part of the western Palaeotethys) shows several methodological problems already mentioned (low number and uncertainty of many taxa, uncertainty of age in some cases, etc.). Consequently, the comparison was done at the generic level and including Visean and Serpukhovian assemblages. It reduces the value of the comparison, but does not invalidate it. When there are genera in common between two areas in different times, it involves that in earlier or later times there was communication between these areas. Most of the identified corals have long ranges; their main expansion was presented in the late Visean (Rodríguez and Somerville, 2007), but many if not all of them occur also in the Serpukhovian and some of them reach the early Bashkirian. In fact, expanded comparisons could cover gaps in the record at some studied areas. The comparisons made by other authors with foraminifers (Davydov and Cózar, 2017) were formulated at species level because that group allows a more detailed temporal resolution, but Bambach (1990), who worked with different groups of invertebrates, selected the generic level.

Table 3 summarizes the occurrence of the genera in the selected areas. The paired comparison (Table 4) shows high level of similarity. It is because many of the genera are widely distributed along the Palaeotethys Ocean. Such a broad distribution is explained by good marine communications related to a high sea level and equatorial currents (Somerville et al., 2013). Similar wide distribution occurs in other invertebrate groups (Bambach, 1990).

4.2. Selection of areas

The selected areas partially coincide with quite large geographical units. This is not completely subjective as already explained in the chapter of methodology. The choice of smaller areas with very few taxa produces anomalous results. Studies done with different fossil groups usually consider larger areas (Bambach, 1990) such as provinces, which include several of our units. The study made at the level of the Carboniferous system with foraminifers by Davydov and Cózar (2017) shows a similar selection of areas, but they omitted some of those selected here (Belgium, Balkans, Germany, Poland) and changed the name of others (Carnic Alps by Austria, Montagne Noire by South France).

4.3. Comparison of results

The rugose corals biogeographic data confirm the conclusions reached by Davydov and Cózar (2017) with foraminifers and previous palaeogeographic information with other techniques (Franke, 2000; Cocks and Torsvik, 2006; Kalvoda et al., 2008). The closest relationship between Belgium and Germany is well known because there was a continuity along the platforms located in the southern border of Laurussia (Franke, 2000; Cocks and Torsvik, 2006; Figs. 5, 6). The Polish basins were also well connected along the same border, but with a continental area interfering partially: the Moravo-Silesian massif (Pharao, 1999; Franke, 2000; Figs. 5, 6). The Donets basin shows less communication because of the presence of the Ukrainian shield (Kalvoda et al., 2008; Okay et al., 2011). The Balkans would be located southwards, around the Moesian Terrane (Yanev, 2000), with good communication with the Polish basins (Figs. 5, 6). The Austrian platforms and slopes would be separated from the northern areas by the Krystalline high (part of the Moldanubian zone) that was cropping out during the Visean and Serpukhovian (Schönlaub, 1997). The low communication of the Nötsch area with the Balkans is difficult to explain, because their distance should not be large and the latitude could be similar. The Southern France area would be separated westwards by longer distance and an ocean branch, which explain the low similarity shown by the indices.

The palaeogeographic map (Fig. 6) represents the location of the mentioned areas during the late Visean, when the main reliefs produced by the Variscan Orogeny were still beginning to crop out and the late Visean transgression covered most epicontinental platforms. During the Serpukhovian, the elevation of many reliefs and the marine regression reduced the interaction between the different areas.

5. Conclusions

The study of new collections notably increases the knowledge of the coral assemblage from the Nötsch area. The assemblage is composed of 11 rugose coral species, two tabulate species and one heterocoral species. The statistical comparison of the rugose coral assemblages from Austria and other regions from central Europe at the genus level allows a better perception of the distribution of the shallow-water carbonatic platforms in that part of the Western Palaeotethys during the Visean and Serpukhovian. The Austrian areas show a certain degree of isolation from the northern areas (Germany, Belgium, Poland) and from areas located today to the west (South France) or to the east (Balkans).

CRediT authorship contribution statement

Isabel Rodríguez-Castro: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Herbert Kabon:** Writing – review & editing, Writing – original draft, Resources, Investigation. **Sergio Rodríguez:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation.

Data availability

No data was used for the research described in the article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This study was funded by the project CGL2016-78738-P of the Spanish Government. This study is a contribution to the IGCP 652. The research of I.R.-C. is funded by grant FPU 18/03207 of the Spanish Ministry of Universities. The thin sections were prepared by Ester Navarro. The authors thank Julien Denayer, Markus Aretz, Viktor Ohar, Ian Somerville and the editors of Geobios for constructive comments that improved this paper.

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