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Phanerozoic Oncoids – an Overview

Phanerozoische Onkoide – ein Überblick

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SCHLÜSSELWÖRTER: PALÖKOLOGIE - FAZIESKRITERIEN - PHANEROZOIKUM - ALGEN/CYANOBAKTERIEN

SUMMARY

Two main groups of oncoids - spongiostromate oncoids and porostromate oncoids (mainly *Girvanella*) - existed in different environmental settings during the Phanerozoic. From the Cambrian to the Jurassic, porostromate oncoids flourished in marine subtidal environments. *Girvanella* oncoids may be tentatively regarded as an indicator of deposition under conditions of slow sedimentation rate. As opposed to this, spongiostromate oncoids occured in lacustrine and, in association with stromatolites, transitional continental-marine environments. Starting from the Jurassic, spongiostromate oncoids replaced porostromate oncoids and became the only type of oncoids in marine settings, and continued to flourish in lacustrine environments. Starting from the Eocene, spongiostromate oncoids are replaced in marine settings by rhodoids.

ZUSAMMENFASSUNG

Ein vergleichender Überblick über die Struktur von Onkoiden (durch Cyanobakterien gebildete "Algen-Knollen") aus dem Zeitraum Kambrium bis Gegenwart zeigt, daß die beiden Hauptgruppen (spongiostromate Onkoide und porostromate Onkoide) in verschiedenen Milieubereichen auftreten. Porostromate Onkoide (meist *Girvanella*) dominieren vom Kambrium bis zum Jura in marinen subtidalen Räumen. *Girvanella*-Onkoide können mit Vorbehalt als Hinweise auf eine herabgesetzte Sedimentationsrate gewertet werden. Spongiostromate Onkoide treten in lakustrinen und - in Verbindung mit Stromatolithen - in randmarinen Bereichen auf. Ab dem Jura ersetzen die spongiostromaten Onkoide die porostromaten Onkoide in marinen Bereichen, treten jedoch auch noch weiterhin in lakustrinen Bereichen auf. Die marinen spongiostromaten

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Onkoide werden ab dem Eozän durch Rhodoide (gebildet durch Rotalgen) ersetzt.

1 INTRODUCTION

The recognized importance of cyanobacterial products for paleoenvironmental and basin analyses resulted in both recent and ancient examples attracting especial attention of sedimentologists. Their interest, however, was concentrated mainly on stromatolites (WALTER 1976; MONTY, in press). Oncoids have only sporadically been investigated and, despite the obvious differences in the structure of many oncoids and stromatolites, the conclusions reached as to the environment of deposition of the latter have been automatically applied to oncoids. Consequently, the depositional environment and evolutionary history of oncoids have been obscured. Terminological problems and the naming of particles of quite different origin, such as ooids or vadose pisoids, "oncoids" also confused the geological significance of oncoids.

The aim of the present paper is to present the data available from personal and literature studies of Phanerozoic oncoids and on that basis to determine the relative environmental significance of particular types of oncoids and to outline their history.

2 TERMINOLOGY AND CLASSIFICATION OF ONCOIDS

The term "oncoid" was introduced in the geological literature by HEIM (1916) for designating non-concentric bodies, composed of more or less concentric envelopes, of cyanobacterial - as we now know - origin. A rock body composed of oncoids is called here "oncolite", similarly as ooid -> oolite and pisoid -> pisolite (TEICHERT 1970). The orthography as used by the creator of the term and employed here is consistent with rules of nomenclature of sedimentary particles used by many authors (e.g.,FÜCHTBAUER 1974, FLÜGEL 1978).

Numerous other terms have been used for the description of oncoids, e.g. oncolite, algal ball, algal biscuit, algal nodule. However, it seems that the strict use of terminology is the best way to avoid the chaos which at the moment exists.

Cyanobacterial oncoids may be opposed to algal rhodoids and RIDING (1979) has proposed the term "cyanolith" for skeletal oncoids formed by cyanobacteria.

In his subdivision of what he thought to be calcareous algae, PIA (1927) distinguished a group "Oncolithi" within "Spongiostromata"; the second group distinguished were "Stromatolithi". Both groups, as opposed to "Porostromata", i.e. tubiform calcareous microfossils such as *Girvanella* or *Ortonella*, do not exhibit, according to PIA (1927), any recognized microfossils. The problems arose when it became clear that many oncoids (i.e., Spongiostromata) contain, or are built by, *Girvanella* (i.e., Porostromata). Those contradictions (some were discussed by RIDING 1977), as will be shown below, resulted in abandonment of the useful subdivision of cyanobacterial nodules in the sedimentological literature.

During the last two decades several classifications of fossil oncoids have been proposed. These were based on the morphology and structure of oncoids (e.g., MASLOV 1960, WOLF 1965, DRAGASTAN 1969, DAHANAYAKE 1977), their size (KUTEK & RADWAŃSKI 1965)and genesis (FLÜGEL 1978), but except for that by FLÜGEL, all resulted from examination of rather small amounts of material and hence they seem to be of local importance only. The evolutionary history of the oncoid types being distinguished was not considered either.

A morphological classification of recent oncoids as proposed by LOGAN et al. (1964) was adapted with success to ancient oncoids (e.g., RADWAŃSKI & SZULCZEWSKI 1966). However, the premise that recent soft oncoids from marine settings are real analogues of the lithified calcareous oncoids in the fossil record was questioned by MONTY(1972). According to him, algal nodules occuring in modern freshwater settings and growing in rather quiet conditions - as opposed to the turbulent ones postulated by LOGAN et al. (1964) - are the nearest analogues to pre-Cenozoic oncoids. What is more, it has recently been emphasized (JONES & WILKINSON 1978) that theassumption of rolling of oncoids to develop concentric envelopes is unsubstantiated.

Since cyanobacterial products exhibit two main categories of microstructures, spongiostromate and porostromate, it has been recently proposed (MONTY 1979; PERYT 1979,1980) to distinguish two main groups of oncoids:

- spongiostromate oncoids
- porostromate (mainly *Girvanella)* oncoids

These are comparable with the distinctions proposed by RIDING (1977) between non-skeletal and skeletal oncoids. Each of these types of oncoids has different environmental significance, as will be discussed below, and hence the classification is both descriptive and genetic. The important contribution of organisms other than blue-greens may be indicated by a prefix, e.g. foraminiferal-porostromate (*Girvanella*) oncoid in the case of "*Osagia*" from the Carboniferous of the U.S.A.(TOOMEY 1974).

One important reservation should be made here. As will be discussed below, due to diagenesis resulting in the destruction of porostromate fabrics, some oncoids that were originally porostromate now exhibit a spongiostromate structure. However, as both types of oncoids differ in their environmental settings, it is usually possible to state their initial structure.

As mentioned above, oncoids have been - and still are - mistaken by some workers for other types of coated grains, mainly ooids and pisoids. In marine settings those three types, having different origin , formed in different sedimentary environments and in many cases the determination of the group a given grain belongs to, is easy, although sometimes it is very difficult. The problem of distinguishing between these types, as well as other non-skeletal grains, goes far beyond the limit of the present paper and therefore will be discussed elsewhere.

3 POROSTROMATE ONCOIDS

The most common oncoids belonging to this group are *Girvanella* oncoids,known to occur from the Cambrian till the Jurassic (pl. 10 ;table 1,2).The well known examples of *Girvanella* oncoids are Silurian (pl. 10/1) and Triassic (pl. 10/2) spherocodia and Carboniferous *"Osagia"*. In the Carboniferous *Girvanella* oncoids are accompanied by oncoids built by other porostromates, such as *Garwoodia* and *Ortonella* (e.g., POLARD & WISEMAN 1971).

A characteristic feature of *Girvanella* oncoids is the alternation of *Girvanella*-bearing and barren laminae; the latter are light and the size of crystals is bigger (pl. 10/3). The alternation may be interpreted as 1. representing the alternation of spongiostromate and porostromate intergrowths, or 2. that the barren or *Girvanella*-pour layers are in fact merely recrystallized *Girvanella*-bearing layers. The latter interpretation has been proved in the case of Middle Triassic oncoids (PERYT 1980). It has been observed that even within one oncoid the preservation of the *Girvanella* structure may be quite different - from very good to the lack of recognizable *Girvanella* (pl. 10/4), and hence a *Girvanella* nature has been postulated even for the whole oncoids which do not now exhibit a *Girvanella* structure but which are associated with other *Girvanella* oncoids. A similar explanation has been given by STEL & de COO (1977) for Silurian spherocodia of Gotland, initially described by ROTHPLETZ as Spongiostromata, and is also favoured by other workers (e.g., PONCET & de LAPPARENT 1975).

A driving force of crystal growth, obliterating the initial *Girvanella* structure and later destroying it, is unknown. Recent counterparts of *Girvanella* are built of low magnesian calcite and the same mineralogy was also envisaged for the Triassic *Girvanella* oncoids (PERYT 1980); it may explain the good preservation of *Girvanella* even in relatively severely diagenetically altered carbonate deposits. However, some environmental factors could result in somewhat less stable calcite mineralogy of calcified sheaths in other cases. It accounts both for lateral changes of structure of oncoids (e.g., in the Upper Muschelkalk of Württemberg, *Girvanella* oncoids have been observed only in one locality, although the oncoid-bearing layer has a very wide distribution - see PERYT 1980) as well as for changes through time, probably seasonal, resulting of *Girvanella*-rich and *Girvanella*-poor (now) laminae. This supposition finds support in mineralogical composition of some *Girvanella* oncoids, which are built by ferroan calcite (YOUNGS 1977 - Cambrian, BOWMAN 1979 - Carboniferous, RICHTER & FÜCHTBAUER 1973 - spherocodia from the Raibler Beds): according to RICHTER and FÜCHTBAUER (1978), this indicates an initial high-magnesian calcite composition.

In some *Girvanella* oncoids other organisms also play an important role in the structure, such as encrusting foraminifera (e.g., *"Osagia"* - cf. HENBEST 1963 or spherocodia from Gotland) and spirorbids (Devonian *Girvanella* oncoids from Afghanistan - PONCET & de LAPPARENT 1975). The latter were also recorded in the Dinantian *Garwoodia* oncoids of England (LEEDER 1975) and according to BURCHETTE and RIDING(1977) are vermiform gastropods.

Because *Girvanella* oncoids are frequent components of many Phanerozoic rocks, their environmental significance was discussed in the past by a number of workers (e.g., WOOD 1957, LAPORTE 1962, HENBEST 1963, TOOMEY 1974). Usually they were thought to be environmental analogues of spongiostromate oncoids and, to some extent because of the "tidal dogma" of stromatolite origin (HOFFMANN 1973, MONTY 1973,1977),

Age	Provenance	Reference	Sample furnished by
Cambrian (Middle)	Wirrealpa Limestone, S. Australia	YOUNGS 1977	B. C. Youngs (Eastwood)
Silurian (Ludlow)	Hamra-Sundre Beds, Gotland, Sweden	STEL & DE COO 1977	J. H. Stel (Groningen)
Carboniferous (Pennsylvanian)	Blackjack Creek Fm., Missouri	NEAL 1969	W. J. Neal (Allendale)
Carboniferous (Pennsylvanian)	Leavenworth Limestone, Kansas, Iowa	TOOMEY 1974	D. F. Toomey (Midland)
Carboniferous (Namurian-Westphalian)	San Emiliano Fm., NW Spain	BOWMAN 1979	M. B. J. Bowman (Aberystwyth)
Permian (Lower)	Grenzland Fm., Carnic Alps, Austria	FLÜGEL 1977	E. Flügel (Erlangen)
Permian (Lower)	Cottonwood Limestone, northern Midcontinent (U.S.A.)	LAPORTE 1962	L. Laporte (Santa Cruz)
Triassic (Middle)	Upper Muschelkalk, Württemberg	PERYT 1980	J. Schedler (Holzgerlingen)
Triassic (Upper)	Raibler Beds, Ehnbach-Klamm, Zirl, Austria	PERYT 1977	H. Jerz (München)

Table 1. *Girvanella* oncoids examined.- Alter und Vorkommen der untersuchten Girvanellen-Onkoide.

Age	Provenance	Reference
Ordovician	Ayrshire, Britain	NICHOLSON 1888
Ordovician	Indiana, U.S.A.	NICHOLSON 1888
Ordovician	Tennessee, U.S.A.	BENEDICT & WALKER 1978
Silurian	Texas, U.S.A.	TOOMEY & LEMONE 1977
Devonian	Nubrigyn complex, E. Australia	WOLF 1965
Devonian	Afghanistan	PONCET & DE LAPPARENT 1965
Devonian (Upper)	Ancient Wall complex, W. Canada	COPPOLD 1976
Carboniferous	N. England	NICHOLSON 1888
Carboniferous	Haut-Pyrenees, France	PERRET 1971
Carboniferous (Lower)	Moravia, Czechoslovakia	OBRHEL 1977
Carboniferous (Visean)	N. England	BURGESS & MITCHELL 1976
Carboniferous (Middle)	Bükk Mts., N. Hungary	NEMETH 1974
Permian	NE Iran	STAMPFLI 1978
Permian	Djebel Tebaga, S. Tunisia	TERMIER & TERMIER 1955
Triassic	Dolomites, Italy	BIDDLE 1979
Triassic (Rhaetian)	High-Tatric zone, Tatra Mts., Poland	RADWANSKI 1968
Jurassic	England	WETHERED 1889
Jurassic (Bathonian)	Normandy, France	DANGEARD 1935

Table 2. Reported occurence of *Girvanella* oncoids.- Vorkommen von Girvanellen-Onkoiden (Literaturauswahl).

they were interpreted as an indicator of shallow water, turbulent environments. Besides, *Girvanella* was thought to be limited to a marine environment. Also the presence (although rare) of broken and abraded, sometimes rounded, organic remains, both in the oncoids (as nuclei) and in the matrix, as well as oncoid sizes, seemed to support the shallow environment origin.

However, *Girvanella* is not a precise indicator of depth (cf.RIDING 1975, WRAY 1977) and the rare presence of broken and abraded organic remains testifies only that some periods of turbulence existed. It is well known that in some cases a very rare process may influence the overall appearance to a great measure, e.g. in condensed sequences. Therefore the rate of sedimentation should be determined first before reconstruction of the sedimentary environment. In the case of *Girvanella* oncoids from the Upper Muschelkalk of Württemberg their relationship to a break in sedimentation was stated by BACHMANN & GWINNER (1971:14). Similarly, *Girvanella* oncoids from the Raibler Beds are connected with sedimentation stops (PERYT 1977), and *Girvanella* oncoids from the Carboniferous of the U.S.A. originated on a slowly subsiding platform (TOOMEY 1974). Assuming a very low rate of sedimentation and subsidence, sporadic geological processes (such as exceptionally strong storms) may lead to the creation of a "turbulent" appearance in an environment which was not turbulent at all. This seems to be the case of great many *Girvanella* oncoid-bearing beds. Critical examination of data presented by workers studying *Girvanella* oncoids(tables 1 and 2) indicates, except in two cases, a tranquil subtidal environment. In fact, such an environment was also assumed by several workers (e.g., PONCET & de LAPPARENT 1975, BOWMAN 1979). The two exceptions mentioned come from the Cambrian of Australia (YOUNGS 1977) and mid-Jurassic of France (DANGÉARD 1935), where the *Girvanella* oncoids are associated with oolites, but at least in the Cambrian oncoids are thought to be deposited on the flanks (but not the crests) of ooid shoals (YOUNGS 1977). Both these occurrences coincide with the appearance and extinction of *Girvanella* oncoids in geological history and therefore the settings in which they were found are thought to be atypical.

In conclusion, there is no proof of shallow-water origin of most *Girvanella* oncoids. On the other hand, a relationship of *Girvanella* oncoids to a sedimentary environment of slow sedimentation rate seems to be valid, and *Girvanella* oncoids may therefore tentatively be regarded as an indicator of slow sedimentation, preferably in deeper (some tens of metres) water.

4 SPONGIOSTROMATE ONCOIDS

Similarly to stromatolites, spongiostromate oncoids exhibit a great variety of structures, e.g., micritic, fenestral, spongy, peloidal (MONTY 1979b), however, because of rapid transformation of filaments of blue-greens into unrecognizable structures (e.g., KRUMBEIN & COHEN 1977), and later sparitization of laminae, only a general organization of laminae is visible.

Age	Provenance	Reference	Sample furnished by
Cambrian (Upper) – s	Western Utah, U.S.A.	HOSE 1961	R.K. Hose (Menlo Park)
Permian (Upper) – d	Zechstein Limestone, Fore-Sudetic Area, Western Poland	PERYT 1978	own collection
Triassic – d	Dolomites, Italy	LEONARDI 1967	P. Leonardi (Ferrara)
Triassic (Carnian) – d	Teteven Anticlinorium, Central Fore-Balkan, Bulgaria	CATALOV 1970	G. Catalov (Sofia)
Jurassic (Lias) – d	Calcare Massiccio Fm., Central Apennines, Italy	COLACICCHI et al. 1975	L. Passeri (Perugia)
Jurassic (Lias)	Oman	ELLIOTT 1966	J. E. Thomas (Reading), G. F. Elliott (London)
Jurassic (Lias)	Sicily, Italy	JENKYNS 1972	H. C. Jenkyns (Oxford)
Jurassic (Dogger)	Burgundy, France	PURSER 1975	B. H. Purser (Orsay)
Jurassic	Central Carpathians, Czechoslovakia	MISIK 1966	M. Misik (Bratislava)
Cretaceous (Lower)	Provence, France and Algeria	MASSE 1979	J.-P. Masse (Marseille)
Cretaceous (Late)	North Horn Fm., Central Utah, U.S.A.	WEISS 1969	M. P. Weiss (DeKalb)
Tertiary (Paleocene–Eocene)	Flagstaff Fm., Central Utah, U.S.A.	WEISS 1969	M. P. Weiss (DeKalb)
Tertiary (Miocene)	Mainz Basin, Germany	DOEBL et al. 1972	P. Rothe (Mannheim)

Tab. 3: Spongiostromate oncoids examined (s-associated with spongiostromate stromatolites, d - severely diagenetically altered, initially *Girvanella* oncoids).

Alter und Vorkommen der untersuchten spongiostromaten Onkoide (s - in Assoziation mit spongiostromaten Stromatolithen, d - diagenetisch stark veränderte *Girvanella* Onkoide).

Some spongiostromate oncoids contain encrusting foraminifera (e.g., Jurassic oncoids of Oman, ELLIOTT 1966), bryozoa (e.g., Jurassic oncoids of France DAHANAYAKE et al. 1976, and Poland - KUTEK & RADWAŃSKI 1965), annelids and problematic organisms, *Bacinella irregularis* RADOIČIĆ (e.g., DAHANAYAKE et al.1976), and other organisms.

The well known examples of ancient marine spongiostromate oncoids are those from the Jurassic (KUTEK & RADWAŃSKI 1965, RADWAŃSKI & SZULCZEWSKI 1966, ELLIOTT 1966, DAHANAYAKE et al. 1976, DAHANAYAKE 1977). They were recently described by DAHANAYAKE (1977) who stated three basic types of lamination; the sequences of those types and other morphological features enabled him to distinguish several types of oncoids that were formed in different environments (DAHANAYAKE 1978).It was stated that *Bacinella*-content in oncoids increases with diminishing energy of the environment (DAHANAYAKE et al. 1976) so it may be supposed that in the Jurassic oncoids built by spongiostromates and *Bacinella* occupied the environments in which *Girvanella* oncoids flourished previously. This conclusion fits with what we know about the distribution of spongiostromate oncoids. They are known in marine settings starting from the Precambrian (e.g., HUBBARD 1972), but in Paleozoic and Triassic (and probably Lower Jurassic) times they rarely,if ever, occurred in normal marine environments. There are only few data on the spongiostromate oncoids of Cambrian to Lower Jurassic age (table 3), and in any case it is questionable whether they were primarily of spongiostromate type. In fact,some Cambrian oncoids retain in areas of good preservation filament molds similar to *Girvanella* (HALLEY 1975:282), and so do Lower Jurassic oncoids of Italy (pl. 11/1). Similary, the severely altered Triassic oncoids (part of spherocodia from the Dolomites (pl.11/2) and other oncoids from the Tethys area,e. g. from Bulgaria - pl. 11/3) reveal many similarities to what is evidently post-*Girvanella* oncoid structure in many cases. Also the Zechstein (Upper Permian) oncoids from western Poland (pl. 11/4) and other areas of the Zechstein basin are devoid of calcified sheaths, but this may easily be ascribed to strong diagenetic modifications. As has been mentioned, grain growth is proved for the *Girvanella* oncoids from the Middle Triassic of Württemberg (PERYT 1980) and was also noted earlier by other authors, leaving no doubt that the primary *Girvanella* structure of many Paleozoic and Mesozoic oncoids has been obliterated. As consequence, some of the oncoids ascribed at present to spongiostromates may in fact be of *Girvanella* origin (table 3). Therefore, the role of *Girvanella* oncoids may have been underestimated and that of spongiostromate oncoids overestimated in Paleozoic and Mesozoic times.

It seems that in normal marine settings spongiostromate oncoids did not occur in Phanerozoic times before the mid-Jurassic. Later they concured in a lot of environments, and they occur both in shallow water (e.g., some oncoids from the Jurassic France - DAHANAYAKE 1977) and deeper water environments (e.g., "microoncoids" - see JENKYNS 1972). Besides, during the Phanerozoic they are the only type of oncoids in lacustrine environments (e.g., in the Devonian - DONOVAN 1975, Carboniferous - BERTRAND-SARFATI & FABRE 1972, Permian - A.SCHÄFER & STAPF 1978).

5. DISCUSSION

From the data presented above it can be inferred that from the Cambrian to the Jurrassic the great majority of oncoids (especially large forms) were - in marine settings- porostromate ones, mainly formed by *Girvanella*. *Girvanella* oncoids occured probably in a number of environments and hence they can be used as an environmental index only to a limited extent. On the other hand, there appears to be a direct relationship between *Girvanella* oncoids and conditions of slow sedimentation, and therefore *Girvanella* oncoids may be tentatively regarded as an indicator of slow deposition, preferably in deeper than shallower water. Anyway, they should not be regarded as an indicator of shallow water environments, and the shallow-water concept of many *Girvanella* oncoids described in the literature should be re-examined.

As opposed to *Girvanella* oncoids, which grew over long periods, spongiostromate oncoids in Mesozoic times grew, according to MONTY (1973), over very short periods in unstable ecological conditions, and therefore are to be mostly found at the base of transgressive sequences, near stratigraphical gaps or condensed sequences. They always seem to occur within settings

		Triassic Girvanella oncolite, Württemberg (after PERYT 1980)	Jurassic spongiostromate oncolites, French Jura (after DAHANAYAKE 1977)
oncoids	Size	1 to 25 mm	1 to 50 mm
	Shape	elliptical to spheroidal (but very often dependent on that of the nucleus)	
	Mineralogy: present		low-magnesian calcite
	infered	low-magnesian calcite	no suggestion
	Nuclei	usually bioclasts	any available grain type
	Laminae	Girvanella-rich and Girvanella-poor (thought to result from grain growth process)	3 types (1) micritic, (2) grumose, (3) organism-bearing (Bacinella irregularis RADOIČIĆ, Lithocodium aggregatum ELLIOTT, foraminifera, worms, bryozoa)
oncolite	Associated fauna		diverse
	Associated lithologies	Fossiliferous pellet-bearing oolitic limestone	fossiliferous limestones, oolites, micrites and pellet-bearing limestones
	Infered environment of deposition	subtidal zone of slow sedimentation rate, with episodic influences of storms	supratidal to subtidal zone (depending on the oncoid type distinguished)

Tab. 4: Comparison of two Phanerozoic oncolites.
Vergleich zweier phanerozoischer Onkoid-Vorkommen.

of a relatively fast rate of deposition.

Therefore, both *Girvanella* oncoids and spongiostromate oncoids are related to sedimentary discontinuities, but of different types, and hence the implications for the sedimentary regimes are quite different. Both these types of oncoids of such different origin are quite similar in appearance (tab. 4) and this is why in the past they have often been mistaken. What is more, the grain growth process has led to the total obliteration of the primary structure of many *Girvanella* oncoids, and this has also influenced the opinion of the earlier workers concerning the common occurrence of marine oncoids built by spongiostromates before the Jurassic. As may be supposed from my own studies and data from the literature, both types of oncoids never coexist; although some authors are inclined to accept their joint occurrence the inferred spongiostromate oncoids represent (as has been proved in several cases) recrystallized *Girvanella* oncoids.

During Jurassic times spongiostromate oncoids replaced porostromate oncoids in marine settings. The Jurassic spongiostromate oncoids occur in all habitats: lacustrine, shallow- and deep-marine. Similarly to *Girvanella* oncoids, Jurassic spongiostromate oncoids were completely lithified when lying on the sea floor (e.g., KUTEK & RADWAŃSKI 1965).

Marine *Girvanella* oncoids are not associated with stromatolites (although stromatolites built by *Girvanella* are occasionally reported, e.g., AHR 1971(because the environment of formation of *Girvanella* oncoids did not favour the development of stromatolites. In contrast, spongiostromate oncoids, both lacustrine and marine, and stromatolites very often occur together.

The Phanerozoic history of oncoids may be summarized as follows:

During the Phanerozoic porostromate (mainly *Girvanella*) oncoids and spongiostromate oncoids existed in different environmental settings. From the Cambrian to the Jurassic, porostromate oncoids flourished in marine subtidal environments. *Girvanella* oncoids may be tentatively regarded as an indicator of deposition under conditions of slow sedimentation rate. As opposed to this, spongiostromate oncoids occured in lacustrine and, in association with stromatolites, transitional continental-marine environments. Starting from the Jurassic, spongiostromate oncoids replaced porostromate oncoids and became the only type of oncoids in marine settings, and continued to flourish in lacustrine settings. Continuous development of calcareous plankton, generating progressive depletion of sea water in calcium carbonate, caused the lack of significant calcification of oncoids at the end of the Mesozoic. Therefore, they could not be fossilized and thus preserved in rock record. Starting from the Eocene, spongiostromate oncoids are replaced in marine settings by rhodoids, as noted by MONTY (1979a), and their occurrence as lithified bodies is now limited to continental setting and, more rarely, some extreme transitional marine-continental environments.

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Plate 10 Porostromate (*Girvanella*) oncoids indicating subtidal environments

Porostromate (*Girvanella*-) Onkoide als Hinweise auf subtidale Ablagerungsbereiche

Fig. 1. *Girvanella* oncoid. Hamra beds, Ludlowian, Silurian. Uddvide 2, Gotland Island, Sweden. Alternation of *Girvanella*-bearing laminae (darker) and barren laminae (light). Sediment: oolitic grainstone. Sample provided by J.H. Stel, Groningen. x 10.

Fig. 2. *Girvanella* oncoid from the Raibl Formation (Carnian, Upper Triassic) of the Ehnbach Gorge near Zirl, Tyrol, Austria. These oncoids have been called "*Sphaerocodium*" originally. Sample provided by H. Jerz, München. x 38.

Fig. 3. Strongly altered *Girvanella* oncoid. Blackjack Creek Formation, Pennsylvanian. Missouri, USA. Sample provided by W. J. Neal, Allendale. x 6,4.

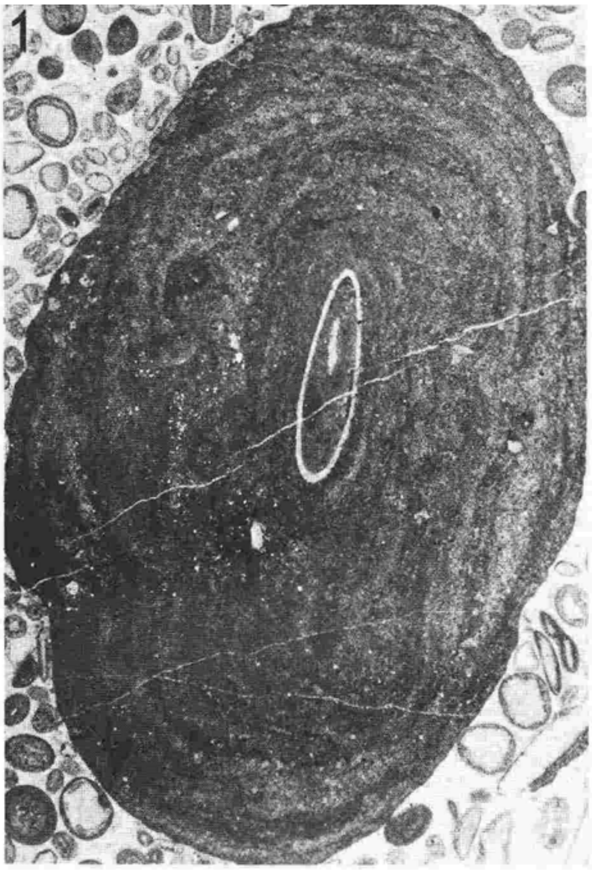
Fig. 4. Detail of Fig. 3, showing distinct filaments of the blue-green alga *Girvanella*. x 200.

Fig. 1. *Girvanella*-Onkoid. Hamra-Schichten, Ludlow, Silur. Uddvide 2, Gotland, Schweden. Der Wechsel von Lagen mit und Lagen ohne Girvanellen drückt sich in Helligkeitsunterschieden aus (helle Lagen ohne Algenfilamente). Sediment: oolithischer Grainstone. x 10.

Fig. 2. *Girvanella*-Onkoid aus den Raibler Schichten (Karn, Ober-Trias). Ehnbach-Klamm bei Zirl, Tirol/Österreich. Diese Onkoide wurden ursprünglich als "*Sphaerocodium*" bezeichnet.

Fig. 3. Stark verändertes und teilweise gelöstes *Girvanella*-Onkoid. Blackjack Creek Formation, Pennsylvanian. Missouri, USA. x 6,4.

Fig. 4. Ausschnitt aus Fig. 3. Die Quer- und Längsschnitte der Filamente der Blau-Grünalge *Girvanella* sind deutlich erkennbar. x 200.



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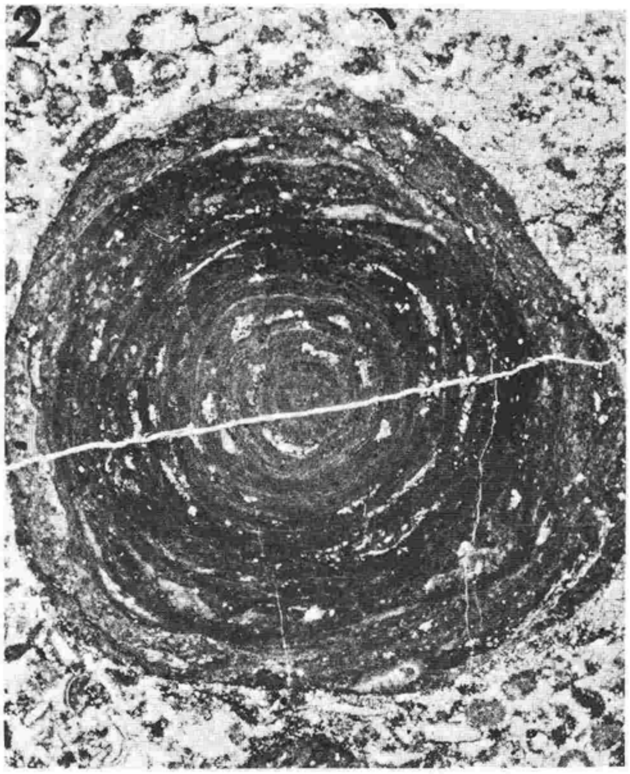

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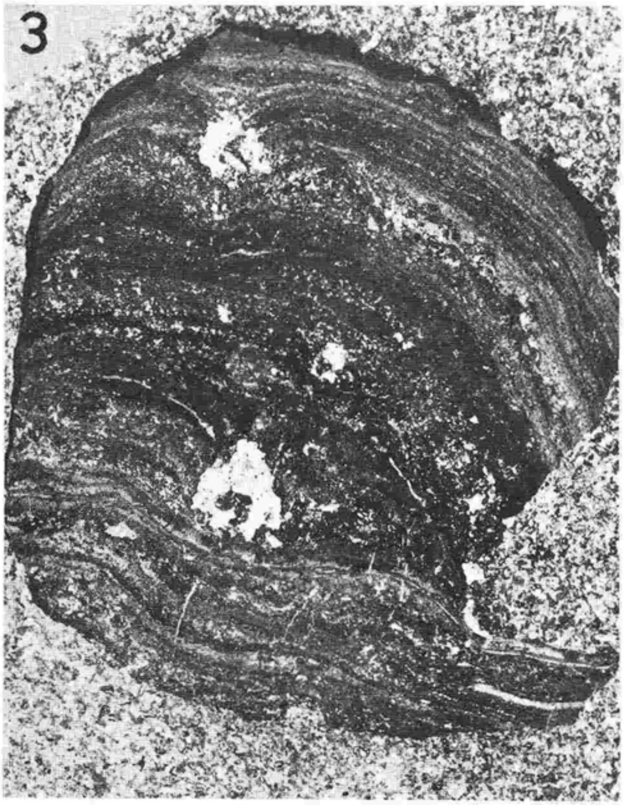

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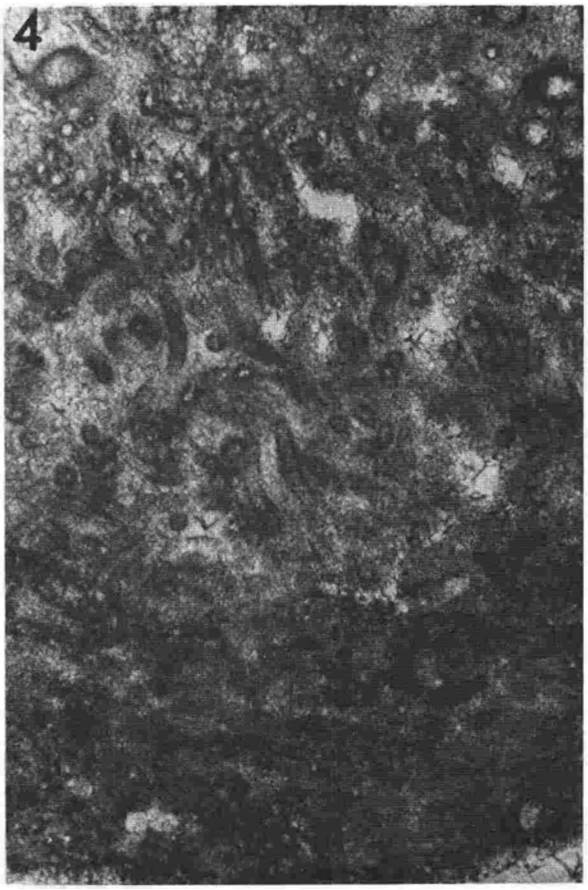

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Plate 11 *Girvanella* oncoids with partly obliterated microstructures

Onkoide, deren "spongiostromate" Struktur auf die diagenetische Zerstörung von porostromaten (*Girvanella*-)Onkoiden zurückgeführt werden kann

Fig. 1. Oncoid with obscure microstructures, probably a primarly *Girvanella* oncoid. Calcare Massiccio, Lower Jurassic. Frasassi, Italy. Sample provided by L. Passeri, Perugia. x 6,5.

Fig. 2. *Girvanella* Oncoid with strongly obliterated microstructures. Triassic. Dolomites, Italy. Sample furnished by P. Leonardi, Ferrara. x 3,8.

Fig. 3. Porostromate oncoid, formed by *Girvanella* circumcrusting bored shell fragments. Triassic. Suhodole, Teteven Anticlinorium, Bulgaria. Sample provided by G. Catalov, Sofia. x 15,5.

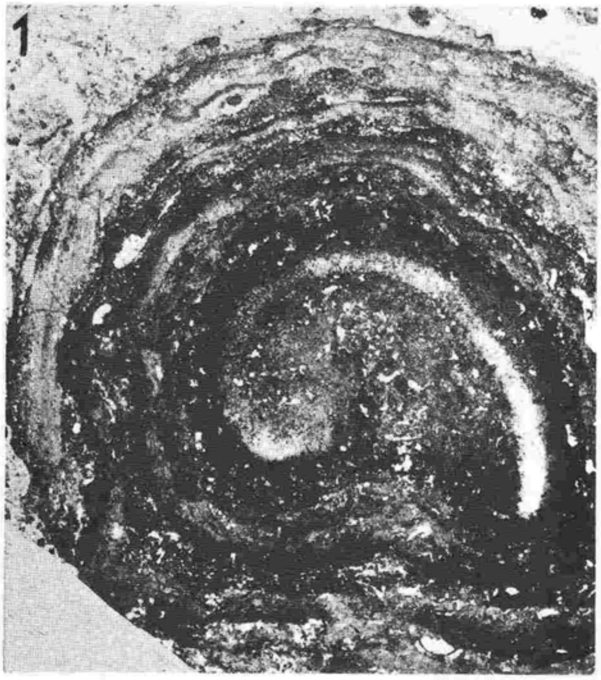
Fig. 4. Oncoid from the Zechstein Limestone, Upper Permian. Wrobliniec 2 well, Fore-Sudetic region, western Poland. Diagenetic modifications may be responsible for the lack of algal remains. The oncoids are encrusted by sessile foraminifera. Other bioclasts are shell fragments, foraminifera and bryozoans (bottom right). x 13.

Fig. 1. Onkoid mit nur undeutlich erkennbaren Mikrostrukturen. Es handelt sich wahrscheinlich um ein *Girvanella*-Onkoid, dessen Feinstrukturen durch Umkristallisation zerstört worden sind. Calcare Massiccio, Lias. Frasassi, Italien. x 6,5.

Fig. 2. *Girvanella*-Onkoid. Mikrostrukturen durch Kornvergröberung (helle Areale) zerstört. Trias. Dolomiten, Italien. x 3,8.

Fig. 3. Porostromates Onkoid. Angebohrte Schalenfragmente werden von *Girvanella*-Filamenten umkrustet. Trias. Suhodole, Teteven Antiklinale, Bulgarien. x 15,5.

Fig. 4. Onkoide aus dem Zechstein-Kalk, Ober-Perm. Bohrung Wrobliniec 2, Vorsudeten, Westpolen. Das Fehlen von Algenresten dürfte durch diagenetische Veränderungen bedingt sein. Darauf hin deuten große, durch die Lamellen durchgreifende Kristalle, insbesondere in den peripheren Lagen. Die Onkoide werden durch Foraminiferen inkrustiert. Andere Bioklasten sind Schalenfragmente, Foraminiferen und Bryozoen (im Bild rechts unten). x 13.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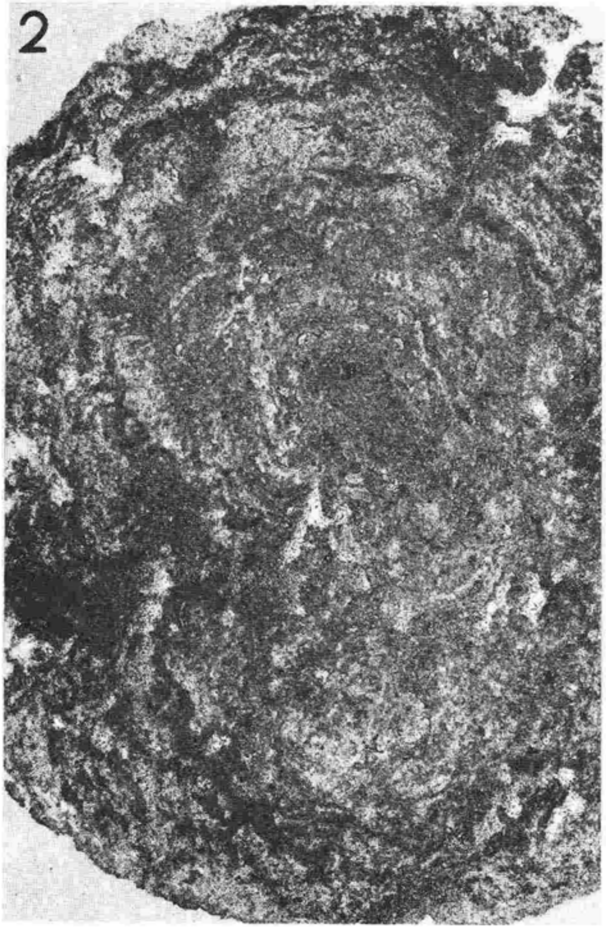
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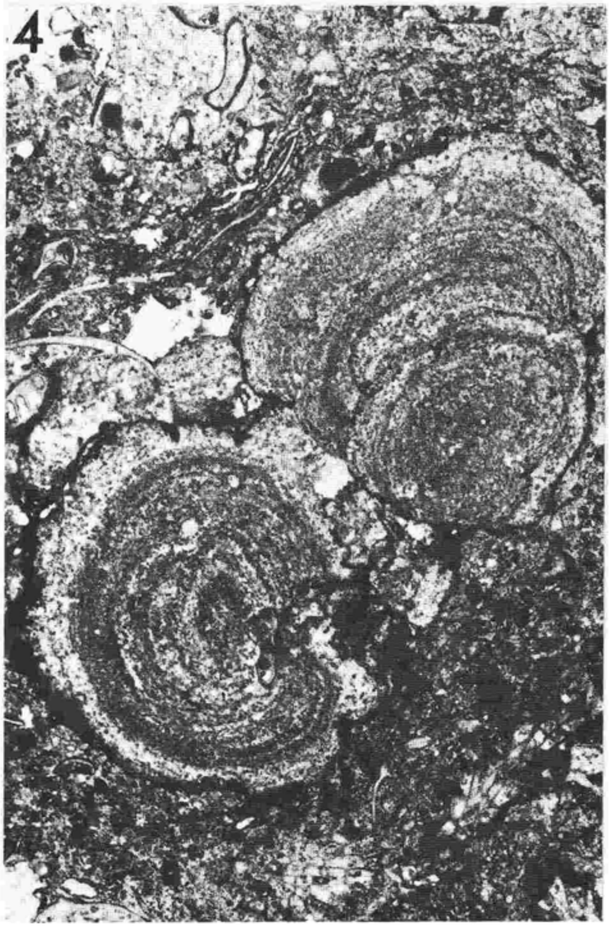
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