Orientation of Spondylus valves cemented to the hard-rock substrates
(Bivalvia, Upper Cretaceous, Bohemia)

Orientace misek rodu Spondylus,
přitmených k pevným horninovým substrátům
(Bivalvia, svrchní křída, Čechy) (Czech summary)

(6 text-figs., 4 plates)

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Data on orientation of Spondylus sp. encrusting the rocky bottom and boulders in the nearshore facies (upper Cenomanian-lower Turonian, Bohemian Cretaceous Basin) are summarized and compared with those on encrusting bivalve Atreta. While the subhorizontal rocky surfaces bear both Spondylus sp. and Atreta orientated chaotically, on sloping substrates (the dip equal to or exceeding 10°) they are usually orientated preferentially, i.e., umbo of valves are directed to the upper left quadrant (so-called slope orientation). In agreement with Seilacher (1960) we tentatively consider this posture to be advantageous for nutrition and providing other biological functions. Most recently, a modified orientation of Spondylus was found on the overhanging root of a small cavity, sheltered from the exterior by a clast barrier. The Spondylus valves are here mostly directed to the lower left quadrant by their umbo. It means that, under the local conditions, the posterior margins of valves were turned to the barrier, through which the cavity communicated with the exterior water environment. A fragment of an irregular cluster with partial radial orientation of Spondylus valves was also found on another substrate of the same locality (Skalka near Velim, center Bohemia). Several extra-Bohemian examples of Mesozoic encrusters are discussed.

Introduction

From the Bohemian Cretaceous Basin (BCB), the spondylids encrusting hard-rock substrates (mostly clasts) have been known for a rather long time (see Příč 1870, 1910, Culek 1944, Závorka 1946, Klein 1962, Soukup 1966, Bouček 1968, Macák et al. 1968, Ziegler 1982). Unpublished observations are also frequent (see table 1). Fauna encrusting the rocky bottom and large boulders which both occur in the nearshore facies, was, however, intensively studied only during the last few years (Houša - Nekvasilová 1984, Nekvasilová - Zít 1988, Žitt - Nekvasilová 1989, 1990, 1991, 1992, 1993, Žít 1992). The bivalve Spondylus sp. was ascertained to be relatively frequented in the studied communities. Most recently, the authors found new rocky surfaces colonized by these bivalves which are so far the richest in number of specimens per area measured and which provided new interesting information on their distribution and orientation. As a result, all the data on cemented Spondylus sp. are summarized from the BCB, and this bivalve growth orientations are compared with those of Atreta in search for preferred orientation causes.

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Geology, substrates, localities

Localities of the studied encrusters are situated in the Korycany Member of the Peruc-Korycany Formation and in the basal parts of the overlying Bílá Hora Formation. Korycany Member consists mostly of conglomerates (containing gneiss or silicate clasts at the studied localities), usually clast supported, very coarse and unsorted, with lithologically complicated but prevailing limestone-claystone matrix. They are of upper Cenomanian age. The base of the lower Turonian Bílá Hora Formation is formed mostly by clayey-silty sediments which pass upwards into siltstones with sponges. There exists a hiatus between the mentioned formations, spanning probably the uppermost Cenomanian. During this interval, sedimentation rate rapidly decreased and phosphogenesis occurred followed by a period of reworking (see Žít - Mikulaš 1994). At the studied localities, the sediments of both units usually fill the depressions eroded in the rocky bottom by transgressing Cenomanian sea (see pls. I and III).

Though Spondylus encrusts several types of hard substrates in the BCB (such as the bioclasts, rock clasts, and rocky bottom), only the specimens from the rocky bottom, and from rock clasts undisturbed in their position since their encrustation till now, are included
in this paper. Basic data on all known localities, types of substrates and partly on the number of encrusting specimens are summarized in table 1. As regards a detailed information on the Radim locality, we refer to Žitt (1992). Localities of Kutná Hora-Karlov and Liševice were described by Nekvasilová - Žitt (1988) and Žitt - Nekvasilová (1992), respectively. New instructive occurrence of encrusting *Spondylus* and other fauna were recently found at the locality Skalka near Velim (about 6 km west of Kolin, central Bohemia). Here, several erosional troughs cutting a low gneiss elevation are exposed in a small abandoned quarry. Most important are two large depressions located in the western (see pl. III, fig. 1, and Nekvasilová 1986, fig. 2) and a small one in the eastern parts of the quarry (see pl. I, fig. 1).

**Encrusting communities**

In the paper by Žitt - Nekvasilová (1993) a preliminary concept of two successive encrusting communities was introduced. The older community is characterized by

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**Table 1**

Distribution of *Spondylus* sp. cemented to the hard-rock substrates in the nearshore facies (BCD, upper Cenomanian-lower Turonian)

<table>
<thead>
<tr>
<th>Locality</th>
<th>Oyster community</th>
<th>Astraea-Kedroloïdina community</th>
<th>Determination</th>
<th>Authors</th>
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<tbody>
<tr>
<td></td>
<td>cl. r.</td>
<td>r. b.</td>
<td>cl. i. s.</td>
<td>r. b.</td>
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<tr>
<td>Chtníky</td>
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<td></td>
<td>-</td>
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<td>+</td>
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<tr>
<td>Kojetice</td>
<td>+(?)(?)</td>
<td>1</td>
<td></td>
<td>8?</td>
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<tr>
<td>Kutná Hora-Karlov</td>
<td>-</td>
<td>-</td>
<td>&gt;50</td>
<td>87</td>
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<tr>
<td>Kutná Hora - Na Vříš</td>
<td></td>
<td>+</td>
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<td></td>
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<td>&gt;51</td>
<td>87</td>
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<tr>
<td>Liševice</td>
<td></td>
<td>-</td>
<td>-</td>
<td>421</td>
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<tr>
<td>Mezholezy</td>
<td>+(?)(?)</td>
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<td>Nové Ves near Kolin</td>
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<td>Odolená Voda</td>
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<tr>
<td>Plaňany</td>
<td>-</td>
<td>+</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Předboj (close to road)</td>
<td>+(?)(?)</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Radim</td>
<td>+</td>
<td>-</td>
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<tr>
<td>Skalka near Velim</td>
<td>+</td>
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<tr>
<td>site No. 1.</td>
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<tr>
<td>site No. 2.</td>
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<td>site No. 3.</td>
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<td>site No. 4.</td>
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<tr>
<td>Skalka near Žehušice</td>
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<tr>
<td>site No. 1.</td>
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<tr>
<td>site No. 2.</td>
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<td>site No. 3.</td>
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<tr>
<td>site No. 4.</td>
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<tr>
<td>Tuchoměřice - Kněžívek</td>
<td>1</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Zbyšov</td>
<td>-</td>
<td>-</td>
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<td>+</td>
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cl. r. = encrusted and then redeposited clasts, cl. i. s. = clasts preserved in undisturbed position since their encrustation, r. b. = rocky bottom, + = number of specimens not recorded, +(?)(?) = number of specimens not recorded and community type uncertain, S(?) = remains of *Spondylus* affinity (bad preservation)
oysters [Exogyra reticulata Reuss, Exogyra haliothioidea (Sowerby), a. o.], the younger one by the bivalve Atreta (two species) and the agglutinated foraminifer 
Bdelloidina cribrosa (Reuss). The first community was replaced by the second when the coarse accumulations of the Korycany Member became stable and sedimentation rate rapidly decreased prior to a phosphogenic episode. The Atreta-Bdelloidina community survived not only during the breaks in phosphogenesis when the supposed anox of the environment was temporarily decreasing, but also after the phosphogenesis, under the fully oxic conditions at the beginning of the lower Turonian sedimentation. Spondylus sp. formed a part of both oyster, and Atreta-Bdelloidina communities. Attribution of the studied bivalves to the respective community types is specified in table 1.

General notes to Spondylus

The genus Spondylus Linné, 1758 belongs to the family Spondylidae Gray, 1826 of pectinacean bivalves. Its right valves are slightly inequilateral, pectiniform (see Hertlein - Cox 1969). In our material they are low and attached to the hard-rock substrate by the whole surface. Left valves were never found in situ by the present authors. Attachment of some specimens on the walls of very narrow crevices, however, suggests their relatively low height. Radial costae but no apparent muscle scars are present in the interiors of the cemented valves. Hinge parts are mostly badly preserved.

In the sediments of the upper Cenomanian-lower Turonian of Bohemia three species of Spondylus were distinguished by Reuss (1845), Frič (1911) and other workers. These are S. lineatus Goldfuss (= S. latus Sowerby according to Frič, op. cit.), S. striatus Sowerby, and S. hystrix Goldfuss. Small fragments of left Spondylus valves found by ourselves in the sediments surrounding the encrusted rock substrates were, however, difficult to determine, as well as the in situ preserved right valves. For that reason, we use only the Spondylus sp. designation for our specimens. Careful taxonomic revision of the above mentioned spondylid species from the BCB is, in our opinion, a prerequisite to more precise determinations.

Orientation of cemented valves on the substrate

In the BCB, the first observation of Spondylus orientations on the rocky surfaces was made by Soukup (1966) at the Pláňany locality in central Bohemia (substrates later destroyed by quarrying). Except for the statement of orientated attachment to the rock, no other details were, however, given by this author. First more precise information from the BCB was published by Nešvadsova - Zitt (1988) from the Karlov locality. Considering those and all the other so far gathered data, the orientations of Spondylus sp. may be summarized into the following three groups:

1. Orientations on horizontal surfaces

At the studied localities, strictly horizontal rock surfaces are scarce. However, on subhorizontal substrates (of about 5° dip angle), both Spondylus and Atreta were observed in chaotic orientations (see pl. IV, fig. 5). While Spondylus is very rare here, Atreta is common and shows the same density as in populations on steeper slopes (see below).

2. "Slope orientation" on inclined surfaces

At Karlov locality, Spondylus sp. formed a part of a community encrusting a large gneiss boulder of the uppermost part of the conglomerate accumulation, immediately overlain by clasticstones of the Bílá Hora Formation. On slopes of minimum dip angle of ca. 10°, both Spondylus and Atreta orientate themselves preferentially, their cemented valves directed by the umboonal parts to the upper left quadrant (see pl. IV, figs. 3, 4, text-fig. 2). It is necessary to note, however, that this orientation does not originate as a response to the general slope of the substrate, but rather as a reaction to its strictly local position. For example, we can see a roughly rugged sloping surface with several specimens orientated in other and sometimes even opposite directions. However, a detailed inspection shows that every Atreta and Spondylus is orientated adequately to the local dip. On flat smooth slopes the orientation is mostly uniform.
This orientation of *Aretea* and *Spondylus* on slopes was, until the present, confirmed several times in the BCB. In accordance with Sellacher (1960), we designated it as the slope orientation (Žitt - Nekvasilová 1991, 1992, Žitt 1992). Orientations of *Dimyodon nilssoni* (Hagenow) on the steep walls of highly convex echinoid tests from the north German Upper Cretaceous (see Schmid 1949, Nestler 1965, Müller 1969, Kutscher 1971) correspond well with the above mentioned slope orientation of the Bohemian *Aretea* on the rock substrates. The identity or at least a close affinity of *D. nilssoni* to our *Aretea* sp. 2 (sensu Nekvasilová - Žitt 1988) seems to be, after all, highly probable.

*Spondylus* is a little different from *Aretea* in its relation to the overhanging surfaces. While we never found *Aretea* cemented to the overhangs (and it is very rare on vertical surfaces), *Spondylus* encrusts them commonly (see text-fig. 1). This corresponds well with the observation of Lescinsky et al. (1991, p. 137) that "spondylids are one of the few bivalves cemented to overhangs".

Measurements of *Spondylus* orientations (see rose diagram on text-fig. 2) on very steep, vertical, and overhanging surfaces of the Karlov boulder (see Nekvasilová - Žitt 1988) showed that the position of substrate in no case substantially affected them. Identical slope orientations of *Spondylus* were found on the rocky bottom of the Radim locality (Žitt 1992, pl. II, fig. 1; pl. IV, figs. 1, 2). At the Libeňnice locality, the orientations were the same both on the oblique, vertical, and overhanging silicate-rock surfaces. The majority of *Spondylus* valves occurred here, however, on boulders, the undisturbed position of which was uncertain (see Žitt - Nekvasilová 1992, fig. 7, and here pl. IV, fig. 2). *Spondylus* sp. in slope orientation was formerly found

Fig. 2. Rose diagram showing a typical slope orientation of *Spondylus* sp. valves, measured on a gneiss boulder from the Kutná Hora-Karlov locality. One sector equals to 15°, one specimen = 4 mm. Number of specimens per sector is marked. N = 43

Fig. 3. Fauna encrusting rock surface at the site No. 4, Skalka near Velim locality. For a precise location see pl. I, fig. 2. Obliquely orientated dashed line shows the bottom of a crevice. Encrusters of the crevice (dotted) were cemented to its rear wall (dashed in the section on the right). A - *Aretea*, B - *Bedeloidina*, Bu - *Bullopora*, O - indetemined oyster, S - *Spondylus*. Note that *Aretea* and *Bedeloidina* are missing on the overhangs.
also at the Skalka near Velim locality. Here, specimens rarely encrusted the steep rock walls of depressions called Václav and Veronika in the western part of the quarry (see sites Nos. 1 and 2 in table 1 and on pl. III, fig. 1).

3. Different orientations on inclined surfaces

Until now we presented here a rather uniform orientation pattern of our Spondylus specimens on the oblique, vertical and overhanging rock surfaces. Different orientations were found to be highly exceptional on our substrates (one specimen at the Radim locality - see pl. IV, fig. 1, one specimen at the Kutná Hora-Karlov locality). The break-through into this "obligatory" scheme of orientations on inclined substrates was made only due to the most recent finds at the Skalka near Velim locality (sites Nos. 3 and 4).

Spondylus sp. observed at site No.3 (see table 1 and pl. III, fig. 2) formed an interesting colony, which was, unfortunately, only fragmentarily preserved. Some specimens are orientated approximately radially, thus resembling those described by Surlyk - Christensen (1974) from the Swedish Upper Cretaceous. Colonized rock is very steep (about 60-70°), morphologically simple and deeply buried by the conglomerate filling of the depression (Veronika depression). Most important is, however, the site No. 4 located in the eastern part of the quarry, on the wall of a shallow depression, where the encrusted rock parts are covered by uppermost clasts of the conglomerate accumulation and by the overlying claystones (see pl. I, figs. 1, 2). Rock substrate highly varies morphologically, being erosively shaped into the deep and long crevices with ledges in between, and with many overhanging parts (local profiles see text-figs. 3 and 4). Text-figures 3, 4, and 5 show the valves of Spondylus on the overhangs and, in part, on vertical surface (text-fig. 4). While on the substrates in figs. 3 and 4 they have, with one exception, a typical slope orientation (see the rose diagram in text-fig. 4), the overhang in text-fig. 5 displays orientations rather different. We can see that the majority of valves is orientated by their umbonal parts subhorizontally or down to the left (see the rose diagram in text-fig. 5). We have ascertained here at least three generations of Spondylus specimens, which do not differ substantially in the position of their growth axes.

Fig. 4. Fauna encrusting rock surface at the site No. 4, close to the surface figured in text-fig. 3. P - pycnodonte oyster, W - worm, for other symbols see legend to text-fig. 3. Upper left - rose diagram of Spondylus orientations figured in text-figs. 3 and 4, N = 17. Note the absence of Atreta and Bedioidina from overhangs.
Search for orientation causes

1. History

Schmid (1949) summarized older data by Dacqué (1921) and Voigt (1929), who related the parallel orientations of cemented epibionts to the currents carrying food. When describing the preferred orientations of Ostrea vesicularis Lamarck and Dimyodon nilssonii (Hagenow) (in addition to the brachiopod Crania parisiensis DeFrance) on the dead echinoid tests from the lower Maastrichtian of Hemmoor, Schmid, however, rejected this idea. He found no parallel orientations of encrusters but, on the contrary, he found echinoid tests having current-independent pattern of the epibiont distribution and of the orientation on their sloping sides. This is what later Seilacher (1960) described as the slope orientation and what we found in the BCB on the rockgounds. Spondylus proper was mentioned by Schmid (op. cit.) as relatively rare encruster of Hemmoor echinoids and its orientation was not specified. Solitary valves of Spondylus labiatus described by Surlyk - Christensen (1974) from Ivö Klak (Upper Cretaceous of Sweden), were found cemented on the steep sides of boulders in random orientations. However, if they settled in clusters, the valves were growing radially from a centre. This orientation in clusters was advantageous for specimens preventing them from the competition for space during growth.

Seilacher (1960) considered a geotropism or phototropism as a tool for encrusting epibionts to be preferentially orientated on slopes in order to attain a position which "suits them best for gathering food and for other biological functions". These preferred orientations may have been obscured by some environmental factors, if they are very intensive (e.g., particularities of a substrate or a density of populations) and if the slope is mild. Seilacher (op. cit.) gives that rheotropism may have a similar effect, too. His conclusions about slope orientations are supported by data on various organisms (bivalves, gastropods, worms, cirripeds) colonizing bioclasts or the still living hosts.

Another example of bivalves (Placunopsis) encrusting the skeleton of living host (in this case of an ammonite shell) is provided by Meischner (1968). He gives also the geotropism or phototropism as the main mechanisms in which the preferred orientation of Placunopsis is reached. Orientation of this bivalve is not, however, on oblique or vertical shell surfaces in any way influenced by currents. Nevertheless, Meischner (op. cit.) mentions the nutritional demands as the main purpose of this preferred Placunopsis orientation. By

Fig. 5. Three parts of the rock surface roofing the cavity at the site No. 4, Skalka near Velim locality (see pl.I, fig. 2; text-fig. 6). Strong arrow - dip of the overhang. Rectangles by dotted line show encrusters figured on pl. II, figs. 1, 2, and 4. Orientation of all Spondylus valves marked by small arrows. O - indeterminable oysters, other indeterminable remains of bivalves without designation. Note absence of Atreus and Bdelloidina. Central upper part - rose diagram of Spondylus valves orientation. N = 65
this author, the oblique orientation of *Placunopsis* on substrate corresponds well with feeding from above, the posterior feeding margin being directed upwards. The same relation of feeding structures to the upward direction (against the planktic rain) was already stated by Seilacher (1954) for encrusters generally.

In some brachiopods (cranids, thecideans) oriented on sloping or vertical surfaces with their anterior commissure pointing downwards (see Schmid 1949, Seilacher 1960, Surlýk - Christensen 1974) a protection against the sediment downfall is believed to be the main cause of this position (see Surlýk - Christensen 1974, Houša - Nekvasilová 1984, 1987). On the contrary, many various factors were responsible for the orientation of thecideans as shown by Nekvasilová - Pajaud (1969) and Pajaud (1970).

Orientations of cemented bivalves were studied also by Fürsich (1979). *Aretia* occurring on the sloping parts of Bathonian hardgrounds of France is orientated preferentially with its hinge directed upwards and subordinately to the upper left quadrant. On the other hand, the examples from planar Bathonian substrates of France and England show the chaotic orientation of *Aretia* valves. *Spondylus* cemented to the sloping hardground surface (foreshore E of Luc-sur-Mer, N of Caen, Upper Bathonian) was orientated with its hinge-line parallel to the dip, i.e. perpendicular to the prevailing *Aretia* orientation of the same substrate. Unfortunately, the actual direction of the valve umbo (i.e., to the left or right) was not mentioned. Fürsich did not discuss the causes of the preferred bivalve orientations in detail. However, when interpreting the chaotic *Aretia* orientations on the horizontal surface of Bajocian rocky sea-floor from Cloford (England), he speculates about the absence of unidirectional currents in the respective environment. Preferred orientation of encrusters is thus believed to be a function of prevailing current direction.

The apparent taxonomic incongruities within the genus *Aretia* (see e.g. Schmid 1949, Žitt - Nekvasilová 1991, and Hodges 1991) and *Spondylus* should be taken into consideration in detailed comparisons of bivalve orientations from the localities of different ages. *Aretia*, described from the Lower Cretaceous of Stramberk (Moravia) by Houša - Nekvasilová (1984), orientated on steep rock walls of fissures similarly to the thecideans mentioned above, represents also the species (or the genus) rather different from those of the Upper Cretaceous Bohemian localities. The same might be true as regards the Bathonian (see above) and Upper Cretaceous *Spondylus* representatives.

2. Discussion on the Bohemian material

Reaction of settling *Aretia* to strictly local slope of the attachment place and not to the general slope of the substrate as well as the identical slope orientations on differently directed surfaces of the same substrate (see text-fig. 1) show, that we may reject the idea on the induction of slope orientation by currents, similarly as did Schmid (1949) for *Dimyodon nilssonii*. The same holds for the majority of our *Spondylus* sp. specimens on sloping, vertical or overhanging substrates where they are orientated identically to *Aretia*. Except for the specific angle of slope, no other substrate features seem to provoke the preferred orientation of both *Aretia* and *Spondylus*. For that reason, we tentatively follow Seilacher's (1960) wide idea on the relevance of this orientation to the best feeding and other biological functions. We do not suggest the reflection of sediment downfall in these orientations, because of probable high tolerance to sedimentation (bivalves encrusting the elevated rocky bottom parts were apparently successful also during clay sedimentation in the surrounding more depressed areas). The same holds for *Aretia*, but yet emphasized by its isochronous rich encrusting of pla-

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Fig. 6. The notch eroded in rock elevation and filled with sediments at site No. 4, Stalká near Velmá locality. 1 - gneiss, 2 - conglomerates with lithologically varied, variously coloured matrix, 3 - overlying claystones filling also the cavity (C) and uppermost last intertacies. Black triangles on clasts - epibions (mostly oysters and rarely *Aretia* and *Spondylus*) from the period of last transportation and reworking. White triangles - younger phase of in situ colonization. Left arrow - direction of water penetrating the clast barrier into the cavity prior to and during clay sedimentation. Small parallel arrows - orientation of *Spondylus* sp. on the cavity roof. Note the oblique orientation of this surface strike to the barrier.
nar surfaces under otherwise identical sedimentary conditions.

Looking for an explanation of "anomalous" Spondylus orientations (see text-fig. 5), we had to rely only upon the particularities of strictly local microenvironment. Text-fig. 6 shows a schematic reconstruction of a small cavity found at the site No. 4 of the Skalka near Velim locality, that was formed by partial filling of a rock notch by a coarse psephite and by contemporary or subsequent separation of remaining free notch space from the surroundings by large clasts. During the following sedimentation of claystones, these clasts functioned as a type of barrier. Inside the cavity roofed by the overhanging rock wall, the sediment is distinctly, even though irregularly (the barrier was only partial) impoverished in bioclasts in relation to the sediments outside the barrier. This shows the microenvironment of the cavity as substantially calmer at the beginning of clay sedimentation. Atreta occurring on the cavity bottom clasts shows the slope orientation demonstrating well their in situ position till the present. This bivalve could obviously live there only before the accumulating claystones covered their substrates. (Atreta colonized the clasts also during their preceding transportation phases but these specimens can be mostly easily distinguished from those mentioned above.) In situ encrustation by Atreta and Bdelloidina has been ascertained also on the uppermost conglomerate clasts situated outside the cavity and, moreover, on clasts sheltering the mouth of the cavity.

When speculating about the timing of encrustation of the cavity roof by Spondylus, we noted different preservation of identically orientated valves. However, even the worse preserved ones demonstrate rather non abrasive wear (slight chemical dissolution, desquamation). Destructions of some specimens could have been also caused by falling away of small highly micaeous substrate parts (encrusted surfaces more or less coincide with foliation planes of paragneiss substrate, where mica is concentrated). Spondylus could thus colonize the cavity roof even under the conditions of partial side closure of the cavity by clasts, which prevented epibionts from stronger abrasion. This analysis has shown that the main feature distinguishing the studied part of the site No. 4 at Skalka near Velim from all the others is just the presence of a barrier and the existence of a type of semicryptic environment behind it. An oblique position of cavity roof strike relative to the barrier direction seems to be also very important (see text-fig. 6). So, if the "anomalous" orientation of Spondylus on the cavity roof is considered in this context, we can see that the posterior parts of valves (i. e., those parts that are directed upwards in usual slope orientations) are directed just to the barrier of clasts closing partially the cavity entrance. Through this barrier the cavity communicated with the exterior water environment. Thus, the "anomalous" orientation of Spondylus could have developed as a response to the influence of modified local hydrologic regime combined with a special position of the substrate.

The identity of orientations of all generations (at least 3) and the reached adult dimensions of some specimens confirm a relative prolongation (we suppose 10 or more years) of the whole encrustation period of the cavity. As mentioned in General notes to Spondylus (see above), the Spondylus valves found in sediments surrounding the encrusted rocks, are very fragmentary. This holds also for those found in the filling of the cavity. We suppose that these fragments, variously worn, were transported from the cavity exterior and derived from another and not just the studied part of population. In the sediments outside the cavity these fragments are yet richer. In our opinion, if Spondylus had inhabited the cavity during sedimentation, its not very damaged upper (left) valves would have been present in the cavity filling. As such valves are missing in this filling, we suppose that the majority of Spondylus specimens colonized the cavity before the beginning of clay sedimentation, when the bidirectional penetration of water through the clast barrier was not yet decreased by new sedimentary fillings and the bioclasts were possibly easily removed from the cavity. For this we suppose stronger currents, as opposed to the following period of clay sedimentation. However, even under these calmer conditions, the rocks of the sea bottom in the nearshore facies of the BCB were still abundantly colonized by Spondylus sp., which was possibly limited only by the advancing clay sedimentation over their substrates (see e.g., upper rock parts of the Velim site No. 4 - text-figs. 3 and 4, or the majority of other occurrences summarized in table 1). This is also true for other species of Atreta-Bdelloidina community.

An extraordinarily rare find of a cluster of Spondylus valves which show a partial radial orientation (site No. 3 at Skalka near Velim) was discussed above (see e.g. the section on different orientations).

Summary of results

Close inspection of so far known occurrences of the bivalve Spondylus sp. encrusting the rocky substrates in the nearshore facies of the upper Cenomanian-lower Turonian of Bohemia provided new interesting data on the growth orientation of cemented organisms. Two types of substrates were studied, namely the rocky bottom and large boulders. Geological sections at four localities were examined, the Kutná Hora-Karlovy and Skalka near Velim being the most important.

Spondylus sp. formed a part of two successive faunal encrusting communities, i.e., of an oyster and following Atreta-Bdelloidina communities. Spondylus and Atreta were found to be chaotically orientated on subhorizontal surfaces, while on slopes of at least c. 10° dip angle they are orientated preferentially. In this
case, the umbonal parts of cemented valves are directed to the upper left quadrant. *Spondylus* is rare on horizontal or subhorizontal surfaces, but both genera are frequent on the inclined ones. *Spondylus* is common also on vertical and overhanging surfaces, while *Arreta* is rare on the former and completely missing on the latter substrates. In accordance with Sellacher (1960), we designated the above mentioned type of *Spondylus* and *Arreta* orientations on more inclined substrates as the slope orientation. A detailed inspection of these bivalves' orientation has shown, however, that it was not a general slope of the substrate, but only a strictly local position of the place of settlement which raised their respective orientation response. When interpreting the causes of this preferred orientation, we tentatively consider them, in accordance with Sellacher (1960), to be a result of food-gathering needs and providing of other biological functions. On the basis of identical *Spondylus* (and *Arreta*) orientations on differently directed sloping surfaces of the same substrate (sides of boulders, walls of rock elevations) we rejected possible induction of this behaviour by currents. However, we are convinced of an urgent need for further special studies, mainly the actualistic ones, to elucidate the problem of preferred orientations in detail.

At the Skalka near Velim locality, we recently found another, rather modified types of *Spondylus* orientations. The first one is represented by a cluster of valves, which show an arrangement resembling that described by Surylk - Christensen (1974). The valves are directed approximately radially to a centre of the cluster by their umbos and grew to the periphery, not disturbing by their cluster.

Of greater importance is, however, a find of an encrusted rock surface where *Spondylus* settled in a rather modified slope orientation, with cemented valves directed by their hinge parts horizontally to the left or, mostly, down to the left. A colony of *Spondylus* encrusted the roof of a small cavity, which was sheltered from the surroundings by a partial cliff barrier. Special interior conditions of the cavity offering a communication with the exterior environment prevailingly only through the barrier, and rather wide angle between the strike of the encrusted surface and this barrier caused probably the changed orientation of settling specimens. Under these conditions, they orientated themselves with their posterior margins to the barrier. Later on, most probably postmortally in relation to the *Spondylus* colony, the cavity was gradually filled with calcareous claystone, covering also *Arreta* specimens encrusting the cavity bottom. The same community continued, however, in encrusting the exterior rock substrates until these were completely covered by sediments of the Bílá Hora Formation.

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Orientace misek rodu Spondylus, přítomelných k pevným horninovým substrátům 
(Bivalvia, svrchní křída, Čechy)

Misek rodu Spondylus tvořili významnou složku společenstev, inkrustujících povrchy skalního mořského dna a balvanů v sedimentačním 
prostředí příběžného vývoje českého svrchního cenomanu-spodního turonu (korycké vrstvy, bazální část bolomorckého souvrství). Na 
subhorizontalně povrchy klastů a dna se Spondylus sp. přitomeloval v libovolné orientaci (chasticky), podobně jako měsí rodu Arrota. Na 
substrátech se sklonil okolo 10° a větším však již oba rody vykazují přednostní, tzv. svahovou orientaci (slope orientation). Přítomelné 
miseky směřují svými vrcholy do levého horního kvadrantu. Svahové orientace patrně nejlépe vyhovuje požadavkům na přijem potravy 
a zajištění ostatních biologických funkcí (Seilacher 1960) a necož závisí na směru vodního proudu. Na případu osidlení převážného 
stromu častěji uzavřené skalní dutiny byla však z lokality Skalka u Velimi popsána přidomí orientace rodu Spondylus, jež je známo 
modifikované. Tato orientace byla zjevně reakcí právě na specifický hydrologický režim dutiny.

V praxi je dále popsán výskyt fragmentárního shluhu jedinců se zřídka radilní orientaci misek a diskutovaly jsou i některé příkazy 
přednostních orientací měsíků a brachiopodů zmíněné z literatury. V případě jsou též shromážděny výskytu misek rodu Spondylus přítomelných 
k pevným horninovým substrátům, dosud zjištěné v české křídě.
J. Žitt - O. Nekvasilová: Orientation of *Spondylus* valves cemented to the hard-rock substrates... (Pl. I)

For explanation see p. 295
J. Žitt - O. Nekvasilová: Orientation of Spondylus valves cemented to the hard-rock substrates... (Pl. II)
J. Žitt - O. Nekvasílová: Orientation of *Spondylus* valves cemented to the hard-rock substrates... (Pl. III)
J. Žit - O. Nekvasilová: Orientation of *Spondylus* valves cemented to the hard-rock substrates... (Pl. IV)
Explanation of plates

Plate I
1. Skalka near Velim, eastern part of the quarry. Depression in the rocky sea bottom filled with Cretaceous sediments, eastern view. Dashed line - surface of rocky bottom, dotted - boundary between conglomerates (cg) and claystones (cl). c- cavity with Spondylus sp. forming a part of the site No. 4.
2. Southern view of the site No. 4 at Skalka near Velim (see fig. 1 of this plate). cg - conglomerates with some clasts sheltering the mouth of the cavity (2) with Spondylus sp. cl - claystones filling the cavity and covering upper parts of the rock elevation with epibionts. 1 - location of surfaces figured in text-figs. 3 and 4, 2 - location of surface figured in text-fig. 5. Photos J. Žitt, 1993

Plate II
1-4. Spondylus sp. attached to the roof of the rock cavity at the site No. 4, Skalka near Velim (see pl. I, text-fig. 5). For the dip of the surfaces see text-fig. 5. 1-3.0x, 2-1.6x, 3-4.1x, 4-1.9x. Photos J. Žitt

Plate III
1. Skalka near Velim, western part of the quarry. Two large depressions in the rocky sea bottom. Left - depression Václav, right - depression Veronika (eastern view). cg - conglomerate, cl - claystone. 1, 2, 3 - sites Nos. 1, 2, and 3 with the occurrence of fauna encrusting the rock. Site No. 2. destroyed by quarrying. Photo J. Žitt, 1991
2. Detailed view of site No. 3 (see above). Orientation of attached Spondylus valves marked by small arrows. Large scale - 1 bar equals to 5 cm, small scales - 1 bar equals to 1 cm. Photo J. Žitt, 1986

Plate IV
1. Spondylus sp. (s) and a pycnodonte oyster (p) on the rock surface at the Radim locality. The dip of substrate marked by long arrows, orientation of Spondylus valves by short arrows. The left Spondylus attached in a slope orientation, the right one in a different orientation. The length of the match is ca. 4 cm. Field photo J. Žitt, 1988
2. Spondylus sp. attached to a siliceous boulder from the Libeznice locality. Original position of substrate unknown but specimen situated as if in a slope orientation. 2.1x. Field photo J. Žitt, 1988
3-5. Encrusters of a gneiss boulder from the Kutná Hora-Karlov locality. 3 - strongly inclined surface with Spondylus (s) and Atreta (a), both in a slope orientation (see arrows). 1.4x. 4 - Spondylus in a slope orientation on another part of the same substrate. 1.3x. 5 - Spondylus (s) and Atreta on a subhorizontal surface. Note chaotic orientation of valves. 1.6x. Field photos J. Žitt, 1985

Field photos J. Žitt, 1985
Nový vydání mezinárodních zásad stratigrafické klasifikace


Tato síce zdolhavou, ale cílevědomou práci se během posledních šestnáct let podařilo získat rozsáhlost a množství kontroverzní materiál, který jistým způsobem odráží "obecně míněný" v otázkách stratigrafické klasifikace, zejména v konfrontaci s příslušným vydáním International Stratigraphic Guide (1976). Tento materiál byl pak použit k připravě druhého vydání, kde pod titulem International Stratigraphic Guide a guide to stratigraphic classification, terminology, and procedure, vydala v r. 1994 v koprodukci Mezinárodní unii geologických věd (IUGS) a Americká geologická společnost (Geological Society of America, Inc.).

Protože již před vydáním "Guidu" závodně ovítilo praktické uplatňování stratigrafických klasifikací principů a výrazně přispělo k i jejich světové integraci (příkladem jsou i čs. zásady z r. 1978), je s podobným vlivem pocítit i u vydání druhého. Proto je účelné upozornit na některé jeho aspekty.

Téba zdůraznit, že nové vydání nepřísluší zásadní změny v klasifikacích principů a hlavních kategorií stratigrafických jednotek (litosтратigrafické, biostratigrafické a chronosтратigrafické jednotky). Nově jsou však přidány i jednotky omezené diskordančemi (Unconformity-bound Units) a jednotky magnetostratigrafické (Magnetostratigraphic Polarity Units). Text je v mnohem přestylován a doplněn, což se týká např. jednotek biostratigrafických.

V obecných kapitolách o principcích klasifikace, definicích, procedurách vymezení jednotek a o stratotypích je jen malo změn. Zásadky potvrzovat jako podloží plněnosti nově vymezených jednotek nesluší publikace v uznávaných vědeckých médiích, k nimž např. nepatří lokální exkurzní práce s omezenou cirku- lací nebo abstrakty publikace či komerční tisky. Nové vydání potvrzuje omezení zásady priorit (zřejmě priorit není sama o sobě důvěru ke změnám běžně užívaných názvů jednotek). V kapitole o stratotypích je zvrácená význam standardních definic, hraničních stratotypů a referenčních profilů (reference sections), a to i u jednotek biostratigrafických. Role typických lokálí je nezastupitelná i u těch vyvřelých hornin a v metamorfovaných souborech klasifikováných jako stratigrafické jednotky.

K hierarchicky seřazeným litosтратigrafickým jednotkám (Group, Formation, Member, Bed) je nově zařazen Flow, tj. proud jako nejmenší definována část ve vulkanickém slodu. V litos Stratigrafická klasifikace je potvrzena zásada užívání v názvech jednotek pouze jednoduché, v terénu aplikovatelné litologické termínologie a napak je zdrožena nevzhodnost genetických, strukturních nebo morfologických termínů (např. žlba, diapýr, batolit).

V nově vězené kapitole o jednotkách omezených diskordance- mi je pro založení jednotky doporučen název systém (Synhem), jehož nápis je analogický s ale stratigrafickými jednotkami amerického stratigrafického kódu (1983). Při současném trendu sekvenční stratigrafie má však systém jen malou nadíl na skutečné vztahy.

Kapitola o biostratigrafických jednotkách dozvolila značných sty- listických změn. Základním termínem zůstala biostratigrafická zóna (biozóna) a jednotlivými základními čluny (Range Zone, Interval Z., Lineage Z., Assemblage Z., Abundance Z). Vyměněn byl pojem Op-