

The cidaroids from the Middle Oxfordian St-Ursanne Formation of the Swiss Jura Mountains

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Abstract

Since the 19th century the echinoid fauna in the St-Ursanne Formation of the Swiss Jura Mountains has been neglected. Therefore the alpha taxonomy of the group is revised here. Particular attention is accorded to representatives of *Cidaroida* Claus, 1880. A further key issue of this study is the correlation of the lithofacies and the cidaroid species associated with this facies. In the coral reef, the reef debris, and the lagoonal facies of the St-Ursanne Formation five cidaroid taxa can be recognized. These can be assigned to the four genera *Paracidaris*, *Diplocidaris*, *Rhabdocidaris*, and *Plegiocidaris*. Amongst these five taxa is one new species, namely *Diplocidaris bernasconii* sp. nov.

Keywords

Middle Oxfordian, Jurassic, St-Ursanne Formation, Buix Member, Chestel Member, coral reef facies, coral reef debris facies, lagoonal facies, Swiss Jura Mountains, *Cidaroida* Claus, 1880.

Zusammenfassung

Die Cidaroiden des Mittleren Oxfordien der St-Ursanne-Formation im Schweizer Jura.- Seit dem 19. Jahrhundert wurde die Echiniden-Fauna der St-Ursanne-Formation im Schweizerischen Jura vernachlässigt. Aus diesem Grund enthält diese Arbeit eine Revision der Alphataxonomie. Dabei wurde ein spezielles Augenmerk auf Vertreter von *Cidaroida* Claus, 1880 gelegt. Ein Kernpunkt dieser Arbeit ist die Korrelation der Spezies der gefundenen Echiniden mit den jeweiligen Lithofazies der Grabungsstellen. In der Lagunen-, der Korallenriff- und der Riffschuttfazies der St-Ursanne-Formation wurden fünf verschiedenen Taxa ausgeschieden. Diese können den Gattungen *Paracidaris*, *Diplocidaris*, *Rhabdocidaris* und *Plegiocidaris* zugeschrieben werden. Darunter ist auch eine neue Cidaroiden-Art: *Diplocidaris bernasconii* sp. nov.

Schlüsselworte

Mittleres Oxfordien, Jura, St-Ursanne-Formation, Buix-Member, Chestel-Member, Korallenfazies, Korallenriffschuttfazies, lagunäre Fazies, Schweizer Jura, *Cidaroida* Claus, 1880.

1. INTRODUCTION

The Jura Mountains mark the north-western border of Switzerland to France. A 1000 to 2000 m thick sequence of sediments is exposed in this region that is primarily composed of fossil-rich, carbonaceous sediments from the Mesozoic (Pfiffner, 2010). During much of the Late Jurassic, a carbonate platform with coral bioherms existed in this region that was connected to the Tethys in the southeast (Gygi & Persoz, 1986) and provided good living conditions for echinoid echinoderms. The coral reef and the reef debris facies of the Buix Member of the St-Ursanne Formation in particular yielded a broad diversity of representatives of the basal clade *Cidaroida* Claus, 1880.

The first comprehensive reviews of the echinoid fauna from the Late Jurassic portions of the Jura Mountains were provided by L. Agassiz (1840) and E. Desor (1858). Faunas of equivalent age were soon after described from France (e.g. Cotteau, 1884), Germany (e.g. Quenstedt, 1885), and England (e.g. Phillips, 1829; Wright, 1857). As collecting had not yet yielded many remains at this point, the vast majority of taxa were originally based on single coronas, isolated spines, or poorly preserved fragments (e.g. *Diplocidaris desori* Wright, 1857). The initial echinoid taxonomy, established over the course of the 19th and early 20th century, was therefore highly unstable, as it was mostly based on incomplete or undiagnostic type material. Aggravating the situation, many type specimens cannot be tracked anymore,

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making it impossible to clarify the validity of the species they represent (Vadet, 1988). Although the taxonomy of cidaroids from the Oxfordian and Kimmeridgian of Europe was partially revised over the course of the last decades (e.g. Vadet, 1988; Hess, 1975; Smith, 2015), Hostettler & Menkveld-Gfeller (2015) noted that a comprehensive revision of Jurassic echinoids is still pending.

Over the course of the last decades, much new cidaroid material was collected in the Swiss Jura Mountains by the Fondation Paléontologique Jurassienne (FPJ) and the Natural History Museum of Bern (NMBE) that provides further insights into the taxonomy and biostratigraphy of Late Jurassic cidaroids, particularly from the Middle Oxfordian St-Ursanne Formation. The primary purpose of this contribution is to describe these remains and to re-evaluate their taxonomy and stratigraphic distribution. This study furthermore aims to investigate habitat preferences by searching for correlations between particular lithofacies with certain taxa.

This study contributes to a series of papers that aim at providing a comprehensive description of the litho- and biostratigraphy of the Swiss Jura Mountains (Hostettler,

2006; Hostettler & Menkveld-Gfeller, 2015; Gründel *et al.*, 2016; Hostettler *et al.*, 2017).

2. LITHOSTRATIGRAPHY

Oxfordian (Late Jurassic) sediments, exposed in the Jura Mountains in the north-western part of Switzerland, have traditionally been subdivided into three successive lithostratigraphic units, the Middle Oxfordian Bärschwil and St-Ursanne Formations, and the Late Oxfordian Vellerat Formation (Bolliger & Burri, 1970; Gygi, 2000). The facies developed in this carbonaceous sequence have complex temporal and spatial relationships relative to one another. Many names have therefore been proposed for various lithostratigraphic units over the course of the last two centuries, which have only been synonymized recently (see Gründel *et al.*, 2016 for summary). Following the recently established consensus, the St-Ursanne Formation is subdivided into four members, of which the Buix and Chestel Member are of significance to this study (see Figs 1, 2). The Buix Member consists mainly of oosparites, biosparites, biomicrites and some

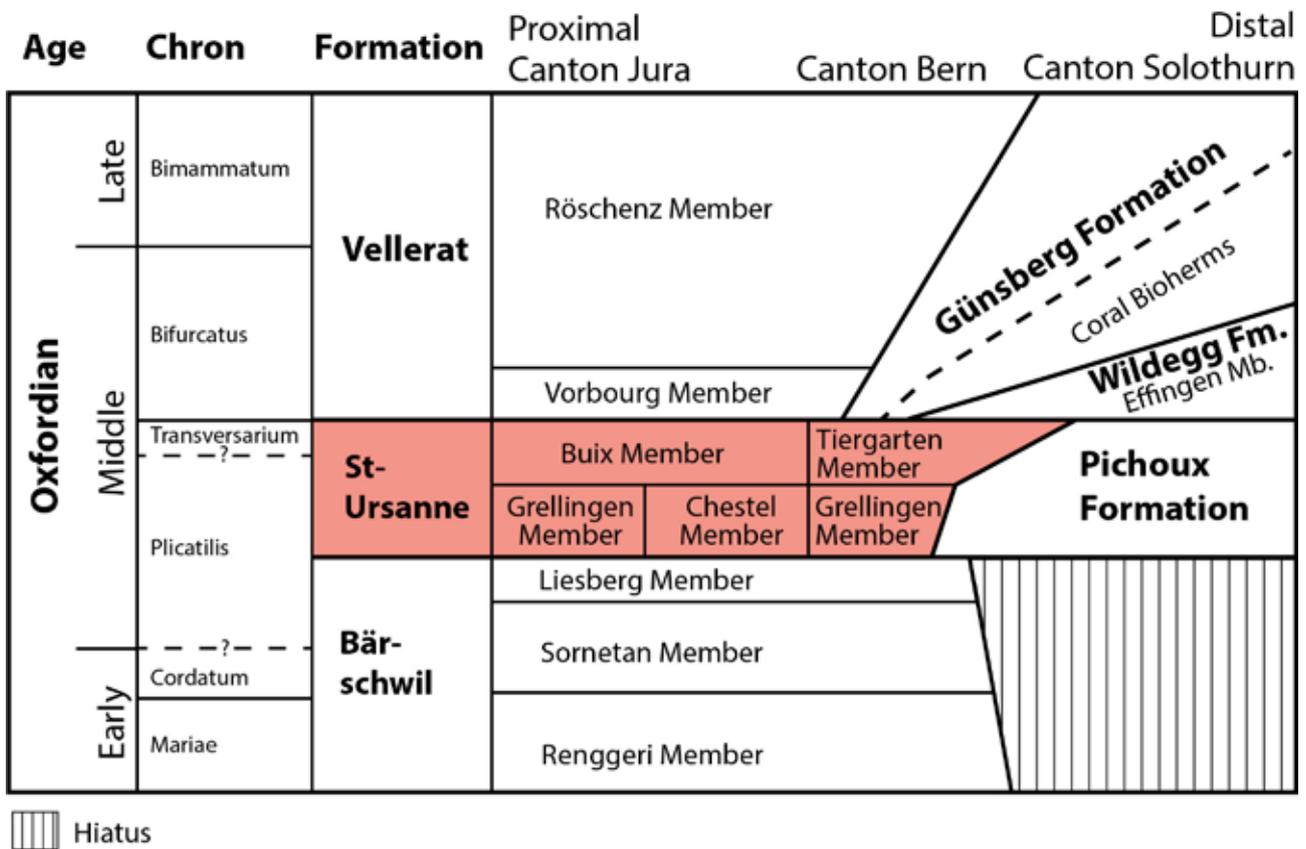


Fig. 1: Chronostratigraphic positions of the formations and members of the Oxfordian in the area of the Swiss Jura Mountains. The figure shows the variation in terminology of the formations and members from northwest (Canton of Jura) to southeast (Canton of Solothurn). Marked in red: St-Ursanne Formation. Proximal and distal refer to the position along the shelf. Modified after Gygi (2000) with additional data on chrono-/ biostratigraphy of Gründel *et al.* (2016).

rare micrites (Fig. 2 and Gründel *et al.*, 2016) that were deposited in lagoons or areas with coral patch reefs and the associated reef debris. The beige-white to pure white limestone can be described as massive and variably porous (Gygi, 2000). In some places, the native rock is very chalky and can therefore easily be pulverized by hand. The Chestel Member is mainly a carbonate oolite that is commonly interspersed by coral bioherms (Gygi, 2000). A more common feature of this member are oncoids, which range in size from 2 mm to 2 cm.

3. MATERIAL AND METHODS

3.1. Field Work

The fossil material studied herein was collected at ten different sites in the Swiss Jura Mountains of the cantons of Jura (JU), Basel Landschaft (BL) and Solothurn (SO), over the course of the last two centuries (see Fig. 3). The Swiss (LV03) and the international coordinates of these sites are as follows:

- #1. Hasenburg near Soyhières, JU, 2°596 950/1°249 075; N 47° 23' 33" E 7° 23' 54".
- #2. Roggenburg Rieij, BL, 2°592 152/1°253 573; N 47° 25' 52" E 7° 20' 05".

- #3. Zwingen Sunnerai, BL, 2°605 628/1°254 312; N 47° 26' 22" E 7° 30' 48".
- #4. Kleinlützel Debris Pit, SO, 2° 596 234/1°253 488; N 47° 25' 57" E 7° 23' 21".
- #5. La Caquerelle, Excavation Site, JU, 2°582 764/1°247 147; N 47° 22' 30" E 7° 12' 38".
- #6. La Caquerelle Roche au Vilain, JU, 2°582 909/1°246 704; N 47° 22' 16" E 7° 12' 44".
- #7. St-Ursanne Fabrique de Chaux, JU, 2°579 519/1°246 377; N 47° 22' 4" E 7° 10' 3".
- #8. St-Ursanne Highway, JU, 2°580 089/1°246 593; N 47° 22' 12" E 7° 10' 30".
- #9. Tariche, JU, 2°576 801/1°241 875; N 47° 19' 38" E 7° 7' 54".
- #10. Césai, St-Brais, JU, 2°574 943/1°239 862; N 47° 18' 32" E 7° 6' 26".

As the majority of the fossils are either fully or partially prepared, lithostratigraphic sections were measured at all available outcrops as a way to assess the lithofacies from which the fossils originated. The outcrops that are still exposed and directly accessible are the following: Hasenburg near Soyhières (Fig. 3, #1), Roggenburg (Fig. 3, #2), St-Ursanne Highway (Fig. 3, #7), and St-Ursanne Fabrique de Chaux (Fig. 3, #8). In each case, one lithostratigraphic section was measured. The observation

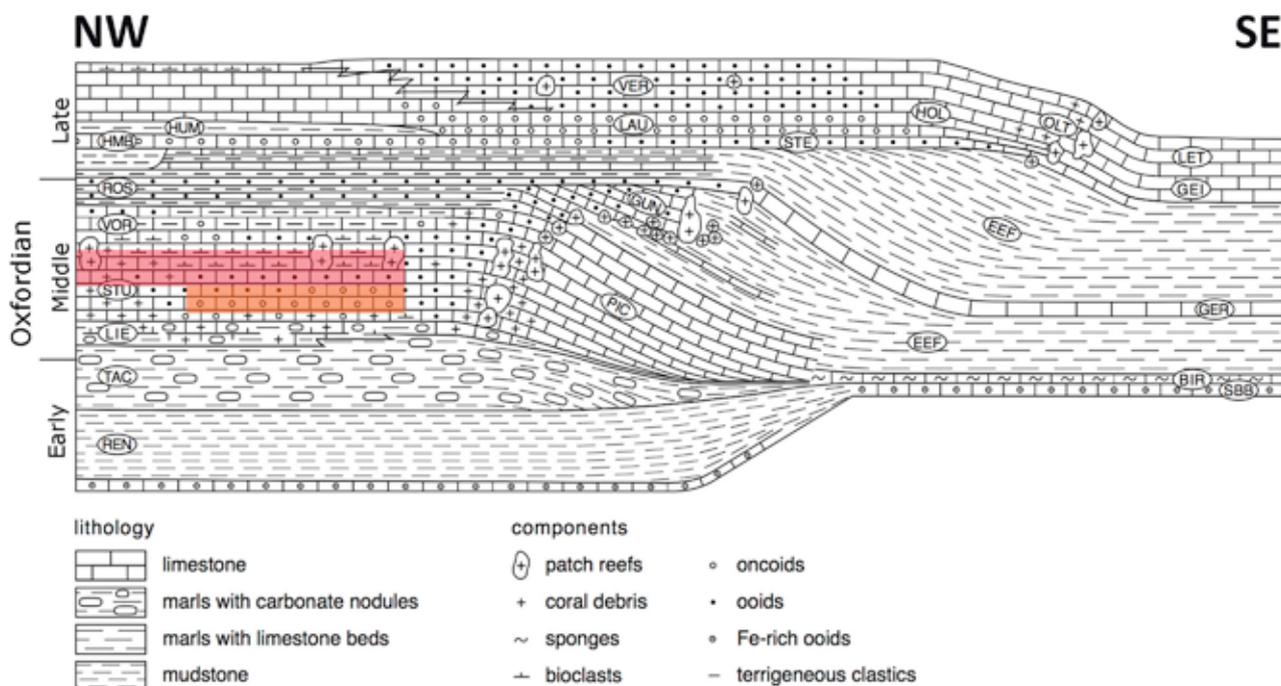


Fig. 2: Schematic cross-section from northwest to southeast highlighting the geometry and correlation of Oxfordian sediments in north-western Switzerland (modified after Wetzel & Strasser, 2001). Marked in red: Bux Member; marked in orange: Chestel Member. Tags refer to stratigraphic units (in alphabetical order): BIR Birmenstorf Mb., EFF Effingen Mb., GEI Geissberg Mb., GER Gerstenhübel Beds, GUN Günsberg Fm., HMB Hauptmumienbank Mb., HOL Holzflue Mb., HUM Humeralis Mb., LAU Laufen Mb., LET Letzi Mb., LIE Liesberg Mb., OLT Olten Beds, PIC Pichoux Fm., REN Renggeri Mb., ROS Röschenz Mb., SBB Schellenbrücke Bed, STE Steinebach Mb., STU St-Ursanne Fm., TAC Terrain à Chailles Mb., VER Verena Mb., VOR Vorbourg Mb.

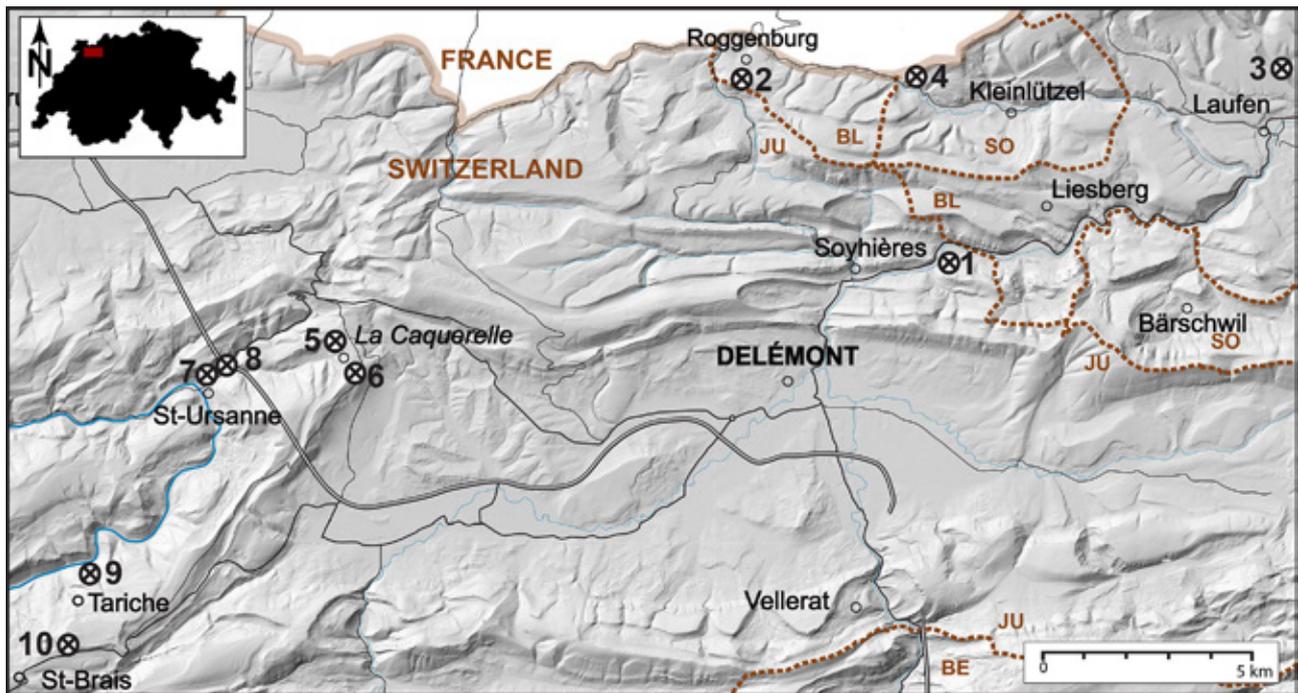


Fig. 3: Geographic location of the sites that yielded the fossil material from northwest Switzerland used herein. The site names are provided in the text. Abbreviations: BE: Canton of Bern; BL: Canton of Basel-Landschaft; JU: Canton of Jura; SO: Canton of Solothurn.

of parameters such as lithology, bedding, fossil content, general rock consistency, and weathering led to an initial interpretation of the bio- and lithostratigraphy of the respective site. On the basis of thin sections the initial determination of the lithofacies was then refined. Since the collecting by the Fondation Paléontologique Jurassienne (FPJ) was carried out levelled, the exact find spots of the old material could be linked to the newly surveyed sections. Furthermore, this work also yielded new fossil material for which the associated lithofacies could be determined objectively.

3.2. Material

The fossil material examined in this study is part of the collections of the Natural History Museum of the Burgergemeinde Bern (NMBE) in Bern, Switzerland, the Fondation paléontologique jurassienne (FPJ, specimens housed at the Natural History Museum in Bern), the Natural History Museum of Basel (NMBS) in Basel, Switzerland, the Jurassica Museum (formerly the Musée jurassien des Sciences naturelles, MJSN) in Porrentruy, Switzerland, and the Naturhistorisches Museum Wien (NHMW) in Vienna, Austria.

The fossil material that was collected during fieldwork was prepared at the Natural History Museum in Bern using pneumatic chisels and the sand blasting technique using sodium bicarbonate. In order to achieve a better

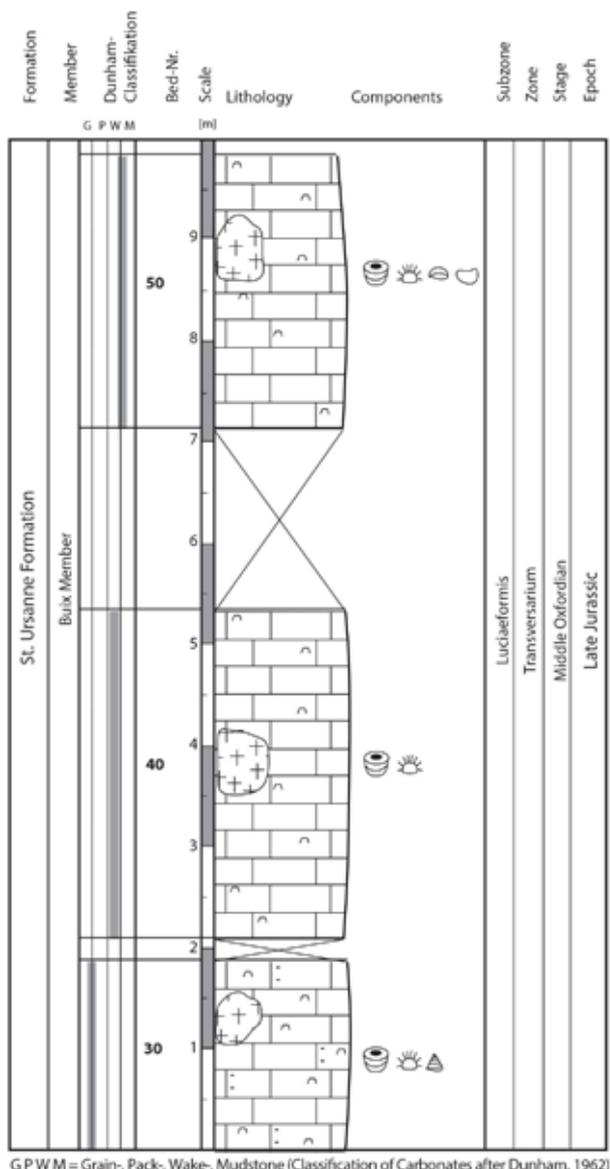
contrast, most objects were coated with Ammonium chloride prior to photography.

4. RESULTS

4.1. Bio- and lithostratigraphic sections

Hasenburg near Soyhières, Buix Member: The sediments of the lithostratigraphic section at Hasenburg near Soyhières were deposited in a coral reef (see Fig. 4). Isolated colonies are spheroid and have a diameter of up to 60 cm. The matrix is sparitic at the base of the section (bed 30), but is gradually replaced by a purely micritic matrix towards the top of the section. The biogenic components in bed 30 are mostly rounded. From the base to the top, the fauna becomes more abundant and the size of the corals increases. There is only a slight difference between bed 40 and 50. The Dunham classification of bed 40 (wacke- to packstone) indicates a somewhat higher energetic depositional environment than that of bed 50 (mudstone). Furthermore the fossil content of the latter is more abundant and the biogenic components are larger. The fossil material that was collected historically at this outcrop derives mainly from bed 50. Continuous collecting along this layer over the course of the years resulted in the formation of a shallow cavern. On the right side of this cavern, a branched coral colony, which is 189 cm long, protrudes from the wall. At this

outcrop, fossil echinoids of the species *Acrocidaris nobilis* (Agassiz, 1840), *Hemicidaris intermedia* (Fleming, 1828), *Gymnocidaris lestocquii* (Desor, 1858), and *Paracidaris florigemma* (Phillips, 1829) are well represented.



G P W M = Grain-, Pack-, Wake-, Mudstone (Classification of Carbonates after Dunham, 1962)

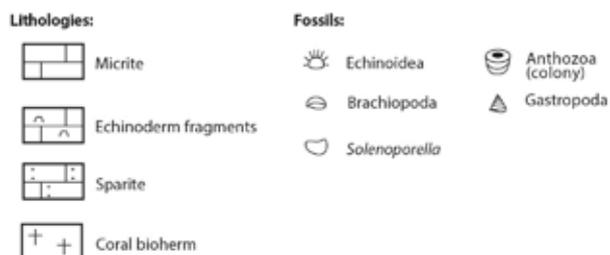


Fig. 4: Lithostratigraphic section through a part of the Buix Member of the St-Ursanne Formation at the outcrop in Hasenburg near Soyhières. Swiss coordinates (LV03): 2°59' 950/1°24' 075.

Roggenburg, Buix Member: In the lower part of the exposed sequence in the quarry in Roggenburg, the rocks consist mainly of mud- and wackestones (Fig. 5a, b). Therefore the sediments are interpreted as having been deposited in the rather calm environment of a muddy lagoon behind a protecting coral reef. Whereas bed 20 is biomicritic and contains mostly gastropods, bed 30 is micritic and poorly fossiliferous. Therefore the rocks of bed 30 are commonly called “leerer Kalk” (empty limestone). From bed 40 to 80, the abundance and size of biogenic components increases. The first evidence for the existence of corals can be found in thin sections of the base of bed 50. Branched coral colonies are present in bed 70 and 80. Due to the presence of sparite and fragmented fossils, the latter two are interpreted as storm deposits, which yielded several individuals of *Hemicidaris intermedia* (Fleming, 1828) with articulated spines. The fact that the spines are articulated indicates a rapid in-situ burial of these sea urchins. In addition to *H. intermedia*, species that are mainly known for lagoonal environments were recorded at this outcrop [e.g. *Pseudodiadema pseudodiadema* (Lamarck, 1816), *Pseudodiadema orbignyianum* (Cotteau, 1851), *Phymechinus mirabilis* (Agassiz & Desor, 1846-1847), and *Pygaster gresslyi* (Desor, 1842)]. The fauna in beds 70 to 90 is notably diverse (i.e. echinoderms, corals, gastropods, bivalves, brachiopods), though less abundant towards the top. According the classification of Dunham (1962), bed 70 and 80 are pack- to grainstones, and bed 90 is a wackestone. Therefore, bed 90 is interpreted as having been deposited in a slightly calmer environment than the beds below.

Kleinlützel, Buix Member: Between the 1980s – 2000s members of the FPJ conducted excavations in the quarry in Kleinlützel and collected a lot of fossil material. Unfortunately this part of the outcrop is not directly accessible anymore nowadays (see Fig. 6; red boxes). The bed, where the fossil material derives from, bears isolated patch reefs and widely distributed coral biostromes. In comparison to Soyhières the bioherms in Kleinlützel are larger. Besides the big isolated patch reefs the sequence comprises only reef debris.

St-Ursanne Fabrique de Chaux, Buix Member: Gründel *et al.* (2016, fig. 4a-b) published the lithostratigraphic section of the type locality that is situated at the old lime factory (Fabrique de Chaux) in St-Ursanne (see Fig. 7). The oosparitic Chestel Member, which underlays the Buix Member, crops out along the path that leads to the main adit. The base of the lithostratigraphic section is set right on top of the Chestel Member, which is located below the workshop of the lime factory (see Fig. 7, red arrow).

The rocks at the lime factory in St-Ursanne were mainly deposited in a relatively calm lagoon, as is indicated by the presence of mud- to wackestones (see Gründel *et al.*,

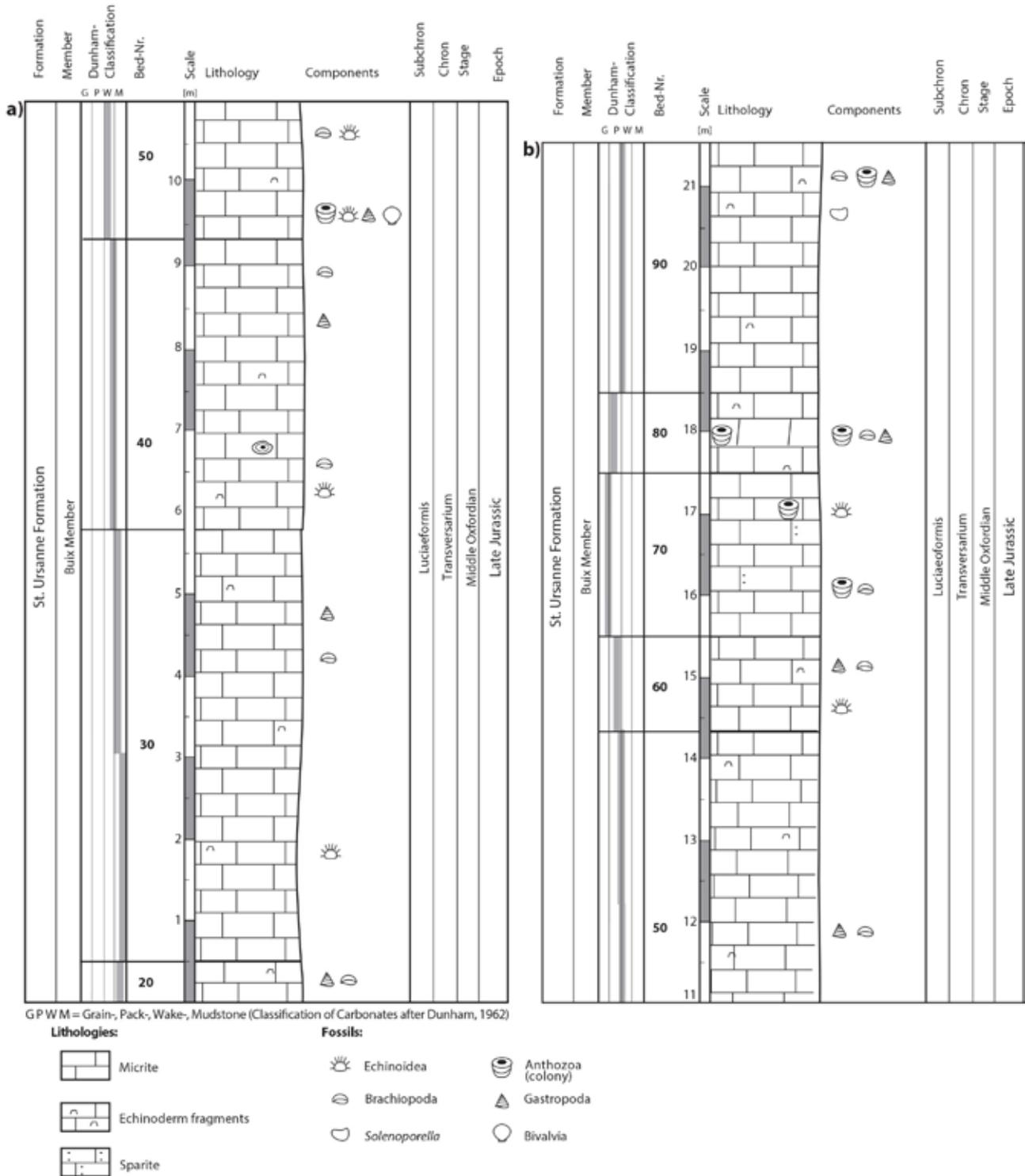


Fig. 5a, b: Lithostratigraphic section through a part of the Buix Member of the St-Ursanne Formation in the old quarry in Roggenburg Rieji (BL); lower part a and the upper part b. Swiss coordinates (LV03): 2'592 152/1'253 573.



Fig. 6: Photograph of the outcrop in Kleinlützel. The section can be attributed to the Buix Member of the St-Ursanne Formation, situation in December 2015. Red boxes: Actual points of origin of the fossil material; 1: *Paracidaris florigemma* (Phillips, 1829); 2&3: *Diplocidaris bernasconii* sp. nov. Scale: 10 m. Swiss coordinates (LV03): 2'596 234/1'253 488.

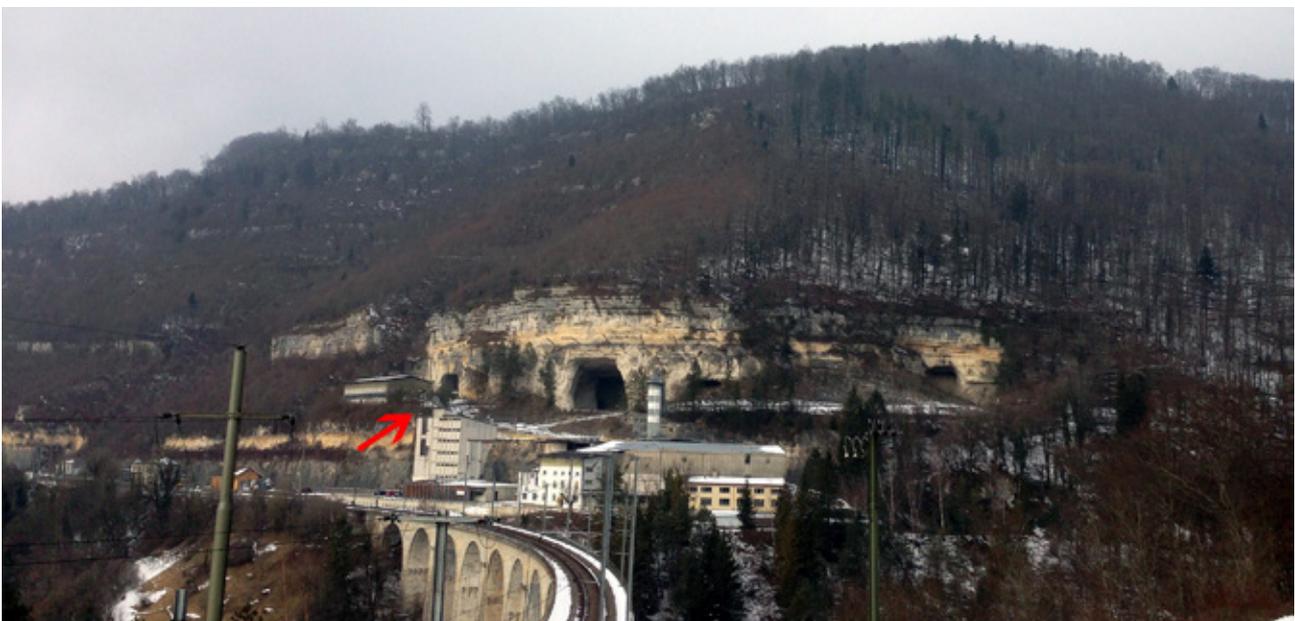


Fig. 7: Photograph of the old lime factory (Fabrique de Chaux) in St-Ursanne, which is the type locality of the St-Ursanne Formation. Red arrow: Base of the measured section, Swiss coordinates (LV03): 2'579 519/1'246 377. Date: 24.01.2017.

2016; fig. 4a-b). The lagoonal sediments are interspersed with smaller patch reefs and the accompanying reef debris such as the bio- to oosparites of bed 21-23 that were deposited in a rather high-energy environment. Bed 24 represents a large coral reef. In the lithostratigraphic section, the first coral patches appear in bed 26. From bed 26 to 27 the corals are accompanied by rolled reef debris with intercalated chalky areas that are bearing many fossils. In addition to bivalves of the genus *Diceras*, bed 27 has a high content of light pink stained nerineid gastropods. Furthermore these beds contain rolled coral fragments, rare brachiopods and isolated coronas and primary spines of regular echinoids. From the base to the top of the whole section, the depositional environment is gradually becoming calmer. However, the micrites and intrasparites of bed No. 39-42 testify to a more turbulent environment again. The fossil content of these layers includes different bivalves (e.g. representatives of the genera *Diceras* and *Pachymytilus*), a diverse gastropod fauna, rolled coral fragments, representatives of *Solenoporella ?jurassica* Rothpletz, 1908, and oncoids. The high energy of the depositional environment led to a splitting and rounding of the components. Due to safety reasons the upper part of the sequence is not accessible. Therefore this description lacks of the upper part of the section.

Echinoid species such as *Phymechinus mirabilis* (Agassiz & Desor, 1846-1847), *Pseudodiadema tetragramma* (Agassiz, 1840), *Pseudodiadema pseudodiadema* (Lamarck, 1816) were detected in the depositional area of a lagoon. Non-cidaroid species such as *Acrocidaris nobilis* (Agassiz, 1840), *Glypticus hieroglyphicus* (Goldfuss, 1826) can be found in conjunction with the coral bioherms. As most of the representative of *Paracidaris florigemina* (Phillips, 1829) are fragmented, it is liable that these remains were mostly washed in. Therefore it is suggested that that this species was not well represented in this habitat.

St-Ursanne Highway, Buix Member: The outcrop along the construction site of highway A16 is situated about 500 m down the road from the train station in St-Ursanne. The lithostratigraphic section is dominated by the lagoonal facies (Fig. 8). The rocks are similar to the ones at the lime factory (see above). However, the boundary of the Chestel to the Buix Member is not exposed. The base of the section was fixed in a biosparitic bed (bed 30). Above this bed, the sediments were deposited in a lagoonal environment with dispersed coral patches. Beds 40 and 50 are biomicritic and partially chalky. The fossils are mainly restricted to the chalky portions and primarily consist of spines and coronas of echinoids [e.g. *Paracidaris florigemina* (Phillips, 1829), *Glypticus hieroglyphicus* (Goldfuss, 1826), *Pseudosalenia aspera* (Agassiz, 1838), *Hessotiara florescens* (Agassiz, 1840), *Pseudodiadema* sp. indet.], single corals, gastropods (primarily representatives of *Nerinea*), *Solenoporella*

?jurassica Rothpletz, 1908, and bivalves (primarily representatives of *Diceras*). Isolated corals characterize the top of the section. The majority of echinoids were found adjacent to corals.

Zwingen, Chestel Member: The primary spine of *Plegiocidaris crucifera* (Agassiz, 1840) was found at the historic outcrop in Zwingen. Unfortunately, the outcrop is currently covered with debris and can therefore not be reached anymore, but it is known that it belongs to the Chestel Member of the St-Ursanne Formation, which mostly consists of oosparites and isolated coral patch reefs. *Paracidaris florigemina* (Phillips, 1829) is the only cidaroid species we record from the oolite facies of the Chestel Member. Non-cidaroid echinoids, such as *Glypticus hieroglyphicus* (Goldfuss, 1826), *Hemicidaris intermedia* (Fleming, 1828), and *Pliocyphosoma supra-coralinum* (Cotteau, 1865) are more common.

4.2. State of preservation of the fossils

The shallow marine environment has a negative influence on the preservation of the dead organisms. Before embedding the remains have mostly been processed through waves and currents. Therefore many fossils and biogenic components are fractionated and rolled. According to Gründel *et al.* (2016) in the St-Ursanne Formation aragonitic shells have been replaced by calcite or have been dissolved. The resulting cavities are often filled with precipitated calcite crystals. On a macroscopic scale the calcitic tests of echinoids, mostly show a rather good preservation. The majority of the fossilised remains are completely preserved. Unfortunately some of them have been broken during the process of excavation. However, as the Buix Member is a chalky sequence, finer structures, such as the pores of ambulacral zones of echinoids, are often badly preserved. Furthermore, the overgrowth with syntaxial rim cement can lead to a covering of finer structures.

4.3. Systematic paleontology

Abbreviations

d amb: diameter of ambulacral plates at ambitus; **d ap:** diameter of apical shield; **d base:** diameter of the base; **d buc:** diameter of buccal system; **d iamb:** diameter of interambulacral plates at ambitus; **d intp:** diameter of interporiferous zone; **d max:** diameter at ambitus; **d por:** diameter of poriferous zone; **d ring:** diameter of milled ring; **h ar:** height of areolas at ambitus; **h max:** maximum height; **l max:** maximum length; **l neck:** length of the neck; **N inc:** number of incisions in the collar; **N ribs:** number of ribs around the shaft; **PIa:** total number of interambulacral plates per interambulacral zone; **w ar:** width of areolas at ambitus.

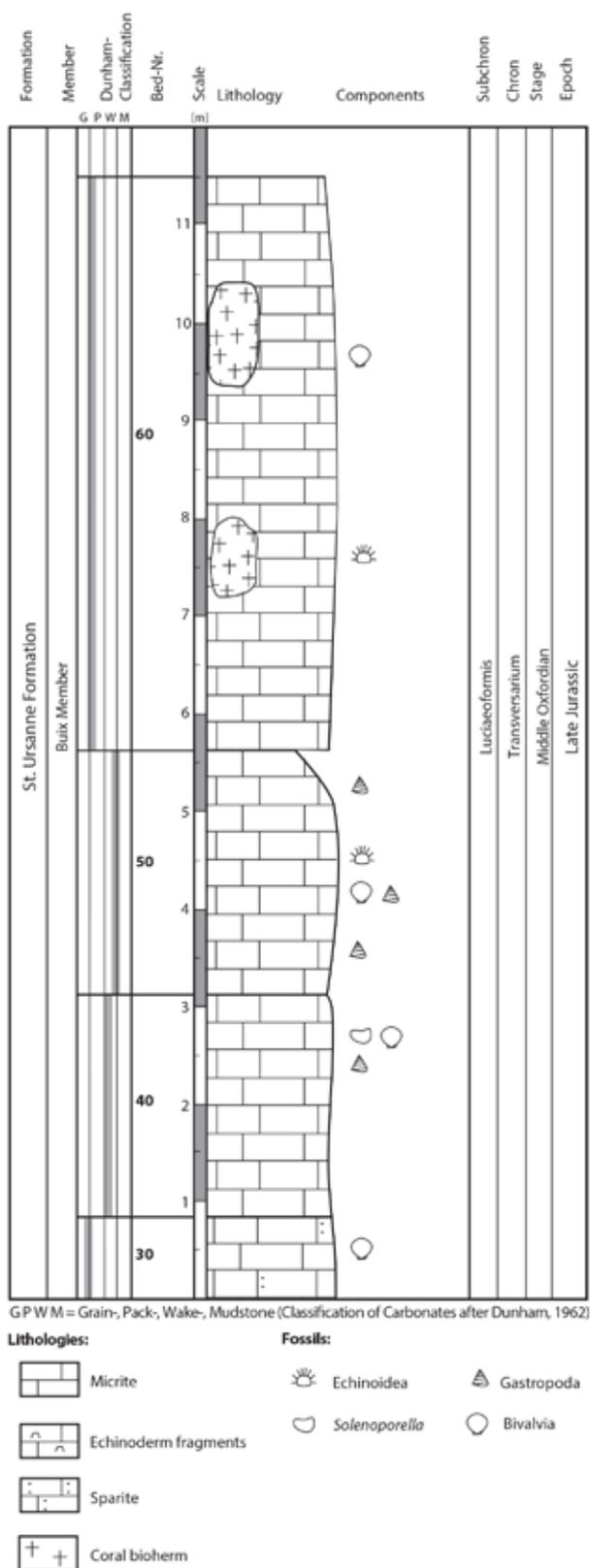


Fig. 8: Lithostratigraphic section through a part of the Buix Member of the St-Ursanne Formation at the outcrop along the highway A16 in St-Ursanne. Swiss coordinates (LV03): 2'580 089/1'246 593.

Cidaroida Claus, 1880
 Polycidaridae Vadet, 1988
 Paracidaris Pomel, 1883

Type species: *Cidaris florigemma* Phillips, 1829

***Paracidaris florigemma* (Phillips, 1829)**

Pl. I, figs 1-8

- * 1829. *Cidaris florigemma* Phillips, p. 127, pl. 3, figs 12, 13.
- 1851. *Cidaris blumenbachii* Wright, p. 248.
- 1857. *Cidaris florigemma* Wright, p. 44, pl. 2, fig. 2, pl. 8, fig. 4.
- 1858. *Cidaris blumenbachii* Desor, p. 5, pl. 3, fig. 14.
- 1868-72. *Paracidaris florigemma* Desor, p. 390, pl. 60, fig. 10.
- 1884. *Cidaris florigemma* Cotteau, p. 804, pl. 491, fig. 5.
- v 1975. *Paracidaris florigemma* Hess, p. 87, pl. 28, figs 2-3.
- 1986. *Paracidaris florigemma* Lewis, p. 51.
- v 1988. *Paracidaris florigemma* Vadet, p. 115, pl. 8, fig. 3, pls 9-12, text-figs 8-10, 12.
- 2002. *Paracidaris florigemma* Vadet et al., p. 16.
- 2004. *Paracidaris florigemma* Vadet, p. 27.
- 2006. *Paracidaris florigemma* Hostettler, pp. 34-36, pl. 3, figs 1, 2, pl. 4, figs 1-8, pl. 5, fig. 1, pl. 6, figs 1, 2, pl. 7, fig. 1, pl. 8, figs 1-7.
- 2015. *Paracidaris florigemma* Smith, pp. 30-31, pls 17-18, text-figs 3e-f.

Types: The syntypes of *Cidaris florigemma* are a corona and a spine from the Coral Rag of Wiltshire that were illustrated and described by Phillips (1829, pl. 13, figs 12, 13), which, unfortunately cannot be tracked anymore (Vadet, 1988; Smith, 2015). Vadet (1988) therefore designated a neotype for *Paracidaris florigemma*, in particular NHM E1678, which was figured in Wright (1857, pl. 2, figs 2b,c) and published under the name *Cidaris florigemma* Phillips, 1829. This specimen derives from the oolitic coral reef facies of Calne, Wiltshire, England and is now part of the collection of the Natural History Museum in London, UK. More recent photographs of the neotype are published in Smith & Kroh (2011).

Material: Kleinlützel (SO): 8 complete coronas (FPJ 1012, 1021, 5371, 5373, 5621, 5719, 5720, 7530), 10 partial coronas (NMBE D5455-D5464), and 17 spines (FPJ 5405, 5372; NMBE D5456-D5479). La Caquerelle, excavation site (JU): 2 partial coronas (FPJ 5375, 5378) and 2 spines (FPJ 5373; NMBE D5699). La Caquerelle Roche au Vilain (JU): 3 spines (NMBE D5516, D5519-D5520). Roggenburg (BL): 1 corona (FPJ 18766), 1 coronal fragment (FPJ 18765) and 7 spines (FPJ 5738, 15852, 15853; NMBE D5695-D5698). Hasenburg near Soyhières (JU): 6 coronas (NMBE5014440, FPJ 5668, 5669, 5670, 5671, 5672) and 4 spines (NMBE 5014449, D5521-D5523). St-Ursanne Fabrique de Chaux (JU): 1 corona (NMBE D5540), 1 coronal fragment (NMBE D5534) and 7 spines (D5530-D5531, D5533, D5535-D5537, D5541). St Ursanne Highway (JU): 1

corona (FPJ 5379) and 1 spine (NMBE D5538). Tariche (JU) 4 spines (NMBE D5524.1-D5524.4). Zwingen Sunnerai (BL): 5 coronas (FPJ 1011, 1013, 5374, 5781, 5782), 1 coronal fragment (FPJ 5790), and 2 spines (FPJ 1015, 5773).

Description: Measurements of the present material are provided in Table 1 and Table 2. The largest corona (NMBE 5014440) is oblate and relatively large (58 mm; Pl. I, fig. 2a). None of the specimens studied have preserved apical or buccal discs. The resulting large openings are round with the peristome being slightly larger (NMBE 5014440: 41 % and FPJ 5621: 64 % of the diameter) than the periproct (NMBE 5014440: 39 % and FPJ 5621: 45 % of the diameter).

The ambulacrum is a thin, sinuous and incised band that is more than three times narrower than the interambulacrum (NMBE D5540: $d_{amb}/d_{iamb} = 0.27$; Pl. I, fig. 3). The width of the ambulacral zone does not increase proportionally with the size of the corona. At the ambitus, every interambulacral plate is in contact with 11 (NMBE D5540; Pl. I, fig. 3) to 19 (NMBE 5014440; Pl. I, fig. 2b) ambulacral plates. The uniserial pore-pairs are subconjugate and regularly ordered with no offset (Pl. I, figs 3, 4). The pores are well rounded and the interporal partition is slightly raised and only as wide as the diameter of a pore (FPJ 5374; Pl. I, figs 3, 4). The interporiferous zone is slightly raised and consists mainly of two parallel rims of equidimensional tubercles and dispersed granulae. In juvenile specimens, smaller tubercles are sometimes intercalated at the

ambitus (Pl. I, figs 3, 4). The interporiferous zone of adult representatives is slightly widened (NMBE 5014440; Pl. I, fig. 2f). Whereas the ambulacral field is undulating in adapical regions (NMBE 5014440; Pl. I, fig. 2b), the field becomes slightly straighter adorally (NMBE 5014440; Pl. I, fig. 2c).

The interambulacrum consists of ten (FPJ 5621) to sixteen (NMBE 5014440) plates per interambulacral zone. The youngest plates are always on the same side and more or less equidimensional (NMBE 5014440; Pl. I, fig. 2b). Each interambulacral plate bears one large, perforated primary tubercle whose sizes decreases adorally (Pl. I, figs 2a, 2b, 2c). Whereas aborally the platforms are symmetrically crenulated and the areolas are circular (Pl. I, figs 1, 2b, 2d) in the lower part of the corona, the platforms are rather smooth and the areolas sub-circular (Pl. I, fig. 2e). The scrobicular circle is slightly depressed and equipped with 14 to 16 dominant scrobicular tubercles at the ambitus (Pl. I, figs 1, 2a, 4). Only the lowest two areolas are slightly confluent (Pl. I, fig. 2e). As the areole occupies almost the whole plate, there is only a rather narrow, slightly depressed zone with fine, miliary tubercles and small granulae in the interradianal zone. At the ambitus, this zone is a little bit enlarged, but still rather narrow (Pl. I, figs 1, 2a).

The primary spines are thick (NMBE D5465: $d_{max}/l_{max} = 0.36$, Pl. I, fig. 7; NMBE 5014449: $d_{max}/l_{max} = 0.16$, Pl. I, fig. 5), club-shaped, have a short and smooth neck (2 mm in NMBE D5465; Pl. I, fig. 7), a thin and smooth ring and a crenulated base (NMBE 5773; Pl. I,

Table 1: Measurements in mm of coronas of *Paracidaris florigemma* (Phillips, 1829) based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations see beginning of this chapter.

Nr.	d max	h max	d amb	d iamb	Pia	h ar	w ar	d ap	d buc
FPJ 1013	24	11	3	12	12	3.5	4.5	-	14
FPJ 5670	19	10	2	9	12	3	3	-	11
FPJ 5374	18	11	2	9	11	2.5	3	8	10
FPJ 5379	42	30	3	22	13	6	7	19	-
FPJ 5621	11	6	1.5	5	10	1.5	2	5	7
NMBE 5014440	58	41	4	27	16	8	10	23	24
NMBE D5540	22	12	3	11	10	4	4	11	-

Table 2: Measurements in mm of primary spines of *Paracidaris florigemma* (Phillips, 1829) based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations see beginning of this chapter.

Nr.	l max	d max	l neck	d ring	d base	N ribs	N inc
FPJ 5373	54	9	3	5	3	24	-
FPJ 5773	49	7	4	4	4	20	12
NMBE 5014449	60	10	4	6	4	22	14
NMBE D5465	14	5	2	-	-	16	-

fig. 8a). The shaft is ornamented with beaded ribs that are topped with short and rounded spinules that slightly point distally (Pl. I, figs 5, 6, 7). Rare preservation of the distal pointing, shovel-shaped protuberances of the spinules (FPJ 5773; Pl. I, fig. 8b). Shaft and neck merge with no distinct margin. The last spinules at the distal end slightly form a platform, which leads to a minor flattening of the tip (Pl. I, fig. 7).

Discussion: *Paracidaris florigemma* (Phillips, 1829) is the most common and therefore maybe the most discussed (e.g. Hess, 1975; Vadet, 1988; Hostettler, 2006; Smith, 2015) cidaroid species in the Late Jurassic. The species was detected at nine of the ten localities investigated in this study. The lithostratigraphic sections of these localities can be attributed to all three facies, which were identified in the Chestel and the Buix Member of the St-Ursanne Formation; the coral reef facies, the reef debris facies and the lagoonal facies. In addition, the spines and coronas of *P. florigemma* were by far the most abundant cidaroid occurrences in the St-Ursanne Formation. For these reasons *P. florigemma* represents the most generalistic species herein.

Occurrence: The species has a wide distribution across Europe. In particular, tests and spines have been collected from the Oxfordian sponge-cyanobacteria facies of Poland (e.g. Radwańska, 2003), the Oxfordian coral reef and reef debris facies throughout France (e.g. Cotteau, 1884; Vadet, 1988), Germany (e.g. Quenstedt, 1885), Switzerland (e.g. Desor & de Loriol, 1868-1872; Hess, 1975; Hostettler, 2006) and the United Kingdom (e.g. Phillips, 1829; Wright, 1857; Smith, 2015).

Diplocidaridae Gregory, 1900

Diplocidaris Desor, 1858 including *Rolliericidaris*
Vadet, 1991

Type species: *Cidaris gigantea* Agassiz, 1840

***Diplocidaris bernasconii* sp. nov.**

Pl. II, figs 1, 2

? 2001. *Rolliericidaris etalloni* Vadet *et al.*, p. 10, pls 1-3.

Holotype: FPJ 5667 (Pl. II, figs 1a–g), Buix Member of the St-Ursanne Formation, Hasenburg near Soyhières (JU), a partially fragmented corona consisting of three of the five zones, though one fifth is disarticulated.

Paratype: FPJ 5722 (Pl. II, figs 2a, b), Buix Member of the St-Ursanne Formation, Kleinlützel (SO), a partially disarticulated corona consisting of one of the five zones.

Material: Hasenburg near Soyhières (JU): 2 partial coronas (FPJ 5666, 5667). Kleinlützel (SO): 5 partial coronas (FPJ 15790A, 5618, 5619, 5722; NMBE D5480).

Derivatio nominis: In honor of G. Bernasconi (Member of the FPJ), the finder of the best preserved fossil material.

Locus typicus: Hasenburg near Soyhières (JU).

Stratum typicum: Middle Oxfordian coral facies of the St-Ursanne Formation, Buix Member.

Diagnosis: A large representative of *Diplocidaris*. Test subrounded and high; interambulacral composed of up to 22 plates per interambulacral zone; youngest plates well developed. Wide interradial zone, densely covered by tubercles and granules; perradial zone densely covered with well-developed tubercles and granules of various sizes. Primary spines proposed herein (see below *Diplocidaris* cf. *bernasconii*) thin and slender, shaft covered with rows of sharp, hook-shaped spinules that point distally.

Description: Measurements of the holotype FPJ 5667 and paratype FPJ 5722 are provided in Table 3. The holotype is a big, fragmented subglobular corona that exhibits an articulation of two of the five zones of a corona. Another fifth broke off, but is still preserved within the same specimen (Pl. II, fig. 1a).

The corona of the holotype is large (estimated diameter of 80 mm; Pl. II, fig. 1a), subglobular, and consists of thick plates (2 mm). The two available specimens lack preserved apical or buccal discs. The estimated relative diameter of the apical shield of the holotype may have been around 40% of the corona.

The ambulacrum is broad and weakly sinuous. The poral partition is distinctly incised and rather broad relative to the whole ambulacrum (Pl. II, fig. 1a, d). Whereas the ambulacral zone is almost a straight line in the lower half of the corona, it is slightly undulating in the aboral region of the ambulacrum (Pl. II, figs 1b, c, d). The pore-pairs are slightly conjugate and offset alternately (Pl. II, fig. 1g). Due to the preservation of the holotype the exact shape of the pores is not recognizable. The interporal partition is three to four times wider than the diameter of a pore (Pl. II, fig. 1g). The interporiferous zone is slightly raised and consists mainly of two lateral rims of small tubercles with interspersed granulae (Pl. II, fig. 1g). At

Table 3: Measurements in mm of the coronas of *Diplocidaris bernasconii* sp. nov. based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations beginning of this chapter. ⁽¹⁾ Estimated values as the specimen exhibits only an articulation of two of the five zones of a corona.

Nr.	d max	h max	d amb	d iamb	Pia	h ar	w ar	d ap	d buc
FPJ 5667H	80 ⁽¹⁾	55	9	35	22	7	9	34 ⁽¹⁾	37 ⁽¹⁾
FPJ 5722P	-	54	6	-	20	8	9	-	-

the ambitus every interambulacral plate is in contact with about 16 ambulacral plates (Pl. II, fig. 1g).

The interambulacrum of the holotype consists of 22 interambulacral plates with large, perforated primary tubercles, whose size decrease adorally. At the ambitus, the interambulacral plates are clearly flattened ($h/w=0.6$; Pl. II, fig. 1d). Whereas aborally the plates are almost square ($h/w = 0.91$; Pl. II, fig. 1b), they get elongated adorally ($h/w = 0.5$; Pl. II, fig. 1c). The mamelons are perforated and the platforms are symmetrically crenulated (Pl. II, fig. 1e). The areolas are sub-circular to oval and have a slightly depressed scrobicular circle (Pl. II, fig. 1e). At the ambitus, the scrobicular circle is equipped with 15-17 scrobicular tubercles. In the upper part of the corona, the scrobicular circles are well separated (Pl. II, fig. 1b) and in the lower part they are slightly confluent (Pl. II, fig. 1c). Along the interradian suture is a broad zone with granulae and miliary tubercles that are sometimes flattened horizontally (Pl. II, figs 1d, f).

The paratype is a coronal fragment that is articulated to one of the five zones of a corona. The pores are better preserved than those of the holotype. The pore-pairs are slightly conjugate and show an alternating offset (Pl. II, fig. 2b). Due to the preservation of the specimen, the shape of the pores can only be estimated. Both pores of a pore-pair are about the same size. Some of the inner pores appear to be somewhat larger. At the ambitus, every interambulacral plate is in contact with about 18 ambulacral plates (Pl. II, fig. 2b).

Full differential diagnosis: *Diplocidaris* differs from all other Jurassic cidaroids by the presence of an alternating offset of the pore-pairs.

Diplocidaris bernasconii sp. nov. most closely resembles *Diplocidaris undulata* (Agassiz, 1840; p. 52, pl. 18, figs 25-26, the senior synonym of *Diplocidaris etalloni* (Desor, p. 85, pl. 13, fig. 3 in Desor & de Loriol, 1868-1872). However, *D. undulata* differs from *D. bernasconii* by the following characteristics:

1. The pores are more rounded and only rarely elongated.
2. The inner pores are slightly undercut instead of being arranged side by side.
3. The perradial zone is not covered by tubercles or granules.
4. The areolas are more rounded at the ambitus.
5. In the upper half of the corona, the primary tubercle is situated decentralized in the lower part of the interambulacral plate instead of in the middle of the plate.
6. The interradian tract is more loosely covered by miliary tubercles and granules.
7. The miliary tubercles are less rounded and stretched in the direction of the respective primary tubercle.
8. Presence of a second type of miliary tubercles with incised mamelons in the interradian tract.
9. The size of miliary tubercles equals the size of the scrobicular tubercles instead of being smaller.

Diplocidaris gauthieri Cotteau (1875-1880; p. 332, pl.

228) differs from *D. bernasconii* through the following characteristics:

1. The corona is more flattened (a diameter of 48 mm corresponds to a height of 28 mm).
2. The interradian tract is less densely covered by tubercles and granulae.
3. The areolas of the youngest plates are very small and indistinct instead of being well developed.
4. The perradial zone is covered by small and poorly developed granulae instead of being densely covered with well-developed tubercles and granules of various sizes.
5. The miliary tubercles along the interradian zone are somewhat stretched in the direction of the respective primary tubercle instead of being round.

Diplocidaris gigantea (Agassiz, 1840; pl. 21a, 22) differs from *D. bernasconii* through the following characteristics:

1. In general *D. gigantea* can grow larger [maximum diameter of 100 mm; Hostettler (2006)].
2. The corona bears less interambulacral plates (12 plates, diameter of corona at ambitus: 61 mm).
3. The scrobicular ring is much larger.
4. The interradian tract is much narrower.
5. In the interradian tract there is a second type of miliary tubercles with incised mamelons.
6. The ambulacral is slightly undulating instead of being almost straight.
7. The perradial zone is not covered by granulae instead of being densely covered with well-developed tubercles and granules of various sizes.
8. The youngest interambulacral plates are bearing reduced or even no primary tubercles instead of being well developed.

Diplocidaris alternans (Quenstedt, 1874; p. 219, pl. 69, fig. 15) differs from *D. bernasconii* through the following characteristics:

1. The corona bears only 10 interambulacral plates per zone (Quenstedt, 1874).
2. The pores are more rounded.
3. At the ambitus every interambulacral plate is only in contact with 11 ambulacral plates.
4. Horizontally the areolas are always in the middle of the plate and not close to the adradial suture.
5. The scrobicular ring is not very distinct.
6. In contrast to *D. bernasconii* there are 4 rows of strictly ordered, alternating tubercles and no granules in the interradian tract.
7. The size of the miliary tubercles equals the size of the scrobicular tubercles instead of being smaller.

Diplocidaris desori Wright (1857; p. 56; pl. VIII, fig. 5) differs from *D. bernasconii* through the following characteristics:

1. The miliary tubercles are elongated and teardrop shaped instead of being rounded.
2. The tubercles in the interradian tract are only somewhat larger than the scrobicular tubercles instead of being smaller.

3. In the interradial tract there is a second type of miliary tubercles with incised mamelons.
4. The interradial tract is only loosely covered by tubercles and granules.
5. The pores are slightly flattened instead of being rounded.
6. The pore-pairs are separated by a high ridge instead of being slightly conjugate.
7. The interporal zone is only as thick as the diameter of one pore and therefore much narrower.

The holotype of *Diplocidaris desori* (Wright, 1857) is a badly weathered corona fragment that is stored in the collection of the Natural History Museum in London (NHM E1535). Nonetheless, the species clearly differs from *Diplocidaris bernasconii*. Whereas Vadet (1991; p. 158) treats *D. desori* as a valid species, Smith (2015; p. 18) advises caution and treats it as an indeterminate species until more complete material is discovered.

Discussion: The coronal segments of the type material are separated along the plate sutures. Therefore it is most likely that the corona disarticulated post-mortem (Smith, 1984). Furthermore the good preservation of the remains highlights a minor transport and a rapid burial after death (Smith, 1984).

It is possible that coronal fragments of *Diplocidaris bernasconii* sp. nov. have already been illustrated unpurposefully in the past. Smith & Kroh (2011) state, that Vadet *et al.* (2001; p. 10, pl. 1) illustrated two segments of a corona under the name of *Rolliericidaris etalloni* (Desor in Desor & de Loriol, 1868-1872) [= junior synonym of *Diplocidaris undulata* (Agassiz, 1840)] that might belong to another species. These fragments look very similar to the above-described *D. bernasconii*. The holotype of *R. etalloni* is a fragmented corona with some similarities to the species to be discussed. However, there are a few differences between the two species. Whereas the areolas of the specimen in the original description of Desor (*in Desor & de Loriol, 1868-1872*) are almost perfectly rounded and isolated, those from specimen in Vadet *et al.* (2001) are clearly oval and are only separated by 1-2 rows of scrobicular tubercles or are confluent. Furthermore the specimen in Vadet *et al.* (2001) seems to have much wider ambulacra and the miliary tubercles of the interambulacra are finer and alternate with granules. The coronal fragments, illustrated in Vadet *et al.* (2001), derive from the Middle Oxfordian chalky coral reef facies

of the protected basin at the back of a coral reef from the Ardennes, France. The environmental conditions were very similar to the Middle Oxfordian of the St-Ursanne Formation. This strengthens the suspicion that the species illustrated in Vadet *et al.* (2001) is identical with the species described herein.

In summary, *D. bernasconii* sp. nov. differs from other representatives of *Diplocidaris* through the dense covering of the per- and interradial tract with tubercles and granules, the absence of the second type of miliary tubercles with incised mamelons in the interradial tract and the high number of primary tubercles per ambulacral zone. Because of these major differences it has to be discussed, whether *D. bernasconii* sp. nov. really belongs to this genus. With the current material it is not possible to fully clarify the assignment of the new species. Therefore it is important to be cautious until more and better preserved material of *D. bernasconii* will be available.

Occurrence: *Diplocidaris bernasconii* sp. nov. is a rare representative of Cidaroida Claus, 1880 that has so far only been recorded in the reef and the reef debris facies of the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. As mentioned above, additional material may have been reported from the chalky coral reef facies of the Middle Oxfordian, Transversarium zone of the Ardennes, France (Vadet *et al.*, 2001). The occurrence of this species seems to be restricted to the coral reef facies.

Diplocidaris cf. bernasconii

Pl. III, figs 1-3

? 2001. *Nenoticidaris parandieri* Vadet *et al.*, p. 14, pl. 5.

Material: Kleinlützel (SO): 15 spines or spine fragments (FPJ 15790.1- FPJ 15790.7, 15799, 5620; NMBE D5481, D5483–D5487).

Description: Measurements of the available material are provided in Table 4. The primary spines are thin and very slender (FPJ 15790B: Pl. III, fig. 1a; FPJ 15790C: Pl. III, fig. 3a, FPJ 15799; Pl. III, fig. 2a). They have a very short neck that is separated from the shaft by a thin ridge. The ring is smooth and the base is crenulated (FPJ 15790B; Pl. III, figs 1b, c). The undifferentiated, poorly developed bases of FPJ 15790C (Pl. III, figs 2b, c) and FPJ 15799

Table 4: Measurements in mm of the primary spine of *Diplocidaris cf. bernasconii* based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations see beginning of this chapter. ⁽¹⁾ Specimen with an undifferentiated, poorly developed spine (see below).

Nr.	L max	d max	l neck	d ring	d base	N ribs	N inc
FPJ 15790B	62	4	3	4	3	none	> 9
FPJ 15790C ⁽¹⁾	61	3	1	none	none	none	none
FPJ 15790D	49	3	1	-	-	none	-
FPJ 15799 ⁽¹⁾	53	3	2	none	none	none	none

(Pl. III, fig. 3) indicate either an aboral origin of the spines or a reduced development of the spines. The ornamented shaft bears rows of slightly connected hook-shaped spinules that point distally (FPJ 15790B; Pl. III, figs 1d, e). Distally the size of the appendages decreases and the spinules are fused and form more dominant beaded ribs (FPJ 15790B; Pl. III, fig. 1e). All of the observed, fully preserved spines have a straight base.

Discussion: So far there were no spines found that were in articulation with the test. In the St-Ursanne Formation there are two other cidaroid species that were recorded by corona finds, namely *Paracidaris florigemma* (Phillips, 1829) and *Rhabdocidaris rauraca* Jeannet, 1929. The primary spine of *P. florigemma* is well known and primary spines of *Rhabdocidaris* can at least be determined to genus level. The two species that were recorded by primary spine finds are *Plegiocidaris crucifera* (Agassiz, 1840) and *Diplocidaris gigantea* (Agassiz, 1840). The primary spines of both species can be attributed to species with known coronas. Presently the test and the spine described above are the only fully unknown cidaroid remains from the outcrop in Kleinlützel and Hasenburg near Soyhières. Therefore we suggest that the above described corona and spine belong together.

Vadet *et al.* (2001; pl. 5) illustrated a section of a slender spine (W973; diameter 3.2 mm) under the name of *Nenoticidaris parandieri* (Agassiz, 1840). The comparison of Vadet's illustration with other literature (e.g. Agassiz, 1840; Hess, 1975; Vadet, 1988; Hostettler, 2006) leads to the assumption that Vadet's classification might be erroneous. Primary spines of *N. parandieri* (Agassiz, 1840) are quite long (up to 145 mm; Hostettler, 2006), stout and much thicker as the one illustrated in Vadet *et al.* (2001). Furthermore the milled ring and the crenulation of the base are much more distinct and the spinules of *N. parandieri* are vertically and horizontally aligned. The fragment illustrated in Vadet (2001) strongly reminds of *Diplocidaris cf. bernasconii*.

If *R. etalloni* Vadet *et al.*, 2001 (non Desor in Desor & de Loriol, 1868-1872) has to be treated as a synonym of the given type, the same kind of corona and spine occur in the chalky coral reef facies of the Middle Oxfordian, Transversarium zone of the Ardennes, France too (see above). The co-occurrence of the same unknown remains in a similar habitat at the same time strengthens the suspicion that the described corona and the primary

spine belong together. A further preliminary conclusion that can be reached is that the distribution of this species seems to be restricted to reef area.

Occurrence: *Diplocidaris cf. bernasconii* is a rare representative of Cidaroida Claus, 1880 that was only recorded in the reef debris facies in a back reef basin of the Buix Member of the St-Ursanne Formation in Kleinlützel of the Swiss Jura Mountains. Additional material may have been reported from the chalky coral reef facies of the Middle Oxfordian, Transversarium zone of the Ardennes, France (Vadet *et al.*, 2001, p. 14, pl. 5).

Diplocidaris gigantea (Agassiz, 1840)

Pl. IV, figs 1a-d, 2a

- * 1840. *Cidaris gigantea* Agassiz, p. 66, pl. 21a, fig. 22.
- 1840. *Cidaris pustulifera* Agassiz, p. 75, pl. 21a, fig. 7.
- 1840. *Cidaris cladifera* Agassiz, p. 75, pl. 21a, fig. 8.
- 1858. *Diplocidaris gigantea* Desor, p. 45, pl. 1, fig. 5.
- 1857. *Diplocidaris gigantea* Wright, p. 67.
- 1858. *Cidarites giganteus* Quenstedt, p. 732, pl. 89, figs 7-21.
- 1868-72. *Diplocidaris gigantea* Desor & de Loriol p. 83, pl. 12, fig. 12-14.

Types: The holotype NHMW 1847/0051/0206 of *Diplocidaris gigantea* (Agassiz, 1840) is stored at the Natural History Museum in Vienna (NHMW), Austria and is part of the collection of M. le comte Dudressier. It was found in Bregilles in the area of Besançon in the terrain à chailles. The specimen comprises a not very well preserved upper portion of an interambulacrum. The original description in Agassiz (1840; p. 66, pl. 21a, fig. 22) is a hand-drawn sketch. Even though the drawing is well done, it is rather insufficient in terms of a description of a holotype. Thankfully, Dr. A. Kroh agreed generously to treat and illustrate the specimen. Pl. IV, fig. 2a herein shows the cleaned and again prepared holotype of *D. gigantea*. According to A. Kroh (pers. comm.) the specimen looks like it would have been treated with acid. As it is only partially silicified, some parts of the specimen are heavily corroded. Lateral parts of the ambulacra are still preserved. The diameter of the whole corona is estimated to be 75 mm.

Material: Césai, St-Brais (JU): 1 spine (FPJ 15798).

Description: Measurements of the available material are provided in Table 5. The cylindrical primary spine is stout and long (FPJ 15798; d max: 8 mm; l max: 91 mm) and thins out distally (Pl. IV, figs 1a, b). The shaft is

Table 5: Measurements in mm of the primary spine of *Diplocidaris gigantea* (Agassiz, 1840) based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations see beginning of this chapter.

Nr.	l max	d max	l neck	d ring	d base	N ribs	N inc
FPJ 15798	92	8	7	9	6	none	20

ornamented with granules (Pl. IV, figs 5a, b, c). Whereas the granules of the proximal half are wider than high (Pl. IV, fig. 1b), they are rather isometric in the upper part (Pl. IV, fig. 1c). Proximally the ornamentation fades out and merges with the short (8 mm) and smooth neck (Pl. IV, fig. 1c). The base is short and bears 20 incisions (Pl. IV, figs 1c, d).

Discussion: The species *Diplocidaris gigantea* (Agassiz, 1840) is not an abundant faunal element. Whilst there were only a few specimens of *D. gigantea* found in the coral reef and the reef debris facies, there are no findings recorded in the lagoonal facies (see Fig. 9). In this context Hostettler (2006) suggests that representatives of *D. gigantea* are specialized to specific ecological niches. *D. gigantea* was originally described from a corona. Therefore the primary spines of this species were unknown for a long time. Even though they did not have an articulated specimen, Desor & de Loriol (1868-1872; p. 84) were the first who synonymized *D. gigantea* with

D. pustulifera. Their assumption has been proven correct more than a century later. Because Tellenbach (1998) figured two specimen of *D. gigantea* with articulated spines, which are comparable to *D. pustulifera* (Agassiz, 1840). Unfortunately the originals, illustrated in Tellenbach (1998) are not stored at a museum. *D. gigantea* and *D. cladifera* have been synonymized in Hostettler *et al.* (2017). As stated above in the synonymy list, *D. pustulifera* (Agassiz, 1840) and *D. cladifera* (Agassiz, 1840) are junior synonyms of *D. gigantea* (Agassiz, 1840).

Occurrence: Liesberg Member (Hess, 1975; Hostettler, 2006; Hostettler *et al.*, 2017), coral facies of the “terrain à chailles” of Besançon, France (Agassiz, 1840; Wright, 1857) and the Buix Member of the St-Ursanne Formation, the Lower Günsberg Formation (Hess, 1975; Hostettler, 2006), Oxfordian of Madagascar (Smith & Kroh, 2011) and the Kimmeridgian of southern Germany (Desor, 1858; Wright, 1857; Hostettler, 2006).

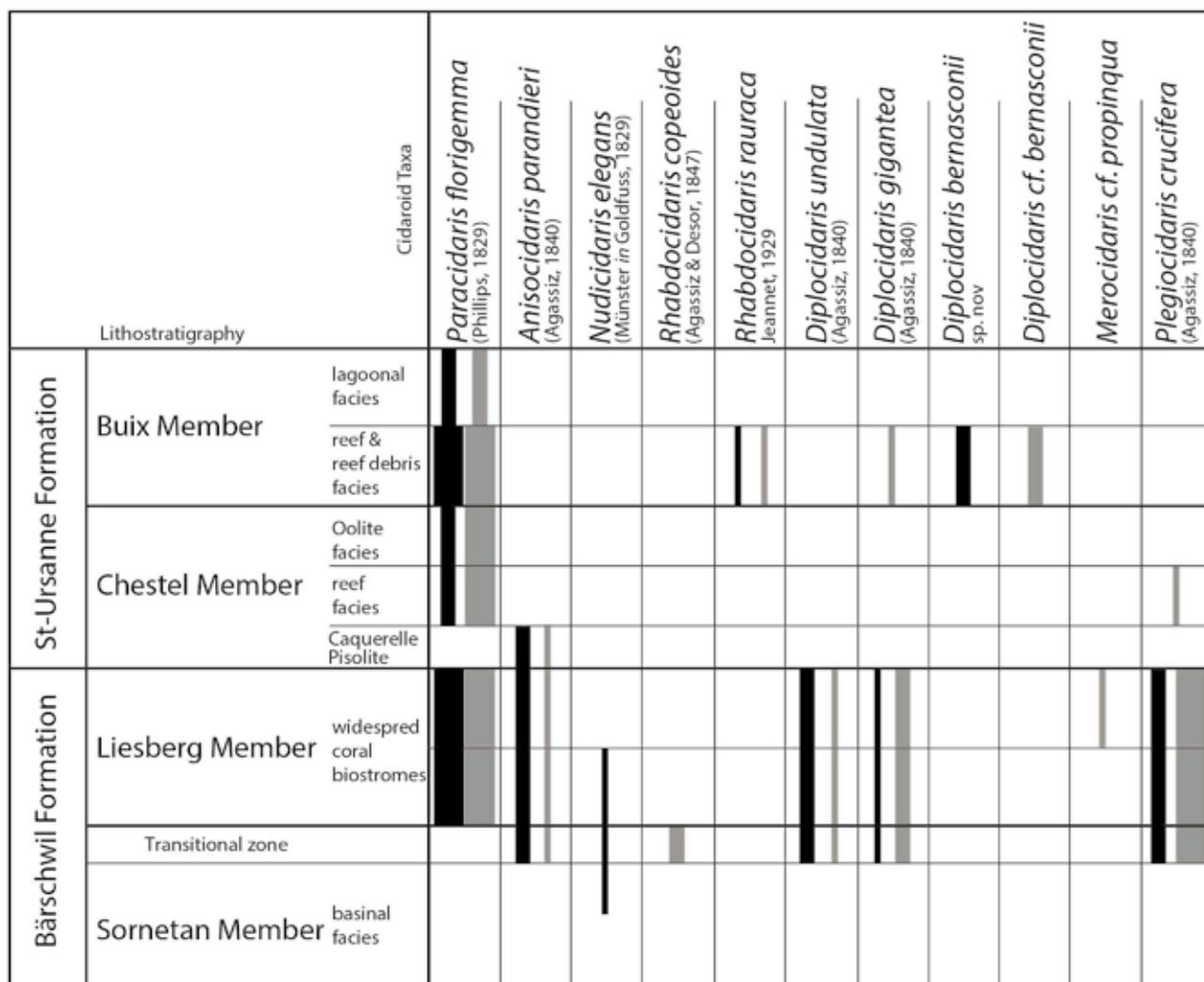


Fig. 9: Spatial distribution of the cidaroid species in the Bärschwil and the St-Ursanne Formation. Black lines: occurrence of corona and corona fragments, grey lines: occurrence of spines; broad lines: >20 specimens, medium sized lines: 6-20 specimens, narrow lines: 1-5 specimens. The data on the Bärschwil Formation are published in Hostettler *et al.* (2017).

Table 6: Measurements in mm of the corona of *Rhabdocidaris rauraca* Jeannet, 1929 based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations see beginning of this chapter.

Nr.	D max	h max	d amb	d por	d intp	d iamb	Pia	h ar	w ar	d ap	d buc
FPJ 3302	84	-	10	3	4	36	-	13	13	32	-
NMB M 9802 H	89	46	11	3.1	4.8	42	12	12.7	11.6	30.2	34.3

Table 7: Measurements in mm of the primary spine of *Rhabdocidaris rauraca* Jeannet, 1929. For explanations on the abbreviations see beginning of this chapter. ⁽¹⁾An undifferentiated, poorly developed spine (see description below).

Nr.	L max	d max	l neck	d ring	d base	N ribs	N inc
NMBE 5014445	74	7	6	none	5	> 9	none ⁽¹⁾

Rhabdocidaridae Lambert, 1900

Rhabdocidaris Desor, 1858

Type species: *Cidaris orbignyana* Agassiz in Agassiz & Desor, 1846-1847

***Rhabdocidaris rauraca* Jeannet, 1929**

Pl. V, figs 1a-d; Pl. VI, figs 1-2

*v 1929. *Rhabdocidaris rauraca* Jeannet, pp. 39-40, pl. 4, figs 10-12, pl. 5, figs 16-18.

Types: The holotype NMB M9802 of *Rhabdocidaris rauraca* Jeannet, 1929 is stored at the Natural History Museum in Basel (NMBS) and comprises one complete corona without apical or buccal discs. The specimen is

illustrated in Jeannet, 1929 (p. 39; pl. 4, figs 10-12) and in Pl. V, figs 1a-d herein.

Material: La Caquerelle, Roche au Vilain (JU): 1 corona (NMB M9802), 1 partial corona (FPJ 3302). Hasenburg near Soyhières (JU): 1 spine (NMBE 5014445).

Description: Measurements of the present material are provided in Table 6 and Table 7. The corona of FPJ 3302, a fragmented specimen, is very large (ca. 84 mm, Pl. V, fig. 1a) and slightly oblate. Only the upper part of the corona is preserved. Furthermore the test has no preserved apical disc. The diameter of the periproctal opening can be estimated to 38 % of the diameter of the corona.

The ambulacrum is a weakly sinuous band that enlarges towards the ambitus (Pl. V, fig. 1c). The uniserial pore-

Explanation on the plates:

Abbreviations: NMBE = Natural History Museum of Bern, FPJ = Fondation Paléontologique Jurassienne, NMB: Natural History Museum Basel, NHMW: Natural History Museum of Vienna.

Plate I

Paracidaris florigemina (Phillips, 1829)

Fig. 1: FPJ 5379 Buix Member of the St-Ursanne Formation, St-Ursanne Highway A16 (JU), d: 42 mm, oblique top view.

Fig. 2a-e: NMBE 5014440 Buix Member of the St-Ursanne Formation, Hasenburg near Soyhières (JU), d: 58 mm, 2a: interambulacrum; 2b: aboral top view; 2c: oral top view; 2d: magnified view of youngest plates; 2e: magnified view of oldest plates.

Fig. 3: NMBE D5540 Buix Member of the St-Ursanne Formation, St-Ursanne Fabrique de Chaux (JU), d: 22 mm, magnified view of ambulacrum.

Fig. 4: FPJ 5374 Chestel Member of the St-Ursanne Formation, Zwingen (BL), d: 18 mm, magnified view of ambulacrum.

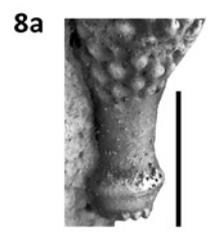
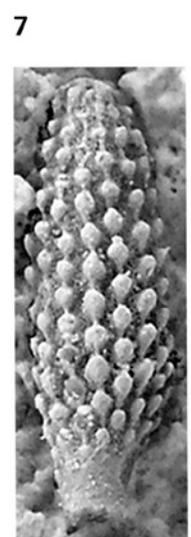
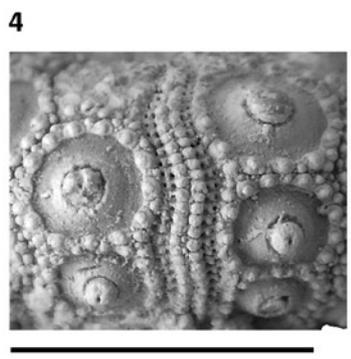
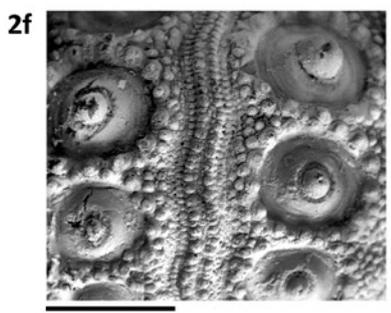
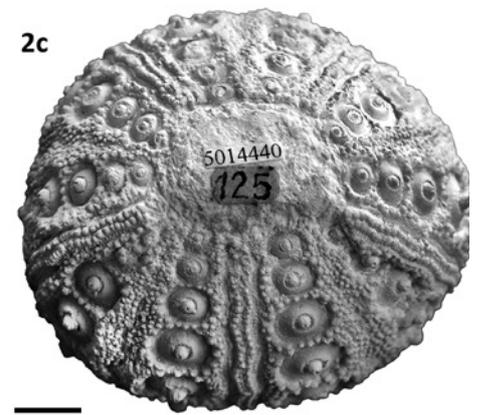
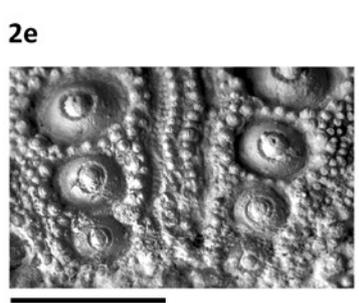
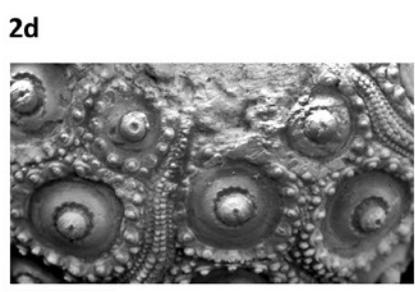
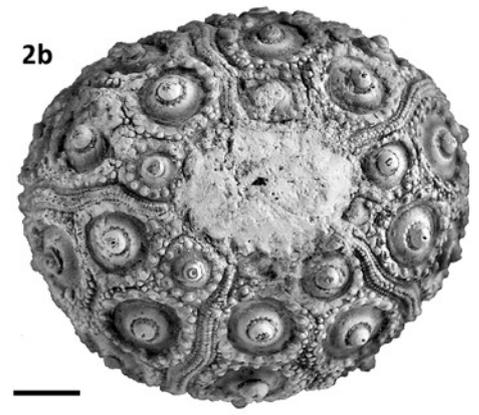
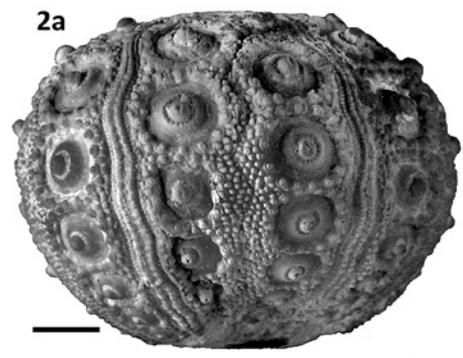
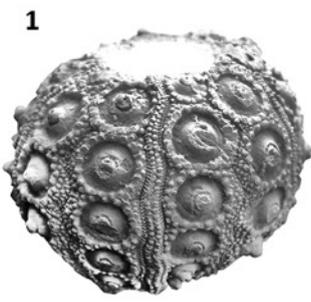
Fig. 5: NMBE 5014449 Buix Member of the St-Ursanne Formation, Hasenburg near Soyhières (JU), l: 60 mm, side view.

Fig. 6: FPJ 5373 Buix Member of the St-Ursanne Formation, Kleinlützel (SO), l: 54 mm, side view.

Fig. 7: NMBE D5465 Buix Member of the St-Ursanne Formation, Kleinlützel (SO), l: 14 mm, magnified side view.

Fig. 8a-b: FPJ 5773 Buix Member of the St-Ursanne Formation, Zwingen (BL), l: 49 mm, 8a: magnified view of base; 8b: magnified view of appendixes on spicules.

Scale bars = 10 mm



pairs are conjugate and show no offset. The two pores are widely separated (Pl. V, fig. 1b). The poral partition is only very little incised and in relative terms to the whole ambulacrum rather narrow ($d \text{ intp}/d \text{ amb} = 0.36$; Pl. V, figs 1b, c). The interporiferous zone is very broad (4 mm) and slightly depressed. The perradial zone bears a marginal series of primary tubercles on each side that enclose an inner series of 3 smaller tubercles. Hence, at the ambitus the interporiferous zone consists mostly of six tubercles per row that are of variable size.

The interambulacra are broad and bear separated, almost perfectly rounded areolas (Pl. V, figs 1a, c). The youngest plates are of variable size, but are always on the same side. From the periproct to the ambitus the size of the areolas increases from 4 mm to 13 mm. The mamelons are perforated and the platforms are symmetrically crenulated. All the areolas are perfectly circular and are not in contact with each other. The very slightly depressed scrobicular circle is surrounded by 16 scrobicular tubercles that are only a little larger than the miliary tubercles (Pl. V, fig. 1a).

The primary spine (NMBE 5014445; Pl. VI, fig. 2a) is stout (7 mm) and long (74 mm). Distally the asymmetric rounded triangular shape flattens. The shaft shows coarse striations (Pl. VI, fig. 2a). Proximally the striations are less distinct and are replaced by coarse and irregularly ordered, rounded thorns that point distally (Pl. VI, figs 2a, b, d). On one side of the specimen these rounded thorns are more abundant. The undifferentiated, poorly developed base (Pl. VI, figs 2b, c, d) indicates either an aboral origin of the spine or that the spine never fully developed.

Discussion: Because specimen FPJ 3302 is fractured along the ambitus, the true diameter of the corona can only be estimated. The diameter of the apical system of the holotype (NMB M9892; Natural History Museum of Basel) illustrated in Jeannet (1929; p. 39, pl. 4, figs 10-12 and Pl. V, figs 1a-d herein) measures around 37% of the diameter of the corona. Furthermore the holotype of the species shows that the areolas are getting smaller and denser arranged adorally (Pl. V, figs 1b, c).

Radwańska (1999) states that Jeannet (1929) based his new species on badly preserved and not representative material. Furthermore she argues that the differences in height of the test and the density of ornamentation, indicated by Jeannet (1929), fall into the normal variability within a species. Therefore Radwańska (1999)

equates *Rhabdocidaris nobilis* (Münster in Goldfuss, 1826; p. 117, pl. 39, figs 4a-f) with *Rhabdocidaris rauraca* Jeannet, 1929. The current authors agree that the two species strongly resemble each other. The depressed shape of the corona and the slight flattening of the areolas in the peristomial region are very similar. Even though the isolation of the areolas is getting less distinct from the top to the bottom, they are never confluent. However, a close look on *Rh. nobilis* reveals that the slightly broader interporiferous zone ($d \text{ intp}/d \text{ amb} = 0.49$) bears smaller tubercles and is not depressed but rather protrudes a little bit. All tubercles in the interporiferous zone are more or less of the same size and are regularly ordered. The interambulacral zone is narrower, the scrobicular tubercles are less distinct and the areolas are perfectly rounded. The surface of the primary spines of *Rh. nobilis* is smooth and the shaft bears coarse and sharp spicules that are aligned on every edge.

Therefore this comparison suggests that the difference between *Rh. rauraca* and *Rh. nobilis* is sufficient to constitute two separate species. The preliminary conclusion is that *Rh. rauraca* is the close ancestor of *Rh. nobilis*.

The main difference of *Rhabdocidaris rauraca* Jeannet, 1929 to *Rhabdocidaris orbignyana* (Agassiz in Agassiz & Desor, 1846-1847) is the much narrower interporiferous zone ($d \text{ intp}/d \text{ amb} = 0.31$) and the rounder and in relative terms higher corona of the latter. Apart from that, the areolas are much larger and occupy almost the whole plate. Therefore the interradian tract is much narrower. The primary spine of *Rh. orbignyana* is quite triangular and is fully covered by sharp spicules and smaller granules.

To summarise, this study suggests that, *Rhabdocidaris rauraca* Jeannet, 1929 is a distinct species within the genus *Rhabdocidaris*.

Occurrence: Coral facies of the Buix Member of Soyhières near Hasenburg and the reef debris facies of the Buix Member, La Caquerelle, Switzerland.

Rhabdocidaris cf. rauraca

Pl. VI, figs 3-4

Material: La Caquerelle, Roche au Vilain (JU): 1 spine (FPJ 15797). St-Ursanne Fabrique de Chaux (JU): 1 spine (NMBE D5542).

Description: Measurements of the present material are

Plate II

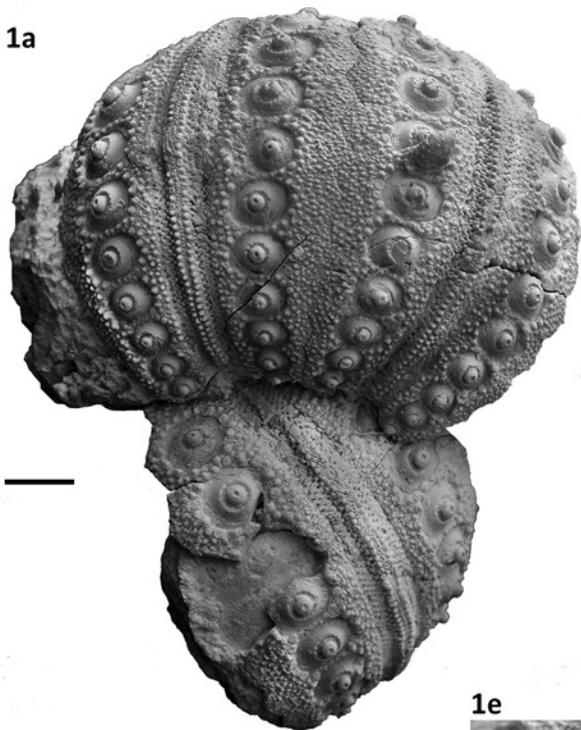
Diplocidaris bernasconii sp. nov.

Fig. 1a-f: FPJ 5667 Holotype, Buix Member of the St-Ursanne Formation, Hasenburg near Soyhières (JU), d: 80 mm, 1a: oblique top view on specimen; 1b: magnified aboral view; 1c: magnified oral view; 1d: interambulacral field at ambitus; 1e: magnified view of ambulacral field, 1f: magnified view of interradian suture; 1g: magnified view of poral partition.

Fig. 2a-b: FPJ 5722 Paratype, Buix Member of the St-Ursanne Formation, Kleinlützel (SO), h: 54 mm, 2a: interambulacral field at ambitus; 2b: magnified view of poral partition.

Scale bars = 10 mm

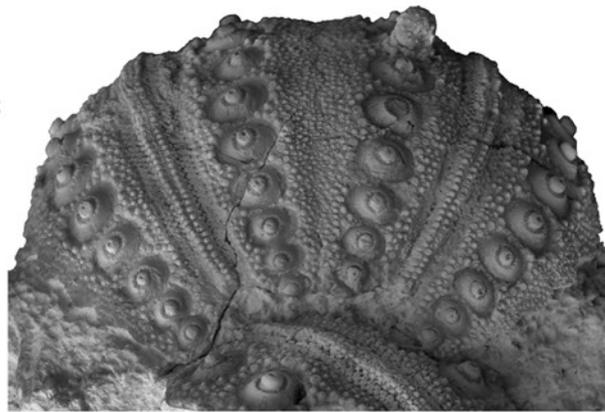
1a



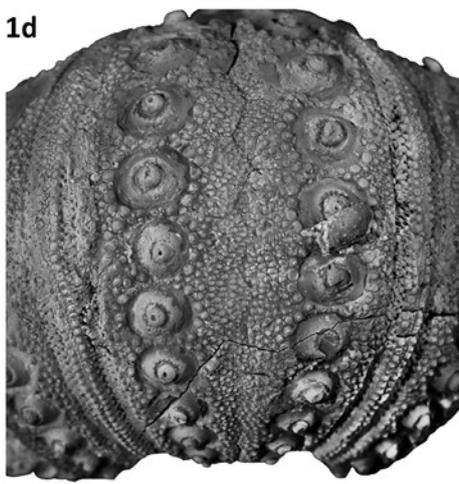
1b



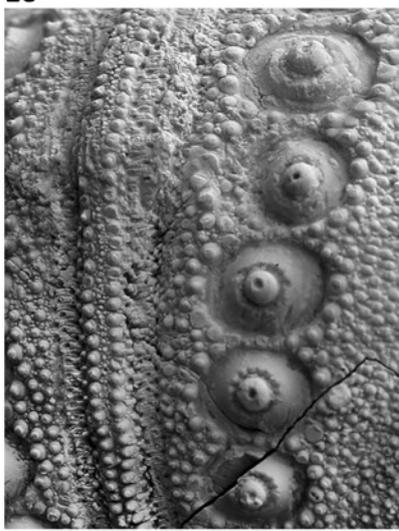
1c



1d



1e



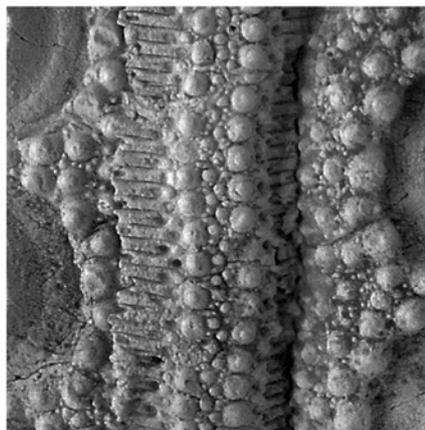
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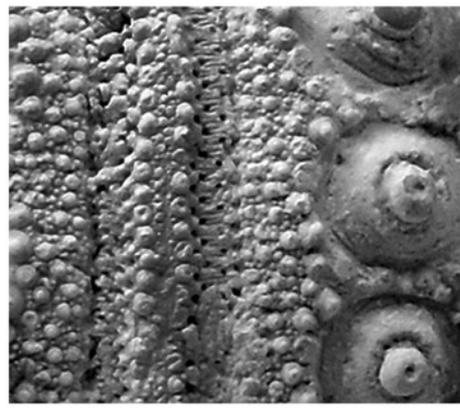
2a



2b



1g



provided in Table 8. Among the material collected from the old lime factory of St-Ursanne and the hilly ridge La Caquerelle, there are another two fragmented spines that high likely belong to the order *Rhabdocidaris*. The fragment of the rather slender and triangular shaped specimen NMBE D5542 bears few separated thorns with no orientation (Pl. VI, figs 3a, b). The fragmented specimen FPJ 15797 is cylindrical and slightly triangular-shaped (Pl. VI, fig. 4a). The shaft bears irregularly ordered thorns that gently point distally (Pl. VI, fig. 4b). Proximally a fine striation can be observed on one side (Pl. VI, fig. 4c). No preservation of neck, collar, ring and base.

Discussion: The spines of *Rhabdocidaris* may take various shapes from purely cylindrical, to distally spatulate, to flattened and finally to fully paddle-shaped. Therefore it was not possible to determine the species of the severely fragmented spines FPJ 15797 and NMBE D5542 with absolute certainty. As *Rhabdocidaris rauraca* Jeannel, 1929 was the only species of *Rhabdocidaris* that was recorded at these locations of the St-Ursanne Formation, these fragments most probably belong to *Rh. rauraca*.

Occurrence: Coral reef debris facies of the Buix Member of La Caquerelle and the lagoonal facies of the old lime factory in St-Ursanne.

Cidaridea Gray, 1825

Plegiocidaris Pomel, 1883

Type species: *Echinites coronatus* Schlotheim, 1820

***Plegiocidaris crucifera* (Agassiz, 1840)**

Pl. III, figs 4a-d

- * 1840. *Cidaris crucifera* Agassiz, p. 61, pl. 21, figs 1-4.
 1840. *Cidaris cervicalis* Agassiz, p. 77, pl. 21a, fig. 10.
 1880. *Cidaris cervicalis* Cotteau, p. 143, pls 178-180, pl. 193.

- v 1975. *Plegiocidaris cervicalis* Hess, p. 86, pl. 27, figs 4-6.
 1988. *Plegiocidaris crucifera* Vadet, p. 122, pls 16-17, pl. 18, figs 1-3.
 1999. *Plegiocidaris crucifera* Radwańska, p. 306, pl. 6, figs 1-4 pl. 7, figs 1-3.
 2003. *Plegiocidaris crucifera* Radwańska, p. 154, pl. 5, figs 1-10.

Types: In his comprehensive revision of the Oxfordian and Kimmeridgian cidaroids of Europe Vadet (1988) states that the holotype of *Plegiocidaris crucifera* (Agassiz, 1840) could not be tracked anymore but a good cast of the specimen is still stored in the collection of the “Ecole des Mines” in Lyon, France (specimen number S.34). Therefore Vadet (1988) did not designate a neotype.

Material: Zwingen (BL): 1 spine (FPJ 5625)

Description: Measurements of the available material are provided in Table 9. The primary spine FPJ 5625 is slightly asymmetric, clavate and has a short neck and a thin and smooth ring (Pl. III, fig. 4a). The base, ring and collar are coated by fine grooves (Pl. III, fig. 4b) and the shaft is slightly asymmetric and separated from the collar by a sharp and clear boundary (Pl. III, figs 4a, b, c). The shaft is ornamented with beaded ribs that are topped by short and rounded spinules that are slightly pointing distally. These lines are separated from each other by interspersed thin lines of much smaller granules (Pl. III, fig. 4c).

Discussion: The spines of *Plegiocidaris crucifera* (Agassiz, 1840) differ from the spines of *Plegiocidaris coronata* (Schlotheim, 1820, p. 313-314) through the more compact shape and the smaller collar. To *Paracidaris florigemma* (Phillips, 1829) the spines differ through the fine groove structure that coats the base, ring and collar of the primary spines. Furthermore the shaft is slightly asymmetric and the collar and shaft are clearly separated.

Table 8: Measurements in mm of the spine fragments of *Rhabdocidaris* cf. *rauraca* based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations see beginning of this chapter.

Nr.	L max	d max	l neck	d ring	d base	N ribs	N inc
NMBE D5542	21	5	-	-	-	none	-
FPJ 15797	45	6	-	-	-	none	-

Table 9: Measurements in mm of the primary spine of *Plegiocidaris crucifera* (Agassiz, 1840) based on material collected in the Buix Member of the St-Ursanne Formation in the Swiss Jura Mountains. For explanations on the abbreviations see beginning of this chapter. ⁽¹⁾ Distally some more ribs are inserted.

Nr.	L max	d max	l neck	d ring	d base	N ribs	N inc
FPJ 5626	22	7	3	4	3	> 26 ⁽¹⁾	-

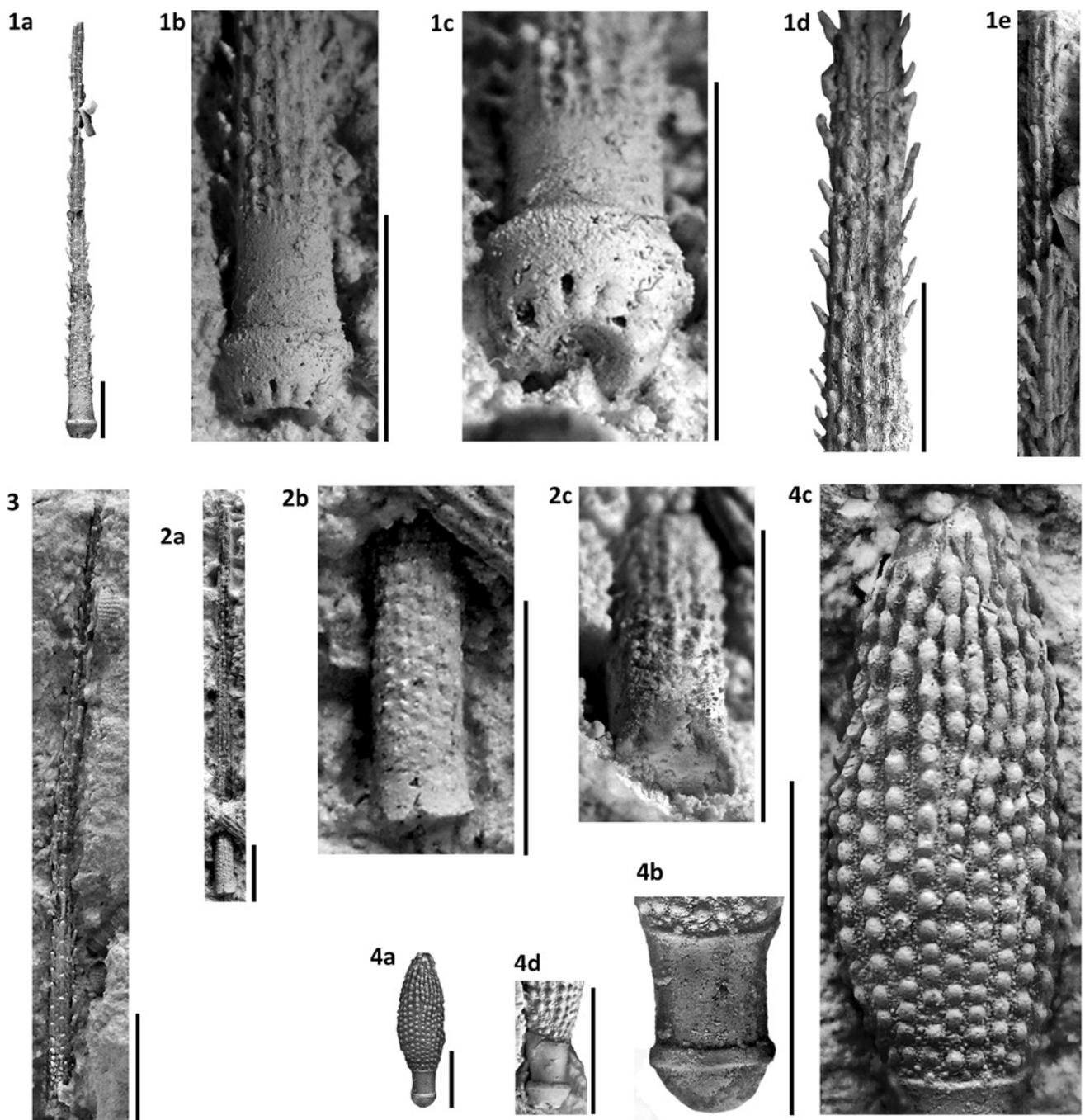


Plate III

Diplocidarid cf. *bernasconii* nov. sp.

Fig. 1a-e: FPJ15790B Buix Member of the St-Ursanne Formation, Kleinlützel (SO), l: 62 mm, 1a: side view; 1b: magnified view of base; 1c: magnified oblique view of base; 1d, e: magnified side view.

Fig. 2a-c: FPJ15790C Buix Member of the St-Ursanne Formation, Kleinlützel (SO), l: 61 mm; 2a: side view; 2b: magnified side view; 2c: magnified oblique view of reduced base.

Fig. 3: FPJ15799 Buix Member of the St-Ursanne Formation, Kleinlützel (SO), l: 53 mm magnified side view, reduced base.

Plegiocidarid *crucifera* (Agassiz, 1840)

Fig. 4a-d: FPJ 5626 Buix Member of the St-Ursanne Formation, Zwingen (BL), l: 2 mm, 4a: side view; 4b: magnified view of striation of milled ring, collar and neck; 4c: magnified view of shaft; 4d: magnified side view of asymmetric neck.

Scale bars = 10 mm

According to Hostettler (2006) *Plegiocidaris crucifera* (Agassiz, 1840) is a pioneer species that populates new developing reefs. Furthermore Hostettler (2006) states that representatives of this species seem to avoid high-energy environments. In later developmental stages of the reef, the species gets rare or absent. This is thought to be the reason why, at the present time, only one spine of *Plegiocidaris crucifera* (Agassiz, 1840) was found in the Chestel Member and none in the Buix Member.

Occurrence: *Plegiocidaris crucifera* (Agassiz, 1840) is an abundant faunal element in the coral facies of the “terrain à chailles” of Besançon, France (Agassiz, 1840). In Switzerland the species was found in the early coral reef facies of the following biostratigraphical sequences in the Swiss Jura Mountains: the Sornetan and the Liesberg Member (Hostettler, 2006; Hostettler *et al.*, 2017), the Chestel Member in the St-Ursanne Formation and the Günsberg Formation (Hostettler, 2006). Furthermore Radwańska (1999) discusses some specimens that derive from the Lower Kimmeridgian of Poland.

5. DISCUSSION AND CONCLUSIONS

5.1. Bio- and lithostratigraphy

A shallow epicontinental sea covered the study area during the Late Jurassic (Gygi, 2000). The sediments that were deposited on the carbonate platform during deposition of the St-Ursanne Formation are mostly pure and beige-grey to white limestones interspersed with chalky sediments. The observations made over the course of this study confirm previous investigations in this regard. The limestones of the St-Ursanne Formation can be attributed to three main facies using the components and fossils they contain: the lagoonal facies, the coral reef, and the reef debris facies.

In addition to its diverse and abundant echinoid fauna, the Buix Member of the St-Ursanne Formation contains brachiopods (e.g. representatives of Terebratulida), gastropods (e.g. representatives of *Nerinea*), bivalves (e.g. representatives of *Diceras* and *Pachymytilus*), and red algae (*Solenoporella ?jurassica* Rothpletz, 1908). The gastropod fauna was recently revised by Gründel *et al.* (2016).

Often the fossils in the Buix and the Chestel Member are not fully preserved, but are a little rolled which indicates a rather high-energetic depositional environment. Furthermore the presence of oncoids and ooids in certain beds indicates steady redistribution activities in the depositional environment and therefore the re-working of the sediment after initial deposition.

5.2. Echinoids as paleoenvironmental indicators

As the test of echinoids consists of many small elements that disarticulate quickly after the death, significant

transport or wave energy causes a disintegration of the corona. Therefore the preservation of echinoid coronas serves as a useful proxy for assessing the amount of energy present in the depositional environment (Smith, 1984). Most of the echinoids from the St-Ursanne Formation studied herein are preserved in one piece. If all groups of echinoids found in the St-Ursanne Formation are taken into consideration, a clear majority (~70%) of specimens are represented by entire coronas, whereas single spines (~17%) and isolated coronal fragments (~9%) are less common. Individuals with articulated spines are very rare (~4.5%). Across all species coronas of smaller representatives were more often found completely. Even though these values are certainly biased by collecting preferences, a clear trend is nevertheless apparent. Prolonged transport prior to embedding can therefore be excluded in most cases. At a macroscopic scale, most fossils show good preservation, but some damage is apparent at the microscopic scale. In particular, finer structures, such as the pores of ambulacral zones of echinoids, are often either badly preserved or overgrown with syntaxial rim cement.

5.3. The distribution of cidaroid taxa in the St-Ursanne and Bärschwil Formation

In the lagoonal, the coral reef, and the reef debris facies of the St-Ursanne Formation, five cidaroid taxa can be distinguished: *Paracidaris florigemma* (Phillips, 1829), *Diplocidaris bernasconii* sp. nov., *Diplocidaris gigantea* (Agassiz, 1840), *Rhabdocidaris rauraca* Jeannel, 1929, and *Plegiocidaris crucifera* (Agassiz, 1840). The number of five different cidaroid species in the Buix and the Chestel Member of the St-Ursanne Formation is rather low. According to Hostettler & Menkveld-Gfeller (2015) at least ten different taxa of cidaroids can be distinguished in the sponge facies of the Middle Oxfordian Wildegg Formation. Furthermore, Hostettler *et al.* (2017) summarize that there are eight species in the late Sornetan and the Liesberg Member of the Bärschwil Formation (see Fig. 9) and seven different cidaroid species in the coral facies of the Günsberg Formation (Hostettler, 2006). A precise description on the members of the Bärschwil Formation and the associated cidaroid species can be found in Hostettler *et al.* (2017) and Hess & Etter (2014).

The distribution of the cidaroid taxa in the St-Ursanne and Bärschwil Formation is summarized in Figure 9. As representatives of *P. florigemma* can be found in high abundance in the coral reef, the reef debris and the lagoonal facies, *P. florigemma* appears to represent the most generalistic species herein, although a slight preference is apparent for areas with more corals. *D. bernasconii* is the second most common cidaroid occurrence and also shows a strong preference for coral reefs. Indeed, not a single specimen was found in the lagoonal facies.

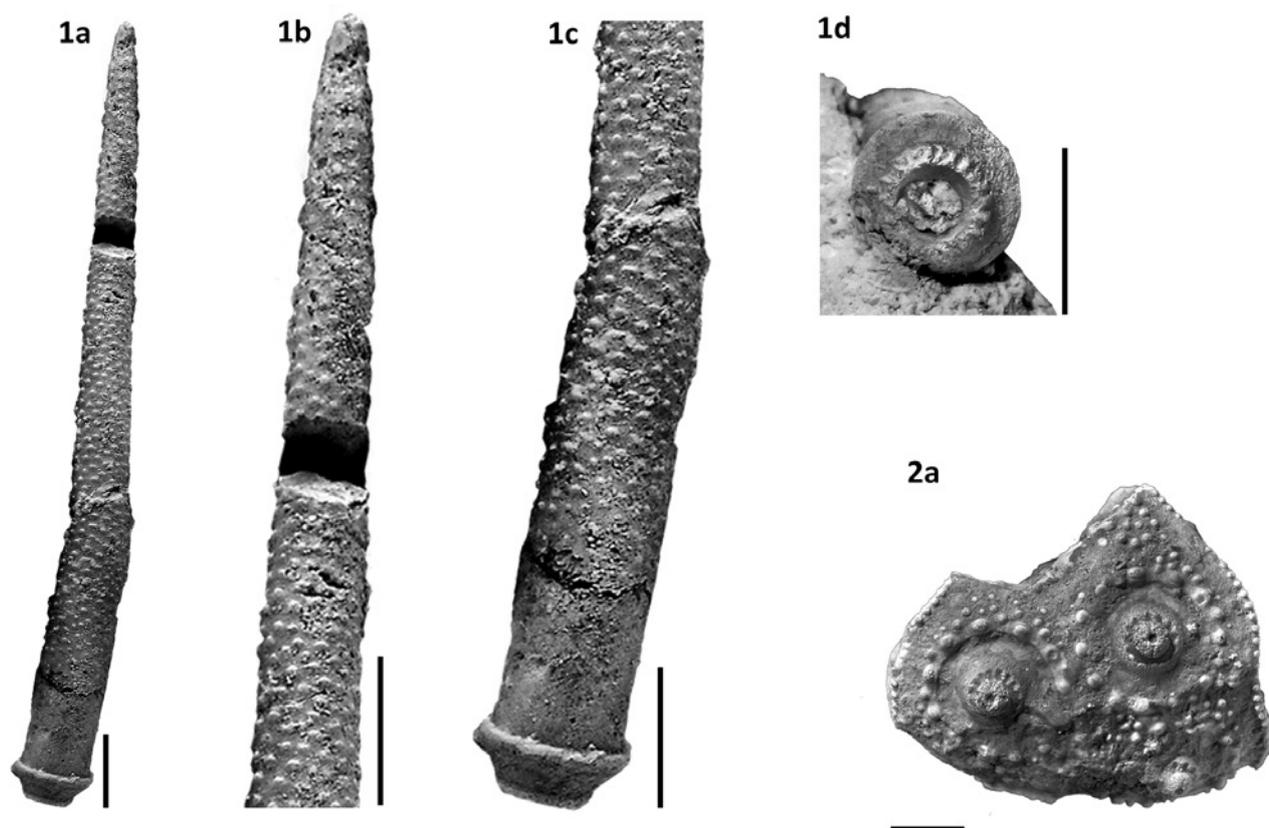


Plate IV

Diplocidaris gigantea (Agassiz, 1840)

Fig. 1a-d: FPJ 15798 Buix Member of the St-Ursanne Formation, Césai (JU), l: 92 mm, 5a: side view; 5b: magnified side view of distal end; 5c: magnified view of base and shaft; 5d: magnified top view of base.

Diplocidaris gigantea (Agassiz, 1840)

Fig. 2a: NHMW 847/0051/0206 (Holotype, collection of M. le comte Dudressier) "terrain à chailles" of Besançon, France, 2a: side view of corona fragment.

Scale bars = 10 mm

D. gigantea, *R. rauraca*, and *P. crucifera* are less common occurrences and their distribution appears to be restricted to the coral reefs and the associated coral reef debris. Along these lines, it is notable that the lagoonal facies is rich in non-cidaroid echinoid remains, indicating that the rare occurrence of cidaroids is not necessarily a taphonomic bias. Therefore, it can be concluded that representatives of Cidaroida Claus, 1880 prefer higher energetic environments, such as coral reefs and areas with the associated reef debris. These results support the general opinion of Kroh & Smith (2010) that echinoids are a useful tool for paleoenvironmental reconstruction.

ACKNOWLEDGMENTS

The Natural History Museum of Bern (NMBE) and the Fondation Paléontologique Jurassienne (FPJ) generously provided the fossil material. W. Joyce (Fribourg) critically reviewed this paper before submission. Most of the photographs were taken by A. Georgy (Glovelier). W. Etter (Basel) and O. Maridet (Porrentruy) kindly showed us the Museum's collections. A. Kroh (Vienna) supplied the impressive images of *Diplocidaris gigantea*. Lionel Cavin (Geneva) and Loïc Villier (Paris) have added helpful comments that have significantly improved the manuscript. All the people listed above made an important contribution to this study. Therefore the authors of this paper would like to express their gratitude to everyone.

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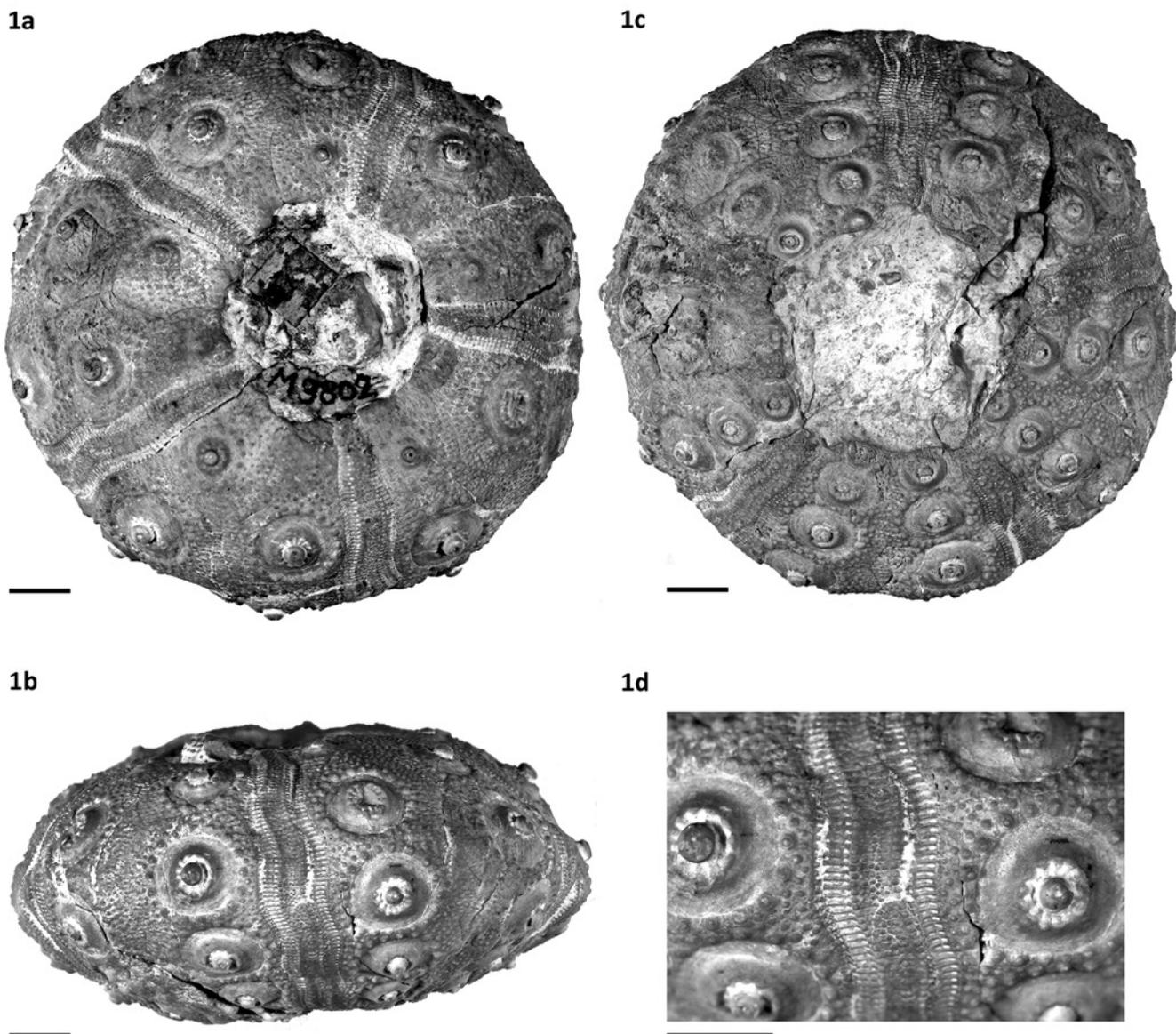


Plate V

Rhabdocidaris rauraca Jeannet, 1929

Fig. 1a-d: NMB M 9802 (Holotype of Jeannet, 1929) Buix Member of the St-Ursanne Formation, La Caquerelle (JU), d: 89 mm, 1a: aboral view; 1b: side view; 1c: oral view; d: magnified view of ambulacra.

Scale bars = 10 mm

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Plate VI

Rhabdocidarid rauraca Jeannet, 1929

Fig. 1a-c: FPJ 3302 Buix Member of the St-Ursanne Formation, La Caquerelle, Roche au Vilain (JU), d: 84 mm, 1a: aboral view; 1b: magnified view of pore-pairs; 1c: magnified view of ambulacral.

Fig. 2a-d: NMBE 4014445 Buix Member of the St-Ursanne Formation, St-Ursanne Fabrique de Chaux (JU), l: 74 mm, 2a: side view; 2b: magnified side view of base; 2c: top view of base; 2d: magnified oblique view of base.

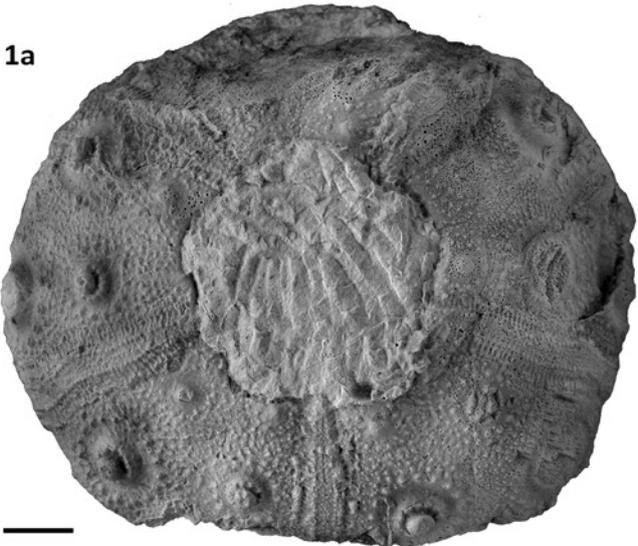
Rhabdocidarid cf. rauraca

Fig. 3a, b: NMBE D5542 Buix Member of the St-Ursanne Formation, St-Ursanne Fabrique de Chaux (JU), l: 21 mm, 3a: side view; 3b: magnified side view.

Fig. 4a-c: FPJ 15797 Buix Member of the St-Ursanne Formation, La Caquerelle, Roche au Vilain (JU), l: 45 mm, 4a: side view; 4b: magnified view, thorns; 4c: magnified view, striation.

Scale bars = 10 mm

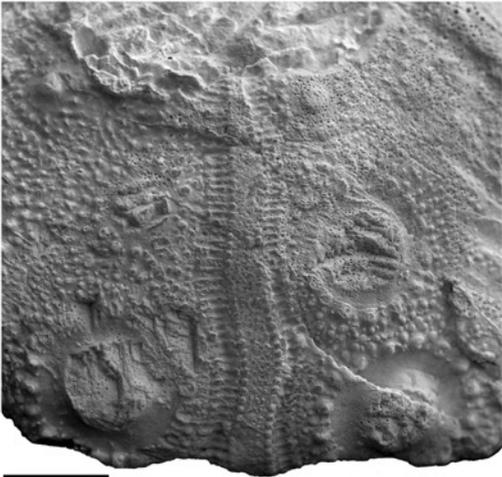
1a



1b



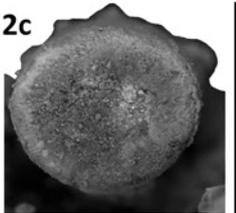
1c



2a



2c



2b



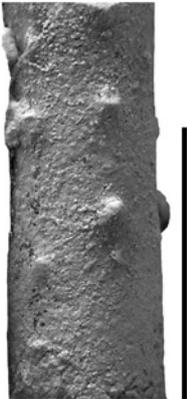
2d



3a



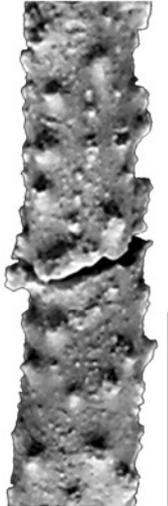
3b



4a



4b



4c

