4th International Symposium

COLEOID CEPHALOPODS
THROUGH TIME

06.09.-09.09.2011
STUTTGART
4th International Symposium
"Coleoid Cephalopods Through Time"

Abstracts Volume
Welcome to Stuttgart and the 4th International Symposium “Coleoid Cephalopods Through Time”

Sponsored by
German Research Foundation (DFG)
Staatliches Museum für Naturkunde Stuttgart (SMNS)

Hosted by
Staatliches Museum für Naturkunde Stuttgart (SMNS)

Organizing committee
Günter Schweigert (Stuttgart, Germany)
Gerd Dietl (Stuttgart, Germany)
Dirk Fuchs (Berlin, Germany)

Scientific committee
Laure Bonnaud (Paris, France)
Michael Vecchione (Washington, USA)
Kazushige Tanabe (Tokyo, Japan)
Jörg Mutterlose (Bochum, Germany)

Layout & Design
Mariepol Goetzinger (Luxembourg, Luxembourg)
Dirk Fuchs (Berlin, Germany)
Welcome address

Dear Colleagues,

the 4th International Symposium “Coleoid Cephalopods Through Time” is again held far away from the next coast. Nevertheless, it is our particular pleasure to welcome you in Swabia, the region whose marine fossils richness considerably inspired the pioneers of palaeontology to start thinking about the origin and evolution of modern cephalopods.

It was both the quantity and quality of fossils, which led our scientific forerunners MAJOR CARL HARTWIG VON ZIETEN, PHILIPPE-LOUIS VOLTZ, COUNT GEORG ZU MÜNSTER, or FRIEDRICH AUGUST VON QUENSTEDT to spend many years or even most of their lifetime in Swabian outcrops for fossil hunting. Especially the achievements of ALCIDE D’ORBIGNY and ADOLF NAEF are essentially based on fossils from southern Germany.

During the 80s and 90s of the last century, Swabia was again a center of coleoid research. THEO ENGESER, JOACHIM REITNER, and WOLFGANG RIEGRAF (all from Tübingen University) were responsible for an enormous progress in understanding the anatomy and evolution of Mesozoic coleoids.

Today, we know that the preservation to be found in fossils from these classical Jurassic localities such as Bad Boll, Holzmaden, Dotternhausen and Nusplingen is extraordinary and belongs to the best worldwide. Therefore, we are proud to show you the fossil sites of Dotternhausen and Nusplingen during the fieldtrip.

Additionally, the collection and exhibition of our host, the Staatliches Museum für Naturkunde Stuttgart, which houses numerous type specimens from Swabian localities, will be open for us.

Finally, it is worthwhile to note that the majority of participants of this 4th Coleoid Symposium are – for the first time – represented by neontologists. We regard this interest as a positive feedback and a great success!

We sincerely thank the German Research Foundation (DFG). Without this financial support, our meeting could not take place.

Many thanks for your participation, and enjoy the atmosphere!

Dirk Fuchs
Gerd Dietl
Günter Schweigert
Contents

Brief schedule................................................................................. 6

Detailed schedule........................................................................... 7

Abstracts of Talks.......................................................................... 12

Abstracts of Posters...................................................................... 52

Field guide: Early Jurassic Posidonia Shales of Dotternhausen........... 66

Field guide: Late Jurassic Plattenkalks of Nusplingen.................... 70

List of Participants......................................................................... 78
**Brief Schedule**

**Tuesday, September 6, 2011**

10:00 am - 18:00 pm: registration  
18:00 pm: welcome address & Icebreaker Party

**Wednesday, September 7, 2011**

09:00 am – 09:10 am: opening address  
09:10 am – 12:30 am: oral sessions  
12:30 am – 14:00 pm: lunch break  
14:00 pm – 18:00 pm: oral sessions  
18:00 pm: Souvenir photo

**Thursday, September 8, 2011**

09:00 am – 12:40 pm: oral sessions  
12:40 am – 14:00 pm: lunch break  
14:00 pm – 17:20 pm: oral sessions  
17:20 pm: closing session

**Friday, September 9, 2011**

9:00 am – 18:00 pm: field trip  
Museum Werkforum Dotternhausen (Posidonia Shales, Toarcian, soft part coleoids), Nusplingen (Nusplingen Plattenkalk, Kimmeridgian soft part coleoids),
**Detailed Schedule**

*Wednesday, September 7, 2011*

09:00 am – 09:10 am: opening address

**Evolution & Morphology (chair: Kazushige Tanabe)**

09:10 am – 10:10 am (keynote lecture)

VECCHIONE, M.
Conflict among cephalopod cladograms is not a bad thing, although conflicting classifications can be

10:10 am – 10:30 am

FUCHS, D. & KEUPP, H.
Multiple reasons why so-called “fossil teuthids” are rather early vampyropods

10:30 am – 10:50 am

DOGUZHAEVA, L., MUTVEI, H., BENGSTON, S., MAPES, R. & WEAVER, P.
Coleoid-related shell ultrastructures in cephalopod molluscs

10:50 am – 11:10 am

Coffee break & Poster presentations

**Evolution & Morphology (chair: Kazushige Tanabe)**

11:10 am – 11:30 am

PACKARD, A.
Coleoid integument through time

11:30 am – 11:50 am

BIZIKOV, V.A. & IPPOLITOV, A. P.
Ability of cephalopod skin to change color could be the key preadaptation to the origin of the Coleoidea

11:50 am – 12:10 am

ARKHIPKIN, A.
Trades off between propulsive movement and buoyancy in evolution of cephalopods
12:10 am – 12:30 am
DOGUZHAEVA, L. & SUMMESBERGER, H.
Pro-ostraca and pro-ostracum-like structure in Triassic coleoids

12:30 pm – 14:00 pm
Lunch break

Evolution & Morphology (chair: Jörg Mutterlose)

14:00 pm - 15:00 pm (keynote lecture)
TANABE, K.
Comparative morphology of modern and fossil coleoid jaw apparatuses

15:00 pm - 15:20 pm
KLUG, CH., SCHWEIGERT, G., FUCHS, D., KRUTA, I. & TAFFOREAU, P.
New material with radula and fins of the Late Jurassic coleoid Acanthoteuthis

15:20 pm - 15:40 pm
HEYNG, A. M. & FUCHS, D.
Coleoid Cephalopods from the Late Jurassic Mörnsheim Formation of Mühlheim (Southern Germany) – a faunal approach

15:40 pm - 16:00 pm
IPPOLITOV, A.P. & ROGOV, M.A.
Plagioteuthis moscoviensis Roemer, 1890 and Auloceras inaequilaterus Trautschold, 1866 – not coleoid, but ammonites

16:00 pm - 16:30 pm
Coffee break & Poster presentations

Embryology & Ontogeny (chair: Laure Bonnaud)

16:30 pm - 16:50 pm
FUCHS, D. & KEUPP, H.
Comparative morphology of modern and fossil coleoid embryonic shells – a critical review

16:50 pm - 17:10 pm
BOLETZKY, S.v.
Hatch as hatch can: wrestling for mobility in coleoid hatchlings (Mollusca: Cephalopoda)
Detailed Schedule

17:10 pm - 17:30 pm
GASALLA, M.A., MIGOTTO, A.E. & MARTINS, R.S.
First occurrence of Doryteuthis plei (Blainville, 1823) egg capsules off São Sebastião, Southeastern Brazil, and characteristics of embryos and newly-hatched paralarvae

17:30 pm - 17:50 pm
CYRAN, N.
The Hoyle organ, differentiation and degradation of a temporary embryonic gland in cephalopods

Thursday, September 8, 2011

Calcification, Preservation & (Paleo-) Environment (chair: Kazushige Tanabe)

09:00 am – 10:00 am (keynote lecture)
MUTTERLOSE, J.
The carbonate skeleton of Recent and past coleoids: Geochemical, biological or ecological signals?

10:00 am – 10:20 am
MANEJA, R. H., PIATKOWSKI, U. & MELZNER, F.
Ocean acidification impacts statolith microstructure and prey capture efficiency in early life cuttlefish, Sepia officinalis

10:20 am – 10:40 am
KOŠŤÁK, M. & WIESE, F.
Late Cretaceous belemnite behavior/distribution patterns related to sea-level changes and climate cooling

10:40 am – 11:00 am
IPPOLITOV, A.P., ROGOV, M.A. & BIZIKOV V.A.
First record of gladius-bearing coleoid with preserved soft-tissue in the Upper Oxfordian (Upper Jurassic) of the Russian Platform

11:00 am – 11:20 am
Coffee break & Poster presentations
Detailed Schedule

Ecology & Diversity (chair: Michael Vecchione)

11:20 am – 11:40 am
GITHAIGA-MVICIGI, J.M.W., ROBERTS, M.J., LUCAS, M. & YEMANE D.
Impacts and implications of the benthic nepheloid layer (BNL) and ambient environmental variables on the spatial distribution of squid (*Loligo reynaudii*) on the Agulhas Bank

11:40 am – 12:00 am
LIPINSKI M. R., STONIER, T., SAUER, W.H.H., SHAW, P. & YEMANE, D.
Spatial structure of the metapopulation of chokka squid *Loligo reynaudi* D’Orb., 1845 in southern African waters

12:00 am – 12:20 am
NIGMATULLIN, C.M.
The macro-scale aspects of ecological role of nektonic ommastrephid squids in the World Ocean

12:20 am – 12:40 am
GUERRA, Á., PORTELA, J.M., ROURA, Á. & VECCHIONE, M.
Discovering biodiversity: is there a second species of bush-club squids (*Cephalopoda: Batoteuthidae*)?

12:40 pm – 14:00 pm
Lunch break

Genetics & Reproduction (chair: Michael Vecchione)

14:00 pm - 15:00 pm (keynote lecture)
NAVET, S., LARGEAU, L., MAUGUIN, O., PATRIARCHE, G. & BONNAUD, L.
Calcified shell internalization: how developmental molecular processes reflect the evolutionary story of the associated muscles emergence

15:00 pm - 15:20 pm
PARDO-GANDARILLAS, M. C. & POULIN, E.
Patterns of genetic diversity and structure of octopus species from south America

15:20 pm - 15:40 pm
GUERRA, Á., ROURA, Á., PORTELA, J.M. & RÍO, J.L.d.
The large–tuberculate octopus *Graneledone macrotyla* from the Patagonian slope.
15:40 pm - 16:00 pm
NIGMATULLIN, C.M.
Two spawning patterns in ommastrephid squids and other cephalopods

16:00 pm - 16:20 pm
IBÁÑEZ, C.M., PEÑA, F., PARDO-GANDARILLAS, M. & POULIN, E.
Evolution of the reproductive strategies in Octopodidae

16:20 pm - 16:40 pm
Coffee break & Poster presentations

16:40 pm - 17:00 pm
FUCHS, D., BOLETZKY, S. V. & KLUG, CH.
Arguments pleading against the Neocoleoidea-concept – a biological and paleontological review

17:20 pm - Closing session
ABSTRACTS OF TALKS
CONFLICT AMONG CEPHALOPOD CLADOGRAMS IS NOT A BAD THING, ALTHOUGH CONFLICTING CLASSIFICATIONS CAN BE

Michael Vecchione¹, Richard E. Young² & Anni R. Lindgren³

¹National Museum of Natural History, Smithsonian Institution, Washington D.C, 200013-7012, USA; VecchioneM@si.edu
²University of Hawaii, Department of Oceanography, 1000 Pope Road, Honolulu, Hawaii 96822, USA
³Portland State University, Department of Biology, PO Box 751, Portland, OR 97207-0751, USA

Recent literature on coleoid systematics can be quite confusing. Cladistic analyses based on a variety of character sets, whether morphological (e.g., fossil, extant adults, ontogeny), molecular (nuclear, mitochondrial, proteins, etc.) or others (distribution, behavior), are a conceptual improvement over more traditional phenetic classifications. However, different character sets often indicate different relationships and all are subject to assumptions, either explicit or implicit. Although systematists like to refer to their cladograms as “phylogenetic hypotheses”, they are derived from an inductive process. The deductive science in systematics involves testing hypotheses about individual characters and their states, which leads to inferences of homology and polarity. Comparing relationships inferred from different types of characters provides focus needed for such hypothesis-testing, as well as examination of the results of analytical assumptions. Phylogenetic trees should have consistent, strong statistical support for the nodes of their branches. The lack of consistent strong support for many nodes across datasets may indicate the need to collect new material, to utilize new analytical approaches, or to explore new characters. Throughout this iterative process it is important to consider that small taxonomic changes have a wide-reaching effect on the rest of biology. Systematists should be very careful and conservative when proposing revisions to classification. The immediate goal of phylogenetic systematics should be to use discord among cladograms to guide hypothesis testing and only when broad concordance is reached should taxonomy respond.
MULTIPLE REASONS WHY SO-CALLED “FOSSIL TEUTHIDS” ARE EARLY VAMPYROPODS

Dirk Fuchs
Freie Universität Berlin, Institute of Geological Sciences, Branch Palaeontology, Malteserstr. 74-100, D-12249 Berlin, Germany; drig@zedat.fu-berlin.de

Gladius-bearing coleoids are frequent and well known from the Mesozoic fossil record and the pioneers of coleoid research already described many details of their soft-body organization. Today, thousands of extraordinarily well preserved soft-tissue coleoids from the Early Jurassic of Holzmaden and Dotternhausen (Germany), the Middle Jurassic of Christian Malford (UK), the Late Jurassic of Nusplingen, Solnhofen and Eichstädt (Germany), and the Late Cretaceous of Hâkel and Hâdjoula (Lebanon) accumulated in museum and private collections.

These coleoids have long been classified as teuthid decabrachians (“fossil teuthids”), mainly owing to the similarity of the gladius. Moreover, some fossil gladii have been attributed to various teuthid families such as Ommastrephidae, Bathyteuthidae, Cranchidae or Tysannoteuthidae. However, an unambiguous character that might confirm a systematic position within the Decabrachia is still missing. BANDEL & LEICH (1986), who first published their doubts about this classification, argued that vampyropod affinities are plausible as preserved arm crowns regularly consist of only eight arms.

Today, we are obviously far from a consensus between the “Decabrachia-Theory” and the “Vampyropoda-Theory”. Unfortunately, this disagreement strikingly hampers our evolutionary thinking and most importantly, it prevents an unambiguous polarization of character states. Workers who reconstruct phylogenetic scenarios regularly navigate into a dilemma as they usually presume the existence of “Mesozoic teuthids”.

A detailed review of the morphology of Mesozoic gladius-bearing coleoids will demonstrate the improbability of the “Decabrachia-Theory”. Characters such as the presence of circular uniserial suckers, long cirri, an unseptated gladius conus, or the absence of rostra and horny rings are - in this combination - incompatible with the phylogenetic system of the Decabrachia.

REFERENCES
COLEOID-RELATED SHELL ULTRASTRUCTURES IN CEPHALOPOD MOLLUSCS

Larisa Doguzhaeva¹, Harry Mutvei¹, Stefan Bengtson¹, Royal Mapes² & Patricia Weaver³

¹Department of Palaeozoology, Swedish Museum of Natural History, Stockholm, Sweden; larisa.doguzhaeva@nrm.se
²Ohio University, USA.
³North Carolina Museum of Natural Sciences, USA.

Ultrastructures of external shelled cephalopods have remained relatively stable throughout their evolutionary history and a few of them, prismatic, spherulitic-prismatic and tabular nacre, have been recorded. In coleoids, ultrastructures are loosely mineralized with presumably increased chitin-protein content. Tabular nacre is eliminated in phragmocone walls of extant Spirula, Sepia and in several fossil forms (DOGUZHAEVA 1996). In all examined coleoids tabular septal nacre is replaced with lamello-fibrillar nacre that is formed by rod-like fibres arranged in lamellae (Figs 1A-C); fibres are parallel in every lamella but oriented at an angle of about 60° in adjacent lamellae (nacre Type II (MUTVEI 1970); lamello-fibrillar nacre (DOGUZHAEVA 1996)).

The oldest known coleoid revealing this ultrastructure is the Late Carboniferous Donovaniconus (DOGUZHAEVA et al. 2003). Lamello-fibrillar septal nacre seems to be flexible and resistant to high pressure. This may have strengthened the shell of Spirula which migrates daily to up-to 1500m depths. Lamello-fibrillar septal nacre and lamello-dendritic ventral plate ultrastructure (Fig. 1C) of the Late Eocene sepiid Mississaepia have been recorded (DOGUZHAEVA et. al., in prep.). Parallel aragonitic laminas with irregular lengths between transverse dendrite-like fibres and the lamello-dendritic ultrastructure differ from prismatic-dendritic ultrastructure of Spirula shells.

Loosely mineralized ultrastructures of the three mentioned coleoids could account for increased organics in the shell as supported by the high content of organics in cuttlebones of Sepia and Mississaepia.

REFERENCES


DOGUZHAEVA, L.A., WEAVER, P. G. & CIAMPAGLIO, C. N. (in prep.): Enigmatic Late Eocene cuttlefish (Cephalopoda: Sepiida) from Mississippi, USA, with presumably chitinous septa in inorganic-organic shell.

Fig. 1A–D. Lamello-fibrillar (A - *Spirula*; B – *Missisaepia*; C – *Donovaniconus*) and lamello-dendritic (D - *Missisaepia*) ultrastructures
COLEOID INTEGUMENT THROUGH TIME

Andrew Packard
Chemin de l’Avelan, La Garde-Freinet, 83680 France; apackard@stanford.edu; andrew@packards.de

In life, the surface area of the skin of the *Octopus vulgaris* seen in the image used for the ‘flyer’ announcing this meeting expanded by 2 to 4 orders of magnitude from paralarva and early benthic stages to adulthood. Fractal-like growth through compartmentalization was accompanied by creation of a nested hierarchy of coloured spots within compartments. (N.B. ‘spots’ = single chromatophores <50 µ resting diameter. Just visible in this detail of the original photograph: Musée National d’Histoire Naturelle de Luxembourg).

Here I summarize hypotheses given in previous publications (see PACKARD 1995) and compare the evidence for different sub-processes in morphogenesis of the integument of squids and cuttlefish (*Loligo, Dosidicus, Sepia*).

I shall draw attention to:

a) changes in morphogenetic field structure and the long-term fates of morphogenetic field boundaries

b) spatio-temporal variables in the observed patterns of intercalary recruitment of chromatophores (onset, numbers, sizes and rates of development of spots).

c) skin-deep self-organizing principles (MEINHARDT 1982; JAEGGER, IRONS & MONK 2008).

d) evidence that ingrowing chromatophore nerves obey the rules governing establishment of their targets at the periphery (see Box).

REFERENCES


**Fig. 21.4.** Autopoietic half-tone screen. (a) Fall of new spots (X) in the ventral skin of a juvenile *Octopus vulgaris* over a 6-day interval and (b) computer model of the same, based on the principle of lateral inhibition, that has inserted the latest spots into an array of pre-existing spots (+) (see text). Both illustrations from Meinhardt (1982), with permission.

ABILITY OF CEPHALOPOD SKIN TO CHANGE COLOR COULD BE THE KEY PREADAPTATION TO THE ORIGIN OF THE COLEOIDEA

V.A. Bizikov¹ & A.P. Ippolitov²
¹Russian Federal Research Institute for Fishery and Oceanography; bizikov@vniro.ru
²Geological Institute of Russian Academy of Science; ippolitov.ap@gmail.com

Origin of the internal shell in COLEOIDEA still represents a great challenge for cephalopod researchers. Rapid diversification of ancient COLEOIDEA in Early Carboniferous indicated that these forms had some advantage(s) over other contemporary cephalopod groups with external shell. The main evolutionary gain from acquiring the internal shell by coleoid cephalopods was the possibility for development of the new organs of locomotion – muscular mantle and fins. However, transformation of the shell into internal position required some transitional stages when the mantle fold did not envelope the shell completely, and the shell has a long tubular living chamber without significant dorsal proostracum and massive rostrum. At these stages, neither muscular mantle nor fins could develop. Still, all these transitional ‘pre-coleoid’ forms were adaptive and competitive. What adaptive advantage was achieved by a mantle fold partly enveloping the shell in coleoid ancestors? The answer to this question could be found in the peculiarities of the skin structure in modern COLEOIDEA. One of the most striking features of coleoid skin is its ability for dynamic camouflage allowing the animal to adjust quickly its body color pattern against different visual background. This ability can be found in all major taxa of recent coleoids, and represents a basic diagnostic feature of this subclass. It could be reasonably assumed that the skin of the earliest COLEOIDEA and their immediate ancestors was also capable to some extent to change its color pattern, helping the animal to hide from potential predator and to be invisible to the prey. In this case, progressive expanding of the mantle fold over the tubular shell in pre-coleoids was a process of improving their camouflage. This finally proceeded to the stage when camouflage fold of the mantle enveloped the shell completely. And after that fins and muscular mantle of coleoid type, which were major evolutionary improvements for locomotion, could develop. Thus, we suggest a following evolutionary scenario for the development of internal shell in COLEOIDEA: formation of a camouflage fold by the mantle, and gradual expansion of this fold over the shell until the shell became completely internal, development of fins, dorsal proostracum and muscular mantle. This scenario implies that bactritoid ancestors of COLEOIDEA most probably had the ability to change color of their skin in the head region. Thus, the ability of skin to change color apparently does not represent an apomorphy of COLEOIDEA. More likely, it was the key preadaptation of BACTRITIDA that lead to the origin of diverse inner-shelled forms during the Early Carboniferous.
TRADES OFF BETWEEN PROPULSIVE MOVEMENT AND BUOYANCY IN EVOLUTION OF CEPHALOPODS

A. Arkhipkin
Fisheries Department, Falkland Islands Government, P.O. Box 598, Stanley, FIQQ 1ZZ, Falkland Islands; aarkhipkin@fisheries.gov.fk

The origin of cephalopod mollusks is traced to the Late Cambrian, when their most primitive representatives such as Plectronoceras and Paleoceras presumably evolved from their monoplacophoran ancestors with a high coned shell. The development of the transverse septa in the apical part of the shell interconnected by the pipe (siphon) resulted in acquiescence of a principally new type of molluscan morphology. Removal of the water from the apical septa through the permeable walls of the siphon by osmotic mechanism (similar to the Recent Nautilus) and its displacement with gas made the whole animal to be neutrally buoyant. The first cephalopods retained their hard calcareous shell, protecting their soft body and possibly withdrawing the head with tentacles into it in case of any danger. However, their shell started to act as a float, lifting the whole mollusk over the bottom, giving the cephalopods the whole array of evolutionary advantages over their bottom crawling counterparts.

Gills were located in the mantle cavity, and most likely the respiration was effectuated by its ventilation via water intake by the mantle edge flaps and ejecting it through the primordial hyponome like in modern Nautilus. Defensive reaction when the head of the animal was withdrawn into the shell by head retractors should sharply displace a significant amount of water from the mantle cavity. As a result, a strong jet of water ejected through the hyponome should move the animal in the opposite direction. This type of defensive behaviour was eventually evolved into one of the primitive types of jet propulsive movement in cephalopods. It is assumed that creating a water jet stream by head withdrawal into the mantle cavity (acting as a piston in the cylinder) was probably characteristic for a great diversity of ectocochlean cephalopods inhabiting Paleozoic and Mesozoic oceans, and it is still retained in Recent Nautilus. Later, after the origin of endocochlean (coleoid) cephalopods during the late Devonian/Early Carboniferous, another type of propulsive movement has appeared that used the muscle contraction of the mantle wall to eject the water from the mantle cavity. These two types of jet propulsive movement together with fin undulations and flapping and jellyfish-like movement using the arm umbrella in some pelagic octopods and deepwater squid make a set of movement types being characteristic to both modern and extinct cephalopods.

In the present study, a new approach has been used to reveal possible ways of animal movement in the water using both buoyancy properties of the shell and adaptations to various types of propulsive movement. Based on these features, it was attempted to deduct possible life styles of extinct cephalopods taking into account the trade offs between the necessities to have 1) a phragmocone to provide neutral buoyancy and 2) development of various types of muscles to effectuate the propulsive movement.
PRO-OSTRACA AND PRO-OSTRACUM-LIKE STRUCTURE IN TRIASSIC COLEOIDS

Larisa A. Doguzhaeva¹ & Herbert Summesberger²

¹Department of Palaeozoology, Swedish Museum of Natural History, Stockholm, Sweden; larisa.doguzhaeva nrm.se
²Department of Geology and Palaeontology, Museum of Natural History, Vienna, Austria.

The Early Carboniferous Hematites formerly referred to Aulacocerida, instances that in early evolution of coleoid cephalopods, forms existed which loss a body chamber, yet lacked a pro-ostracum (DOGUZHAEVA et al. 2010). Triassic aulacocerid Austroteuthis (JELETZKY & ZAPFE 1967) preserving what can be referred to as a pro-ostracum-like structure (DOGUZHAEVA et al. 2010). The phragmoteuthids Breviconoteuthis and Phragmoteuthis preserve a fan-like pro-ostracum with median and two lateral fields and deep sinuses between them; lateral fields lack longitudinal striation (RIEBER 1970, MOJSISOVICH 1882, DOGUZHAEVA et al. 2007). The Late Triassic Lunzoteuthis shows a relatively short pro-ostracum in which the median field is boarded with longitudinal ribs (DOGUZHAEVA et al. 2006). The pro-ostracum of Lunzoteuthis is formed by two finely laminated loosely mineralized layers and is similar, in the ultrastructural aspect, to that in Phragmoteuthis (DOGUZHAEVA et al. 2006, 2007). Lunzoteuthis type of pro-ostracum, because of its ribbed lateral fields, possibly provided an advantage in articulation of pro-ostracum and mantle and, on account of this, was further developed in Early Jurassic belemnites (DOGUZHAEVA, in press).

REFERENCES


COMPARATIVE MORPHOLOGY OF MODERN AND FOSSIL COLEOID JAW APPARATUSES

Kazushige Tanabe
Department of Earth and Planetary Science, University of Tokyo, Hongo 7-3-1, Tokyo 113-0033, Japan; tanabe@eps.s.u-tokyo.ac.jp

All cephalopods possess a well-developed jaw apparatus as a primary feeding organ. It is made mainly of chitin-protein complex (DILLY & NIXON 1976), and consists of upper and lower elements that are accommodated in the globular-shaped proximal portion of the digestive system called the buccal mass (TANABE & FUKUDA 1999). In modern cephalopods, the inner side of the lower jaw and the outer side of the upper jaw are connected by jaw muscles, with a thin layer of tall columnar cells, called beccublasts, lying between them. The branching ends of the beccublasts may serve to provide firm attachment of the jaw muscles onto the jaw lamellae, in addition to the primary function of secreting chitin-protein complex of the jaws.

Fossilized cephalopod jaws are rarely found in situ within the body chambers of ammonoids and nautilids, and in the mouth part of soft tissue remains of coleoids preserved in Paleozoic and Mesozoic Konservat-Lagerstätten, but more commonly, they occur solitarily in sediments.

The jaw apparatuses of extant coleoids exhibit diagnostic features which allow us to distinguish them from those of modern and fossil nautilids and ammonoids. Namely, they lack a calcified element, which occurs in the jaws of modern and fossil nautilids and some Mesozoic ammonoids. The lower jaws of coleoids consist of a widely open, outer lamella and a posteriorly projected inner lamella, the latter of which can be partly seen from the lateral side. In contrast, in the lower jaws of ammonoids and nautilids, the inner lamella is shortly reduced. The upper jaws of coleoids are easily distinguished from those of ammonoids, because the inner lamella of the latter is distinctly partitioned into a pair of wings.

Although the fossil record of coleoid jaws is still insufficient, recent discoveries of well-preserved jaws referable to octobrachiate and teuthid coleoids from the Late Cretaceous of the circum-North Pacific regions (e.g., TANABE et al. 2008) fill the gap of the poor fossil record of the Coleoidea. They clearly demonstrate that large, non-belemnoid coleoids existed in the Late Cretaceous North Pacific, together with ammonoids and nautilids.

REFERENCES


NEW MATERIAL WITH RADULA AND FINS OF THE LATE JURASSIC COLEOID
ACANTHOTEUTHIS

Christian Klug¹, Günter Schweigert², Dirk Fuchs³, Isabelle Kruta⁴ & Paul Tafforeau⁵

¹Paläontologisches Institut und Museum, Universität Zürich, Karl Schmid-Strasse 4, CH-8006 Zürich, Switzerland; chklug@pim.uzh.ch
²Staatliches Museum für Naturkunde, Rosenstein 1, D-70191 Stuttgart, Germany; guenter.schweigert@smns-bw.de
³Freie Universität Berlin, Geologische Wissenschaften, Fachrichtung Paläontologie, Malteserstrasse 74-100, Haus D - Raum D.032, D-12249 Berlin, Germany; drig@zedat.fu-berlin.de
⁴UMR-CNRS 7207, Département Histoire de la Terre, Muséum National d'Histoire Naturelle, 47 rue Cuvier 75231 Paris Cedex 05, France; kruta@mnhn.fr
⁵European Synchrotron Radiation Facility (ESRF), BP 220, 6 rue Jules Horowitz, 38043 Grenoble Cedex, France; paul.tafforeau@esrf.fr

Acanthoteuthis is one of the more abundant coleoid genera from the Late Jurassic Fossillagerstätten of southern Germany. Thanks to the extra-ordinary soft-part preservation of these Lagerstätten, Acanthoteuthis represents one the best known belemnoid and regularly sheds new light on the morphology of belemnoid coleoids. It is often preserved with the shell, commonly showing both phragmocone and the proostracum. As far as other body parts are concerned, the arm crown with the strong hooks has been discovered repeatedly. Acanthoteuthis recently attracted interests through the first record of suckers in a belemnoid coleoid.

Because of similarities in the morphology of phragmocone, proostracum, and the hooks, the affinity to belemnites has been discussed repeatedly. Some authors suggested that the fossils of Acanthoteuthis represent members of the genus Hibolithes, which has somehow lost its rostrum. In the new specimen, this appears rather unlikely, because at the apical end, semicircular imprints are visible, which appear to be slightly phosphatised (slight glow under UV-light). These imprints are here interpreted as remains of the fins. It is difficult to explain a taphonomic loss of an extensive rostrum when the fins are preserved.

In addition to the fins, the buccal mass with the radula is preserved. As seen under the light microscope, the radula resembles those of Recent coleoids, except for an accessory row of small multicuspidate teeth. The radula is currently investigated at the synchrotron in Grenoble, hopefully revealing further morphologic details of the radular teeth.

According to the fins, which indicate a nektonic habit, in combination with the squild-like buccal mass and the stomach contents, a carnivorous diet and a predatory habit appear likely. Therefore, Acanthoteuthis, and probably also the closely related belemnites, have to be considered as efficient nektonic predators, which successfully preyed upon fish and other moderately large nekton.
COLEOID CEPHALOPODS FROM THE LATE JURASSIC MÖRNSHEIM FORMATION OF MÜHLHEIM (SOUTHERN GERMANY) – A FAUNAL APPROACH

Alexander M. Heyng\textsuperscript{1} & Dirk Fuchs\textsuperscript{2}
\textsuperscript{1}Dept. of Earth and Environmental Sciences, Ludwig-Maximilian-University, Richard-Wagner-Str. 10, D-80333 Munich, Germany; a.heyng@lrz.uni-muenchen.de
\textsuperscript{2}Freie Universität Berlin, Institut für Geologische Wissenschaften, Malteserstr. 74-100, Haus D, D-12249 Berlin; drig@zedat.fu-berlin.de

The Late Jurassic Lithographic Limestones of “Solnhofen” are famous owing to their fossil richness and particularly to their extra-ordinary soft tissue preservation. The general appearance of Jurassic coleoids would be a black box without this evolutionary window.

Fossils from the limestones are often labelled as “Solnhofen/Tithonian” (especially older fossils). However, experts know well that this information is only vague and that the true origin of the specimens is more or less unclear as it might have been found also in many other localities in the neighbourhood of Solnhofen (i.e. Eichstätt, Painten, Mörnsheim, Daitting or Mühlheim). The latter localities represent isolated basins of different ages in a large lagoon scenery.

A faunal analysis that clearly distinguishes between the basins in the Solnhofen region is still missing. Consequently, what has been previously stated about the coleoid diversity of “Solnhofen”, is a strong generalization.

A systematic excavation campaign at Mühlheim (http://www.geomnia.de/) provides a unique opportunity to map the coleoid diversity in a clearly delimited locality. Our study area exposes the Tithonian Mörnsheim Formation („Malm Zeta 3“), which is slightly younger than the Solnhofen Formation („Malm Zeta 2“). From 2008 until today, we collected a total number of 200 coleoid specimens from this outcrop. Preliminary studies yielded at least 8 gladius-bearing species. The occurrence of \textit{Leptotheuthis gigas} and \textit{Palaeololigo oblonga} is restricted to the lower parts of the Mörnsheim Formation. Both are particularly common finds in the siliceous, platy limestones of the “Fossil-Flinze”. Surprisingly, \textit{Palaeololigo} appears to be more abundant at Mühlheim than in “Solnhofen”. The most frequent coleoid, \textit{Plesioteuthis prisca}, is common in the whole section, but most abundant in the lower parts. A gladius of \textit{Senefelderiteuthis tricarinata}, a close relative of \textit{Plesioteuthis}, represents the first record of this species outside the Solnhofen Formation. Similar to its co-existing relatives, records of \textit{Muensterella scutellaris} and \textit{Trachyteuthis} sp. indicate a fluctuating abundance through time. At present, the total number of \textit{Trachyteuthis} species must remain open. Additionally, we recorded two previously unknown gladius types.

The most frequent belemnoid, \textit{Hibolithes semisulcatus}, occurs in the whole section of the Mörnsheim Formation and is particularly common in the “Fossil-Flinze”. The occurrence of the belemnoids \textit{Rhaphibelus aciculatus} and \textit{Acanthoteuthis} sp. is documented by isolated specimens from the lower part of the section.
Fossil coleoids are very variable, and include numerous taxa with very poor paleontological record. Situation becomes more complicated, if we take into account that nature of several single records, which cannot be placed in certain group, remains unclear; but, they of course should be placed somewhere in Coleoid system. There are two such records of rostra-like fossils from the Jurassic of Central Russia:

1. *Auloceras inaequilaterus*, based on single specimen, described by H. Trautschold in 1866 from ?Oxfordian of Murom district (Vladimir region).

2. *Plagioteuthis moscoviensis*, described by F.A. von Roemer (1890) from Lower Oxfordian of Moscow region, which is known among researchers much better.

Both specimens are clearly asymmetrical, and therefore, so could be considered to be injured. The problem is that injury of the sample does not make unavailable names according to the ICZN Article 1.3.2, and they should be considered valid in such case.

We investigated new finds of these “rostra”, collected in Moscow region in locality Peski in Lower Oxfordian, and which clearly show that these “rostra” consist of nacreous layers and are not coleoid rostra, but spines of ammonite shells of family ASPIDOCERATIDAE. Aspidoceratid spine-bearing ammonites of the Oxfordian age from the European Russia are relatively well-studied. They are represented by two subfamilies (PELTOCERATINAE and EUASPIDOCERATINAE), in both these groups macroconchs are characterized by remarkable spines. Unfortunately spines usually were not matter of special investigation of ammonitologists and their special features and variability are little known. As has been shown by Zeiss (1962), spines within the single genus *Paraspidoceras* vary much. Some Upper Callovian aspidocerastids also has spines which are very close to *Plagioteuthis*.

In spite of the problems with precise identification of host ammonites, discussed names of “coleoids” could be considered as senior available names for their possible aspidoceratid counterparts *Peltoceras* Waagen, 1871, *Euaspidoceras* Spath, 1931 or *Paraspidoceras* Spath, 1925. Formally they even cannot be considered as nomina oblita, because they were used as coleoid, not ammonite names! The proposal we can offer here is to appeal to ICZN decision to suppress both generic names, since their use would make unstable generic classification for aspidoceratid ammonites, and specific names, since they can not be compared with any relevant ammonite species.
COMPARATIVE MORPHOLOGY OF MODERN AND FOSSIL COLEOID EMBRYONIC SHELLS – A CRITICAL REVIEW

Dirk Fuchs & Helmut Keupp
Freie Universität Berlin, Institut für Geologische Wissenschaften, Malteserstr. 74-100, Haus D, D-12249 Berlin; drig@zedat.fu-berlin.de; keupp@zedat.fu-berlin.de

As in many mollusc groups, the initial cephalopod shell (protoconch) is known to represent a significant key character in higher-level classifications and phylogenies. The presence of a caecum, the blind end of the siphuncle, that enters the lumen of the protoconch set the Spirulida (and Sepiida?) sharply apart from the Belemnoidea in which the protoconch aperture is completely sealed by an organic membrane (closing membrane). According to JELETZKY (1966: p. 9), “This discredits the generally accepted idea that Sepiida [Spirulida included] are direct descendents of the Belemnitida. Presence of caecum and prosipho allies the Sepiida instead with ectocochlian Cephalopoda (...) which almost invariably possess a caecum....”

JELETZKY (1966: p. 82) and later workers elaborated this idea and concluded that spirulids inherited the caecum directly from their bactritoid ancestors, while belemnoids considerably modified their embryogenesis (e.g. ENGESER 1990, HAAS 1997, BANDEL & STINNESBECK 2005, WARNKE & KEUPP 2005, FUCHS 2006). Alone HEWITT & JAGT (1999: p. 308) argued against the presumed homology between the spirulid and the ammonoid/bactritoid caecum and rather suggested an adaptive convergence as a result of similar hatching depths.

A detailed comparison, in fact, yields some striking differences between the spirulid and the ammonoid/bactritoid protoconch (ultrastructure and extension of the proseptum, extension of the protoconch wall), and, on the other hand, many similarities between the belemnoid and the ammonoid protoconch (ultrastructure and extension of the proseptum, extension of the protoconch wall).

It is therefore our aim, to re-consider the protoconch morphologies, to show that the direct development of spirulid coleoids from a bactritoid subgroup is not without doubts and to re-open the discussion about the probability of a de novo development of a spirulid caecum.

REFERENCES


HATCH AS HATCH CAN: WRESTLING FOR MOBILITY IN COLEOID HATCHLINGS
(MOLLUSCA: CEPHALOPODA)

Sigurd v. Boletzky
C.N.R.S., Laboratoire Arago, F-66651 Banyuls-sur-Mer; boletzky@obs-banyuls.fr

A common feature of coleoid cephalopods is their «endocochleate condition», which is achieved during embryonic development by formation of a shell sac (containing the shell gland) embedded in the dorsum of the mantle anlage. Thus, at an early stage of organogenesis, the forming shell or shell remnant is definitively covered by the surface tissues of the mantle. Subsequently the embryonic integument forms a set of glandular cells in the surface zone (“scar”) where the shell sac once closed. This prominent set of cells, situated on the caudal end of the mantle, is known as Hoyle’s organ. Its function as a hatching gland was demonstrated in the late 1920s. At the end of the embryonic phase, the organ is pushed against the inner chorion surface, the stored hatching enzyme leaves the glandular cells and dissolves (locally) the chorion membrane and any gelatinous material surrounding it – thus opening a hole or a tunnel for the hatchling. Depending on the thickness of the barrier formed by the capsule material, the hatchling has to move more or less actively in caudal direction, either using muscular body contractions and extensions, or ciliary locomotion (the motile cilia of the integument acting against the inner surface of the hatching tunnel), or both. Octopod hatchlings are devoid of motile cilia but have a passive “one way” device (integumental tufts of stiff bristles, known as Kölliker’s organs). Experiments using individuals of different species, when taken from their capsules shortly before hatching and thereafter placed in capsules of a different species, suggest that the hatching enzymes are not species specific, but they are always present in much greater quantities than what is normally necessary for an individual to leave its egg capsule. Loliginid squid hatchlings can open relatively thick cuttlefish capsules. However, a broad group specificity seems to exist, since loliginid squid hatchlings are unable to hatch from an octopodid chorion. These experiments have also shown that hatchlings placed in an artificial situation requiring greater hatching efforts than those normally required, are in general able to cope with these harder conditions. They truly wrestle for gaining unhampered mobility in the open water.
FIRST OCCURRENCE OF *DORYTEUTHIS PLEI* (BLAINVILLE, 1823) EGG CAPSULES OFF SÃO SEBASTIÃO, SOUTHEASTERN BRAZIL, AND CHARACTERISTICS OF EMBRYOS AND NEWLY-HATCHED PARALARVAE

M.A. Gasalla¹, A.E. Migotto² & R.S. Martins¹

¹Fisheries Ecosystems Laboratory, Department of Biological Oceanography, Instituto Oceanográfico, University of São Paulo, São Paulo, SP, Brazil; mgasalla@usp.br; rsmartins@usp.br
²Marine Biology Centre of the University of São Paulo, São Sebastião, SP, Brazil; aemigott@usp.br

Studies on loliginid squid in Brazil date back to 1970s and *Doryteuthis* (formerly *Loligo*) *plei* has been the most surveyed species in more recent years due to seasonal abundance peaks that are commonly exploited by the fisheries. However, data on egg masses and deposition are virtually unknown since surveys (including SCUBA) have failed in finding egg pods on the seabed. Here, a note on first-ever egg laying data of *Doryteuthis plei* in the region is reported, with a detailed description of the capsules and some embryonic and early-life developmental stages.

A recent summer survey around the São Sebastião Island included on-board jigging, bongo-nets stations, diving, and communication with local fishers. Fragments of loliginid eggs capsule with embryos were found by a qualified fisherman during a small-scale gillnet fishing operation on a muddy bottom 20 m deep and transported to a flow through seawater system in the Marine Biology Centre of the University of São Paulo. In the laboratory, the egg and embryos were identified as *D. plei* based on the chromatophores pattern.

The eggs were arranged in a three dimensional spiral fashion within the jelly matrix of the capsule fragments. Embryos were initially at stage 28, followed by stages 29 and 30 in the two consecutive days. The most remarkable feature in embryos and newly-hatched paralarvae were the two distinctive large, oval-shaped, red-brownish chromatophores on the dorsal side, which is a key diagnostic feature for identification of this species (Fig. 1). However, the general aspect and morphology of the egg complex (Fig. 2) seemed to differ from other loliginids elsewhere. For instance, the capsules were found to be narrower, shorter and apparently more fragile than the egg capsules of *Loligo reynaudii*, *L. vulgaris* and *D. opalescens* and *D. gahi*. In addition, the capsules are translucent, contrasting with bright orange colored egg capsules of *L. reynaudii* and the milky egg capsules of *L. vulgaris*, *D. opalescens* and *D. gahi*. Moreover, our material seemed to be narrower and shorter than the brownish *D. plei* egg capsules filmed on a sandy bottom 60 m deep in Gulf of Mexico.

Paralarval (Fig. 3) highest abundances were recorded in the channel between the island and the continent, coinciding with the location from which the identified fragments of egg capsules were recovered. In conclusion, it has been confirmed that egg pods occur in coastal waters off São Sebastião which further support the species seasonal aggregation for reproduction.
Fig. 1. Newly-hatched *D. plei* paralarvae (Red chromatophores are expanded).

Fig. 2. *Doryteuthis plei* egg pod fragment found in São Sebastião, State of São Paulo, Southeastern Brazil, in summer 2011.
Fig. 3. Newly-hatched *D. plei* paralarvae (Red chromatophores are contracted while the yellow are expanded).
THE HOYLE ORGAN, DIFFERENTIATION AND DEGRADATION OF A TEMPORARY EMBRYONIC GLAND IN CEPHALOPODS

Norbert Cyran
University of Vienna, Faculty of Life Science, Core Facility Cell Imaging & Ultrastructure Research, Vienna Austria

Since the embryonic development of invertebrates mostly takes place within a protective egg shell, the challenge for the hatchling is to penetrate through this enclosure. A common strategy in several cephalopods is the use of digestive enzymes to disintegrate the egg shell. These enzymes are assembled in a temporary embryonic gland.

The embryonic development in cephalopods is defined as a 30 stages-progression. A part of the dorsal mantle epithelium differentiates during the late embryonic stages to a specialized gland system, named Hoyle organ. It splits from the posterior mantle pole in two or three bands, one along the dorsal mantle (lacks in Octopus) and one along each fin base. The Hoyle organ consists of one or two glandular cell types (depending on the species) with mostly globular secretory granules. In some species the secretory cells are furthermore intermediated or bordered by specific non-secretory cells.

Within hours or a few days after hatch the cells of the Hoyle organ degrade completely by programmed cell death and become replaced by regular epithelium cells. The Hoyle organ was observed in several cephalopods however detailed reports of morphology, differentiation and secretory contents are still rare.

Within the current study the development of the glandular system of four species (Euprymna scolopes, Idiosepius pygmaeus, Loligo gahi and Sepia officinalis) will be compared. Main objective is a comprehensive investigation of the Hoyle organ with regard to its general morphology, the composition of cell compartments and in particular the internal and external transformation during development and degradation. Therefore each stage of the development and degradation will be considered.

Ultrastructural techniques (scanning and transmission electron microscope) provide detailed information about the external and internal glandular morphology, the time of first appearance, its growth and finally its complete degradation. The performed 3D-reconstructions helps to visualize the entire complexity of the organ and the cellular orientation. Immuncytochemical techniques are applied to elucidate the mechanism of cell degradation (e.g. apoptosis, autophagic cell death, necrosis) by means of specific markers.

Present results mediate a more consistent image of the cell types in the Hoyle organ as expected.

All four species have only one secretory cell type within the organ. The shape and size of the secretory granules are comparable but contain unexplainable inclusions for two species (Loligo and Sepia). Only in Euprymna an other cell type, relating to regular epithelium cells, intermediates the glandular cells. In Loligo, Idiosepius and Sepia the
glandular cells are bordered by a particular cell ridge which gives them a brush-like appearance in cross section.

First indications for HO cells were detected at embryonic stage 23 (Sepia). The cells continuously assemble secretory material until stage 30. The timespan of secretory activity can be dated to about five days, beginning at stage 28. That relates to the external egg transformation. The degradation of the Hoyle organ comprises a timespan of less than one day (Loligo) until more than two days (Euprymna).

The present study will improve the knowledge of glandular systems in cephalopods and contribute to the understanding of cell death mechanisms.
The carbonate skeletons of belemnites are important proxy carriers of past environments. They have been widely used for more than 50 years to obtain $\delta^{18}O$ and $\delta^{13}C$ data of Jurassic and Cretaceous sediments. Fluctuations of the $\delta^{18}O$ values indicate variations of the ice volume and palaeotemperature, those of the $\delta^{13}C$ values are explained by changes in the bioproductivity. The data have been used to postulate temperature or productivity variations of the sea water. These studies have, however, neglected any palaeobiological aspects (life style, migration, biofractionation).

In order to test the impact of these biological factors the stable isotope signatures ($\delta^{18}O$, $\delta^{13}C$) of recent *Sepia* sp. have been studied. The $\delta^{18}O$ signal of the cuttlebone mirrors precisely water temperatures in consideration of ecological factors, life cycle and annual temperature trends. Changes between summer and winter temperatures are recorded. The $\delta^{13}C$ data measured in individual cuttlebones show, however, considerable variations suggesting biofractionation.

The geochemical findings of past belemnite guards are more ambiguous. 1) Ontogenetic investigations indicate little variation of the $\delta^{18}O$ composition during the ontogeny of particular specimens. Problematic are observations on mono-specific assemblages. Up to 120 specimens from one thin horizon, show a variation of the $\delta^{18}O$-values up to 2‰ (~8°C). These findings make it difficult to use data from individual belemnites for palaeotemperature interpretations. 2) The Mg/Ca and the $\delta^{18}O$ data do not always go along with each other and seem to be controlled by factors other than temperature. The data show on one hand relatively positive $\delta^{18}O$ and corresponding low Mg/Ca ratios for certain taxa, on the other hand are very positive $\delta^{18}O$ coupled with high Mg/Ca ratios. 3) An offset of warm TEX$_{86}$ and fish apatite temperature data and by 5 - 10°C cooler $\delta^{18}OBel$ findings suggest a deep dwelling habitat for the belemnites. 4) The recently developed clumped-isotope thermometer ($\Delta_{47}^{18}O_{\text{Bel}}$) which is independent of the unknown oxygen isotope composition of the past sea-water, provides 5 - 15°C warmer palaeotemperatures than those reconstructed from the $\delta^{18}O_{\text{Bel}}$. This asks for a $\delta^{18}O$ of the past sea-water of +1.3‰.
Increasing ocean acidification is believed to reduce calcification processes in marine molluscs (ORR et al. 2005). It is suggested, however, that juvenile cuttlefish (*Sepia officinalis*) maintain calcification of their cuttlebone under elevated seawater pCO$_2$ and can even increase it (GUTOWSKA et al. 2008, 2010). We investigated the influence of elevated seawater pCO$_2$ on statolith calcification and prey capture efficiency in the early life stages of the common cuttlefish, *Sepia officinalis*. Cuttlefish were reared at 15°C and 35 psu in a flow-through seawater system under three pCO$_2$ conditions, 700 µatm (control), 1400 µatm, and 4000 µatm during 63 days in June to August 2009. Statoliths of both, embryonic and hatchling cuttlefish raised under 4000 µatm showed deformed microstructural characteristics leading to reduced statolith calcification, whereas those grown under control and 1400 µatm did not. Reduced calcification was demonstrated by comparing 18 transects characterizing the anterior surface of the statoliths. The statolith morphometrics that showed the most remarkable changes between the different pCO$_2$ conditions were total statolith length, rostrum transects, wing area and statolith weight. Statolith microstructure was significantly affected by irregularly arranged statoconia, which were typical of the statolith wing area, replacing the highly compact and well arranged crystals of rostrum and spur in normal growing statoliths. This abnormal crystal structure can have profound effects on statolith density and consequently on its normal functioning as a tool for detecting acceleration and movement (ARKHIPKIN & BIZIKOV 2000). Changes in statolith morphology and microstructure may have influenced the prey capture efficiency of the hatched cuttlefish. At 4000 µatm they showed a reduced ability to capture prey and were not able to successfully launch attacks against prey organisms. In order to verify these observations, a second experiment was conducted over 85 days in May to August 2010. Preliminary results showed that statolith morphology and microstructure differed again in the 4000 µatm group. On the other hand, prey capture ability of the hatchlings showed recovery during the experiment.

REFERENCES


Late Cretaceous Belemnite Behavior/Distribution Patterns Related to Sea-Level Changes and Climate Cooling

Martin Košťák¹ & Frank Wiese²

¹Institute of Geology and Palaeontology, Faculty of Science, Charles University in Prague, Albertov 6, Prague 2, 128 43; kostak@natur.cuni.cz.
²Georg-August-Universität Göttingen, Courant Research Centre Geobiology, Goldschmidtstr. 3, 37077 Göttingen, Germany

Three well-constrained belemnite (belemnitellid) events (Middle Cenomanian primus Event, Upper Cenomanian plenus Event, Upper Turonian bohemicus Event – see KOŠŤÁK & WIESE 2011) and a Lower Coniacian belemnite occurrence in Bohemia correlate with periods of sea-level fall and cooling (DAMSTE et al. 2010), presumably due to glacioeustacy (BORNEANN et al. 2008).

As discussed by WIESE et al. (2009), our belemnite behaviour model supposes belemnite migration from the east into the European shelf seas due to expanded shallow water shelf settings during sea-level low. These biotopes were suitable for breeding as expressed by the occurrence of all ontogenetic stages. During the sea-level rise, belemnites disappeared. From the Middle Coniacian on, belemnites started to spread in the distal depositional settings of the central European shelf seas, characterized by chalk, calarenitic facies and marls and became permanent residents. The reason for this dispersion is unknown, but might be due to the general cooling trend in this interval.

Interestingly, the Cenomanian/Turonian Praeactinocamax has a very shallow alveolus, but from the Middle Coniacian, the aveolus became deeper (Goniocamax) due to progressive calcification of the aragonitic parts of the rostrum. It is possible that this was a morphological response to the occupation of more distal habitats, but these inferred relations are under more detailed investigation at the moment.

REFERENCES
In contrast to gladius-bearing coleoids from the Callovian and Kimmeridgian-Tithonian, records of such fossils from Oxfordian are scarce. Rarity of black shales and plattenkalk facies of the Oxfordian age, caused by worldwide sea-level rise and wide distribution of the carbonate platforms explains at least partly the virtual absence of gladius-bearing coleoids at this time. A rare exception is the black shales layer found in the central parts of the Russian platform at the base of the Upper Oxfordian (Illovaiskii Subzone, Glosenze Zone). This remarkable layer has been studied in details recently. It is rather thin (10-15 cm) and can be traced over 25000 square km. Organic geochemistry data indicates that this layer has been deposited under unstable anoxic conditions coupled with a short-term increase of the phytoplankton productivity, caused by eutrophication of water column.

In 2006 fossil remains of a large gladius-bearing coleoid were discovered in Upper Oxfordian black shales of the Mikhalenino section (Kostroma region). Specimen is presented by fractioned gladius, partially covered by fossilized muscle remains, imprints of slender muscular mantle with two small posterior triangular fins and partially preserved head with incomplete arm crown. Exceptional preservation of the mantle in the posterior part of the body allows to see its anatomic features and arrangement of myofibrils. Total length of the specimen is about 80 cm.

Second studied specimen, accompanied with an imprint of *Acanthoteuthis*, has been found one year later by paleontology amateur A. Nelikhov in the same locality and bed. This record represented by anterior part of the gladius with fossilized muscles and head remains.

Though morphological study has shown that this specimen is a certain member of family Plesioteuthidae. Generic attribution is problematic, since it combines morphological traits of several nominal genera, different in preservation: general form of the gladius is similar with Toarcian *Paraplesioteuthis*, central and lateral keels on the gladius remind those of *Romaniteuthis? ommastrephiformis*, and fins are very close to *Rhomboseuthis* (gladius for which is not known). The gladius structure, body proportions and fins shape indicate that this coleoid apparently inhabited pelagic environment at shelf and could be an active nektonic swimmer. This find replenishes information on paleoecosystems of the Oxfordian seas of the Russian platform and fills stratigraphic gap between Middle and Upper Jurassic representatives of the family. It also gives new insight into taxonomy of the whole family, since allows to compare morphological traits for several nominal genera with different kind of preservation.
IMPACTS AND IMPLICATIONS OF THE BENTHIC NEPHELOID LAYER (BNL) AND AMBIENT ENVIRONMENTAL VARIABLES ON THE SPATIAL DISTRIBUTION OF SQUID (*LOLIGO REYNAUDII*) ON THE AGULHAS BANK


Zoology Department, University of Cape Town, Rondebosch 7701, South Africa; jmwicigi@deat.gov.za

Understanding the functional relationship between species distribution and their associated environmental conditions can greatly contribute to sustainable exploitation of our fisheries resource. However, studies on such effects are rare. Based on data from research surveys, we examined environmental (temperature, dissolved oxygen, turbidity, depth), time (time of day, season), location (longitude, region) and stock (adult and juvenile) effects on the distribution and abundance of adult and juvenile squid *Loligo reynaudi* on the Agulhas Bank, southern Africa. Generalized additive models (GAMs) were used to test the effect of these covariates on data collected from routine research trawl surveys. Results show mean *Loligo* catches were highest in autumn in shallow waters and lowest in autumn in deep waters. GAM results showed that for all years, depth, total trawl catch, and most importantly, turbidity were significant covariates affecting adult and juvenile squid catches. Location in terms of region was important for all categories but explained very little of the variation, while location in terms of oceanographic province was important for all squid and adults but not juveniles. Temperature was a significant covariate for adult squid but not juveniles and oxygen was a significant covariate for juveniles but not adult squid. The final model showed that *Loligo* catches were highest between depths of 60 to 120m, with bottom turbidity of <2.0NTUs (0.035ml/l PMC tur) in locations between 20 and 23°E in the western to central Agulhas Bank when total trawl catches did not exceed 1 metric ton. Incorporating the effects of these covariates and their underlying relationships into the regional oceanographic model (ROMS) will improve our forecasting techniques for squid catches to better manage this important resource.
SPATIAL STRUCTURE OF THE METAPOPULATION OF CHOKKA SQUID *LOLIGO REYNAUDI* D’ORB., 1845 IN SOUTHERN AFRICAN WATERS

M. R. Lipinski¹, T. Stonier, W. H. H. Sauer, P. Shaw & D. Yemane

¹Fisheries Management, Department of Agriculture, Forestry and Fisheries (DAFF); Private Bag X2, Roggebaai 8012, Cape Town, South Africa; MarekL@daff.gov.za; mrlipinski@nashuaisp.co.za; Lipinski@mweb.co.za

Stock structure of chokka squid (*Loligo reynaudi*) was investigated using genetic and morphometric methods. Samples were collected from five sites along the SA coast (from Cape Point to Port Alfred) and from one site in Angola. Results indicated an existence of two components of the stock: eastern, stretching from Mossel Bay to Port Alfred (with the minor sub-component in the easternmost site of the range) and western, stretching from Mossel Bay along the south and west coast, with the sub-component in Angola. Divergence was proportional to the geographic distance within each region.

Morphometric analysis confirmed these findings in principle, although more detailed analysis is advisable in the future.
THE MACRO-SCALE ASPECTS OF ECOLOGICAL ROLE OF NEKTONIC OMMASTREPHID SQUIDS IN THE WORLD OCEAN

Chingis M. Nigmatullin
Atlantic Research Institute of Fisheries and Oceanography (AtlantNIRO), Kaliningrad 236022, Russia;
chingiznigmatullin@rambler.ru

Squid of the family Ommastrephidae with 21 species is the bulk of nektonic squid stock in terms of distribution, abundance and ecological activity. They are widely distributed throughout the World Ocean from Subarctic to Subantarctic with 45-70 million t (on average ~55 million t) of total instantaneous biomass, 318-476 million t (~400 million t) of total annual production. Assuming the daily individual consumption rate of adult squid to range between 5 and 12% of the body weight, ommastrephid squid consume 820-1277 million t (~1,000 million t), annually. With increase in body size during their life cycle, most ommastrephids “permeate” the trophic oceanic pyramid, consecutively transferring from consumers of II-III to IV-VI orders and respectively changing the spectrum of their prey and predators. Thus, they are one of the key “strong interactors” that to organize the community structure at the consumer levels from II-III to V-VI orders and to direct energy and matter flows. Ommastrephids are members of rapid energy flow in trophic webs and play an important role to transfer the resources from: 1) meso- and macroplankton to middle-leveled predators (very different inshore teleosts, lancet fish, dolphin fish, tunas and sea birds) and 2) micronektonic fishes (mostly myctophids) to top-level predators (swordfishes, sharks, dolphins and other toothed whales).

In terms of the rate and amount of matter and energy transformation, ommastrephids are the leaders among nektonic animals. Owing to the unique combination of their population parameters such as very high abundance, biomass, production, food consumption, level of metabolism, rates of somatic and generative growth, short (mainly annual) life cycle and highly diversified trophic relations, ommastrephids act as the peculiar “ecosystem enzymes” in the World Ocean ecosystems that significantly accelerates of biogeochemical processes, especially in habitats where these squid are concentrated.

Nearly all ommastrephids perform active and passive regular migrations. During their daily vertical (up to 1000-2000 m) and ontogenetic seasonal - bathymetric (up to 1,000 m) and horizontal (up to 1000-1800 miles) migrations squids cross through the diversity of vertical zones, climatic zones and local/large ecosystems. As a result of these migrations, squids have transported the matter and energy from one part of ecosystem to another, or between different ecosystems. Therefore they are important element in the “integrity framework” of migrants that integrate local ecosystems into ecosystems of the next higher level, and eventually into the whole ecosystem of the World Ocean.
DISCOVERING BIODIVERSITY: IS THERE A SECOND SPECIES OF BUSH-CLUB SQUIDS (CEPHALOPODA: BATOTEUTHIDAE)?

Ángel Guerra¹, Julio M. Portela², Álvaro Roura¹ & Michael Vecchione³

¹Eduardo Cabello 6, 36208 Vigo, Spain; angelguerra@iim.csic.es
²Instituto Español de Oceanografía (IEO) C. O. de Vigo. P. O. Box 1552 36200 Vigo, Spain; julio.portela@vi.ieo.es
³NMFS National Systematics Laboratory, National Museum of Natural History, MRC-153, Smithsonian Institution, P.O. Box 37012 Washington, DC 20013-7012, USA; VecchioneM@si.edu.

One specimen of Batoteuthidae was caught during the research cruise ATLANTIS 2009 on 21 March 2009 at 45º09.51’ S- 45º08.07’ S - 59º29.04’ W -59º27.98’ W (Patagonian slope), depth 1198-1221 m. This specimen is a juvenile male, 105 mm dorsal mantle length. It is the largest Batoteuthis with complete tentacles captured to date. We compared this specimen with the types of Batoteuthis skolops, the only species in the family. Our specimen shows several differences from the types, which suggest that it might be a different species. However, until additional good specimens become available or molecular analyses are undertaken, we recommend a conservative approach of considering our specimen tentatively to be a growth form of Batoteuthis skolops.

Fig.1. Previous records (crosses) and record of the specimen caught in ATLANTIS 2009 cruise (circle).
Fig. 2. Dorsal view of the Batoteuthis skolops (?) caught in ATLANTIS 2009 cruise.
CALCIFIED SHELL INTERNALIZATION: HOW DEVELOPMENTAL MOLECULAR PROCESSES REFLECT THE EVOLUTIONARY STORY OF THE ASSOCIATED MUSCLES EMERGENCE

S. Navet\textsuperscript{1}, L. Largeau\textsuperscript{2}, O. Mauguin\textsuperscript{2}, G. Patriarche\textsuperscript{2} & L. Bonnaud\textsuperscript{1}

\textsuperscript{1}MNHN, DMPA UMR BOREA CNRS 7208-IRD 207-UPMC, 55 Rue Buffon, 75005 Paris, France; navet@mnhn.fr
\textsuperscript{2}LPN, CNRS UPR20, Route de Nozay, 91460, Marcoussis, France

The shell regression occurred during evolution in many groups of Mollusca. The cuttlefish \textit{Sepia officinalis} is the only extant cephalopod (with \textit{Spirula}) to show internal calcified shell. Morphological novelties have been selected and confer adaptive advantages. Mantle and arms and funnel both derived from the foot, are perfectly suited for the locomotion in open water and to its necto-benthic mode of life.

In order to infer evolutionary hypothesis concerning shell internalization and locomotory structures emergence, morphological novelties, we have intended to describe in \textit{S. officinalis} their setting up during development with a structural and molecular approach.

We show that the mineralisation of the cuttlebone starts from stage 25, early in the development, as soon as the first chambers are formed. Some mollusc larvae present several calcitic phases and amorphous calcium carbonate (ACC) as a support of transition from aragonite to calcite. Unlike them, in \textit{S. officinalis}, the bone is made as soon as the beginning of aragonite, as shown by X-Ray diffraction analysis of the embryonic shell. The crystalline orientation is not random, already arranged, suggesting that there is no transition phase between embryonic and adult shell.

The mineralisation during the development (larvae/or embryo) is under the control of several genes; engrailed has been shown to be expressed at the margin of the future shell in a wide range of mollusks (JACOBS et al. 2000). We have evidenced this gene in \textit{S. officinalis} and \textit{Loligo peali}, devoid of calcified shell, and showed a role of ENG in \textit{S. officinalis} shell sac delimitation. This clearly indicates a conservation of its function in cephalopods’ skeleton formation despite shell internalization, but not in mineralization. Moreover, the setting up of the main muscular effectors funnel, arms and mantle for the locomotion by jet propulsion, is controlled by eng and other genes, not identified until now in such structures. NK4 implied in cardiac myogenesis in vertebrates (CRIPPS & OLSON 2002) and Pax2/5/8 related to mechanosensorial development in many species (TORRES et al. 1996) could surprisingly complete each other in \textit{S. officinalis} for the development of the locomotory structures. This strongly suggests that NK4 and Pax2/5/8 could have been secondary recruited in cephalopods for the establishment of the muscular hydrostat, indispensible for an efficient locomotion by jet propulsion in the absence of protective shell.

These results highlight the diversity of molecular mechanisms that underly morphological modifications in response to environmental pressure, both shell internalization and concomitant muscles development.
REFERENCES


PATTERNS OF GENETIC DIVERSITY AND STRUCTURE OF OCTOPUS SPECIES FROM SOUTH AMERICA

M. Cecilia Pard-Gandarillas & Elie Poulin
Instituto de Ecología y Biodiversidad, Universidad de Chile, Santiago, Chile; pardogandarillas@gmail.com

Comparative phylogeographic studies have revealed that historical processes, especially the Pleistocene glacial-interglacial cycles, can generate latitudinal patterns of genetic variation within and between species (KELLY & EERNISSE 2007). The evidence is consistent with an increase in genetic diversity towards the tropics in several terrestrial and marine species. This latitudinal pattern of genetic diversity has also been associated with highest genetic structure between populations in warmer latitudes in relation to cooler latitudes. In this study we used two octopus species Octopus mimus and Enteroctopus megalocyathus with similar life histories, but different distribution ranges along template and cold latitudes of South America respectively. In this context, we expected a latitudinal pattern in diversity and genetic structure associated with the effects of the last glacial-interglacial cycle. To test this prediction, we collected both octopus species along their contrasting distribution ranges. We sequenced a fragment of mitochondrial DNA gene Cytochrome Oxidase III to estimate the genetic diversity and population structure of both species. In Octopus mimus genetic diversity decreased with increasing latitude, meanwhile the population structure increased. In contrast, E. megalocyathus did not show any latitudinal gradient in diversity or in genetic structure. As predicted, the southern species E. megalocyathus exhibited less genetic diversity and structure than O. mimus from template latitudes. These results show a distinctive pattern of connectivity, where the species that inhabit in template latitude tend to have less connectivity between populations. Moreover, we detected the signal of an ancient population growth in the species of template latitude, meanwhile the specie of cold latitude showed signal of recent population expansion. In summary, our results suggest that these species have been affected differently by the last glacial period. Enteroctopus megalocyathus were probably extincted in the southern Patagonia and further recolonized this area during Holocene. In contrast, the effects of the glaciations on Octopus mimus were moderated, permitting the persistence of population along the Humboldt Current System. However, lower diversity and greater genetic structure found in the southern part of its distribution range could involve strong ocean-atmospheric events such as El Niño Southern Oscillation.

REFERENCES
New insights of the morphology, reproductive strategy and distribution of the large-tuberculate octopus *Graneledone macrotyla* from the Patagonian slope are reported. This new information is based on 11 specimens caught in the bottom trawl surveys ATLANTIS 2009 and 2010 carried out on the high seas of the Southwest Atlantic, between 24 February and 1 April 2009 and from 9 March to 5 April, respectively. A new diagnosis and a complete description of the species are provided. This is the first time that mature females have been studied allowing the description of their reproductive system as well as ovarian eggs. As other eleodontid octopods, *G. macrotyla* does not have spermathecae in the oviducal glands. The presence of fertilized eggs inside the ovary suggests that fertilization takes place within the ovary. The spawning strategy of this species is discussed. The specimens collected extend the habitat of *G. macrotyla* both in depth, which range from 475 to 2044m, and latitude from 45° 44’S to 45° 16’S. From a biogeographical point of view, these data show that *G. macrotyla* inhabits the plume of cold sub-Antarctic waters, which is pushed far into the south-western Atlantic by the Falkland (Malvinas) Current.
TWO SPAWNING PATTERNS IN OMMASTREPHID SQUIDS AND OTHER CEPHALOPODS

Chingis M. Nigmatullin
Atlantic Research Institute of Fisheries and Oceanography (AtlantNIRO), Kaliningrad 236022, Russia: chingiznigmatullin@rambler.ru

The peculiarities of individual spawning activity during adult spawning part of cephalopod ontogenesis had been poorly studied, and correct data are known for a few groups only. For most species, especially oceanic, the direct observations are impossible. The results of aquarium observations on the spawning rhythm of coastal cephalopods are not in full correct with respect to natural situation. The most effective method is the reconstruction of female spawning activity by data of ontogenetic series of females at different stages of maturation and spawning to spent condition. The present study describes it for ommastrephids. Theirs females are intermittent spawners with at least more than 10 filling and evacuation of the oviducts during the final spawning period of life. There were revealed two types of spawning patterns.

1. The coastal type is characteristic for Illicinae, Todaropsinae, Todarodinae with potential fecundity (PF) of 0.04-2.5 million oocytes and relative fecundity (RF) of 500-2000 oocytes/g. After maturation and start of the spawning activity they cease to feed. During spawning period of life, for continued oocytes maturation and periodical egg-masses laying, the main source of energy is the digestive gland and mantle tissue. This is a descending type of spawning: initially several first egg-masses are the largest and then number of eggs in them is gradually decreased due to decreasing of female energetic reserves. As a result, the somatic growth becomes negative and to the end part of spawning the female’s body proportions are significantly changed and body weight decreased. In these squid the size of each adult is nearly stable after maturation.

2. The oceanic type is characteristic for Ornithoteuthinae and Ommastrephinae with PF - 0.1-35 million oocytes, RF – 2000-7000 oocytes/g). During spawning period, a significant number of oocytes still undergoes maturation, periodical egg-masses laying, approximately the same size with active feeding between egg-laying events and substantial somatic growth. During spawning stage, the size of given adult squid increases significantly due to continued somatic growth that runs parallel to generative growth.

In ommastrephids, the initial type was first one. The second type developed during their expansion to oceanic realm with high unpredictability of the habitat that gave rise to significant increase in fecundity, and respectively increased energy demand for oocyte maturation and spawning. Same situation was detected in spermatophorogenesis patterns of ommastrephid males. On the contrary, in other cephalopod groups (including Nautilus) both types of spawning patterns occur in both macro-habitats.
EVOLUTION OF THE REPRODUCTIVE STRATEGIES IN OCTOPODIDAE

Christian M. Ibáñez, Fabiola Peña, M. Cecilia Pardo-Gandarillas & Elie Poulin
Instituto de Ecología y Biodiversidad, Universidad de Chile, Santiago, Chile; ibanez.christian@gmail.com

Octopuses of the family Octopodidae are exceptional among cephalopods in their reproductive behavior. Both sexes are promiscuous and sperm competition has been described in several taxa. After mating, females care for their eggs until hatching and then die. Octopuses exhibit two major life history strategies (VILLANUEVA & NORMAN 2008): the first is the production of few and large eggs resulting in well-developed benthic hatchlings. The second strategy is production of numerous much smaller eggs resulting in free-swimming planktonic hatchlings. Here, we develop a robust phylogeny of the family and use it to understand the evolution of these and associated traits. The present work is based on literature data for mantle length (ML, mm), egg length (mm), spermatophore length (mm) and the benthic or planktonic hatchling strategies of 61 octopus species. We sequenced 12 octopus species and sequences of 49 more species were obtained from Genbank of 16s rRNA (16S) and Cytochrome Oxidase III (COIII), trying to include the most representative species and genera of the family. Phylogenetic reconstruction was inferred in a Bayesian framework from a matrix including the concatenated dataset (16S + COIII). The evolution of discrete (benthic and planktonic development) and continuous (eggs size, mantle and spermatophore length) traits, were evaluated by Parsimony, Maximum Likelihood and Bayesian approaches. We found evidence of a directional model of correlated evolution between developmental strategies and egg size as well as between spermatophore length with body size. In contrast, there was no evidence of correlated evolution between egg size and body size of the octopus. The evolution of these traits follows a gradualist model of change in the phylogeny. Apparently octopodids have evolved gradually toward larger body sizes, and consequently large spermatophores, while egg length relates more to the type of development strategy and adaptation to particular habitats.

Funding: Grants FONDECYT 3110152, P05-002ICM, PFB-23.

REFERENCES
ARGUMENTS PLEADING AGAINST THE NEOCOLEOIDEA-CONCEPT –
A BIOLOGICAL AND PALEONTOLOGICAL REVIEW

Dirk Fuchs¹, Sigurd von Boletzky² & Christian Klug³

¹Freie Universität Berlin, Institute of Geological Sciences, Branch Palaeontology, Malteserstr. 74-100, D-12249 Berlin, Germany; drig@zedat.fu-berlin.de
²C.N.R.S., Laboratoire Arago, F-66651 Banyuls-sur-Mer, France; boletzky@obs-banyuls.fr
³Paläontologisches Institut und Museum, Universität Zürich, Karl Schmid-Str. 4, CH-8006 Zürich, Switzerland; chklug@pim.uzh.ch

The idea of a sister-group relationship between the cephalopod superorders Decabrachia (squids and cuttlefishes) and Vampyropoda (octopods, cirroctopods and vampire squid) has been widely accepted since JELETZKY (1966: Fig. 2). In their phylogenetic analyses, BERTHOLD & ENGESER (1987) and ENGESER & BANDEL (1988) regarded the presence of suckers as a character that supports the monophyly of what they called the “sucker-bearing Coleoidea”. In 1997, HAAS introduced the terms “Neocoleoidea” for coleoid groups with living representatives and “Palaeocoleoidea” for a group of hook-bearing coleoids also known as “Belemnoidea”, which is generally thought to have disappeared at the end of the Cretaceous. VECCHIONE et al. (2000: p. 187) based their phylogenetic analyses on three autapomorphies of the “Neocoleoidea”: 1) presence of suckers, 2) absence of a nacreous layer in the conotheca and 3) presence of fins.

We doubt the monophyletic origin of the “Neocoleoidea” for the following reasons:

1. The arms of belemnoids were likewise equipped with suckers (MANTELL 1852, DONOVAN & CRANE 1992, FUCHS et al. 2010).
2. Absence of tabular nacre in the conotheca might have emerged independently in Decabrachia and Vampyropoda (FUCHS & TANABE 2010).
3. Belemnoids were likewise equipped with fins (KLUG et al., this volume).
4. The two characteristic arm crown modifications of the Decabrachia and Vampyropoda could not have been developed by a single step, but must have occurred in at least two transformational steps (BOLETZKY 1992: p. 756, Fig. 1; 1999: p. 10; 2003: p. 147).
5. Development of a caecum and prosipho might represent an adaptive convergence as a result of similar hatching depths (HEWITT & JAGT 1999: p. 308, FUCHS & KEUPP, this volume).

REFERENCES


ABSTRACTS OF POSTERS
EXAPTATIONS IN ARGONAUTOIDEA

Giambattista Bello
Via Colombo 34, 70042 Mola di Bari, Italy; giamb.bello@gmail.com

The term “exaptation” was introduced by GOULD & VRBA (1982) to indicate a character, previously shaped by natural selection for a particular function – an adaptation – that is co-opted for a new use. In cephalopods, extremely few exaptations have been reported in spite of the much evidence for such phenomena in this taxon. The superfamily Argonautoidea, which evolved from benthic octopod ancestors, embraces species that have become fully adapted to holopelagic life. This was achieved thanks to the evolution of peculiar characters, mainly relating to neutral buoyancy and egg brooding away from the sea floor. Some of these adaptations are indeed exaptations.

Brooding – (1) Both the egg-bearing rods on the inner side of the dorsal arms of female *Tremoctopus* and the brood case of female *Argonauta* are secreted by glandular tissue located in the 1st arm web. The secretory function of the interbrachial membrane is also an exaptation. (2) *Ocythoe tuberculata* is the only live-bearing cephalopod. Ovoviviparity evolved through the co-option of the oviducts to serve as uteri.

Neutral buoyancy – (1) The calcareous brood case of female *Argonauta*, in addition to its primordial brooding function, was co-opted to act simultaneously as a floating device. (2) The hydrostatic organ, a true swim bladder, in the females of all argonautoid genera, except for *Argonauta*, derives from the shell sac which subsequently evolved for a new function.

Mating – In males of all argonautoid species, the sealed pouch holding the long hectocotylus derives from the interbrachial membrane bordering it. This occurred thanks to the co-option of part of the arm web for the new function of hectocotylus sheltering.

Defense – *Tremoctopus* females exhibit another newly co-opted function of the arm web, which is rather wide on both sides of each dorsal arm. When a female is pursued by a predator, it can detach a fragment of its dorsal arm and the adjoining web by autotomy at predetermined weak lines, and the fragment is left behind to act as a lure for the pursuer.

REFERENCES
Belemnites, a very successful group of Mesozoic cephalopods, flourished in Cretaceous oceans until the Cretaceous–Paleogene event, when they became globally extinct. Following this event the modern types of cephalopods (squids, cuttlefish, octopus) radiated in the Cenozoic in all oceans. In the North Pacific, however, a turnover from belemnites to the modern types of cephalopods about 35 m.y. before the Cretaceous–Paleogene event documents a more complex evolutionary history of cephalopods than previously thought. This faunal turnover in the Albian can be considered as a crucial episode for the understanding of the evolutionary history of coleoid during the Mesozoic to Cenozoic. The last belemnite record in the North Pacific is that of *Neohibolites*, a taxon which favored warm water conditions. Thus we hypothesize that the decline of belemnites was possibly caused by the shrinkage of the area of warm water conditions in the North Pacific (IBA et al. 2011). This scenario is concordant with the stepwise demise of the typical Tethyan biota (e.g., rudist) in the Albian of the North Pacific and also paleoclimatic numerical simulations based on the mid-Cretaceous conditions: increasing of atmospheric CO2 and the opening of the South Atlantic Gateway. The absence of belemnites in the North Pacific throughout the Late Cretaceous was probably caused by the closure of the Bering Strait as a physical barrier between the North Pacific and Arctic-North Atlantic where was a “hotspot” of belemnite radiation at that time. In the Late Cretaceous the former niches of the fast-swimming belemnites were taken over by the modern types of cephalopods, which evolved endemically. The Cretaceous–Paleogene event only allowed the modern types of cephalopods to spread globally and to take over the niches previously held by belemnites.

REFERENCES
Earliest Jurassic Belemnites from Japan: A reassessment of Coleoid Radiation

Yasuhiro Iba¹, Shin-ichi Sano², Yasuo Kondo³ & Jörg Mutterlose⁴

¹Hokkaido University of Education, Kushiro, Hokkaido 085-8580, Japan; ibayasuhiro@gmail.com
²Fukui Prefectural Dinosaur Museum, Fukui, 911-8601, Japan
³Kochi University, Kochi, 780-8520, Japan
⁴Ruhr-Universität Bochum, 44801, Germany

Belemnites are the major player of the coleoids in Jurassic-Cretaceous oceans. Although considerable palaeontological and biogeographical research of belemnites has been conducted, their records in the earliest Jurassic are still limited. Two genera, Schwegleria and Nannobelus, which are characterized by very short rostra, are so far the only known belemnites from the earliest Jurassic. Doyle (1994) reviewed the early Jurassic belemnite records worldwide, and summarized the early evolutionary history. Belemnites evolved in Europe as small forms in the Hettangian and remained restricted to the European shelf seas up to the Toarcian.

In contrast to this current view, we report here early Jurassic belemnite findings from Japan, which have been known for quite some time. Yokoyama (1904) already described early Jurassic belemnites from the Trigonia-Sandstone of the Niranohama area (Miyagi Prefecture, northeastern Japan). A re-evaluation of these specimens and additional own new findings confirm the occurrence of belemnites in the Niranohama Formation. Based on the co-occurring ammonite genus Alsatites the material from this unit has been assigned a Hettangian (=earliest Jurassic) age.

The Niranohama belemnite specimens can be attributed to two morphologically different groups: Type 1 represents medium size rostra (diameter about 1cm, maximum length about 5cm) with a well-developed possible ventral alveolar groove. Type 2 is rare, known are only a few specimens of incomplete very large rostra (diameter over 2.5 cm) in which no grooves are recognized.

The occurrence of Hettangian belemnites in Japan clearly indicates that belemnites already had a worldwide distribution during their earliest evolutionary stage. Furthermore, size and external morphology of the Niranohama belemnites completely differs from those of the European coeval genera such as Schwegleria and Nannobelus. The new findings from Japan suggest that earliest Jurassic belemnites had a higher species-diversity than hitherto thought. The presence of a possible ventral alveolar groove in Type 1 suggests its taxonomic assignment to the suborder Belemnopseina. This is the earliest record of this suborder, which otherwise flourished in the world’s oceans from the Middle Jurassic to Cretaceous/Paleogene boundary. The systematic assignment of Type 2 is difficult at the moment, but its rostra indicate the presence of large sized belemnites during this early phase of belemnite radiation. Future discussions of the origin and early evolutionary history of belemnites need to be held in a broader palaeogeographical context that has to include the Pacific.
REFERENCES


YOKOYAMA M. (1904): On some Jurassic fossils from Rikuzen. Journal of the College of Science, Imperial University of Tokyo, 18: 1–13
“-TEUTHIDAE” OR “-TEUTHIDIDAE”? A CASE INVESTIGATION OF TAXONOMIC TERMINOLOGY

A.P. Ippolitov
Geological Institute of Russian Academy of Sciences; ippolitov.ap@gmail.com

Numerous generic names of Recent and fossil coleoids are ended on stem “-teuthis”, originating from the Greek word “τευθίς”, meaning “squid”. Early researchers were producing family names by adding suffix “-idae” to the base of this word, and Jeletzky in his monography by 1966 was the first one to see that correct family names to “-teuthididae”, according to grammar rules recommended by International Code of Zoological Nomenclature (ICZN). Later this was consequently supported by Riegraf and his co-authors, who corrected all known family names into “-teuthididae” in their large review “Fossilium Catalogus” (published 1995 and 1998). During the last decade in fossil coleoid literature such family names are most often used in form of “-teuthididae”.

Corrections made by Jeletzky and Riegraf were absolutely valid, and satisfied demands of the 2nd and 3rd editions of ICZN, published in 1964 and 1985, respectively. New, 4th edition of ICZN, published in 2000, made such emendation of family names optional: according to Article 29.3.1.1: “…if the stem so formed ends in -id, those letters may be elided before adding the family-group suffixes”. But “…if, however, the unelided form is in prevailing usage, that spelling is to be maintained, whether or not it is the original spelling”. Problem is that no definition of “prevailing usage” is not given in the Code, neither by the period of publication, nor by the number of publications.

Anyway, in literature on Recent coleoids, only suffix “-teuthidae” has been used historically, and according to 4th edition of the Code emendation into “-teuthididae” became unnecessary. All this leads to a paradox situation, that today we use different suffixes for fossil and Recent family-group names.

The suggestion here is to suppress suffix “-teuthididae” in taxonomy, turning it back into “-teuthidae” using power of International Comission on Zoological Nomenclature, in order to unify Recent and Fossil taxa and to make coleoid suprageneric taxonomy stable.
The vampyropod family Trachyteuthididae belongs to one of the best-known fossil groups and therefore regularly attracts our interests. Our newest find concerns a specimen of *Trachyteuthis hastiformis* (Münster), which was found in summer 2009, during palaeontological excavations in the latest Kimmeridgian bituminous marls of Rygol quarry, near Painten, Eastern Bavaria. The specimen is part of a gladius originally about 50 cm long and exhibits some extra-ordinarily well-preserved remains of soft tissues. As well as relicts of the gills, the posterior part contains a spirally rolled and segmented cord, 5-6 mm wide and at least 14 cm long. We interpret this structure as the Needham sac containing the mature spermatophores. An alternative interpretation of these remains as a possible chain of eggs seems unlikely because, immediately during spawning, the eggs of extant coleoids are stabilized by a mucus cover, which is a prerequisite for fossilization. The finding of spermatophores gives reason to speculate on a possible sexual dimorphism in *Trachyteuthis*. 
ADHESIVE SYSTEM OF EUPRYMNA SCOLOPES - NEW DATA, NEW IDEAS

Lisa Klinger*, Norbert Cyran*, Waltraud Klepal* & Janek von Byern#
*University of Vienna, Faculty of Life Science, Core Facility Cell Imaging & Ultrastructure Research, Vienna Austria
#Center for Integrative Bioinformatics Vienna, Max F Perutz Laboratories, University of Vienna, Medical University of Vienna, University of Veterinary Medicine, Vienna Austria

Adhesive substances with a variety of functions are known in molluscs. Mussels produce so-called byssus-threads for sticking permanently to the substrate (WAITE 1986, WAITE et al. 1989), while gastropods adhere temporary by mucus substances (SMITH ET AL. 1999, SMITH & MORIN 2002).

Four genera of cephalopods belonging to four different families (Euprymna, Sepiolidae; Idiosepius, Idiosepiidae; Nautilus, Nautiliidae and Sepia, Sepiidae) also produce glue for temporary attachment (VON BYERN & KLEPAL 2006).

Euprymna lives in near-shore benthal habitats of the Indo-Pacific Ocean (SINGLEY 1982, SHEARS 1988). They are nocturnal active and bury into the seafloor during the day (MOYNIHAN 2002). The animals secrete glue to coat themselves totally with sand. In case of danger they release the adhesive glue as a sinking decoy instantaneously to deflect predators (SHEARS 1988, NORMAN 2000). Recent ultrastructural and histochemical investigations of the epithelium of Euprymna scolopes (KLINGER et al. 2010) provide new details of the adhesive region. Contrary to SINGLEY’S (1982) observations, we found three different gland cell types instead of two:

1. **Ovate cells** are not only in the adhesive region of E. scolopes, but also in the regular mantle epithelium at the ventral side of the animal and on the base of the fins. The secretory material of the ovate cells appears to consist of highly sulfated proteins; the granules are unreactive for sugars but remain strongly reactive to basic proteins (SINGLEY 1982). A pH shift from basophilia to acidophilia, as proposed by SINGLEY (1982), could no be confirmed. The secretion always stained strongly positive for basic and only weakly for acidic proteins.

2. The **goblet cell** occurs in the dorsal part of the mantle and at the fin base. Its granules (diameter 0.8–1 μm) are electron lucent, but become more electron-dense the closer they are to the apical end of the cell. They are always of equal size and homogenously dense. The granules are strong PAS positive (neutral sugars) and show only a weak reaction for basic (Biebrich Scarlet at pH 6.0 - 10.5) and acidic protein stains (Alcian Blue at pH 1.0 and 2.5).

3. Beside the aforementioned cell types described by SINGLEY (1982), a further cell type was identified and named **cell type 4**. This cell type always occurs in the immediate vicinity of a goblet cell and can only be found in the adhesive region. Similar to the goblet cells this cell type contains spherical, membrane-bound, and very electron-dense granules. These granules, however, are much smaller (0.2–0.4 μm) and evenly distributed within the cell. They are transported to the surface by microtubules inside
the cell. The secretory content of the newly described cell type 4 remains too small to show any clear positive reactivity to the staining tested so far.

SINGLEY (1982) assumed that neutral mucopolysaccharides, secreted from the goblet cells, were responsible for adhesion, whereas de-adhesion was caused by acidic mucoproteins released from the ovate cells. Our histochemical re-characterization (KLINGER et al. 2010) showed that the secretory material of ovate cells does not react strongly to tests for acidic groups. We were unable to confirm the hypothesis of SINGLEY (1982) because the pH-value of the glandular material within as well as outside the cells remained steady.

Based on our data we argue against a duo-gland adhesive system, as suggested earlier (SINGLEY 1982). We rather suggest that the goblet cells and the newly found cell type 4 produce together the glue (as duo-component system). Release of sand particles from the epidermis might be mechanically induced, as indicated by the numerous dermal and mantle muscle layers beneath the epithelium (KLINGER et al. 2010). A chemically caused release as proposed by SINGLEY (1982) is to our opinion too slow and not supported by the histochemical results.

REFERENCES


MORPHOLOGICAL QUANTIFICATION OF BELEMNITE ROSTRA (TOARCIAN, LOWER JURASSIC)

Jean-Daniel Pinard & Pascal Neige
Laboratoire Biogéosciences, University of Burgundy, Dijon

The morphology of the belemnites rostra is commonly used in systematics. However species are often based on weak morphological differences (DOYLE 1985, 1990,1992; SCHLEGELMILCH 1998), which may be interpreted in a subjective way. Indeed, except some biometric studies (e.g. BARSKOV & WEISS 1992), the major part of the studies is only qualitative and the significance of the intra- and intertaxa variations of the shape of the rostrum is not statistically tested.

The aim of this study is to use morphometric analysis, unreleased on belemnites, in order to quantify the shape of the rostrum, and to test the significance of this character in systematics.

Two belemnites assemblages, one from the early Toarcian (Serpentinum zone) and the other one from the middle Toarcian (Bifrons zone), were studied in this work. This study was focused on the shape of the stem and of the apical region (DOYLE 1990-1992) also called rostrum solidum (SCHLEGELMILCH 1998). Each rostrum was characterized by the shape of the outline (in dorsal view), of the profile (in lateral view) and of the transverse section. The shape of alveolar region (or rostrum cavum) was not used because this region is currently destroyed and it is consequently impossible to have well-homologous points for the morphometric analysis. To quantify the shape, B-spline functions were used to make polynomial regressions of each type of outline (as in TERRA et al. 2004 or MONNA et al., in prep). The obtained parameters were so used as quantitative parameters for statistical analysis (principal components analysis). In order to determine the significance, a kernel discriminant analysis (KDA) was developed (based on DUONG 2007).

It appears from this topic that the differences in the shape of the rostrum between the different studied genera (Acrocoelites LISSAJOUS, 1915; Parapassaloteuthis RIEGRAF, 1980; Simpsonibelus DOYLE, 1992; Youngibelus RIEGRAF, 1980; Dactyloteuthis BAYLE, 1878) are not always significant: only Dactyloteuthis is significantly different from the other genera. For the others, only the different types of grooves allow to discriminate the different species. It will be very interesting to extend this kind of analysis to other species to improve the use of the shape in systematics, and thus to have a better view of the belemnites biodiversity trough time, by means of a combined quantitative and qualitative approach.

REFERENCES


MONNA, F., JEBRANE, A., GABILLOT, M., LAFFONT, R., SPECHT, M., CAMIZULI, E., CHATEAU, C., ALIBERT, P. (in prep.): Morphometry of Middle Bronze Age palstaves. II - Study of the regional variation of shape in two typological groups, implications on trade and production.


3D-MICROANATOMY OF CEPHALOPOD BRAINS: A COMPARATIVE STUDY ON THE HATCHLINGS OF SIX SPECIES

Elvira Scharpf, Gerhard Haszprunar & Martin Heß
Biozentrum LMU München, Großhadenerstr. 2, 82152 Planegg-Martinsried, Germany; hess@bio.lmu.de

The nervous system of cephalopods is the largest of all invertebrates and the most complex within molluscs. Directly after hatching cephalopod paralarvae start to interact with their environment, e.g. food capture and predator avoidance with the aid of their eyes. For this purpose already the hatchlings possess well-developed visual systems, which differ between species in size, internal organization, and developmental stage in accordance with differing integrative capabilities and behavioural patterns.

For a comparative morphological approach we acquired 3D structure-data of the head region of six coleoid cephalopod species (Sepia officinalis, Rossia sp., Sepietta obscura, Loligo vulgaris, Octopus vulgaris) with light microscopic resolution, based on semithin section series (transversal planes, 2 µm, epoxy resin). Digital light micrographs of the slices were aligned, segmented lobe by lobe, surface-rendered, and analyzed with Amira® 3D software.

We obtained virtually explorable, digital 3D models which display the complex structures of the central nervous systems. The six investigated species have most lobes and nerves in common, whereupon the complexity, relative size of lobes and eyes, and the degree of centralization differ. For instance one can observe an increasing centralization from decapod to octopod brains. O. vulgaris hatchlings have the smallest and most compact CNS due to shortening of the connectives between the lobes. Loligo vulgaris has rather long connectives, Sepia officinalis shows intermediate conditions.

The morphological differences, with partly functional implications, can be discussed in the interdependent contexts of 1. the importance of vision immediately after hatching (e.g. transiently lecithotrophic Octopus vs. hunting Sepia), 2. the adaptation to different photic habitats (benthic vs. pelagic) and 3. the phylogenetic position (e.g. body shape; preformation of adult conditions).
PRELIMINARY RESULTS OF POPULATION GENETICS OF OCTOPUS VULGARIS, LOLIGO VULGARIS AND SEPIA OFFICINALIS FROM THE MEDITERRANEAN BASED ON AFLP ANALYSIS

Kerstin Martina Warnke
FR Paläontologie, Freie Universität Berlin, Malteserstr. 74-100, Haus D, 12249 Berlin, Germany; warnke@zedat.fu-berlin.de

The amplified fragment length polymorphism (AFLP) technique was used for the first time for decabrachians (viz. Sepia officinalis and Loligo vulgaris from the Adriatic Sea) and Octopus vulgaris (from the Aegean Sea, the Adriatic Sea, the Gulf of Naples and the Gulf of Lion). Previous the AFLP method was used just once in cephalopods. ZHANG et al. (2009) analysed O. ocellatus from limited sampling locations in the Yellow Sea (China). Recently, the favourite markers to investigate population genetics of cephalopods were microsatellites, but their development and application are much more expensive and time-consuming as the AFLP fingerprinting method (VOS et al. 1995, BENSCH & ÅKESSON 2005, MEUDT & CLARKE 2007). GAUDEUL et al. (2004) stated that AFLP markers are more useful than microsatellites for fine scaling population research. Altogether for the present study with only few samples from limited sampling sites the AFLP technique appears more efficient.

The results of the AFLP analysis showed that S. officinalis and L. vulgaris collected from just one sampling location are from one single population each. O. vulgaris from well spread apart sampling locations within the Mediterranean Sea are from more than one population. Therefore, the AFLP analysis proves successful on cephalopods and hence is useful for population genetic analyses of these animals.

REFERENCES
FIELD GUIDE:

EARLY JURASSIC POSIDONIA SHALES OF DOTTERNHAUSEN
THE POSIDONIA SHALE AT DOTTERNHAUSEN (WESTERN SWABIAN ALB, SW GERMANY)

Manfred Jäger & Günter Schweigert
HOLCIM GmbH, Dotternhausen
Staatliches Museum für Naturkunde Stuttgart; guenter.schweigert@smns-bw.de

The Swabian Alb and its foreland are famous for its richness and diversity of fossils from the Jurassic, going back to the early roots of palaeontology in the beginning of the 17th century. One of the reasons is the Posidonia Shale (= Posidonienschiefer Formation, Fig. 1) of Toarcian age. This black shale is one of the worldwide best-known examples of a Konservat-Fossillagerstätte. Stagnant conditions during a global anoxia event (PEARCE et al. 2002) caused hostile life conditions at the sea floor, which are crucial for the exceptional preservation of vertebrates (e.g., ichthyosaurs, crocodiles, pterosaurs, fishes) and invertebrates (large crinoid colonies, ammonites, coleoids, lobsters). Almost every museum in the world shows some specimens from this formation in the exhibition. The most famous place where these rocks are quarried is the village Holzmaden, SE of Stuttgart. This place is, however, far away from our field trip route to the western part of the Swabian Alb. Therefore, we will visit another locality where the same beds are even better exposed. This locality is the HOLCIM cement work at Dotternhausen. First we will visit the exhibition of the local museum “Werkforum”, where the rich and nicely preserved fauna of the Posidonia Shale from Dotternhausen is presented in a modern style. Another part of the exhibition is dedicated to the Jurassic succession in the neighbourhood and its fossils, e.g. the faunas from the Late Jurassic sponge-microbial mounds and from coeval bedded limestones which are exploited in another quarry of the cement factory (Plettenberg quarry).

After lunch we will visit the present quarry where a section from the marly beds with intercalated limestones of the Upper Pliensbachian (= Amaltheenton Formation, Costatenkalk Member) rich in belemnites and the overlying Posidonia Shale of the Toarcian are well-exposed. The section of Dotternhausen, its stratigraphy and its fossil content has been studied numerously in the last decades (e.g. RIEGRAF et al. 1984, SCHMID-RÖHL 1999, RÖHL et al. 2001, SCHMID-RÖHL et al. 2002, SCHMID-RÖHL & RÖHL 2003, besides others).

For details of the museum “Werkforum” and the fossils from the Posidonia Shale the participants of the field trip will get a museum’s guide book in English or German language.
Fig. 1 Lithostratigraphy of the Southern Germany Jurassic. Rheintal = Rhine Valley; “Wutach” = Wutach Gorge (On the south-western boundary of the Swabian Jura near the Swiss border. “Schwäbische Alb” = Swabian Alb; “Franken” = Franconian Alb. Derived from the „Stratigraphische Tabelle von Deutschland 2002 (STD 2002)“. See http://www.stratigraphie.de/std/index.html.
REFERENCES


FIELD GUIDE:

LATE JURASSIC PLATTENKALKS OF NUSPLINGEN
THE NUSPLINGEN PLATTENKALK FOSSIL SITE (WESTERN SWABIAN ALB, SW GERMANY)

Gerd Dietl & Günter Schweigert
Staatliches Museum für Naturkunde Stuttgart; gerd.dietl@gmx.de; guenter.schweigert@smns-bw.de

The visited outcrops are located W of the village Nusplingen, on top of the “Westerberg” hill (Fig. 1). Along the road from Nusplingen to the top of the hill the exposed Upper Jurassic mainly consists of spongiolithic limestones of Oxfordian to late Kimmeridgian age. In an abandoned quarry the strong palaeorelief developed in this area is well visible due to the dipping of the beds (lower Kimmeridgian).

Fig. 1. Map showing the location of the fossil site Nusplingen in SW Germany. From KLUG et al. (2005).
Geological setting and history of research

The Nusplingen Plattenkalk, also known as “Nusplingen Lithographic Limestone”, represents a ‘Fossillagerstätte’ similar to the famous lower Tithonian Solnhofen Lithographic Limestones in Bavaria. It is located in the western part of the Swabian Alb, about 12 kilometres N of the Danube Valley. It is the only occurrence of fossiliferous laminated limestones in Swabia. The laminated limestones were deposited in a more or less anoxic environment of a lagoon surrounded by sponge/microbial mounds. Some of them were partly tectonically uplifted over the sea level as small islands.

Spectacular fossils from the Nusplingen Plattenkalk were reported since the middle of the 19th century. Several excavation campaigns took place, at first with more commercial aspects as prospecting for limestones to be used for lithography or for roof tiles, later restricted to scientific interests. The Nusplingen Plattenkalk is of late Kimmeridgian age and thus approximately 0.5 my older than the Solnhofen limestones (SCHWEIGERT 1998b, 2007). Since 1983 the whole area of the Nusplingen Plattenkalk is a Protected Excavations Area because of its fossils. The Nusplingen Lithographic Limestone is actually well exposed and excavated in two small quarries (Nusplingen and Egesheim quarries). The total thickness of the Nusplingen Plattenkalk is between 10.5 and 17 metres (Fig. 2). For detailed sections see DIETL et al. (1998) or BANTEL et al. (1999). General overviews on this fossil site are given in DIETL & SCHWEIGERT (1999, 2001, 2004), for a bibliography of older publications see SCHWEIGERT (1997).

New excavations by the Natural History Museum of Stuttgart in the abovementioned two quarries have proliferated new data on sedimentology, palaeoecology, taphonomy, biostratinomy, and on the fossil content of the Nusplingen Lithographic Limestone. Since 1993 more than 8.000 fossils were recovered. They belong to c. 360 taxa, many of them are new. They tell us interesting stories about sea life in or around the Nusplingen lagoon and from the surrounding shallow sea of the Upper Jurassic in SW Germany. In contrast to Solnhofen, Nusplingen had a pelagic situation far away from larger continental islands like the Rhenish and Bohemian Massifs in the N and in the NE. Another interesting aspect is the preservation of the fossils within the Nusplingen Plattenkalk. Some of the fossils which are embedded in bituminous layers occurring in the upper part of the succession exhibit an extraordinary preservation of organic matter.

Fossil content

The Nusplingen Plattenkalk yields a significant amount of debris from the nearby reefs and from the water column. Among the microfossils the coccolithophorids are of great importance, because they characterize the laminates as marine alginites (BANTEL et al. 1999). Some bedding planes exhibit structures pointing to a temporary development of microbial mats. More than 60 species of radiolarians were identified by dissolving the limestone with acid.

In the higher part of the succession, especially in the bituminous layers, many land plants occur. They are derived from nearby uplifted islands and still preserved with their organic tissue showing finest anatomical details like cell-structures and stomata.
Some years ago we were even able to identify amber. This amber occurs in situ within the resin vessels of isolated araucariacean cone scales.

The most frequent invertebrate fossils of the Nusplingen Plattenkalk Limestone are ammonites and their aptychi. Some ammonites are very spectacular because they are preserved with their complete jaw apparatuses and stomach contents. The lower
jaw is the well-known calcitic aptychus, whereas the upper jaw which was originally chitineous is preserved in carbon (SCHWEIGERT & DIETL 1999a). Also nautiloids have been found with both jaws still in their body chambers, sometimes together with stomach-contents. The belemnites occur frequently. Their guards are very often bitten by predators (SCHWEIGERT 1999). Coleoids are often preserved with their ink sacs and their beaks still in original position (SCHWEIGERT & DIETL 2010, KLUG et al. 2005, 2010a, b). The following coleoid taxa are recorded:

Belemnites and belemnoids:
Deinuncus sp.
Hibolithes semisulcatus Münster
Pavloviteuthis kapitzkei Engeser
Rhaphibelus acicula (Münster)

Vampyropods:
Leptotheuthis gigas Meyer
Pearceiteuthis n. sp.
Plesioteuthis prisca (Rüppell)
Trachyteuthis nusplingensis Fuchs, Engeser & Keupp

Among the arthropods, the horseshoe crab Mesolimulus is quite rare. One of the specimens, however, shows its compound eyes and even the muscles preserved, together with microbial layers covering the phosphatic muscle tissue (BRIGGS et al. 2005). The newly excavated fossils include the first record of a Jurassic centipede (SCHWEIGERT & DIETL 2997). Other remarkable fossils are several insects like beetles and dragonflies. Most of these specimens are preserved in organic matter. Decapod crustaceans, especially natant shrimps and prawns, besides polychelids are typical of the Nusplingen Plattenkalk, and many of them are well-preserved (e.g. SCHWEIGERT & DIETL 1999b, SCHWEIGERT et al. 2000). About 20 different taxa have been recorded. Other benthic organism such as echinoids, brittle stars and crinoids occur only sporadically. Especially the echinoids are usually bitten resulting from the activity of predators (GRAWE-BAUMEISTER et al. 2000). The most frequent echinoderm, however, is the small planktic crinoid Saccocoma. The isolated ossicles of this crinoid also occur within the widespread coprolites known as Lumbricaria, which were produced by aspidoceratid ammonites – as it is demonstrated from crop contents.

Among the vertebrate fauna the fishes predominate. They are represented by selachians, holocephalans and numerous actinopterygians. Most typical of the Nusplingen Plattenkalk is the angel shark Pseudorhina acanthoderma (O. Fraas) which is preserved with its complete skeleton and the outline of the skin.

Reptiles rarely occur. They are represented by three genera of pterosaurs and at least three genera of marine crocodiles. In summer 2004 the excavation team of the
Stuttgart Museum recovered parts of a skeleton and the skull of a *Cricosaurus suevicus* (E. Fraas) with remains of the skin and its stomach content. The preservation of this specimen results from predation. One of the most interesting fossils ever recovered in Nusplingen is a tiny feather in organic preservation which may stem from *Archaeopteryx* or another feathered reptile (SCHWEIGERT et al. 2010, 2011).

In contrast to the typical Lithographic Limestone of Solnhofen, the ichnofauna of the Nusplingen Plattenkalk is much more diverse, but mostly restricted to special layers (SCHWEIGERT 1998a). Coprolites are generally frequent indicating marine life in the water column above the anoxic sea floor.

**The Egesheim quarry**

The Egesheim quarry was exposed for extraction of road material in 1979/80. Because of intervention of the State Museum of Natural History Stuttgart the quarrying stopped at the end of 1980 because of the danger to destroy important fossils. Here are the lowermost 5 metres of the Nusplingen Plattenkalk Formation exposed. In this outcrop the excavations reached the bottom of the Plattenkalk lagoon formed by the so-called Liegende Bankkalke Formation, a highly bioturbated micritic limestone thus contrasting the nearly non-bioturbated lithographic facies. The bottom of the lagoon is dipping with about 15 degrees. In other outcrops the submarine relief can reach until 45 degrees. The western border of the lagoon consists of sponge/microbial mounds. They are exposed directly behind the blockhouse. Some years ago there was an isolated slumping fold exposed within the laminated facies of this quarry.

**The Nusplingen quarry**

The exploitation of the limestones in the Nusplingen quarry goes back until the middle of the 19th century. Since that time the Nusplingen Plattenkalk has been excavated sporadically for commercial purposes. At the same time the first important fossils were recovered, but lacking any detailed data. The first scientific excavation started in 1929 under the supervision of the University of Tübingen. But it took not much longer than one summer. Two other scientific excavations (1935, 1962) carried out again by the Geological Institute of the University of Tübingen were also restricted to a single summer campaign. The State Museum of Natural History in Stuttgart started new excavations in this quarry in 1994. Since that time the excavations are going on with great success.

During the new excavations only the uppermost five metres of the Nusplingen Plattenkalk were exposed. The total thickness of this formation within this quarry area is about 10.5 metres. Especially in the upper part of the section some bituminous layers are remarkable in respect of their extraordinary preservation of fossils. They are easy to identify due to their blue-grey colour.

Within the succession of the laminated limestones, several turbidites with graded bedding (so-called “allodapic limestones”) and several thicker bioturbated beds indicating a better oxygenation are intercalated. The turbidites yield angular lithoclasts
and other components like calcareous ooids, sponge spicules and sponges, and even some fragments of hermatypic corals from shallower areas surrounding the lagoon. With the help of these maker beds it is possible to correlate the outcrops in the two quarries. Also some silica layers occur throughout the basin. In the Nusplingen quarry it is visible that the deposition of laminated limestones stopped abruptly. We presume a strong seakey being the reason for this dramatic event. From the nearby sponge/microbial reefs, a lot of boulders had been broken off, gliding into the central parts of the lagoon as olistoliths, where they were deposited directly above the laminated limestone. This olistolith cover reaches a thickness of several metres in the northern part of the basin. The allochthonous nature of the boulders is indicated by geopetal fillings in hollow fossils (e.g. brachiopods) and several ammonites significantly older than those from the underlying laminates. Below the olistolith, a thin succession of siliceous laminites occurs. They have not been studied yet. Between these laminates (Bed A) and the laminites of Bed C, there is a succession of slumped beds (Bed B). The top of this slumping consists of a calcareous mudstone, which we interpret as the fine fraction which was deposited after the slumping event. Within the slumping bed, the original stratification of the laminates is strongly disturbed by folding, boudinage, lateral compression, and repetition by stapling. The whole bed is inversely stratified. Originally the slumping bed was deposited in shallower areas along the southern margin of the basin.

Because of Cenozoic erosion no data about the younger Upper Jurassic of this area are available. Tithonian beds younger than the Nusplingen Plattenkalk occur south of the Danube valley, but nowhere true lithographic limestones occur.

REFERENCES


SCHWEIGERT, G. & DIETL, G. (2010): The Coleoidea of the upper Kimmeridgian Nusplingen Lithographic Limestone (Upper Jurassic, SW Germany) – diversity, preservation and palaeoecology. – Ferrantia, 59: 165-175.


LIST OF PARTICIPANTS
PARTICIPANTS (in alphabetical order)

1. **Arkhipkin, Alexander**, Fisheries Department, FIPASS, FQQ 1ZZ Stanley, Falkland Islands; aarkhipkin@fisheries.gov.fk

2. **Bello, Giambattista**, Via Colombo 34, 70042 Mola di Bari, Italy; giamb.bello@gmail.com

3. **Bergér, Daniel**, Museum Bergér, Harthof 1, 85072 Eichstätt, Germany; berger.daniel90@gmail.com

4. **Bergér, Georg-Heinrich**, Museum Bergér, Harthof 1, 85072 Eichstätt, Germany; g.h.berger@t-online.de

5. **Boletzky, Sigurd von**, CNPS-Laboratoire Arago, 6 Bd des Evadés de France, 66550 Banyuls-sur-Mer, France; sigurd.boletzky@sfr.fr


7. **Byern, Janek von**, Faculty of Life Science, University of Vienna, Althanstr. 14, 1090 Wien, Austria; vByern@freenet.de

8. **Chorazy, Wawrzyniec**, Institut GMG, Ruhr-Universität Bochum, Universitätsstr. 150, 44801 Bochum, Germany; wawrzyniec.chorazy@rub.de

9. **Cyran, Norbert**, Faculty of Life Science, University of Vienna, Althanstr. 14, 1090 Wien, Austria; norbert.cyran@univie.ac.at

10. **Dietl, Gerd**, Staatliches Museum für Naturkunde, Rosenstein 1, 70191 Stuttgart, Germany; gerd.dietl@gmx.de

11. **Doguzhaeva, Larisa**, Department of Palaeozoology, Swedish Museum of Natural history, Box 50007, 10405 Stockholm, Sweden; larisa.doguzhaeva@nrm.se

12. **Donovan, Desmond**, 4 North Grove, Wells, Somerset, BA5 2ST, UK; desmond.donovan@virgin.net

13. **Fuchs, Dirk**, Institut für Geologische Wissenschaften, Fachrichtung Paläontologie, Freie Universität Berlin Malteserstr. 74-100, Haus D, 12249 Berlin, Germany; drig@zedat.fu-berlin.de

14. **Gasalla, Maria**, Fisheries Ecosystems Laboratory, Department of Biological Oceanography, University of São Paulo, Brazil; mgasalla@usp.br

15. **Guerra, Angel**, Instituto de Investigaciones Marinas (CSIC), Eduardo Cabello 6, 36208 Vigo, Spain; angelguerra@iim.csic.es

16. **Heyng, Alexander**, Department of earth and environmental Sciences, Ludwig-Maximilian-Universität, Richard-Wagner-Str. 10, 80333 München; heyng@amh-geo.de
17. Iba, Yasuhiro, Hokkaido University of Education, 1-15-55 Shiroyama, 085-8580 Kushiro, Hokkaido, Japan; ibayasuhiro@gmail.com

18. Ibáñez, Christian, Universidad de Chile, Las Palmeras 3425, 7800024 Santiago, Chile; ibanez.christian@gmail.com

19. Ippolitov, Alexei, Geological Institute of Russian Academy of Sciences, Pyzhevski lane 7, 119017 Moscow, Russia; ippolitov.ap@gmail.com

20. Keupp, Helmut, Institut für Geologische Wissenschaften, Fachrichtung Paläontologie, Freie Universität Berlin Malteserstr. 74-100, Haus D, 12249 Berlin, Germany; keupp@zedat.fu-berlin.de

21. Klug, Christian, Paläontologisches institute und museum, Karl schmid Str. 4, 8006 Zürich, Switzerland; chklug@pimuzh.ch

22. Košťák, Martin, Faculty of Science, Charles University Prague, Albertov 6, Praha 2, 12843 Prague, Czech Republik; kostys@centrum.cz

23. Lipinski, Marek Roman, Department of Agriculture, Forestry and Fisheries, Private Bag X2, Roggebaai 8012, Cape town, South Africa; Lipinski@mweb.co.za

24. Meissner, Philipp, Institut GMG, Ruhr-Universität Bochum, Universitätsstr. 150, 44801 Bochum, Germany; philipp.meissner-f4w@rub.de

25. Mutterlose, Jörg, Department of Geology, Ruhr-Universität Bochum, Universitätsstr. 150, 44801 Bochum, Germany; joerg.mutterlose@rub.de

26. Nigmatullin, Chingiz, Atlantic Research Institute of Marine Fisheries and Oceanography, Donskoj st. 5, 236022 Kalininograd, Russia; chingiznigmatullin@rambler.ru

27. Packard, Andrew, Hopkins Marine Station, Stanford University, La Goure, Chemin de l’Avelan, 83680 La Garde-Freinet, France; apackard@stanford.edu

28. Pardo-Gandarillas, María Cecilia, Universidad de Chile, Las Palmeras 3425, 7800024 Santiago, Chile; pardogandarillas@gmail.com

29. Piatkowski, Uwe, Leibniz-Institut für Meereswissenschaften an der Universität Kiel, IFM-GEOMAR, Düsternbrooker Weg 20, 24105 Kiel, Germany; upiatkowski@ifm-geomar.de

30. Pinard, Jean-Daniel, M2 Géobiosphère, Biogéosciences,University of Burgundy, 14-16, rue du Bourg, 21000 Dijon; jeandaniel_pinard@yahoo.fr

31. Scharpf, Elvira, Biozentrum LMU München, Großhaderner Str. 2, 82152 Planegg-Martinsried, Germany; elvira.scharpf@gmx.de

32. Schweigert, Günter, Staatliches Museum für Naturkunde, Rosenstein 1, 70191 Stuttgart, Germany; guenter.schweigert@smns-bw.de

33. Summesberger, Herbert, Naturhistorisches Museum Wien, Burgring 7, 1010 Wien, Austria; herbert.summesberger@nhm-wien.ac.at
34. **Tanabe, Kazushige**, Department of Earth and Planetary Science, University of Tokyo, Hongo 7-3-1, Tokyo 113-0033, Japan; tanabe@eps.s.u-tokyo.ac.jp

35. **Vecchione, Michael**, National Museum of Natural History, 200017 Washington D.C, U.S.A; vecchione@si.edu

36. **Warnke, Kerstin**, Freie Universität Berlin, Institut für Geologische Wissenschaften, Fachrichtung Paläontologie, Malteserstr. 74-100, Haus D, 12249 Berlin, Germany; warnke@zedat.fu-berlin.de

36. **Wiese, Frank**, CRC Geobiologie, Universität Göttingen, Goldschmidtstr. 3, 37077 Göttingen, Germany; frwiese@snafu.de
**Contents**

Vecchione, M.: Conflict among cephalopod cladograms is not a bad thing, although conflicting classifications can be..................13
Fuchs, D. & Keupp, H.: Multiple reasons why so-called “fossil teuthids” are early vampyropods.....................................................14
Doguzhaeva, L., Mutvei, H., Bengtson, S., Mapes, R. & Weaver, P.: Coleoid-related shell ultrastructures in cephalopod mollusca......15
Packard, A.: Coleoid integument through time..........................................................17
Bizikov, V.A. & Ippolitov, A. P.: Ability of cephalopod skin to change color could be the key preadaptation to the origin of the Coleoidea.................................................................19
Arkhipkin, A.: Trades off between propulsive movement and buoyancy in evolution of cephalopods.................................................20
Doguzhaeva, L. & Summesberger, H.: pro-ostraca and pro-ostracum-like structure in Triassic coleoids............................................21
Tanabe, K.: Comparative morphology of modern and fossil coleoid jaw apparatuses......................................................................22
Klug, Ch., Schweigert, G., Fuchs, D., Kruta, I. & Tafforeau, P.: New material with radula and fins of the Late Jurassic coleoid Acantothethus.................................................................23
Heyng, A. M. & Fuchs, D.: Coleoid Cephalopods from the Late Jurassic Mönchsheim Formation of Mühlheim (Southern Germany) – a faunal approach.....................................................................24
Ippolitov, A.P. & Rogov, M.A.: Plagioteuthis moscoviensis Roemer, 1890 and Autoceras inaequilaterus Trautschold, 1866 – not coleoid, but ammonites.................................................................25
Fuchs, D. & Keupp, H.: Comparative morphology of modern and fossil coleoid embryonic shells – a critical review......................26
Boletzky, s. v.: Hatch as hatch can: wrestling for mobility in coleoid hatchlings (Mollusca: Cephalopoda)........................................28
Gasalla, M.A., Migotto, A.E. & Martins, R.S.: First occurrence of Doryteuthis plei (Blainville, 1823) egg capsules off São Sebastião, Southeastern Brazil, and characteristics of embryos and newly-hatched paralarvae....................................................29
Cyran, N.: The Hoyle organ, differentiation and degradation of a temporary embryonic gland in cephalopods...............................32
Mutterlose, J.: The carbonate skeleton of Recent and past coleoids: Geochemical, biological or ecological signals?.....................34
Košták, M. I. & Wiese, F.: Late Cretaceous belemnite behavior/distribution patterns related to sea-level changes and climate cooling........................................................................................................................................37
Ippolitov, A.P., Rogov, M.A. & Bizikov V.A.: First record of gladius-bearing coleoid with preserved soft-tissue in the Upper Oxfordian (Upper Jurassic) of the Russian Platform.................................................................................38
Nigmatullin, C.M.: The macro-scale aspects of ecological role of nektonic ommastrephid squids in the World Ocean..............41
Guerra, A., Roura, A., Portela, J.M. & Río, J.L. d.: The large–tuberculate octopus Graneledone macrotyla from the Patagonian slope...42
Nave, S., Largeau, L., Mauquin, O., Patriarche, G. & Bonnou, L.: Calcified shell internalization: how developmental molecular processes reflect the evolutionary story of the associated muscles emergence........................................................................44
Pardo-Gandarillas, M. C. & Poulin, E.: Patterns of genetic diversity and structure of octopus species from south America........46
Guerra, Á., Portela, J.M., Roura, A. & Vecchione, M.: Discovering biodiversity: is there a second species of bush-club squids (Cephalopoda: Batoteuthidae)?.................................................................47
Nigmatullin, C.M.: Two spawning patterns in ommastrephid squids and other cephalopods.......................................................48
Fuchs, D., Boletzky, s. v. & Klug, Ch.:Arguments pleading against the Neocoleoidea-concept – a biological and paleontological review ............................................................................................................................50
Bello, G.: Exaptations in Argonautoidea..............................................................................................................................................53
Iba, Y., Mutterlose, J., Tanabe, K., Sano, S., Misaki, A. & Terabe, K.: Belemnite extinction and the origin of modern coleoids 35 m.y. prior to the Cretaceous-Paleogene event..................................................54
Iba, Y., Sano, S., Kondo, Y. & Mutterlose, J.: Earliest Jurassic belemnites from Japan: a reassessment of coleoid radiation...........55
Ippolitov, A.P.: “teuthidae” or “teuthididae”? A case investigation of taxonomic terminology.........................................................57
Keupp, H., Engeser, T., Fuchs, D. & Haeckel, W.: Fossil Spermatophores of Trachyteuthis hastiformis (Cephalopoda, Coleoidea) from the Upper Kimmeridgian of Painten/Bavaria.................................................................58
Pinard, J.-D. & Neige, P.: Morphological quantification of belemnite rostra (Toarcian, Lower Jurassic)..........................61
Warnke, K.M.: Preliminary results of population genetics of Octopus vulgaris, Loligo vulgaris and Sepia officinalis from the Mediterranean based on AFLP analysis.................................................................65
Jäger, M. & Schweigert, G.: The Posidonia Shale at Dotternhausen (western Swabian Alb, SW Germany).......................................67
Dietl, G. & Schweigert, G.: The Nusplingen Plattenkalk fossil site (western Swabian Alb, SW Germany)..................................71