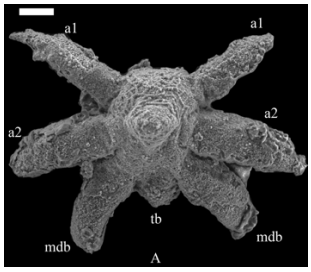
More recent projects on 'Orsten' fossils until 2016 of the Ulm Team and continued by Dieter (hopefully in further collaboration with Andreas too)

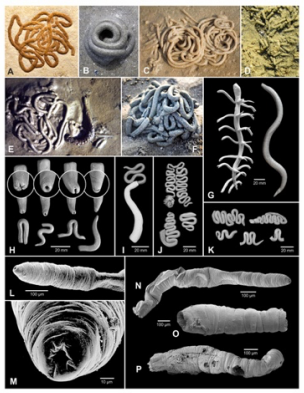
(including ongoing collaborations with Swedish, Polish and Chinese collaborators from the former C.O.R.E.-Group)

2025 – 2014: 'Orsten' fossils from China



Project of the former CORE-grouper Huaqiao Zhang, now Professor in China, started for his dissertation. His work together with further Chinese colleagues concentrates on exceptionally preserved mainly scalidophoran nemathelminths from the Middle to Upper Cambrian (Furongian) of China, including larval stages. Several papers were published in the course of the project, the exciting new aspect of a recently published paper, involving Andreas and Mats Erikson, was the possible preservation of muscle tissue, so far found only in a few pentastomid fossils from the Isle of Öland, Sweden, published by Dietmar Andres from Berlin (Andres 1989). A new paper, this time on strangely preserved fossil, putatively early annelids in internal-mass preservation, is under construction.

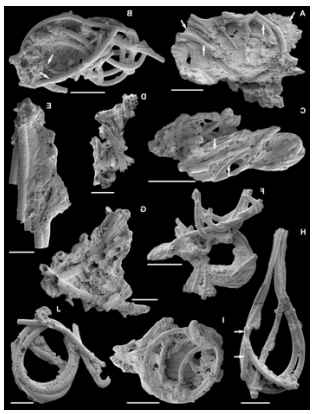
2024 – 1991: Orsten-type fossils from Poland



In this project, started with Hubert Szaniawski and continued with Ewa Olempska and colleagues originally focused on crustaceans from Poland, stem taxa and phosphatocopines.

Recently we worked out the morphology of exceptionally preserved faecal pellets, bromalites.

2018 – 2009: Orsten odds and ends



Project started by Christopher Castellani for his dissertation, finished 2013; several papers were published in the course of the project, such as on **pentastomids** (20111), on **sponge spicules** (2012),on **facetted eyes** (2 papers 2012), and on **cyanobacterians** (2018). Main issues have, regrettably, never been submitted. Particularly, missing is still the ms on worm-shaped forms and isolated bits and pieces.

2010 – 2006: Orsten arthropods from China

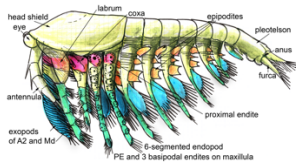
Project started with Xiguang Zhang, Professor in Kunming, China.

***Wujicaris klausmuellerae*, the oldest known eucrustacean metanauplius, and *Yicaris dianensis* , the first eucrustacean from the Lower Cambrian**

The name Wujicaris has been given in June 2010 to a tiny larva from the same locality in China as *Yicaris*, but from a slightly younger horizon. The species name in honor of the late Klaus J. Müller. The larval status of ***Wujicaris*** – an early metanauplius – can be derived from its fairly immature maxillula and the initial maxilla, which is represented by only a spine. The larva is of a

clearly entomostracan eucrustacean species and has a more modern-fashioned look than *Yicaris*. Exceptional are its posterior head shied spine and another spine extending perpendicularly from the hypostome in front of the labrum, features shared, strangely, by different eucrustacean taxa, shield spine by barnacle larvae (Cirripedia), and hypostomal spine by fish lice (Branchiura). The descriptive paper on this new form has been published in ***Current Biology*** and even made it to the cover page of this journal.

Yicaris dianensis



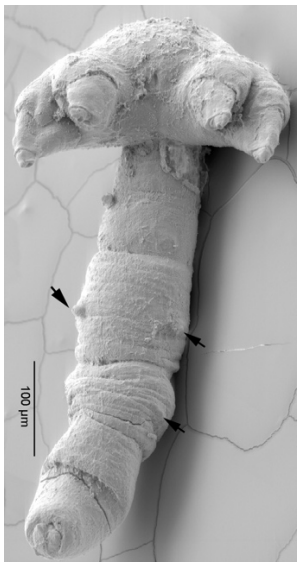
This species is, according to our analysis, a member of the crown group of Crustacea, the eucrustaceans, and, even, more, fits nicely into the Entomostraca, so strengthening the monophyly of this taxon. This can be drawn from several features, which are shared only with cephalocarids, maxillopods and branchiopods, members of this clade.

Furthermore Yicaris added **two remarkable features to the discussion of eucrustacean/ entomostracan features**: presence of **epipodites** and **six-segmented endopods** on the trunk limbs. Lastly, the endopods of the anterior limbs have more endites than known from any of the extant entomostracans and any of the hitherto described 'Orsten' forms representing members of this clade: *Dala*, *Bredocaris*, Skaracarida, *Walossekia* and *Rehbachiella*.

This formed the basis for another crustacean we could then describe from the Orsten of Sweden: ***Paulinecaris siveterae***. More soon.

2011 – 1994: Pentastomida

Pentastomida, the oldest known arthropod parasites

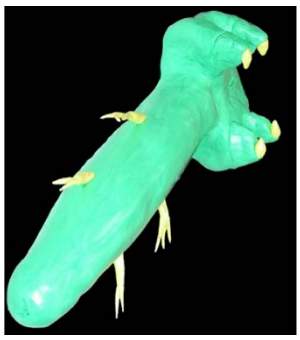


Project finished, paper published 2011. The so far latest paper on this remarkable animal group deals with the ontogeny and structural details, based on a material of almost 70 specimens. Several species and different larval stages could be distinguished adding significantly to our understanding of the ontogeny, morphogenesis and evolution of this parasitic arthropod taxon. Indeed only few parameters change during growth except size. The segment number does not increase at all, implying that already hatchlings have the definite number of body segments. This is very unusual among arthropods and, again, besides the head composition, refutes any affinities to Crustacea of any kind. Less significant chances and specific differences concern the head, the shape of the already highly reduced trunk limbs, and the caudal end. The last paper was mainly the work of **Christopher Castellan**i from 2007 to to 2008.

We know that all this contradicts molecular data (e.g. Abele et al. 1989) and sperm morphology (Wingstrand 1972), but also have to stress that sperm is just a weak character, and the molecular data apparently cheat the view on true relationships because they cannot distinguish from symplesiomorphies and long-branch effects cannot be filtered out. Relationship interpretations, according to Phylogenetic Systematics, have to be based on characters, individuals in populations of species only react on morphologies, and only characters allow biological interpretation of functions, ontogenetic development, and evolutionary change. Only characters can be assembled in ground patterns of species and lead to proper phylogenetic discussion, "trees" derived from molecular data are just to be taken, so cannot be discussed in any scientific way.

The Pentastomida project included the collaboration with **John Repetski** (joint paper published in 2006, as the third paper on a Cambrian pentastomid dealing mainly with a new Cambrian species, named ***Aengapentastomum andresi***, from Västergötland). Also there we appreciated the kind help of **Wolfgang Böckeler**, pentastomid specialist, and from **John Ahlgren** discovering a piece of rock that contained about 70 new specimens aiding in the description of the larval cycle in 2011.

Early collaboration with Dietmar Andres from Berlin regrettably did not result in a common paper, but he himself published his early data, specimens from the isle of Öland, in 1989 – with the exceptional report of muscle strands in the head and trunk of one of his specimens. Regrettably his material shows several stages and different species, also different from the material from Västergötland, so would contribute nicely to the knowledge about these Cambrian pentastomids, but not even species names were published until today, so making the material available to the public.

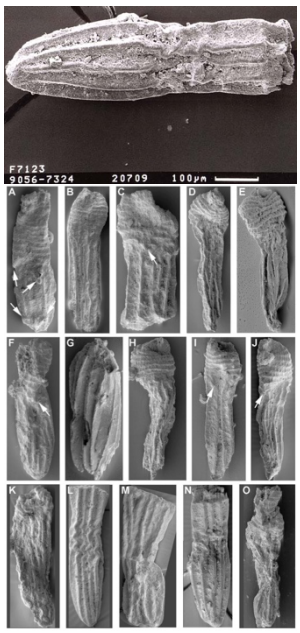


plasticine pentastomid model as a project of a school pupil in our department

2009 – 1993: Orsten Fossils from Australia

1) Loricate scalidophoran larvae from the Middle Cambrian of Australia – published 12/2009

Our material from the Middle Cambrian of Australia (and only this), collected in the outback of Australia in 1986 by DW and Raimond Below, a colleague from Bonn, contained also several bag-like fossils, so-called loricae, resembling at first site priapulid (Cycloneuralia scalidophoran) nemathelminths. The loricae are about 500-700 µm long and are made of 20 long plates in a specific shape and arrangement to enable the animal to intrude and extrude the – not preserved – front (introvert). By this the fossil matches exactly the lorica of the larva of the extant priapulid *Tubiluchus*. **BUT**: In the meantime, we had to learn that such larvae have also some aspects in common with the Loricifera, the putative sister taxon of the Priapulida. So things have become more complicated and also more exciting. The larva and its shape, is therefore considered a symplesiomorphy, not syn apomorphy. Specific spines sticking out from the ridges may even be found in the related taxon Kinorhyncha, leaving open if the fossils may just belong to a very basal representative of the entire grouping (left open because the minute kinorhynchs have no larvae). The ms on these fossil was published in 2009 in the second volume in honor of the late Dr. John Shergold.



2) New species of *Markuelia* from Australia – published 12/2009

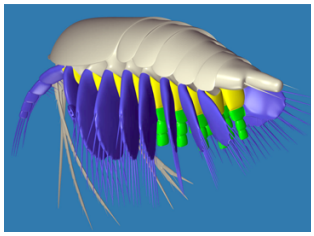
The Australian material also contained two specimens of a new species of *Markuelia*. The description also appeared in the second volume in honor of the late Dr. John Shergold in 2009; one specimen has died a second time regrettably in the meantime.

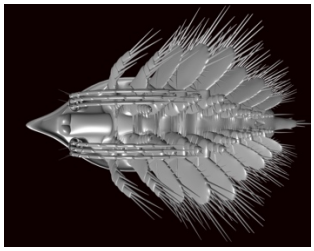
3) *Shergoldana australiensis*, a larval nemathelminth – published 2008

A single specimen of a 145 µm long apparently larva of a cycloneuralian has been published by the Ulm team in the first AAAP volume in memoriam of the late Dr. John Shergold, formally Canberra, Australia. Actually John had guided our expedition in the outback in 1986 (Dieter Waloszek and Raimond Below). The fossil received, thus,
the name *Shergoldana australiensis*.

2008 – 2004: Orsten crustacean from the Isle of Öland, Sweden

***Oelandocaris oelandica* Müller, 1983**



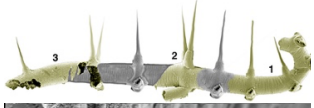


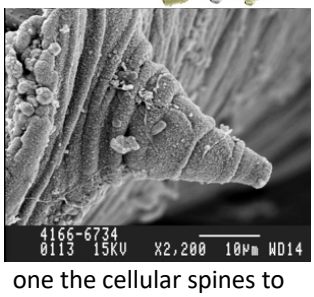
The species was originally described by Klaus J. Müller in 1983. Together with **Martin Stein**, we wrapped up a more detailed paper than our first paper on this species in 2005 on this animal, based on several new specimens with limbs found in addition to the single leg-less specimen of this taxon. Our investigations led to the discovery of various new features. One is the huge antennula comprising of three long spike-bearing extensions. Another is that there is only a single **proximal endite**, one of the crustacean features sensu Walossek & Müller (1990), present on the third head limb (mandibula). The proximal endite is embedded within the arthrodial membrane at the inner proximal edge of the basipod. Again, fine pores on the thoracic tergites and the large flap-shaped exopods of the serial post-„mandibular" limbs (plesiomorphy) may have been the holes for sensilla. This supports a mainly swimming life style of this form considered as a derivative of the stem lineage of the Crustacea toward the Labrophora.

With the help of two young volunteers – pupils from the Humboldt Gymnasium in Ulm –, we had built a **plasticine model** (magnification 500 times), which we used for our reconstruction of the morphology and for the improvement of our understanding of functional-morpho-logical aspects (food intake etc.). Subsequently **Martin Stein**, now in Copenhagen, Denmark, started to build models in **Blender** – actually he started this –, which even became **animated,** allowing a first glimpse onto the metachronal beating and swimming mode of such early crustaceans in a surprisingly plausible way and very similar to small living crustaceans.

2008 – 1994

Cambrian Series 3 lobopodian





one the cellular spines to anchor the legs of the animal to the bottom during crawling

This was an investigation in co-operation with Reinhardt M. Kristensen, Copenhagen, Denmark and Georg Mayer, currently Australia: The new form is indeed the smallest, the youngest and the best preserved lobopodian ever found. The most important aspect of the **animal from the Swedish Orsten** is: It has a **single gonopore**, see on right, just as in Recent onychophorans, below the image. This is the definite proof that arthropods, having paired gonads with gonoducts, but started out having a single gonopore and not paired ones as, e.g. in eucrustaceans (known only from living forms).

Another new aspect is its insertion of the appendages ventro-laterally at a kind of bridge, which preformed the orientation to a strict lateral one. The most likely pretty long legs were as tubular as the body and likewise annulated. From this we can deduce now that the legs were held straight laterally and were anchored lifted and turned forward for crawling (Stemmbewegung).

Anteroventrally and posteroventrally the appendages bore spine-like outgrowths of two different types, a multi-cellular outgrowth and a telescoping spine nesting in a socket. We could identify this so well because

the specimens are hollow and we could look into the leg! These spines must have been used to anchor and push the legs so that they could operate in a crawling like lizards, but with more legs involved.

The surface of the very soft cuticle of this lobopodian is finely ornamented, but it is unclear if this honey-comb pattern reflects the cells underneath.

Since the fossil specimens are hollow, one can look on the lower surface of the cuticle, a view never seen before on a fossil.

Work seems still not finished: Here my recently developed model of the animal to demonstrate the lateral extension of the long soft legs. These have even been published in the meantime by a colleague from China, but this fact is still ignored when describing lobopodians – does not fit to the main-stream ideas of certain colleagues.