

History of 'Orsten' Research

Early Phase (Bonn I) – The discoverer, Klaus J. Müller, and his first activities

In 1963 Klaus J. Müller moved from Berlin, where he had finished his dissertation and habilitation, to Bonn, where he had received a C4 professorship of micropalaeontology at the Institute of Palaeontology of the University of Bonn. In Bonn he established a research group and, for a long time, worked systematically on Cambrian conodonts and on their inner fine structure, partly together with his Japanese colleague, Prof. Nogami, and undertook field trips to Sweden searching for microfossils, e.g. to collect limestone nodules, in Swedish orstenar, which then were crushed to pieces and dissolved in a diluted acetic acid.



Already in 1964, Klaus produced a long paper on Swedish Cambrian bivalved euarthropod crustaceans, called Phosphatocopina, but it took until 1975, when he and his team discovered the first fossils in an 'Orsten'-type soft-cuticle preservation in the etching residues. Klaus immediately realized the importance of these findings because of their high quality of preservation and completeness, and because of their high age. Using considerable personal and laboratory effort (including special microscopes [Zeiss] for sorting), > 1 1/2 tons of 'Orsten' limestone rock were dissolved in a specifically designed laboratory in Bonn.

Within the next years, the insoluble residues were picked by technical assistants and documented using a scanning electron microscope (the first was the legendary Cambridge S4). Without this extremely high effort, Klaus' knowledge of chemistry, his organizational skills, and his continuous high interest, this exceptionally rare material would have never been assembled in a quantity needed for a thorough analysis. Yet, a severe illness caused Klaus to pause in the late 19seventies. He had to stay at the hospital for quite some time, but during this period, Klaus could rely on several invaluable and skilled assistants, who continued picking and sorting the material, putting specimens in micro-slides or on SEM stubs, doing the SEM work and more.

Four persons have to be mentioned here in particular:

- Mrs. Peilert, one of the first assistants and name-giving for the 'Orsten' eucrustacean *Dala peilertae*, thanked for her sorting effort;
- Mrs. Grossman, his secretary, helping to do the archiving and paper work.
- Mrs. Helga Rehbach, name-giving for the 'Orsten' eucrustacean *Rehbachella kinnekullensis*, working for Klaus in the 1970s and 80s;
- Mrs. Gossmann, name-giving for one of the pentastomids (*Heymonsicambria gossmannae*), helped far into the 1990s.



Besides the intense 'Orsten' research, Klaus continued his work on other phosphatic microfossils, mainly conodonts, which culminated in a large monograph on this taxon together with Ingelore Hinz-Schallreuter in 1993, published in *Fossils and Strata* (for this long pioneering research he received the Pander medal of the Pander Society in 2003). Klaus also continued to work on shelly fragments, e.g. in material from Australia (named cambrogeorginids), which also contained cuticular elements and 3D-preserved trunk pieces of certain cycloneuralian nemathelminths, called palaeoscolecids. Papers on this material were also published in conjunction with Ingelore.



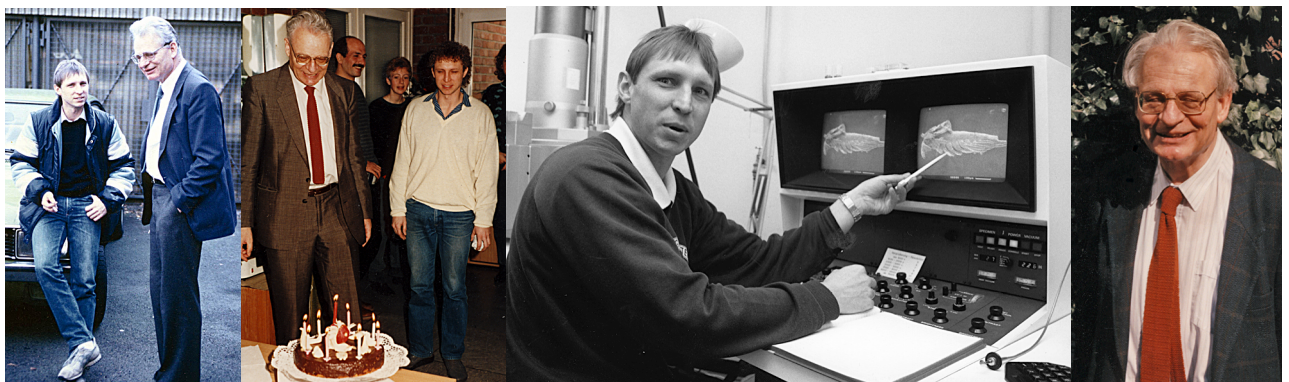
Klaus 1971

Pander medal 2003

President Rick Aldridge and Klaus

Co-operation between Klaus Müller and Dieter Waloszek (Bonn Phase II)

Very early, Klaus realized that he alone would not be able to work up this diverse fossils, preserved in a quality like "biological " material. At this step, he had to decide between putting more effort into the search for other 'Orsten'-like occurrences worldwide or investigating the 'Orsten' fauna in much depth. Klaus decided in favour of an in-depth-study of the 'Orsten' fauna and to postpone further search for similar 'Orsten'-type faunas. Searching for an assistant with a biological background, he interviewed Dieter Waloszek, who was working at the University of Hamburg on his PhD, and hired him. First this was only for a one-year project in 1981 (paper on 6 non-phosphatocopine Orsten Crustacea published in 1983) and then for longer. Starting as a part-time assistant in fall 1982, Dieter received a full job , funded by the Deutsche Forschungsgemeinschaft in Klaus's team after he had defended his doctoral thesis in March 1983.



Klaus and Dieter 1981

Klaus's birthday 1988

Dieter at the SEM

Klaus 1990

Dieter became responsible for the entire study of the fossils at the scanning electron microscope SEM, illustrations incl. reconstructions and preparation of texts and plates for the manuscripts. At the beginning of this period, Klaus went again to Sweden (1981) to collect more material, specifically in the Kinnekulle area and the quarry Gum, while Dieter went to Australia in 1986 to collect rock material in the Georgina Basin near Mount Isa. Until 1990, Klaus and Dieter had published three big monographs in *Fossils and Strata*, the series of the Royal Swedish Academy of Sciences at that time, and several shorter papers on 'Orsten' fossils. Several were made also in collaboration with colleagues around the globe. 1990 was of significance also in two other ways, the publication of the first paper following the method of phylogenetic systematics (Walossek & Müller 1990), and the submission of Dieter's habilitation thesis. Habilitation in Bonn was not possible, so that Dieter finished the habilitation in Hamburg, where he also studied, and received his diploma and doctor degrees.

Klaus, Dieter and Andreas Braun, in Bonn at that time, went also to Moscow in 1992 to receive a small amount of rock material from Siberia, which unexpectedly yielded a tiny tardigrade. In 1993 Klaus and Dieter underwent a trip to the Isle of Öland, Västergötland and Östergötland (Motala). The successful collaboration continued not only after Klaus' emeritation in 1988, but also after Dieter had finished his habilitation at the University of Hamburg and the end of his DFG funding in Bonn in spring 1994. In the same year, Dieter and Klaus published a paper on the oldest parasites ever found, members of Pentastomida (tongue worms); an unexpected discovery because these worm-like arthropods today live in the lungs or related organs of land vertebrates (all living groups from turtles, snakes, lizards and geckoes etc., crocodiles to birds and also mammals). 1994 was a big break, because Dieter received a substitute professorship in Kiel for one year. This temporary position resulted in the successful application for a permanent professorship in Ulm – and not in Hamburg, as expected or hoped by Dieter because of his northern German origin.

Some key events of this phase:

- 1984: Klaus and Dieter are invited by Euan Clarkson to a conference in Edinburgh on "Fossil arthropods as living organisms";
- 1986: Klaus becomes Corresponding Member of the Royal Swedish Academy of Sciences in 1986
- 1986: Dieter visits Robert Hessler and William Newman at the SCRIPPS Institution of Oceanography in California;
- 1986: Dieter travels to Australia in the same year to collect Orsten-type rock material (mentioned above);
- 1989: "Keith Medal" of the Royal Society of Edinburgh given to Klaus and Dieter;
- 1990: Dieter is invited by the Royal Swedish academy of Sciences to a workshop with leading international scientists on the Phylogeny of Crustacea
- 1993: Dieter's habilitation is published as the fourth big monograph in *Fossils and Strata*.

The Ulm Phase - Part I

1995 Dieter moved with his family to Ulm to start a professor position at the university of Ulm. Together with the professorship he received the position of a head of the newly established Section for Biosystematic Documentation, closed down in 2006 by the University due to a so-called "structural re-organisation". That 'Orsten' research could be taken over by Dieter and his team of assistants/PhD students was guaranteed by Klaus, who kindly permitted the transfer of the whole material to Ulm. Nevertheless, Klaus continued to participate in our studies in various ways, discussing matters with us or supporting our work in many ways. For example, in 2001 he financed a costly trip of Andreas Braun and Dieter to Siberia to collect more Orsten-type rock, a superb expedition, but scientifically unsuccessful adventure.



Helicopter bringing the team to the locality view from opposite side reindeer

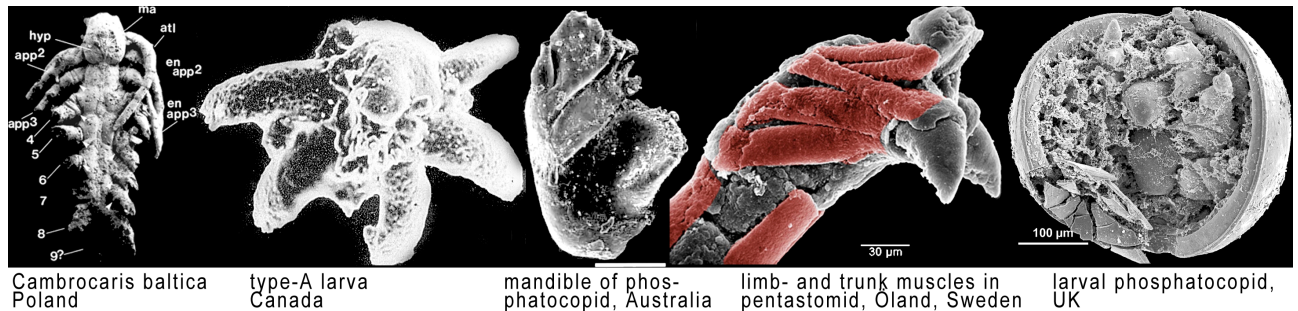


view from the hills down to the valley where we tented

In 1997 Andreas Maas, born in the same small town Kellinghusen as Dieter, joined in, starting to work on the larval cycle of the Krill (*Euphausia superba*) and the phylogeny of euphausiids as the topic of his diploma work. The real comeback of 'Orsten' research took some more years, after Dieter received a DFG grant for Andreas to investigate the huge material of Phosphatocopina as his doctoral thesis. The results were published in 2003 as our fifth monograph in Fossils and Strata. Subsequently Dieter hired Andreas as his research assistant, the collaboration lasting until shortly before the end of the section and retirement of Dieter in 2016, when Andreas had to leave because of "governmental rules". In the frame of a DFG-funded joint venture of German and Chinese scientists Dieter and Andreas underwent several trips to China between 2002 and 2005, collaborating with Jun-yuan Chen on Chengjiang fossils. Besides jointly produced papers on such material, also more papers appeared on 'Orsten' fossils. In 2008 Andreas successfully finished his habilitation and in 2010 received the honourable degree of an "extraordinary professor" by the university of Ulm.

Exploration of new 'Orsten' occurrences outside Sweden progressed with finds in Poland (Walossek & Szaniawski 1988), Canada (paper published by Roy and Fåhræus on tiny larvae, which Klaus and Dieter had described as type-A larvae in 1986), and Australia

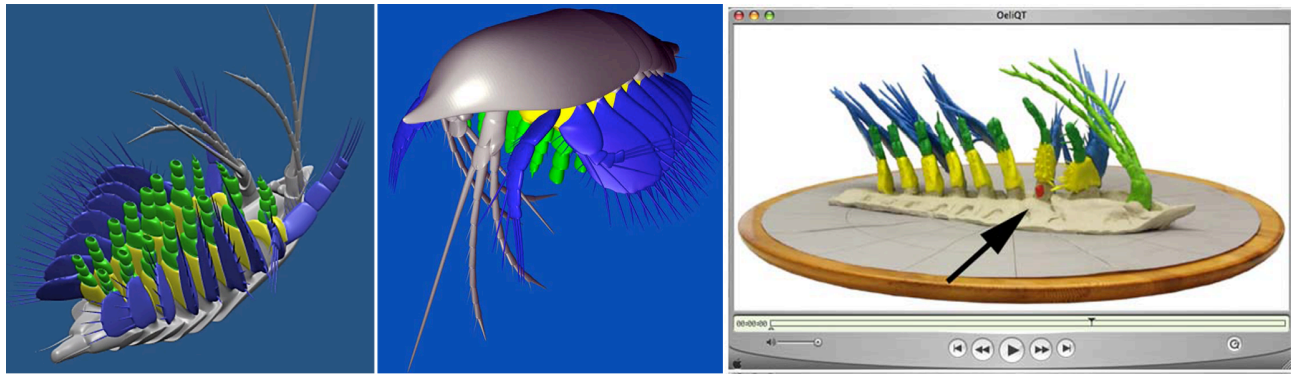
(Walossek et al. 1993). Also an **exceptional find of muscle preservation** in 'Orsten' fossils, pentastomids, by Dietmar Andres was of significance, until now, however, the only report of internal structures (Andres 1989). Regrettably more material, though collected by Andres, was never published. In 1995 we published a short report on the finds of 'Orsten'-type preserved fossils in the little rock pieces from Siberia, but which were still awaiting a detailed publication. And in 2001 finds of few early instars of a phosphatocopid were reported from Great Britain.



All this demonstrated the possibility of discoveries also outside Sweden, but systematic investigations, as in Sweden remained a hope. All other finds were isolated finds of one to few specimens. Therefore, the extended field trip to the tundra of north eastern Siberia (Olenek river area south of the Lena delta) by Dieter and Andreas Braun in 2001 (above) aimed at bringing up many more fossils from there by collecting much more material from a successful locality. We collected about 100 kg of rock material and took it back to Germany, but the large material did not yield a single specimen!

Lastly, also our investigations in China, i.e. the ones of Andreas Braun, Andreas Maas and Dieter, also aiming, at least in part, to find 'Orsten'-type fossils from there, failed, although initially promising because of discoveries of phosphatic early embryonic stages = cleavage stages with two cells to blastomeric stages preserved from the late Precambrian. Yet, these are primarily phosphatized, and all efforts to find 'Orsten'-type fossils were unsuccessful.

In 2003 Martin Stein, palaeontology student from the university of Marburg, joined our team for one year to work on 'Orsten' material and helped also in the China project. First using modelling clay for the production of models, which we also animated by combining a series of pictures, Martin was the first to start with 3D modelling using the open-source program **Blender** (see chapter Methods). He could even animate the model in a nice and persuasive manner. Another highlight was a trip in 2004 of Dieter, Andreas Braun and Martin Stein as our translator, to Öland and Västergötland (Falbygden and Kinnekulle), where we met John Ahlgren, amateur palaeontologist and expert of the Kinnekulle area and its fossils sites, who gave us some rock material for processing (no results regrettably).



Computer model in different directions

Modelling clay model for serial photography



The Big Five: Monographies published in Fossils & Strata between 1985 and 2003.

The Ulm Phase - Part II

For us, 2005 was the beginning of a new period, when we founded the international C.O.R.E. group of people interested in the 'Orsten' and research on it. For long we had thought of something like possibilities to expand our workgroup aiming at a concentration of expertise and the possible/ hopefully even exploration of new sites, but this was pure theory, and we could immediately attract eventually about 30 colleagues from various disciplines and from nine nations, spanning from the U.S.A., UK, Danmark, France, Germany, and Sweden to Poland, China and Japan to join in. The principle ideas (objectives) of the group were to combine skills and expertise, to train youngsters and to help each other in the research on 'Orsten' and related issues. At least some of the aspects could be initiated or put into reality until the time of the official end in 2016.

Even better, or most importantly, exciting new 'Orsten' material was brought up by the Chinese C.O.R.E. members Dong Xi-ping and Zhang Xi-guang, and also Huaqiao Zhang, who discovered 'Orsten' 3D arthropods in different localities in China, even kindly allowing us to collaborate with them. Noteworthy that also from Poland more material was etched by Ewa Olempska. Collaborations yielded several nice papers and increased the publicity of the 'Orsten' significantly.

During that time, we were happy to recruit colleagues like the palaeontologists Nigel **Hughes** and John **Repetski**, and the zoologist and Low-Reynolds specialist and high-speed cinematographer Rudi **Strickler** from the U.S.A.; David **Siveter**, Mark **Williams**, Tom **Harvey**, Phil **Donoghue** and Euan **Clarkson**, UK, well-known palaeontologists (David worked on various Palaeozoic forms, including the 3D-preserved phosphatocopine from Comley, UK; Euan has been working for long on trilobites from the Swedish alum shales); Phil added his expertise on embryo fossils, mainly nemathelminths); from Copenhagen, Danmark Jens **Høeg**, Jørgen **Olesen**, working on crustaceans, Martin **Stein**, Bo **Rasmussen**, and Reinhardt **Kristensen** working on minute animals like tardigrades; from Germany Jason **Dunlop**, palaeontologist and chelicerate specialist, Michael **Steiner**, Georg **Mayer**, zoologist, and Wolfgang **Böckeler**, pentastomid specialist; from

Sweden John **Ahlgren**, Mats **Eriksson** and Frederik **Terfelt**; from Poland Ewa **Olempska**; from France: Lean Vannier; from Japan Gengo **Tanaka** and Haryoshi **Maeda**; from China Dong Xi-ping, Xi-guang **Zhang**, Huaqiao **Zhang**, Liu **Zheng** and Yu **Liu**. From the Ulm team: Andreas **Maas**, the entire family **Haug**, Christopher Castellani, and me; and our honorary member **Klaus Müller** of course.

Already the first few months of Joachim's in-depth investigations indicated that new things could be expected. Indeed his effort and enthusiasm led to a much better insight of the ontogeny of stem crustaceans, corrected various views based on our previously incomplete and, partly rough study from 1990. The increased background in arthropods and the theory of Phylogenetic Systematics of all of us also helped much. Furthermore, Joachim's intensive studies of the larval cycles, morphogenetic changes and the 3D reconstructions (with Blender), initiated by Martin, brought us much forward in a better way of comparing the different taxa and to make comparisons with extant counterparts in terms of relationships or morphological/ecological similarities. Ontogenetic series as 3D models and through time were then called 4D, created by Joachim. More will be added step by step

Highlights of this phase to be mentioned:

- 2005, joint paper on the 'Orsten' in general;
- 2005–2016, >30 jointly written papers, many in collaboration with our colleagues, several on extant crustaceans;
- 2007 and 2010, publications of larval stages of Lower Cambrian crustaceans of China in collaboration with our member Xi-guang Zhang;
- 2011 and 2012, publications of Christopher's work on 'Orsten' pentastomids and on sponge spicules;
- 2016, first paper together with our colleague Huaqiao Zhang, who continued collaboration with us until now.

Two sad events need to be added. One and a severe drawback was that Dieter was diagnosed prostate cancer in May 2007, which forced him to be operated, with radiation treatment from October to December. The problem remained, however, and a further operation and radiation treatment followed in 2013 followed.

The second one was that our colleague Klaus J. Müller died peacefully in February 12, 2010, age 87. With Klaus we really lost the most important person having worked on the 'Orsten', even more a personal friend. Thank you Klaus for inspiring us to keep up with science of its purest kind.



2006 Klaus and Joachim discussing Andreas, Klaus, Joachim and Dieter Klaus in 2009

After-end continuation of C.O.R.E. activities

To be added.

- publication of Christopher's work on cyanobacterians in 2018.