Prospective Lithologies, Techniques and Chances for Microscopic Paleontology at the Vendian/Cambrian Boundary

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Abstract

Based on own laboratory experience and a literature review, techniques for processing of different sedimentary lithologies and microscopical investigation in Neoproterozoic-Cambrian sequences are described. Emphasis is placed on etching and sequential sectioning techniques in cherts, phosphorites and limestones, widespread lithologies during this time interval in West Gondwana and elsewhere. Based on the hypothesis that ancestral metazoans in the Late Precambrian are likely to be expected as plankton or meiobenthos preserved in deeper water environments, prospective lithologies and possible paleoenvironments are indicated where future search should be centered.

Key words: Paleotechniques, microscopy, meiofauna, Vendian, Cambrian.

Introduction

Following the discovery of new rich fossil "Lagerstätten" in the last decade, the problem of "cause and course" of the apparently explosive appearance of many metazoan groups during the Lower Cambrian (Fortey et al., 1996; Conway Morris, 1998b; Bottjer et al., 2000) has moved into the centre of many research projects. Well known Lagerstätten of exceptionally preserved biota like Chengjiang (Yangtze platform, Shu et al., 1996; Chen and Zhou, 1997; Hou and Bergström, 1997) and Sirius Passet faunas (Greenland: Conway Morris and Peel, 1995), yielding "soft-bodied" (better: "soft integument") preservation, provide macroscopic information on the evolutionary stages of metazoans from sponges to chordates in Lower Cambrian times, although compaction and access to critical body parts often remains a problem in the reconstruction and taxonomic assignment of these fossils. However, diversity and complexity of body constructions existing at the time of the first trilobite biozones in the Lower Cambrian strongly support a metazoan evolutive history in the Precambrian, which is largely cryptic in terms of paleontological findings. More recently, results coming from molecular biology (Wray et al., 1996) indicate a considerable gap in the actual paleontological record, the reasons and duration of which is still not entirely clear (Wray et al., 1996; Conway Morris, 1997). In discussing molecular data, the timing of divergence (origin) as well as the speed of molecular evolution remains a subject of debate. Additional support from paleontological findings is therefore strongly needed in addition to molecular data and hypotheses (Conway Morris, 1994; Edlinger, 1994).

Search for paleontological evidence during the critical Proterozoic/Early Cambrian time interval has for a long time been somewhat traditional, in that it was predominantly looking for macroscopic remains, visible on bedding planes and assignable to recent animal groups in terms of size and body plan construction. Many occurrences of Ediacaran-type fossil communities have been found but are still being controversly discussed with respect to their constructional and systematic nature (Pflug, 1974; Seilacher, 1989, 1992, 1999; Zhuravlev, 1993). New trace fossil occurrences along with better age determinations give a complementary insight into the development of organismic complexity, feeding and movement from about 600 Ma onwards (Jaeger and Martinsson, 1980; Fortey and Seilacher, 1997; Bottjer et al., 2000; Jensen et al., 2000). This is flanked by the search for chemofossils, biomarkers or biomolecules in ancient rocks from different aquatic habitats as well as from paleocontinental surfaces (Bergen et al., 1995; Briggs et al., 2000). However, while referring to the scarcity of Late Precambrian macrofossil localities and the nature and meaning of the trace fossils, it is not clear whether we actually look in the right size dimensions, in the right ecosystems and on the basis of suitable theories in

searching for paleontological evidence for early metazoan history. New directions and stimulation for further search and exploration come from microscopical remains showing remarkable preservation, gathered by special search and processing techniques from Late Precambrian through Cambrian rocks. These are increasingly important in adding to theories and knowledge on the basis of macroscopic finds. Multiple prospection and processing techniques must be applied to different lithologies and preservation stages, to allow adequate isolation and investigation of these remains. Chances to find and investigate these important remains seem better if the prospecting paleontologist is trained for microfossil and plankton research in lithologies quite different from those traditionally looked at in the search for ancestral metazoans. The following paper gives an overview of examples, techniques and future directions of "microscopic scale search" to be applied to promising rock series around the Precambrian-Cambrian boundary. The primary aim is to give an overview of the scientific potential of the different methods. Thus, examples and illustrations are not limited to the Precambrian/Cambrian boundary interval, but were chosen from different ages.

Exceptional Preservation in Micro- and Meiofossils Extracted from the Rock

Of all the preservation states, early phosphatization is certainly the most informative and promising. Phosphatic "Orsten-type" preservation, as exemplarily shown by the works of K.J. Müller and D. Waloszek (see Waloszek and Müller, 1992 for one review), may preserve details down to minute morphological level of soft integument structures (see Fig. 1A). Müller (1979) stated that this kind of soft integument phosphatization is more common and stratigraphically widespread than expected, provided that search is carried out systematically. The abundant material collected but only briefly described by Andres (1989) indicates that such fossils may even occur in great abundance in relatively small rock samples. Phosphatization is known to be an early postmortal process ("taphomineralization" *sensu* Wilby, 1993), occurring within days or weeks after death (Allison and Briggs, 1991; Lucas and Prévot, 1991; Briggs et al., 1993; Briggs, 1995), and capable to invade and thus preserve soft part structures (Wilby and Whyte, 1995; Li et al., 1998). Although microbial activity has been described as mediating phosphate genesis (Hirschler et al., 1990) it is not certain to which extent phosphate taphomineralization is exclusively a result of microbial mediation. Phosphatization may preserve internal soft part structures down to the histological and even subcellular level,

enabling researchers to investigate these fossils as if they were recent biological material (Allison, 1988; Lucas and Prévot, 1991). Small, internally phosphatized remains from the Precambrian/Cambrian boundary interval include eggs, embryos and early ontogenetic developmental series (Bengtson and Zhao, 1997; Conway Morris, 1998a; Xiao et al., 1998; Chen et al., 2000; Xiao and Knoll, 2000).

Due to preparation techniques with acids, early phosphate mineralization has been almost exclusively described from limestones, but it is not restricted to such lithologies. In view of the distribution of phosphatization in a variety of lithologies other than limestones, it is essential to apply other techniques of separation and investigation of phosphatic fossils to cherts, phosphorite, clay and siltstones. Phosphatized small fossils have been observed by the author in the sparry calcite matrix on section planes of the Swedish "Orsten" limestone nodules by incident light microscopy. Observation of sections under incident light should offer further possibilities in non-carbonatic rocks. This could be especially valuable in attempts to find levels in the sediments where a kind of early seafloor mineralization and eventually an autochthonous phosphatization of the whole meiofauna took place. Thin sectioning of phosphatic rocks is still widely and excessively used to investigate and document the fossil content of these rocks (Li et al., 1998; Chen et al., 2000).

There is currently no chemical technique to extract phosphatic fossils from an entirely phosphatic matrix without the danger of significant loss (Bragin, 1997 published one of the few exceptions in extracting well preserved phosphatized radiolarians from phosphatic nodules from the Mesozoic of Russia). However, as solubility of phosphate minerals may depend on slight mineralogical differences, a large field for further testing exists in the thick phosphorite sequences of the Precambrian/Cambrian boundary interval. Phosphatic remains from cherts may be isolated by conversion into flouride by action of concentrated HF (Upshaw et al., 1957), but during the process of recrystallization and chemical transformation, the fossils commonly become coarsely crystaline and fragile (own unpublished observations), making the method not likely to yield any well preserved "phosphatized" fossils in great morphological detail.

Organic ("cuticular") preservation obtained from palynological bulk processing and subsequent isolation from fine and coarse, acid-resistant residues (see Fig. 1B, C, H), has yielded well preserved material predominantly from pelitic rocks of different ages (Butterfield, 1990; Braun, 1997). This mode of preservation plays a significant role in investigations on early terrestrial ecosystems in the Silurian and Devonian (Sherwood-Pike and Gray,
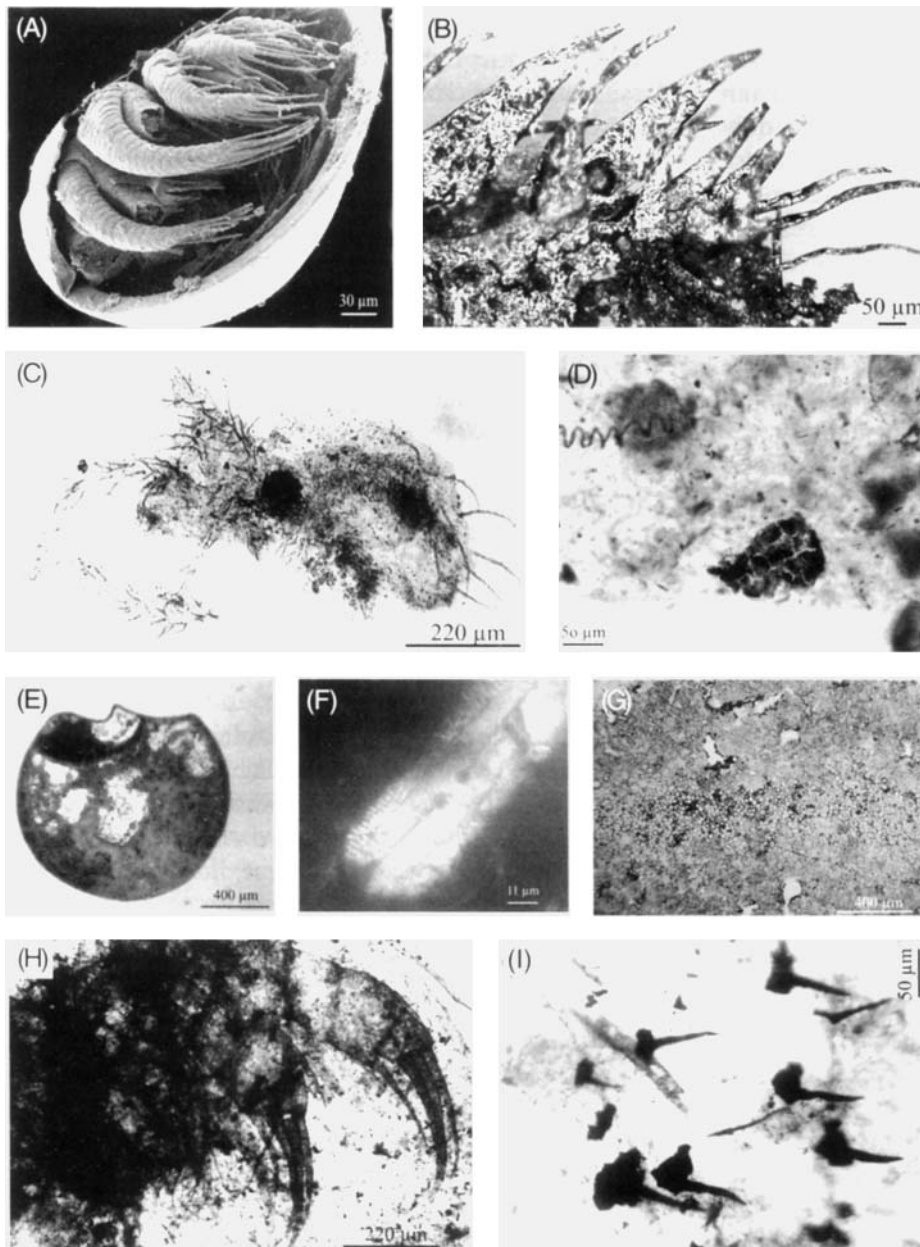
Fig. 1. Examples of promising preservation states and preparations, different ages and localities, obtained by the methods described in the text. (A) Scanning electron micrograph of *Hesslandona unisulcata* Müller (Phosphatocopida), one of the valve-like shields broken off to show limbs with long setation. Example of the remarkable preservation obtained from the "Orsten-type" phosphatization. Upper Cambrian, Sweden. Collection of K.-J. Müller, Bonn. Length of the scale bar: 30 μm. (B) Fragment of a ventral appendage of an Eurypterid, viewed in incident light with dark field illumination showing well preserved spines an setae of different magnitudes. Lower Devonian, Lower Emsian, Nellenköpfchen formation, dark plant-bearing shales, Alken an der Mosel/Germany. (C) Almost complete mite in two-dimensional cuticular preservation, isolated from a bulk maceration residue of dark, plant bearing shales, Upper Carboniferous, Saar region/Germany. (D) Different palynomorphs (tracheid with helicoidal wall thickening, plant spore) showing strong fragmentation, enclosed and embedded within Si-flouride flakes forming during acid attack. Transmitted light micrograph. Bunter Sandstone Formation, Lower Triassic, limnic green shale interbed, Bremke near Göttingen/Germany. (E) Individual thin section of a millimeter-sized egg of unknown systematic assignment, displaying an internal, dark, segmented, elongated structure near the upper half of the egg (embryo?). Lowermost Cambrian, Kuanshuanpu, Shaanxi prov., China. (F) Diatom skeleton, preserved in a Tertiary limnic chert, observed with high magnification incident light and oil immersion objective. Tertiary, Rott formation, Rott/Siebengebirge near Bonn/Germany. (G) Discrete layer of spherical phytoplankton found in a small concretion of bituminous Phosphorite. Section plane slightly etched and transferred on an acetate peel, embedded and viewed in transmitted light. Lower Cambrian, Hetang formation, Xintangwu, W Zhejiang province, China. (H) Frontal appendages of a freshwater ostracode isolated from a bulk maceration residue of a dark, plant-bearing shale. Upper Carboniferous, Piesberg near Osnabrück/Germany. (I) Small setae with broad bases situated originally on the weakly sklerotized ventral side of a small Eurypterid (*Parahughmilleria?*), as transferred on a transparent peel from the dark rock surface and viewed in transmitted light. Lower Devonian, Lower Emsian, Nellenköpfchen formation, Alken an der Mosel/Germany.

1985; Edwards, 1986; Jeram et al., 1990; Selden et al., 1991; Shear, 1991). In terms of lithologies, the search for organic preservation in the Precambrian/Cambrian boundary interval appears somewhat more widely applicable than the specific search for high quality phosphatization, as the respective lithologies (pelitic rocks, cherts) are more widely distributed in time and space in comparison to phosphate-bearing limestones and phosphorites. Paleopalynology and "organic" fossils are thus an important field of research in this time interval. The palynomorphs obtained, however, are somewhat more difficult to assign systematically in comparison to phosphatized remains, as they are often fragmentary (see Fig. 1B; Butterfield, 1990) or, if complete, flattend and otherwise distorted (see Fig. 1C, H; Selden et al., 1991; Braun, 1997). Experiences mentioned by Butterfield (1990) with organic microfossils from the Burgess shale, indicate that search and sampling must be carried out in fresh, unweathered rock material preferentially from subsurface, even if the surface exposures do not show any evident sign of weathering.

Investigation and sorting of palynological residues following disintegration of the rock matrix is best achieved using strong magnification under a binocular stereomicroscope. Fossils are kept in a petri dish under shallow water cover in order to avoid drying, incrustation and deformation of the thin and flexible walls of the residue. Mounting of isolated specimens or the whole residue is best done in an embedding medium suitable for wet specimens. A variety of microscopical techniques, including infrared and incident light microscopy are in use to get maximum information even from opaque remains (Walton, 1935; Göke, 1988; Pflug and Reitz, 1992).

Such standard palynological processing techniques remain unsuccessful if the palynomorphs are, by heat or small-scale tectonic deformation, disintegrated into small pieces and held together only by the surrounding rock matrix. If certain parts of composite organic remains are extremely thin (e.g., the intersegmental membrane), sieving procedure and development of gas during acid disintegration of the rock matrix is likely to tear the individual parts of the fossil apart. Disintegrated or easily disintegratable palynomorphs, however, can in certain cases still be prepared as entire units from the residue if the Si-flouride flakes, forming during HF action, are not dissolved but retained in the washing screen and embedded in glycerine jelly on microscopic slide preparations (see Fig. 1D). In this case, the flouride flakes are taking over the protective and supporting function of the rock matrix and the organic bodies can be investigated *in situ* and original context through the transparent, whitish matrix of the flouride flakes (Braun, 2001).

Other techniques applied to fragile organic remains, such as incident light microscopy, avoid separating the fossil from the rock matrix. Serial sectioning techniques, followed by sequential documentation of the section planes, yielded spectacular results without the necessity of any acid disintegration of the enclosing rock matrix (Briggs et al., 1996). The methodology, described by Sutton et al. (2001a) involves serial grinding, digital photography and graphic processing, resulting in three-dimensional images. These can be deeply focused and rotated in short video sequences in electronic publications or figured in paper publications as composite pictures (Sutton et al., 2001b, c). If serial sectioning could be used along with the peel technique in the future, this would allow for an even better "storage" and documentation of material by this method.

Besides, other preservation modes and lithologies treated with special chemical extraction and optical investigation techniques are likely to yield more exceptionally preserved material. Early silicification in cherts, in iron-carbonate nodules (Aulenback and Bramann, 1991) and small nodules of bituminous, pedogeneous calcium carbonate (Palmer, 1957), stresses the lasting importance of silicification (Müller, 1964; Carson, 1991) besides the somewhat more spectacular phosphatization process. At the same time, more complex solution techniques must be applied to non-carbonatic rock types in order to recover silicified fossils from somewhat unusual lithologies such as siderite (Aulenback and Bramann, 1991) or rocks associated with banded iron formations (BIFs; Gaucher, 2000). The discovery that soft tissues of fossils may be preserved by clay minerals (Gabbott, 1998) may lead to further search in equivalent lithologies of older age.

As far as documentation and investigation of isolated, small-sized fossils is concerned, the SEM-standard technique is indispensable and most important for external imaging of microscopic fossils. As usual in Biology, ordinary SEM investigation may be preceded by freeze-drying methods in the case of organic, soft-integumented fossils obtained from palynological wet residues which are not covered and stiffened by early diagenetic phosphate. Specific techniques must be applied, if information about internal structures of opaque or "closed" small fossils is desired (preservation of soft integument ventral structures in closed carapaces, soft parts in shells of early molluscs, eggs with embryonic structures). Individual thin sectioning of preselected small fossils (Eisenack, 1965), allows for internal and fine structure investigations within a reasonably short preparation time (see Fig. 1E). Compared to larger, whole-rock sections such small individual sections are more easily ground down to

a thickness below 25 μm ("ultrathin sections"), allowing for a more detailed microscopic investigation under high magnifications. The only (but major) disadvantage is the total loss of material outside the section plane. Laser scanning microscopy can be successfully applied, when optical section and three-dimensional reconstrutions of the internal structures of small organic or phosphatic fossils are needed. An alternative technique, widely in use in medicine and biology is micro-computertomography which allows for destruction-free single or sequential investigations. The resolution however is currently not fine enough to resolve internal details of fossils of only about 100 μm in total length/diameter, and the costs of equipment and maintenance are extremely high (Sutton et al., 2001a). One good alternative is a serial sectioning technique applied to such microfossils (Grotzinger et al., 2000; Watters and Grotzinger, 2001), accompanied by sequential documentation of the section planes, embedded in a resin block. The method of grinding, documentation and storage is similar to that referred for organic-walled fossils (Sutton et al., 2001a). As in the latter, this method is time-consuming and laborious, but yields valuable and clear results, especially if the mineralogy, texture and composition of sequential section planes of the fossil can be saved on a peel as a "micro-transfer-replica". Especially small phosphatic (for example eggs or embryos) and siliceous structures are suitable objects for this method.

Search in Whole-rock Samples

Other preparation techniques are applied to investigate organic micro- and meiofossils, which are not extractable from the rock matrix by the use of acids. In rocks with a somewhat "transparent" matrix, like Precambrian cherts, thin section investigation is the standard method (Barghoorn and Schopf, 1965, 1966). In view of clayey and silty lithologies in the Precambrian as well as highly bituminous and pyritic lithologies, thin sectioning should be flanked by more elaborate microscopical techniques used in the investigation of fine-grained sediments, which, for reasons of "opacity", are not suitable to ordinary thin sectioning (Nöltner and Zimmerle, 1991). Through the use of incident light microscopy and oil immersion objectives, H.-D. Pflug and co-workers have successfully applied a microscopic technique, which possess a wide potential field of application in microscopic paleontological and stratigraphic research even in highly metamorphic rock series (Pflug and Reitz, 1992; Reitz and Höll, 1998). The technique avoids any acid preparation of the rock and, by largely eliminating reflections and refractions at boundary surfaces through oil immersion objectives, allows to "look inside" a rock surface for at

least a few μm (see Fig. 1F). Dark, organic-rich cherts and other organic-rich rocks may be investigated by incident light microscopy using surface reflectance, as applied in coal and ore petrography. Braun (1994) lists some examples of the potential of incident light microscopy as a tool in paleontological investigations. If magnification is kept within the stereomicroscope range, reflections at the rock surface may be minimized by a cover of a clear varnish (Braun, 1990).

Extensive black shale lithologies of Neoproterozoic/ Early Cambrian age on the Yangtze platform, China (some of which show signals for hydrothermal activity; Erdtmann and Steiner 2001), similarly call for special search methods. Due to abundant organic carbon and/or finely disseminated pyrite they are barely transparent in thin sections. The search for fossils may be successful in rocks and minerals of very unusual facies (precipitates near black smokers, pyrite, carbonaceous cherts and shales), provided that the right incident or electron microscopic methods are used (Cloud et al., 1965; Ehlers et al., 1965; Schopf et al., 1965). Considering the possible significance of hydrothermal activitiy (vents or seeps) and hydrothermally-influenced ocean floor areas for life and evolution of organisms (Konopka, 1975; Steiner et al., 2001), such environments and search strategies may lead to exciting paleontological discoveries (Peckmann et al., 2001) with a particularly promising field in palaeo-microbiology (Schmaljohann, 1993). In clastic, noncarbonatic sediments, remains of microbial mats and interstitial faunas should be looked for in those parts of the sequence in which pore spaces have been filled rapidly by early diagenetic mineral cements, preferentially quartz or phosphate. Incident light microscopy, particularly under crossed nicols to enhance contrast between the clastic grains and organic (coaly or cuticular) substance, is a useful technique in thin sections of coarse-grained clastics. Colour and contrast of organic remains in thin sections is better studied under incident light than in transmitted light.

Besides incident light microscopy the peel technique is a promising, fast, and very material-saving technique to be applied in investigations of various opaque sedimentary rocks, like bituminous phosphorites, black shales and bituminous cherts. Peels gathered from section planes of these rocks are no pure surface replicas, but due to organic, microcrystalline apatite or pyrite still adhering to the film (a kind of transfer preparation: Galtier, 1970), it is also suitable for fine structural as well as mineralogical investigations using the polarizing microscope and highly magnifying oil-immersion objectives (see Fig. 1G). Galtier (1970) applies the peel method in the analysis of sequential sections of phosphatized plant fragments from oceanic black shale lithologies of Carboniferous age.

In black chert lithologies, the peel technique is applied following slight HF-etching, and gives extremely clear results as recently experienced in the investigation of Graptolites and microbiota in black Lower Silurian cherts ("bitumen lydites" *sensu* Correns, 1924) from Thuringia and the Frankenwald area, Germany (Braun, unpublished). Apart from light microscopic investigations, individual areas of the peel may be cut out, sputter coated and investigated using the SEM.

The peel technique, incident light microscopy using small field microscopes as well as etching of rock samples may be directly applied during field sampling or at the field station, enabling a pre-selection of productive samples for further laboratory work.

Histological microtomes using special, resistant knives or heavy duty microtomes may reveal important details in the analysis of fossils and sedimentary rocks as long as the matrix is still soft enough to be cut without a significant degree of fracturing of the sections and destruction of the microtome knife (cf. Braun and Pfeiffer, 2002 for experiences with microtomy in a Pleistocene lake sediment). In harder and more consolidated rock types sawing microtomes may be used instead of normal microtomy, the minimal thickness of obtainable sections being normally about 30 µm. Schopf et al. (1965b) used ultramicrotomy to cut ultrathin sections of Precambrian chert but mentioned the difficulties caused by conchoidal microfracturing. On the other hand, the ion mill technology allows preparation of sections with thicknesses suitable for TEM observations of diverse objects in mineralogy and materials science, an approach offering further possibilities for TEM observations even of very hard rocks in Paleontology.

Microscopic Techniques in Macroscopic Fossils

The thin sectioning technique of small fossils may also be applied to very tiny pieces, isolated by breaking off or small-scale drilling from parts of macroscopic fossils in order to get results on the mineral composition and fine structures of the fossil, as applied to Ediacaran fossils by Pflug (1974) and Steiner and Reitner (2001). Likewise, tiny pieces of bedding planes may be sectioned to find evidence of intergranular organic matter, representing – for instance – ancient microbial mats (Seilacher et al., 1998; Steiner and Reitner, 2001; Porada, 2002). As described above, thin sectioning may be accompanied or replaced by incident light techniques.

Special approaches are in use in macrofossil-bearing dark and bituminous rocks in which the organic (cuticular) substance is still preserved. Isolated pieces obtained from acid residues yield taxonomic and physiologic information (Eisenack, 1956). Some occurrences of larger fossils yielded coherent cuticles of almost the whole animal in the residue (Holm, 1888; Jeram, 1994). If cuticular preservation is not complete and coherent, it is much more difficult to get cuticular fragments still *in situ* for localized microscopical investigations. Specific transfer techniques on peels or varnish films, being currently applied in cuticular analysis in Paleobotany, may also be used in investigations of macroscopic palaeozoological findings, if parts of the cuticular substance are preserved. Transferred cuticular and softpart substance may be investigated in great detail microscopically (see Fig. 1I; Voigt, 1949; Braun, 1999). Such transfer techniques may be applied to certain "Burgess-type" macrofossils in shales. Experiences in fossils from surface exposures of the Burgess or Chengjiang occurrences indicate that the material available is too weathered to be suitable for cuticular transfer. Fresh, dark, pyrite-rich lithologies should be looked for in order to obtain successful transfer preparations.

Pyrite impregnation in fresh, unweathered rocks offers good possibilities for X-ray investigations, X-ray stereophotographs (Stürmer, 1980; Habersetzer and Schaal, 1990; Bruton and Haas, 1999) and sequential sectioning and peeling, as long as the fossils are not completely flattened.

The Importance of Microscopic Remains and Microscopic Paleotechniques in Proterozoic Successions

The field of micro- and meiofaunal research has a great potential in the search for evidences of ancestral representatives of major organism groups. It is quite possible that ancestral metazoans, the origin and ancestral forms of which have been discussed largely on the basis of macroscopical fossils (Pflug, 1974), were only millimeter-sized and probably belonged to the pelagic plankton or deeper water meiobenthos. Thus they should be looked for in sedimentary rocks of the "pelagic facies realm", as indicated by different authors (Grabert, 1973; Conway Morris, 1998b). This notion gains support from theoretical predictions in evolutionary biology, similarly postulating millimeter-sized ancestral metazoans (Grasshoff, 1993; Davidson et al., 1995; Grasshoff and Gudo, 2001). The processes of early diagenetic ("tapho") mineralisation, especially by phosphate, currently turns out to be the key preservation for such fossils. The exceptional preservation of these remains and their geologic occurrence demand a close cooperation between neontologists working on fields like embryology, construction morphology, phylogenetic systematics (cf. Davidson et al., 1995; Waloszek et al., 1996; Olesen and Waloszek, 2000) and paleontologists. Fossils of small

organisms discussed in this evolutionary context cannot be expected to be easily visible on rock surfaces, but must be searched for using prospective techniques which are based on field and laboratory experience as well as on geological and biological-ecological predictions, as exemplary shown by W. G. Kühne in some younger fossil Lagerstätten (Kühne, 1961).

Besides meiobenthos and meioplankton research, "paleo-microbiology" currently gains increasing importance. Such studies are connected to questions of an upper Proterozoic/Early Cambrian "substrate revolution" *sensu* Bottjer et al. (2000), to "biomat-related lifestyles" *sensu* Seilacher (1999) during the Late Precambrian, and to investigations of sea floor-microbiology or other environments (Lochte, 1993). The study of microbial communities in carbonate and clastic environments will profit from many of the techniques mentioned herein.

Many lithologies should be reinvestigated in the light of recent descriptions of exceptionally preserved fossils, using the whole range of possible paleotechniques.

Without doubt, many of the Proterozoic through Cambrian series of phosphorites, phosphoritic limestones and cherts worldwide will prove to be equally important as the currently known Chinese occurrences of Vengan (cf. for example the fossils in figure 18.10 in Perconig et al., 1991 found in sections of a Proterozoic phosphorite in Spain).

Phosphorites as such, redeposited or as thin crusts (hardgrounds or karstic surface covers), are common in rocks of this age interval (Cook and Shergold, 1991). They have been found to contain well preserved microfossils, but only in some cases attracted major paleontological attention ("Vengan" phosphorites of the Doushantuo Formation, China; Xiao et al., 1998; Chen et al., 2000; Xiao and Knoll, 2000; Steiner, 2001), leaving a large prospective area for further search, which might be extended even to slightly metamorphic successions (Aikäs, 1981). With regard to Gondwana, prospective lithologies occur in South America and Africa (e.g., Nama, Arroyo del Soldado and Corumbá groups) containing cherts, limestones and phosphorites, which have already yielded interesting results (Germs, 1972; Acenolaza and Miller, 1982; Hahn et al., 1982; Zalba et al., 1992; Saylor et al., 1998; Gaucher, 2000; Grotzinger et al., 2000; Meinold et al., 2000; Brain et al., 2001; Gaucher and Poiré, 2002) but still await application of some of the laboratory techniques described above. Finally, transferring laboratory and field experiences from the Precambrian/Cambrian boundary interval further towards the 1 Ga range may eventually yield data on metazoan ancestors, as suggested by molecular biology. Phosphatic and siliceous lithologies occur deeper in the Precambrian

(Baarghoorn and Schopf, 1965; Gulbrandsen, 1966; Cook et al., 1991), only a few of which have been tested using the methods indicated above. Fossil material showing unexpected preservation and completeness described in the last years, strongly indicates that Paleontology has not reached its limits in terms of possible fossil documentation. This might enable a closer comparison of fossil evidence to hypotheses and data on the basis of molecular biology, in order to reach conforming results in phylogeny and systematics (see for example Mehl et al., 1998).

A laboratory with a wide equipment used specifically for such microscale investigations might be of great use for newly developing fields like Geobiology, Astrobiology and Geomicrobiology. If size and facies predictions concerning early metazoans and the biomat issue near the Precambrian/Cambrian boundary turn out to be correct, then microscopic Paleontology, used in a broader sense than "Micropaleontology" and approaching the "Microgeology" *sensu* Ehrenberg (1854), will be of great scientific importance.

Acknowledgments

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