Berliner geowiss. Abh.	(E) 9	293-329	13 Abb., 7 Tafeln	Berlin 1993

Oldest entirely preserved sponges and other fossils from the Lowermost Cambrian and a new facies reconstruction of the Yangtze platform (China)

M. STEINER, D. MEHL, J. REITNER & B.-D. ERDTMANN

Oldest entirely preserved sponges and other fossils from the Lowermost Cambrian and a new facies reconstruction of the Yangtze platform (China).- M. STEINER, D. MEHL, J. REITNER & B.-D. ERDTMANN, Berliner geowiss. Abh. (E) 9: 293-329, Berlin.

Kurzfassung: Eine Faziesrekonstruktion und Korrelation obersinischer-unterkambrischer Schichten der Yangtze-Plattform (Südchina) wird vorgestellt. Dabei wird zwischen geschütztem Becken, Schwelle und tiefem Becken unterschieden. Die unterkambrische Schwarzschiefer-Transgression, der "Badaowan" Event, wird als diachron gekennzeichnet. Nach Untersuchungen der Lithologie und Geochemie der unterkambrischen Sedimente, vorwiegend Schwarzschiefer des Profils Sansha (nahe Dayong, N-Hunan), kann zwischen Sedimenten, die unter teilweise anoxischen Bedingungen oder im stagnierenden Becken abgelagert wurden, unterschieden werden. Schwammnadeln sind im untersten Unterkambrium Zentralchinas weit verbreitet. Neufunde vollständiger hexactinellider Schwämme *Sanshadictya microreticulata* gen. et sp. n., *Hyalosinica archaica* gen. et sp.n., *Triticispongia diagonata* gen. et sp. n., *Solactiniella plumata* gen. et sp. n., *Hunanospongia* sp. QIAN & DING, 1988, Hexactinellida indet., eines fraglichen Vertreters der Demospongiae, *Saetaspongia densa* gen. et sp. n. sowie eines Vertreters der Malacostraca *Perspicaris* sp., und einer unbenannten Algenform, werden vorgestellt. Schwammnadeln wurden ebenfalls neu in Gesteinen des Shibantan Mb. (Dengying Fm., Ob. Proterozoikum) vom Straßenaufschluß Liantuo (nahe Yichang, S-Hubei) gefunden. Die Fauna vorwiegend hexactinellider Schwämme von Sansha wird im Zusammenhang mit den taphonomisch ähnlichen Spongienfaunen des Red Hills Quarry (Mitteldevon, Nevada) und des Arnager Kalkes (Kreide, Bornholm) diskutiert.

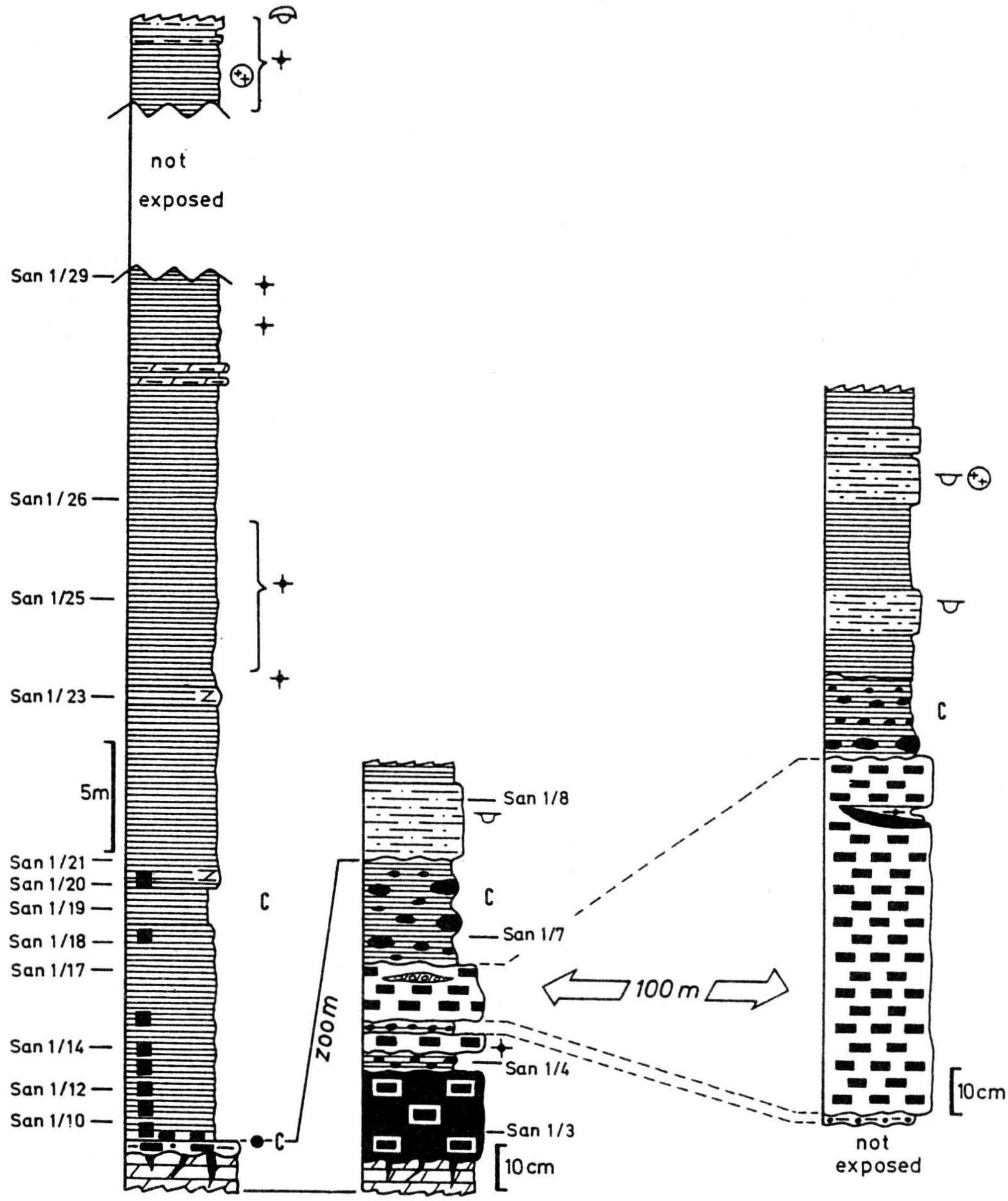
Abstract: A facies reconstruction and correlation of Upper Sinian - Lower Cambrian strata of the Yangtze platform (South China) is presented. Protected basin, uplift and deep basin development may be distinguished. The Lower Cambrian black shale transgression, the "Badaowan" Event, is characterized as diachronous. As a result of these investigations of lithology and geochemistry of the Lower Cambrian sediments (mainly black shales of the Sansha section, near Dayong, N. Hunan), sediments deposited under partially anoxic conditions or in a stagnant basin have been recognized.
Sponge spicules are widely distributed in the lowermost Lower Cambrian of Central China. Recently discovered more or less complete sponges, including *Sanshadictya microreticulata* gen. et sp. n., *Hyalosinica archaica* gen. et sp. n., *Triticispongia diagonata* gen. et sp. n., *Solactiniella plumata* gen. et sp. n., *Hunanospongia* sp. QIAN & DING, 1988, Hexactinellida indet., a questionable demosponge, *Saetaspongia densa* gen. et sp. n., and the Malacostraca *Perspicaris* sp., and an unnamed alga are described. Sponge spicules additionally were found in rocks of the Shibantan Mb. (Dengying Fm., Upper Proterozoic) from the road section of Liantuo (near Yichang, S.Hubei province). The fauna of mainly hexactinellid poriferans from Sansha is discussed with regard to the similar taphonomy of the sponge faunas from the Red Hills Quarry (Middle Devonian of Nevada) and from the Arnager limestone (Cretaceous, Bornholm).

Keywords: Porifera, China, Yangtze platform, Lower Cambrian, megaalgae, Malacostraca, black shales, facies, stratigraphy

Authors' adresses: M. STEINER & B.-D. ERDTMANN: Technische Universität Berlin, Institut für Geologie und Paläontologie, Sekr. ACK 14, Ackerstraße 71-76, D-13355 Berlin, Germany / D. MEHL & J. REITNER: Institut für Paläontologie, Freie Universität Berlin, Malteserstr. 74-100, Haus D, D-12249 Berlin, Germany

1. Introduction

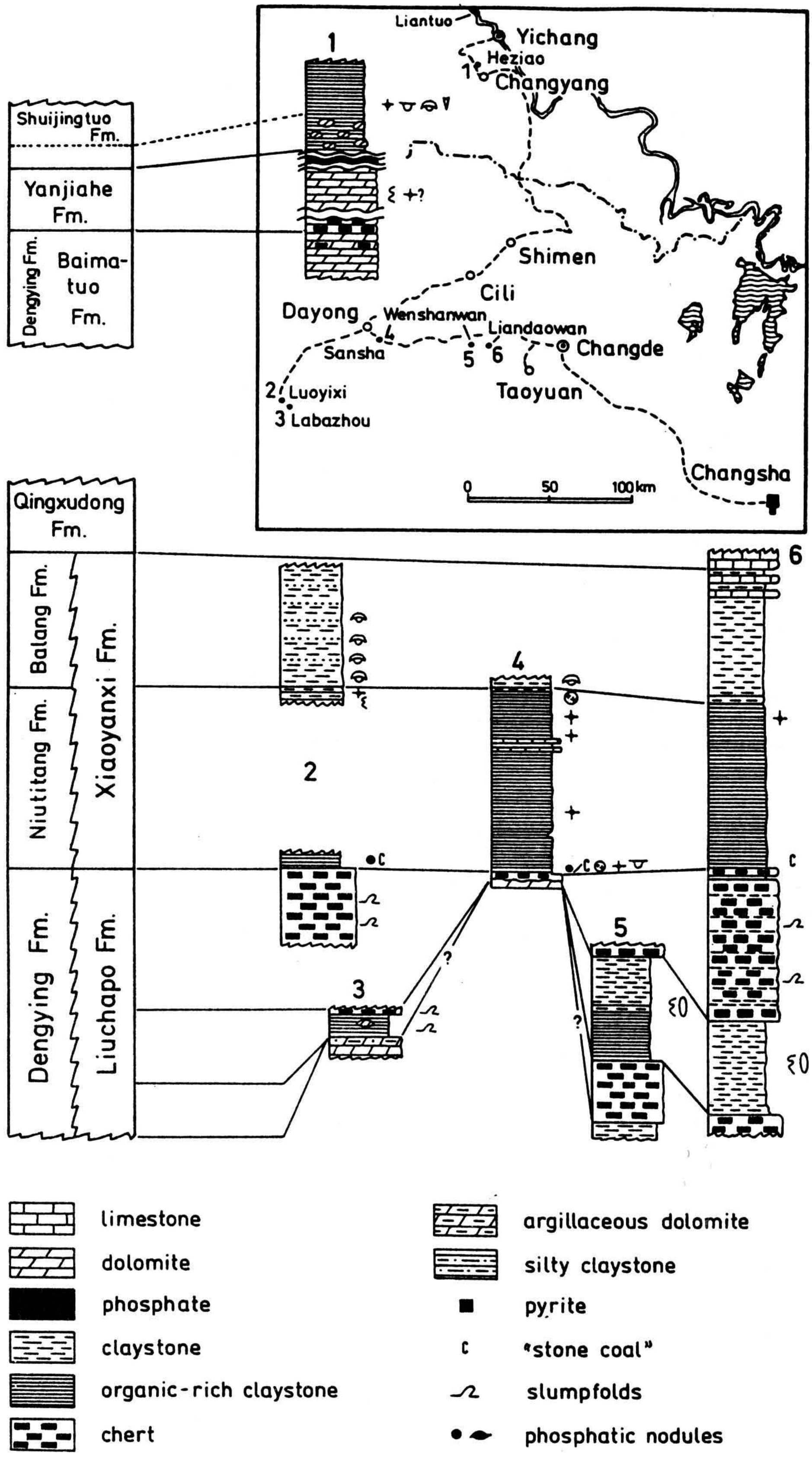
The present paper includes first results of a palaeontological-sedimentological correlation project on the Yangtze platform, China. Team members on the German side concentrate on the investigation of phosphogenesis and lithofacies correlation at the Precambrian - Cambrian transition (SIEGMUND, TU Berlin) and on studies of the Precambrian-Lower Cambrian "mega-algae" (STEINER, TU Berlin). Additionally primary results concerning a palaeogeographic/facies reconstruction of the Yangtze platform, and the stratigraphic correlation, geochemistry and palaeontology of Lowermost Cambrian (Nemakit-Daldynian, Tommotian) strata are presented here. New tectonic data (CHEN et al., 1991; XING et al., 1992; pers. comm. R. BREWER, Sept. 1992), a re-evaluation of literature (e.g. HE & YANG, 1982; CHEN, 1984; anonymous, 1987) and field observations in 1991 and 1992 clearly show that a simple palaeobathymetric subdivision of the Upper Proterozoic-Lower Cambrian sediments of South China into shelf-platform-sediments, slope sediments and basin-sediments (e.g. YANG, CHENG & WANG, 1986; anonymous, 1987) is not satisfactory. First doubts concerning the former model were expressed after initial palaeontological and sedimentological investigations by STEINER, ERDTMANN & CHEN (1992).



Text-fig. 1: Investigated sections in N.Hunan and S.Hubei provinces (for explanation of fossil symbols see fig. 5).

Fossil records from the Upper Precambrian-Lowermost Cambrian are of great interest because of the implication to the evolution of life and to a higher stratigraphical resolution. Small shelly fossils (SSF) and sponge spicules are the most widely distributed fossil remains near the Precambrian-Cambrian transition.

Entirely preserved Porifera, the oldest ones described so far, are found in several horizons in an excellent preservation. They are fairly small specimens and are attributed mainly to the Hexactinellida. All taxa of Porifera here presented are analysed, described and documented by MEHL & REITNER (working group "Porifera", FU Berlin). The non-Porifera taxa are described by STEINER.



Text-fig. 2: Lithology and location of samples and fossiliferous horizons of the section ca. 1km SW of the traffic check point Sansha (near Dayong, N.Hunan province)(for explanation of lithological signs see fig. 1, for fossil symbols see fig. 5).

2. Geological setting

2.1. General scope of study

During field investigations in N.Hunan and S.Hubei five sections in the Wuling Mountain area and one section at Heziao near Changyang were measured and compared (fig. 1). One additionally section in the Huangshan area (S.Anhui), which exposes a similar facies as in the Liandaowan and Wenshanwan sections, and three sections in Jinning and Chengjiang county (Yunnan prov.) provided data for a facies reconstruction, roughly extending over the Yangtze platform.

The stratigraphic sections, investigated most closely and described herein represents the Precambrian-Cambrian transition. A comprehensive correlation table over the complete Yangtze platform did not exist untill now. Previous correlation attempts between several provinces (e.g. anonymous, 1987, 1988, 1990) were based mainly on lithostratigraphy.

Our recent investigations include studies of the Dengying Fm., Yanjiahe Fm. and Shuijingtuo Fm. in the Heziao section; the Dengying Fm., the Niutitang Fm. and Balang Fm. in the Luoyixi, Labazhou and Sansha sections; and the Liuchapo Fm. and Xiaoyanxi Fm. in the Wenshanwan and Liandaowan sections.

The localities at Liandaowan, Wenshanwan and in the Huangshan area (S.Anhui) document that chert was deposited during the Uppermost Precambrian (Liuchapo Fm., Piyuancun Fm.), but in the regions farther to the N, e.g. in Sansha and Heziao, the sedimentation remained under carbonatic influence (Dengying Fm.).

Because of lateral facies changes, the Yangtze, Jiangnan and South-east regions have been distinguished (e.g. YANG, CHENG & WANG, 1986). The investigated sections are situated along a traverse from the Yangtze region to the Jiangnan region.

2.2. Localities

Among the investigated sections in N.Hunan, S.Hubei (see text-fig. 1), the section ca. 1km SW of the traffic check point Sansha (text-fig. 2) was selected for a first closer examination because of its rich fossil content. In the Sansha section (text-fig. 2) phosphates, dark cherts, black shales with phosphatic nodules, and black metalliferous shales of Lower Cambrian age were deposited above a distinct and visible disconformity. In the subjacent Dengying Fm., SIEGMUND (in prep.) observed several well defined karst features. Locally erosional surfaces are refilled with transgressive phosphatic sediments. The thickness of the dark cherts and carbonaceous shales with phosphate nodules above the erosional disconformity is highly variable, compensating for relief differences caused by karstification of the Dengying dolostones. Narrow and deep channels, eigther filled with carbonates that contain small chert nodules, or phosphate and carbonaceous shale that contain small phosphatic nodules, occur within the black cherts. These cherts contain the oldest sponge spicules in this section (SIEGMUND, in prep.; see plate 6, figs. 2-4). SSF could not be clearly identified, but DING & QIAN (1988) reported SSF of the *Protohertzina*/ *Conotheca* association and sponge spicules (*Hunanospongia delicata* QING & DING 1988) from basal phosphatic, carbonaceous silicolites that contain silty carbonaceous shales and phosphatic concretions of the Lower Cambrian from Yangjiaping (Shimen, Hunan prov.).

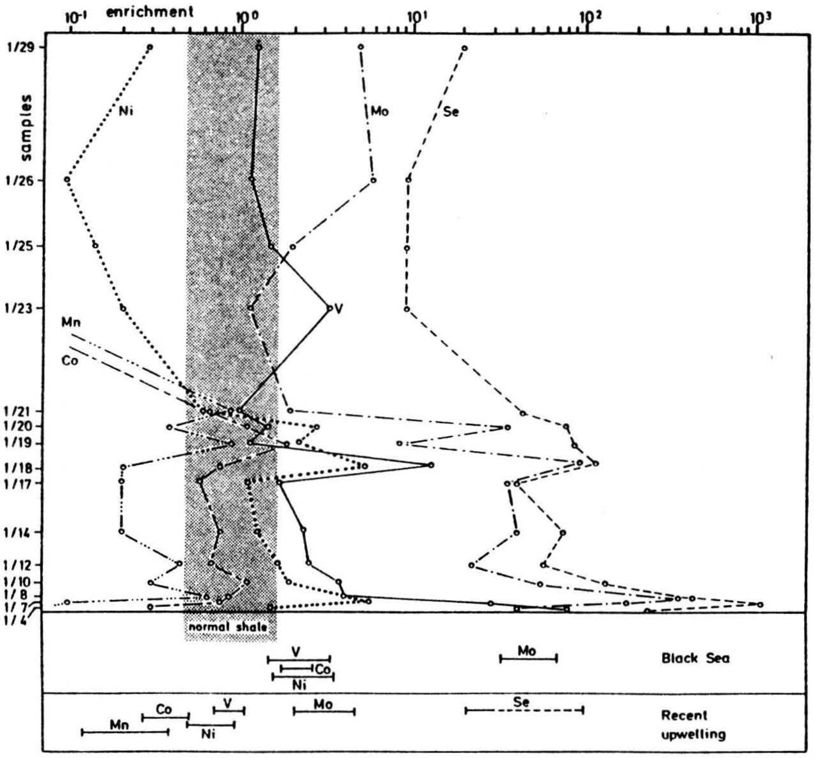
A carbonaceous shale with large phosphatic nodules was deposited above the cherts. It is called "the lower stonecoal bed" and is locally mined for lime-burning purposes. With a TOC of approx. 11 %, this bed has the highest organic content of the entire section.

COVENEY & CHEN (1991) and COVENEY et al. (1992) reported nodular Ni-Mo-ore beds (2-15 cm) from Guizhou and Hunan provinces. These beds directly overlie the Lower Cambrian phosphates in Hunan and a thin black shale bed above the phosphates in Guizhou province. Although we couldn't detect an ore layer with Ni and Mo enrichments in % scale, the carbonaceous shales with phosphatic nodules contain unusually high element enrichments of V (up to 1,1 wt. %), Cr (up to 0,5 wt. %), Ba (up to 0,5 wt. %), Se, Mo, Cd, U and Ni (see figs. 3, 4).

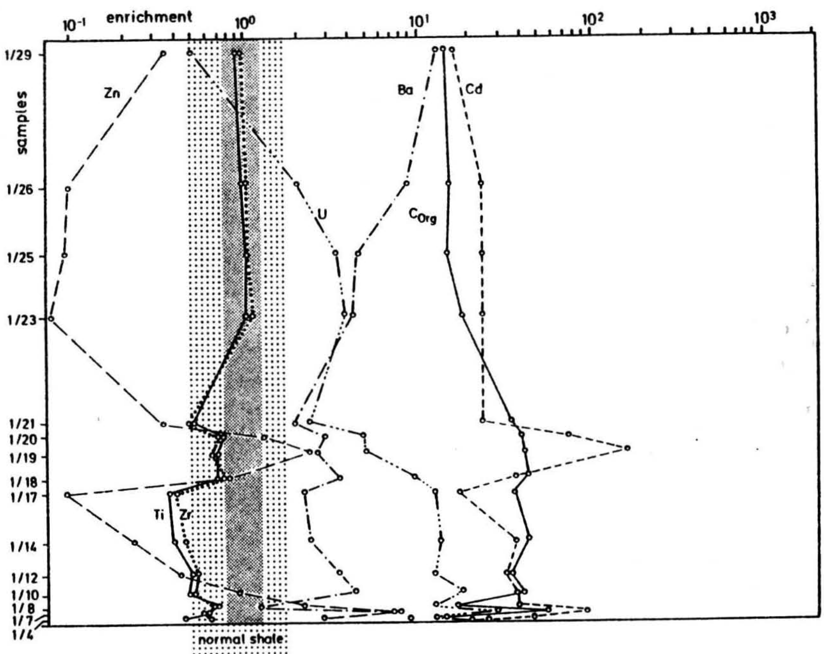
The "lower stone coal" is succeeded at Sansha by 1-2 silty horizons with local mass occurrences of *Perspicaris* sp. and with isolated organic compressions of Porifera. The poor state of preservation of the bivalved arthropods, as well as the absence of mineralized spicules, support the hypothesis of their transportation into the depositional area by water currents.

More than 12 m pyrite-rich black shales (TOC, 6-9%) were deposited above the fossiliferous siltstones. Between 1,5 and 3 m above the top of the Sinian the black shale shows fine pyrite and barite bands spaced 1-2 mm apart. Such pyrite generation is regarded as primary, but pyrite nodules, lenses and nests, however, are regarded as secondary, probably diagenetic. Both generations are pure pyrite.

COVENEY & CHEN (1991) demonstrated that both early and late pyrite generations coexist in the Ni-Mo-ore beds, with the later generation containing higher amounts of Ni, Se and Mo (?).



Text-fig. 3: Enrichment resp. depletion pattern of the elements Mn, Co, Ni, V, Mo and Se of the section 1km SW of the traffic check point Sansha (near Dayong, N.Hunan province) to a normal shale, low in TOC, with a comparison to enrichment patterns of these elements in Recent upwelling zones and the Black Sea (data for normal shale from WEDEPOHL, 1970; for data of Recent upwelling zones and of the Black Sea see compilation in BRUMSACK & THUROW, 1986).



Text-fig. 4: Enrichment resp. depletion pattern of the elements Zr, Ti, U, Zn, Cd, Ba and of Corg. of the section 1km SW of the traffic check point Sansha (near Dayong, N.Hunan province) to a normal shale, low in TOC (data for normal shale from TUREKIAN & WEDEPOHL, 1961; WEDEPOHL, 1970; for U the assumption of 4 ppm for a normal shale was choosen)

Between 3 and 13 m above the top of the Sinian, mainly secondary pyrite occurs. At the top of the black pyrite-rich shales, secondary Cu-minerals (such as chrysocolla, malachite a.s.o.) were precipitated. Probably identical secondary minerals were observed in similar positions in the outcrops at Wenshanwan (Hunan) and Piyuan (S.Anhui).

The black pyrite-rich shales are succeeded at Sansha by 40 m of dark shale (TOC, 3-4 %), rich in sponge spicules. Occasional thin carbonate horizons are intercalated. The black shales of the Niutitang Fm. conformally grade into the superjacent fine, grey and yellowish weathering claystone of the Balang Fm. in the entire Wuling Mountain area (e.g. Sansha, Luoyixi). The Balang Fm. is correlated with the Shuijingtuo Fm. of the Yichang and Changyang areas, based on trilobites.

2.3. Geochemical data and facies interpretation

To obtain a facies interpretation of the Lower Cambrian black shales, three sections were investigated geochemically (Sansha, Hunan; Heziao, Hubei and Chengjiang, Yunnan).

Enrichments in Ni and Mo (several wt. %) and to a lesser degree in As, V, Se, U, Zn, Ag, Au and PGE of Lower Cambrian black shales of South China have been known for a long time (e.g. CHEN et al., 1982; anonymous, 1987; COVENEY & CHEN, 1991; COVENEY et al., 1992).

Element enrichments that are unusually high for black shales (VINE & TOURTELOT, 1970) were observed, both in the lower part of the Niutitang Fm. in Sansha (Se, Cd, Mo, V, Cr, Cu) and at a horizon of the Shuijingtuo Fm. near Heziao (Se, Cd, Mo, V). The latter is rich in hyolithids and yields some sponge spicules and trilobites. A replacement of the original material by Zn-sulfide (with Cd) and by chalcopyrite in the outer part was detected in one of these sponge spicules.

Enrichment pattern of trace metals in the investigated Lower Cambrian black shales can be best compared to those of Cenomanian/Turonian (CTBE) black shales (BRUMSACK & THUROW, 1986; BRUMSACK, 1992).

Text-figs. 3 and 4 show the enrichment resp. depletion of selected elements of the Sansha section compared with an average shale low in TOC (TUREKIAN & WEDEPOHL, 1961; WEDEPOHL, 1970).

Although an actualistic model for the stratification and/or distribution of water masses for the Lower Cambrian time is unlikely, in text-fig. 3 a comparison to recent enrichment patterns in upwelling zones (e.g. Gulf of California) and stagnant basins (e.g. Black Sea) is given (see also compilation in BRUMSACK & THUROW, 1986). Recent sediments, deposited under the influence of upwelling, show enrichments only in Se, Cd, Mo and perhaps slightly in Cu. At the same time they are depleted in Co and Mn, a pattern attributed to an increasing mobility under reducing conditions and their removal from the system.

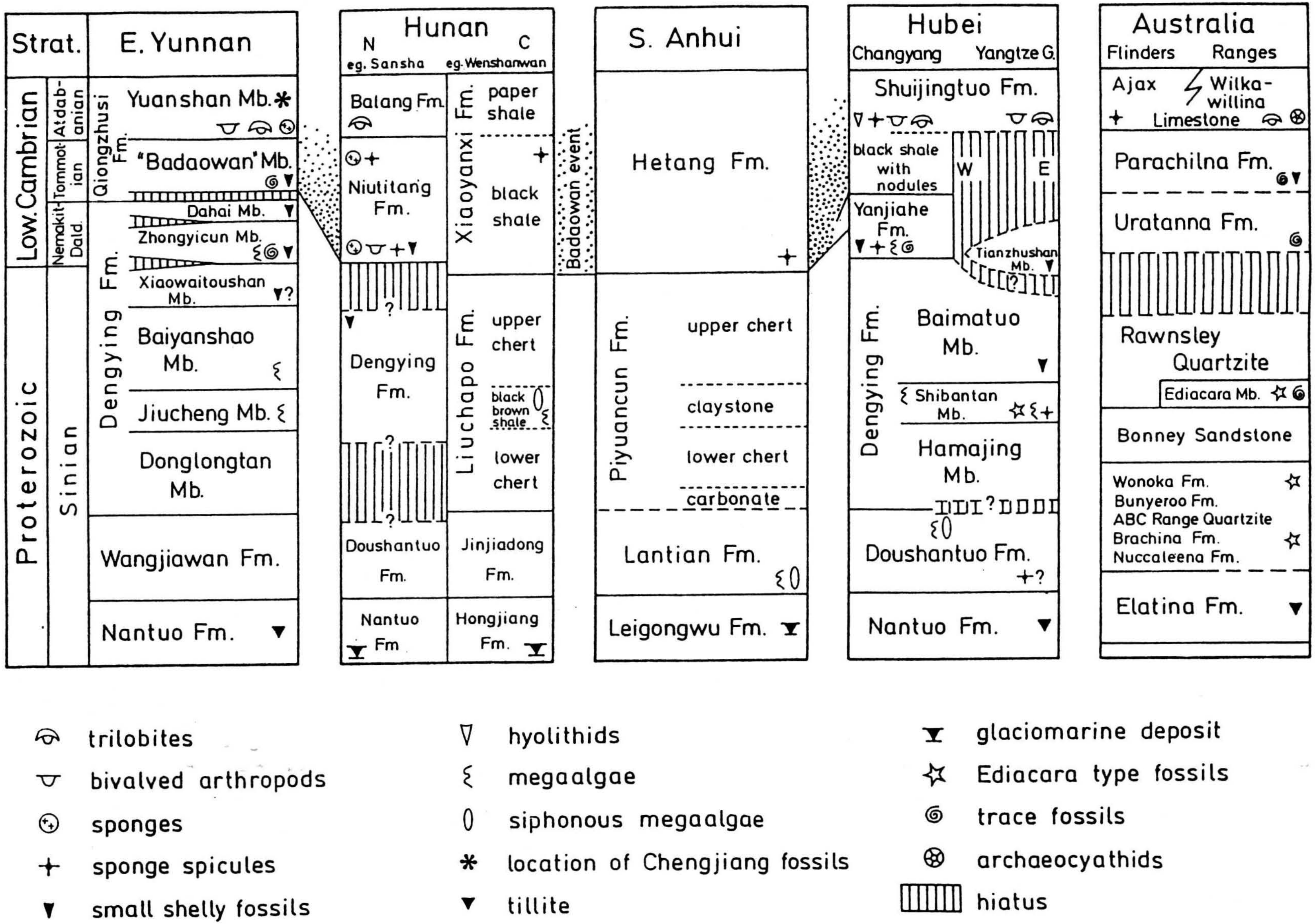
Nearly all elements may be enriched in recent deep sea clays (COLLEY et al., 1984), but Cd, Se, Cr and V are not at all or only slightly enriched.

In recent stagnant basins with extended anoxic conditions apart from the elements Se, Mo, Cd and Cu, which can be enriched in upwelling sediments too, additionally Co, V and Ni can have higher values than in normal shales. Unfortunately, only incomplete data are published for the largest recently existing stagnant basin - the Black Sea (see compilation in BRUMSACK & THUROW, 1986).

Especially the basal part of the black shales, which is probably comparable to extremely Ni-Mo-rich horizons described by COVENEY et al. (1992) from other areas, is considerably enriched in V, Cr, Mo, Se, Cd, Zn and to a certain extent Ni is also enriched, in contrast to maximal values found in recent stagnant mainly anoxic basins. Additional mechanisms, such as hydrothermal influence, diagenetic enrichment, or deep palaeokarst / weathering may explain these unusually high element enrichments. Although a meteoric impact was envisaged as an explanation for some element enrichments (FAN, 1983; FAN et al., 1984), an extraterrestrical influence appears unlikely (COVENEY & CHEN, 1991; COVENEY et al., 1992).

In spite of the incomplete data base for comparison and the essential application of a probably anactualistic model for Cambrian times, the documented enrichment pattern may serve as a tool for facies interpretation.

The basal transgressive phosphates, cherts (with channels) and basal black shales with phosphatic nodules (samples San 1/3-1/7), indicate an established anoxic environment (Mn-Co-depletion). Completely anoxic conditions, however, were developed (normal Cr- and Co-values and enrichment in V, Ni and Cu) during the accumulation of the superjacent strata (samples San 1/7-1/20). Diagenetic processes and palaeokarst phenomena (SIEGMUND, in prep.) probably led to extreme element enrichments in Se, Mo, V, Cr, Ni and Zn in the basal black shales with phosphatic nodules. The distribution pattern of Zn (see text-fig. 4) in particular, probably points towards a mobilization by diagenetic processes. Especially Se, U, Cd and Mo are positively correlated with the organic content, although the distribution of U is not only dependent on the organic contents and Cd still can be secondarily enriched by Zn-sulfide (see text-figs. 3 & 4).



Text-fig. 5: Correlation of Sinian-Lower Cambrian strata of the Yangtze platform (correlation of E.Yunnan and Australia according to SUN, 1989).

Higher Ba-values occur throughout the entire section, except for the siltstones that contain mass occurrence horizons of bivalved arthropods and sponges, and the basal micritic phosphorites. The clastic influences increase in the upper part of the section (samples San 1/23-1/29), indicated by increased Zr and Ti values, that resulted from a heavy mineral input (see text-fig. 4). Only partially anoxic conditions developed (Co, Mn, Ni depletion, normal values of Cr, V) in the upper part of the section (samples San 1/23-1/29). Under these latter conditions sponges found a wide distribution.

At the Heziao section fully anoxic conditions were developed during the lower Atdabanian, for the first time. Such conditions were never established in the Chengjiang region (Yunnan).

2.4. Summary of sedimentological, palaeogeographical and geochemical observations

A correlation of Sinian-Lower Cambrian sediments of the E.Yunnan, Hunan, Hubei and S.Anhui provinces is proposed in text-fig. 5. It is based on all available palaeontological and sedimentological data and field observations. The first occurrence of trilobites, the distribution of different small shelly fossil (SSF) associations (HE & YANG, 1982; CHEN, 1984; LUO et al., 1982, 1984; DING & QIAN, 1988; QIAN, 1989; QIAN & BENGTSON, 1989), the distribution of *Phycodes pedum*, as well as other trace fossils (e.g. LUO et al., 1984; SUN, pers. comm. Oct. 1991) and of acritarch zones (ZANG, 1992) were considered as important stratigraphic markers. According to the IUGS Working Group on the Precambrian-Cambrian boundary (decision July 1991), the first appearance of the tracefossil *Phycodes pedum* is indicative of the Precambrian-Cambrian boundary. The present correlation proposal exeeds previous correlation attempts, which were based on palaeontological and sedimentological data and isotope geochemistry (e.g. SUN, 1989; BRASIER et al., 1990; BRASIER, 1992a, b).

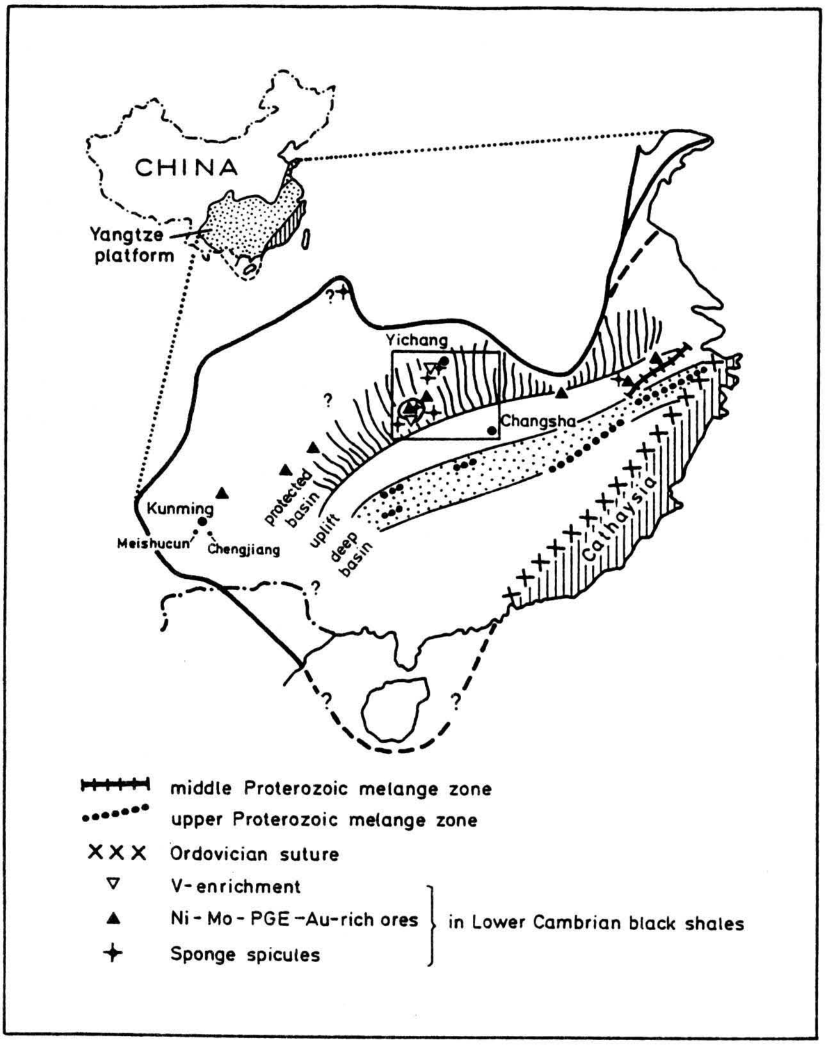
A facies reconstruction for the Yangtze platform during Lowermost Cambrian times, based on sedimentological and palaeontological data, is presented herein (text-fig. 6). A distinction between protected basin, uplift (also called Jiangnan islands by other authors, as e.g. YANG, CHENG & WANG, 1986), and deep basin facies is proposed.

New tectonic data and the occurrence of melange-zones indicate a local subduction of oceanic crust during Middle Proterozoic time (pers. comm. BREWER, Sept. 1992). This zone expanded to an elongate belt, but the subduction ceased completely in Late Proterozoic time. But the geotectonic influence upon sedimentation by compensation movements and hydrothermal exhalations, was active well into the Palaeozoic Era.

Whether this facies reconstruction (text-fig. 6) can be compared to an island arc tectonic situation or not remains unanswered. To be certain would require additional especially tectonic investigations. Nevertheless, this hypothesis seems reasonable because sequences of basic volcanic rocks, including pillow structures, have been described from the Pre-Sinian of Sichuan province (anonymous, 1991). But results of magmatic activities were further reported (anonymous, 1991) from SW. and N. Sichuan for the Early Sinian, subsequent to the so called Jinning movement. The uplift belt (Jiangnan islands of YANG, CHENG & WANG, 1986), which existed in the Upper Sinian and Lowermost Cambrian, could not be detected as clearly for the Lower Sinian as for the Upper Sinian times. But an uplift, not as morphologically significant as in Upper Sinian, could well have existed before (see anonymous, 1987). The wide occurrence of black shales with element enrichments of V, Ni, Cr a.s.o. in the Doushantuo Fm., Niutitang Fm., Yanjiahe Fm. and Shuijingtuo Fm., as well as the appearance of phosphates during the whole Sinian/Lower Cambrian might also indicate increased outcrops of volcanites, as e.g. back arc basin basalts or volcanic arc basalts, during the Upper Proterozoic. Thus, submarine volcanites may have served as a source for an additional supply of elements to the sea water.

During the Upper Sinian (post Nantuo glaciation), N and NW of the uplift-belt a protected basin developed. This protected basin prograded with a general tendency towards the NW at least until the Atdabanian. Maximum subsidence occurred during the Tommotian, with the depocenter situated in the Sichuan province. An increased subsidence of the protected basin from the beginning of the Cambrian onwards led to a widely distributed diachronous deposition of black shales, here called the "Badaowan" Event (see text-fig. 5). That event was possibly, but not necessarily, connected with eustatic sea level changes. The diachronity of the black shales is indicated by data of SSF (CHEN, 1984; DING & QIAN, 1988; QIAN & BENGTSON, 1989), of trace fossils, and by sedimentological data. The general palaeo-geographic situation appears to support this conclusion.

Geochemical and palaeontological data clearly point out the existence of a stagnant basin with an extended anoxic zone. The development of anoxic conditions was variable in both time and space. Life was possible at least sometimes, depending upon the environment. SSF and sponge spicules belong to the remains of life forms with widest distribution throughout the lowermost Lower Cambrian. However, the occurrence of these fossils is mainly allochtonous or parauthochtonous.



Text-fig. 6: Facies reconstruction for the Yangtze platform during Lowermost Cambrian times (location of platform margins, melange zones and of the Ordovician suture after BREWER, pers. comm. Sept. 1992; distribution of Ni-Mo-PGE-Au-rich ores, completed after COVENEY et al., 1992). Working area, described in the text, framed (compare also fig. 1).

The clastic influence on the sedimentation in the protected basin increased during the Upper Tommotian. This, and probably decreasing rates of subsidence led to a shallowing of the protected basin. It became more and more aerated, and nutrients were readily accessible. Altogether, this led to a rapid radiation of life forms during the Upper Tommotian / Atdabanian time. The preservation of some Porifera from the Upper Niutitang Fm. of the Sansha section, described herein as well as the spiculite mats from the same strata, underline the authochtonous nature of the fauna in the Upper Niutitang Fm..

Magmatic activities are indirectly detectable in Upper Sinian sediments. Tuffs were mentioned in the Doushantuo Fm. by FAN, YE & LUI (1992), as well as by CHEN & XIAO (1992), and in the Lower Cambrian by COVENEY & CHEN (1991) and COMPSTON et al. (1992). During field investigations in 1992 SIEGMUND & STEINER (unpubl.) discovered probable synsedimentary magmatic rocks within the fossiliferous Lantian Fm. in S. Anhui.

An increased subsidence of the protected basin, connected with fracturing, is assumed for the period of deposition of the Dengying Fm. Slump folds in claystones and cherts of the Liuchapo Fm. (N.Hunan prov.) and Piyuancun Fm. (S.Anhui prov.), as well as channels in the Jiucheng Mb. (Yunnan prov.; STEINER, unpubl.), which can be correlated with carbonates of the Dengying Fm. (N.Hunan prov., S.Hubei prov.), support an increased subsidence in the area N of the uplift. Because of the fracturing, the sedimentation was hydrothermally influenced. Thus, among others, stratiform Hg-ore-layers could have originated within the Dengying Fm. in the Hubei and Guizhou provinces (see e.g. YAN & LIU, 1989; XING, 1989). COVENEY & CHEN (1991) and COVENEY et al. (1992) have proven a hydrothermal influence on the Lower Cambrian Mo-Ni-rich deposits. Cherts of the basal transgressive succession were assumed to be of exhalative origin by the latter authors, whereas BRASIER (1992a) described cherts in similar stratigraphic positions from other areas as spiculites. We consider the basal cherts of the "Badaowan" Event (see text-fig. 2) as exhalites. This opinion is supported by the high Ba-values of the cherts (up to 4500 ppm). Ba is an element that mainly indicates an endogenous origin (DILL, 1986). A barite-facies of the Upper Sinian (anonymous, 1987), as well as the thick cherts of the Liuchapo Fm. and Piyuancun Fm. follows the uplift (see text-fig. 6) and were probably controlled by hydrothermal influences via marginal faults. The sediments of the Lower Cambrian strata are characterized by generally increased Ba-values, both in N.Hunan and S.Hubei, which indicates a possible continuous hydrothermal influence. However, an increased input of reworked Ba-minerals coeval with increasing clastic influence in the depositional area must be additionally expected (see text-fig. 4).

The linear belt-like arrangement of the Ni-Mo deposits at the base of the Lower Cambrian black shales (see text-fig. 6) further supports the existence of basement fractures (COVENEY & CHEN, 1991).

3. Palaeontology

3.1. Introduction

With the progress of investigations into the Precambrian-Cambrian rocks, the Yangtze platform turned into focal attention for palaeontological research. The discovery and description of a Lower Cambrian soft-body fauna from Chengjiang (e.g. ZHANG & HOU, 1985; HOU, 1987; CHEN, HOU & LU, 1989; CHEN & ERDTMANN, 1991), the description of Ediacara-type fossils of the Shibantan Mb. from the Yangtze Gorges (DING & CHEN, 1981; SUN, 1986), the discovery of highly developed "mega-algae" in the Doushantuo and Dengying Fm. (ZHU & CHEN, 1984; CHEN & XIAO, 1991, 1992; STEINER, ERDTMANN & CHEN, 1992) and the evidence of diverse SSF associations (e.g. QIAN & BENGTSON, 1989; QIAN, 1989) certainly represents only a minor part of further discoveries still to be expected.

With regard to the porifera, several records and doubtful documentations of sponge spicules from the Doushantuo Fm. and Dengying Fm. have been published.

TANG, ZHANG & JIANG (1978) named questionable siliceous sponge spicules from thin sections of siliceous banded dolomites of the Doushantuo Fm. as *Archaeoprotospongia* and mentioned *Protospongia* from the Dengying Fm.. XING et al. (1985) and DING & XING (1988) also mentioned sponge spicules from the Precambrian of S.Hubei province. They distinguished between *?Eospicula yichangensis* and *?Hazelia liantuoensis*. To the latter they also assigned *Archaeoprotospongia* of TANG, ZHANG & JIANG (1978). QIAN (1989) described spicules of *Protospongia* sp. from the Dengying Fm. (Maidiping Mb.) from Sichuan. LUO et al. (1982) reported *Protospongia?* sp. from bed 2 (= Dengying Fm., Xiaowaitoushan Mb.) of the Meishucun section and *Calcihexactinia isophyllus* from bed 13 (=base of Yuanshan Mb., Qiongzhusi Fm.) (LUO et al., 1984), but similar observations were not confirmed in QIAN & BENGTSON (1989).

Sponge spicules of Lower Cambrian black shales from Hunan and Hubei provinces (anonymous 1988, anonymous 1990) have been known for a long time. Most evidence comes from the protected basin facies (see text-fig. 6), but sponge spicules have also been reported from sandstone/slate intercalations and from thin layered siliceous rocks and carbonaceous shales with phosphate nodules in the basal part of the deep basin in S.Hunan (anonymous, 1988).

Entirely preserved Porifera were only known to date from the Atdabanian fossil lagerstätte Chengjiang (Yuanshan Mb.) in Yunnan. Recently discovered sponge spicules from the Shibantan Mb. of the Liantuo section (Hubei) and entirely preserved sponges from the base and the top of the Niutitang Fm. of the Sansha section are described herein. Associated with Poriferans, we discovered accumulation layers of *Perspicaris* sp. near the base of the black shales at Sansha. Remains of "mega-algae" in layers rich in sponge spicules from the top of the Niutitang Fm. at Luoyixi extend our knowledge of the fossil record from the Lowermost Cambrian .

Because the Porifera constitute the phylogenetically most original group within the Metazoa (e.g. AX, 1989; REITNER & MEHL, 1993) they are expected to be traced back very far within the fossil record. Actually, all major poriferan groups have been documented from the Early Cambrian, mainly as isolated spicules, but in isolated occurrences also as body fossils. In basal Cambrian strata, especially from China, triaxons of the Hexactinellida are by far the most common spicule type. From the Early Cambrian of South Australia BENGTSON et al. (1990) documented a diverse spicule association including various triaxons (especially hexact-, pectact- and stauractins) of the Hexactinellida. Also triaene most probably demospongiaen spicules (*Dodecaactinella cynodontota* BENGTSON & RUNNEGAR, the authors interpret these spicules as calcarean) were found. Further, various Heteractinida (stem lineage representatives of the Calcarea) e.g. *Eiffelia* WALCOTT were documented. Definite sterraster spicules (Tetractinellida, Demospongiae) were documented from the Atdabanian of Flinders

Range sections, South Australia by GRUBER & REITNER (1991). Some probably post-Tommotian Early Cambrian Hexactinellida and Demospongiae (?*Protospongia, Hazelia, Leptomitus*) in body preservation have been described from North America (RIGBY, 1987). From Sibiria also an Early Cambrian sponge body fossil (*Lenica unica* ?Demospongiae) has been reported (GORJANSKY, 1977).

The Middle Cambrian was a time of radiation within all poriferan major groups, and highly diverse sponge body fossil as well as spicule associations have been documented from all over the world. The Middle Cambrian Burgess Shale of Canada brought about diverse faunas of many metazoan groups in body preservation (WALCOTT, 1920) including sponge fossils of the Hexactinellida, the Demospongiae and the Calcarea (RIGBY 1986). Middle Cambrian demosponges and hexactinellids, in similarly good body preservation, were documented from the House Range and Drum Mountains in Utah (RIGBY 1983, 1990). An entirely preserved silicified heteractinid sponge (Calcarea), *Jawonya gurumal* KRUSE, 1987, was published from the Middle Cambrian of North Australia (originally misinterpreted as a "sphinctozoan", later revised by RIGBY, 1991: p. 84, REITNER, 1992). In Middle Cambrian sediments of the Georgina Basin, Northern Territory, Australia, also the oldest hitherto known representative of the Anthaspidellidae, "Lithistida", has been published (KRUSE, 1983). Further, a highly diverse poriferan spicule assemblage in phosphatic preservation is found. From these sediments van KEMPEN (1990) described various spicules from hexactinellides and demosponges (e.g. calthrops and different triaenes). A detailed description and documentation of the very rich spicule association of the Georgina Basin is currently in preparation by one of the authors (MEHL).

Preservation state and stratigraphic distribution

About 50 pieces of dark shale (some as part and counterpart) with spicule impressions of sponges. Some of these obviously are fossilized entire sponge bodies. The sponge fossils are percieveable by naked eye as few cm large, dark spots on the shale surfaces. Most of the specimens San 100-150 also contain spicules, which are mainly preserved as internal moulds of axial canals or entire spicules in secondarily silicified preservation, but weathered specimens (on yellowish shale surfaces) often only contain hollow spicule impressions. Part of the spicules from the paratype of *Hyalosinica archaica* (San 106B) were analysed by EDAX, the anylysis confirmed that the material is silica. The spicules must have been silicified secondarily from solutions invading the sediment, after dissolution of the original skeletal opal, dissoltions which normally occurs during very early diagenesis.

Except questionable demosponges and Porifera *indet*., the fossils of this collection are all Hexactinellida. Some of the samples, (e.g. San 107A,B; Pl.5, Fig.1), obviously are hexactinellide spicules accumulated unsorted and without any visible orientation. They are interpreted here as spicule mats, which were formed on the ocean bottom after the decay of sponges and their decomposition *in situ*. Similar spicule accumulations are observed in the present to form *in situ* spiculites at the Arctic Vesterisbanken (HENRICH et al., 1992).

Older samples San 050-060 show dark round spots, similar to those desribed above, but with no definite spicules and only very indistinct "ghosty" linear impressions, which indicate that spicules were originally present (e.g. San 50B; pl.5, fig.3). From the basal chert, definite hexactinellide spicules (hexactins) are found in thin section (pl.6, figs.2-4). The presense of spicules here may be due to better preservation potiential and to accumulation in the course of a possible transportation.

Precambrian spicule remains

Hexactinellid sponges and may be demosponges are thus definitely documented from the basal "Badowan" event. Their phylogenetic history, however, reaches back far beyond this. In a dolomitic limestone of the Dengying Formation, Shibantan Member (Ediacara Member equivalent, compare text-fig. 5) from the Liantuo section (Hubei Province, about 200 km N` of Sansha), spicules are frequently observed in thin section. These are preserved as moulds secondarily filled with sparitic cements and then silicified. Most of them are monaxone, whose attribution is uncertain, because central canals are only exceptionally observed. A few of these moulds, however, appear to be rather definite "crosses", which are interpreted, with some caution as paratangential rays of isolated hexactine spicules (pl. 7).

Material

This material is still under study. The Porifera collection is currently kept at the Institut für Paläontologie of the Freie Universität Berlin, and the samples, so far, still have their original field numbers.

3.2. Systematic palaeontology

Protoctista
Division, Order, Family unknown

unnamed alga
(Plate 2, figs. 3 a,b, 4)

Description: Irregular coaly imprint with stalk-like appendages. The appendages end up in funnel-shaped extensions.
Dimensions: Total length of the irregular body 5 mm; length of the stalklike appendages 0,5-0,9 mm with an approx. width of 50-75 µm; maximum width of the funnel-shaped extensions 0,2-0,25 mm
Material: 2 specimens (Luo 025, Luo 027) from the top of the Niutitang Fm. of Luoyixi near Wangchun (Hunan prov.)
Discussion: Speculations about the biology of the organism are premature because only one specimen can be clearly placed into the unnamed Forma. If the funnel-shaped extensions of the appendages are only destructional remains of protoplasm filled bladders, this organism could represent a siphonous organized alga.

Animalia
Malacostraca LATREILLE 1806
Phyllocarida PACKARD 1879
Vanadaspidida NOVOZHILOV in ORLOV 1960
Perspicarididae BRIGGS 1978
Genus *Perspicaris* BRIGGS 1977

***Perspicaris* sp.**
(Plate 1, figs.1-5, Plate 2, fig. 5, Plate 3, fig. 4)

Diagnosis (from BRIGGS, 1977, p.597): "Carapace with hinge line, valves sub-oval, tapering anteriorly, rostral plate absent. Pedunculate eyes large, borne on an elongate projection of the cephalon. Abdominal somites lacking appendages, telson not posteriorly produced, caudal furca spinose."
Description: bivalved carapace of suboval outline, hinge line slightly convex, with a short postero-dorsal process. Carapace surface smooth apart from secondary folds and destruction structures. The border of carapace shows a thin rim.
Dimensions: maximum length 6-14 mm; maximum heigth 4-8 mm
Material: 22 specimens from the lowermost Niutitang Fm. from Sansha near Dayong (Hunan prov.).
Discussion: The genus *Perspicaris* was errected by BRIGGS in 1977 on the base of specimens with soft parts. The present material from Sansha does not show these diagnostically important soft parts. Thus, the taxonomical classification remains unclear to some degree. The isolated carapaces are possibly closer related to *P. dictynna* (SIMONETTA & DELLE CAVE) BRIGGS 1977 than to other species, including *P.? laevigata* HOU & BERGSTRÖM 1991 from the Chengjiang Lagerstätte (Yunnan).

The carapaces of *Perspicaris* sp. occur in mass layers within a limited horizon (see text-fig. 2). The sedimentology and geochemistry of this horizon, as well as the fragmentary state of preservation of these fossils, support the assumption of an drag transportation into the depositional environment by water currents. Several decomposed carapaces are only preserved as circular closed ribbons, representing the more resistant borders of the carapaces (see plate 3, fig. 4). The specimen San 003 (plate 1, fig. 5 a,b) shows a possible rounded injury.

Porifera GRANT, 1836

The poriferan taxa are described by MEHL & REITNER.

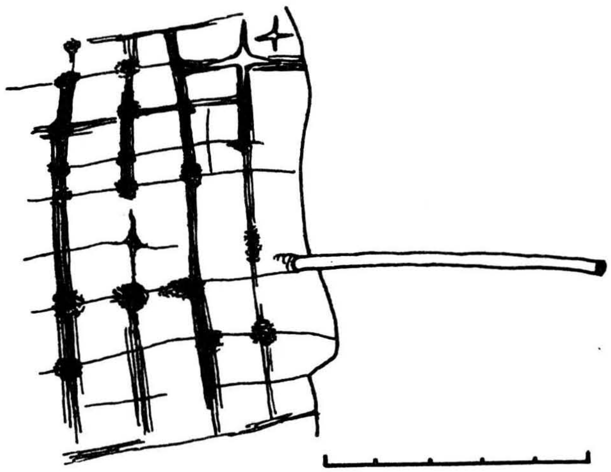
Hexactinellida SCHMIDT, 1870
Reticulate Hexactinellid Sponges (Dictyospongiidae HALL, 1884)

***Sanshadictya* n.g.**
(Pl. 2, fig. 2; text-fig. 7)

Derivatio nominis: *Sanshadictya*: Dictyosponge like hexactinellid from the type locality Sansha.
Type species: *Sanshadictya microreticulata.*
Diagnosis: Spicules are thin diactins and stauractins arranged in parallel bundles and forming a regular network with at least three orders of very fine quadrules. The sponge possessed coarse, probably anchoring spicules.
Description: See the type species.

***Sanshadictya microreticulata* n.g., n.sp.**

Derivatio nominis: *microreticulata* (lat.) refers to the small dimensions of reticulate meshes.
Description: Fragment of sponge wall, only 5 x 7 mm, characterized by small quadrules of bundled diactins, partly in body preservation and partly only as impressions. The crossing points are visible as dark spots, probably limonitic. Three orders of quadrules can be recognized, of which the largest is only about 1 mm long. The best preserved regions show very thin diactins in parallel bundles, between 5 and 7 spicules can be identified, but probably there were originally more. A few stauractins appear to be present in the best preserved area of the framework (plate San 117 B). Part of a thick monaxon, 4.5 mm long and about 100 µm in diameter, projects from the fragmentary sponge wall.



Text-fig 7: *Sanshadictya microreticulata*, holotype (San 117); scale 5 mm.

Probably, it represents the proximal part of a basal anchoring spicule, by means of which the sponge was originally attached.

Discussion: The large Palaeozoic group of the Dictyospongiidae HALL is especially well-known from the Devonian of New York (HALL & CLARKE, 1898), however, representatives of this group are found throughout the Palaeozoic since the Silurian. The youngest definite dictyospongiide was described from the Permian of Texas as *Stereodictyon* FINKS, 1960. According to the diagnosis given by HALL & CLARKE (1898) the Dictyospongiidae are characterized by a regular meshwork composed of vertical and horizontal bundles of diactins, normally with an outer layer of stauractins, forming quadrate or rectangular meshes in several orders of size. At the present stage of knowledge it is uncertain, whether this spicule organization characterizes a monophyletic group of hexactinellids, or if such regular reticulate patterns evolved several times convergently. Taking into consideration that dictyosponges s.str. are, so far, unknown from Later Cambrian and Ordovician strata, it is unlikely that the reticulate spiculation of *Sanshadictya* may have evolved independently of that of the Dictyospongiidae sensu HALL (1870). The meshwork of *Sanshadictya microreticulata* shows diactins and stauractins in rectangles of three size orders, however, the largest meshes only measure about 1 mm across. Thus, reticulation is considerably finer than in any Dictyospongiidae known. Although only a small fragment is preserved, this sponge is significant, because it shows a derived type of spicule organization, and it might even be the oldest representative of the Dictyospongiidae described so far. Since the basic spicules of Hexactinellida are neither diactins nor stauractins, but hexactins (MEHL, 1991), the dictyospongids must be considered an already derived type of hexactinellide sponges.

Material: The holotype is an unicate: San 117A, B (plate + counterplate)

Hexactinellida *incertae sedis*

***Hyalosinica* n. g.**

(Pl. 4, figs. 1a, b; text-fig. 8)

Derivatio nominis: *hyalos* (gr.) = transparent, clear., refers to the stalk of long twisted spicules, like a "glas-rope" similar to that of the recent *Hyalonema* GRAY, 1835.

Type species: *Hyalosinica archaica*

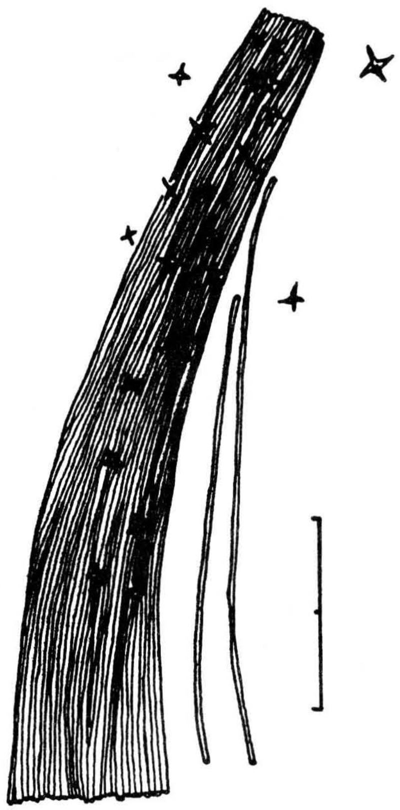
Diagnosis: Stalk and root tuft consisting of coarse anisoactine, triaxial spicules loosely twisted in clock direction. Remark: Sponge body, except the tuft and few triaxial spicules in its proximal end, is unknown

Description: See the type species.

***Hyalosinica archaica* n. g., n. sp.**

Derivatio nominis: *archaios* (gr.) = primary, original, these sponge are the oldest representatives of lyssacine stalk-bearing hexactinellids.

Description: Only fragmentary twisted root/stalk tufts of these sponges have been found. The tuft pieces are broken at both ends, thus it cannot be determined, whether the spicules are diactins or monactins. The incompletely preserved spicules were originally longer. The holotype (text-fig. 8) is a tuft, 5.5 cm long, with rays twisted in clockical direction. Individual spicules are about 250 µm in maximal diameter and show no sign of compaction. As a result of twisting, the spicules diverge and thus one end of the tuft measures ca. 7 mm and the opposite one only 4 mm across. In additionally to the long spicules, smaller triaxons hexacts, pentacts and stauracts, about 300 to 500 µm are scattered over the surface of the tuft, especially at its proximal end. About 7 mm under the inferred proximal edge of this tuft, several short rays perpendicularly project from its surface. The short rays clearly appear to be projecting from the long spicules directly, and more short rays projecting in right angles to each other seem to be present at the same location as well. Thus, the tuft spicules of *Hyalosinica archaica* may well be true triaxons with two greatly prolonged rays and with their 4 paratangential rays projecting from the spicule centre. In all specimens, the spicules are in body preservation, but some of them are weathered out, so only hollow impressions are left.



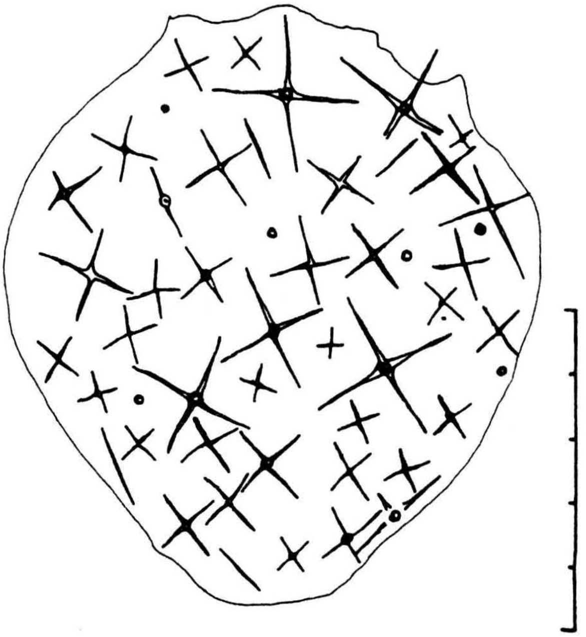
Text-fig. 8: *Hyalosinica archaica*, holotype (San 109); scale 10 mm.

Discussion: *Hyalonema* GRAY is the only recent hexactinellide sponge that is elevated above the sediment on a long stalk of spirally twisted monactine (and some associated diactine) spicules. The *Hyalonema* tuft, which can be more than one meter long, is twisted generally counter-clockwise. According to the divergence of the tuft spicules in *Hyalosinica archaica*, a decision about the probable orientation of the tuft in respect of the sponge body is possible: The twisting of stalks in recent and fossil lyssacine hexactinellids becomes looser towards the distal ends. Thus, the narrow 4 mm end is interpreted here as proximal, whereas the looser 7 mm end was probably closer to the outer terminal anchoring point. One of the paratypes, (San 106A), measures ca. 8 cm in total length. This tuft appears more tightly twisted in one, presumably the proximal end (about 7.5 mm across), than the opposite, probably distal end (about 10 mm across). Using this inferred orientation, the twisting of the tuft is again in a clockwise direction. So far, a tuft with the main sponge body attached to it has not been found. However, the proximal half part the holotype tuft is covered by many smaller triaxons (hexacts, pentacts and stauracts). Because similar spicules occur scattered all over the sediment, it cannot be certain that they really belong to the sponge. However, the small triaxons occur much more commonly on and in between the tuft-spicules than outside of it, and additionally they are concentrated almost exclusively in the proximal half of the tuft. Thus, it seems most probable that the small triaxons were originally part of the sponge body, which might have been torn off from the tuft. The tuft spicules of *Hyalonema* are monactins with the axial cross and five rudimentary, atrophied rays located terminally form an anchor. A few Early Palaeozoic sponges, which possessed similarly long twisted stalks, were described in entirely preserved body fossils as *Retifungus* RIETSCHEL, 1970, from the Lower Devonian Hunsrück Slate (Germany), and some Cambrian *Protospongia div. sp.* described by DAWSON (1889) from Quebec (Canada). The 30 cm long stalk of *Retifungus rudens* is twisted counter-clockwise (compare Figs. by RIETSCHEL, 1970 and KOTT & WUTTKE, 1987) and thus similar to that of the recent *Hyalonema* GRAY. The *Protospongia* specimens of the DAWSON-collection possess long anchoring spicules, but they are only very few in number and hardly twisted at all (MEHL, pers. obs. 1992). *Hyalostelia* ZITTEL from the Carboniferous of England is a hexactinellide sponge with a tuft of long anchorate basalia, which according to the material available so far, shows no clear twisting. A stalk-like tuft was documented also from the Upper Cretaceous Arnager limestone (Denmark) by MEHL (1992: pl.5, fig.8) and attributed to the recent genus, *Hyalonema* GRAY. According to the systematic classification by SCHULZE (1887), *Hyalonema* belongs to the Amphidiscophora. Since so far, no miroscleres have been found associated with any of the fossil stalks, their systematic position within the Hexactinellida cannot be established with absolute certaincy. *Hyalosinica archaica* is the oldest stalk-bearing sponge reported from the fossil record. Isolated long root-tuft spicules were found in sample San 1/24 (see text-fig. 2), which represents the earliest documentation of this type of sponges.

Material: Holotype: San 109 A,B (plate + counterplate). Paratypes: San 111; San 106 A, B.

***Triticispongia* n. g.**
(Pl. 3, fig. 3; text-fig. 9)

Derivatio nominis: *triticum* (lat.) = grain of wheat, refers to the outer shape and the small size of this sponge.
Type species: *Triticispongia diagonata*.



Text-fig 9: *Triticispongia diagonata*, holotype (San 143-x); scale 5 mm.

Diagnosis: Sponge body hardly exceeds 10 mm total size. Spicules are small triaxons, mainly stauracts with their paratangentialia in a diagonal arrangement.
Description: See the type species.

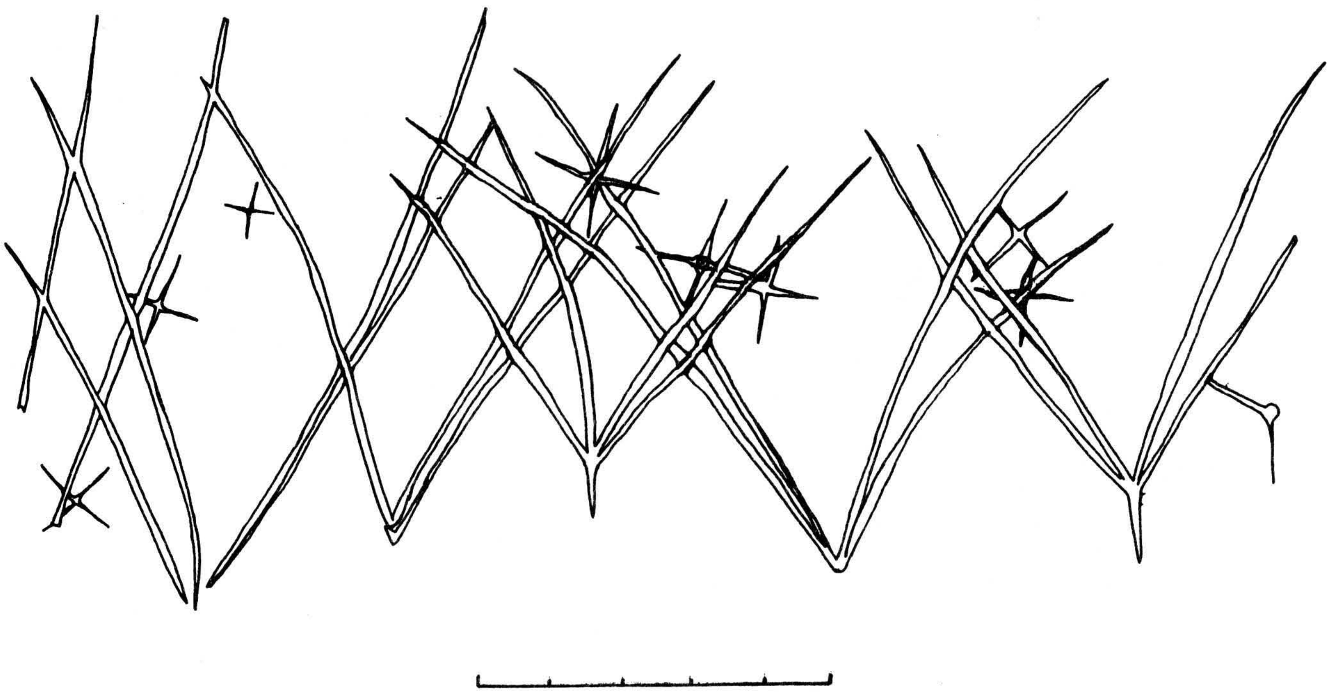
***Triticispongia diagonata* n.g., n.sp.**

Derivatio nominis: *diagonata* refers to the diagonal orientation of its spicules.
Description:
Sponge body round to vase-shaped and very small, maximal diameter about 1 cm. Only impressions of spicules are preserved. The rays of these measure about 0.5 mm to 1.5 mm in length, they clearly show the paratangential rays, which are generally in a diagonal orientation to the outlines of the sponge body. In the crossing points of the paratangentialia of some of the spicules, holes from vertical, proximal/distal rays can be observed. Part of the spicules of this sponge thus may be reconstructed as hexactins additionally to the stauractins.
Discussion: *Triticispongia diagonata* is small in its total body size and spicules, these sponges may be juveniles. However, no similar larger sponges were found, to which they may be attributed. So far, no young buds or juvenile sponges from strata of the Lowermost Cambrian have been reported. From the Upper Cambrian of Queensland BENGTSON (1986) documented tiny (only about 250 μm) globular bodies apparently consisting of siliceous, triaxial spicules fused into a rigid framework: *Echidnina runnegari*, and he interpreted them as juvenile hexactinellide sponges. Provided that these fossils are not radiolarians, which in our opinion cannot be definitely excluded, they would be the only planktic rigid buds known within fossil or recent Porifera.
Material: Holotype, San 143-x, and one paratype, San 118A,B (plate and counterplate).

***Hunanospongia* QIAN & DING, 1988**

?*Hunanospongia* sp.
(Pl. 4, fig.2; text-fig. 10)

Description The most conspicuous feature of the incomplete specimen are six large (5-10 mm across) spicule impressions that all occur in the same orientation. Each of these possesses four long rays that point in the same overall direction, they are arranged bilaterally symmetrically in two pairs with about 45^{o} in between. A fifth short ray that points in the opposite direction, can be observed in two of these six spicules. Scattered among these large spicule impressions, smaller (1-2 mm) hexactinellide spicules occur, mainly stauractins some of which show small holes within the ray junctions indicating the former presence of proximal / distal rays.
Discussion: The large impressions are interpretet here as derived triaxial spicules with their four, probably paratangential, rays all "bent" in one direction, whereas the fifth short ray still shows its original orientation, and the sixth one is atrophied. The smaller triaxons might not belong to the same sponge as these large spicules, since the smaller ones are found all over the surface of plate San 118. However, they are in a much denser concentration among the larger impressions than outside these, so they may well belong to the sponge. No recent nor fossil sponges in body preservation with a type of main spicules similar to the large ones are known so far, but a few isolated similar spicules from the fossil record have been described. Isolated spicules with four rays that point in the same overall direction are reported from probably the same stratigraphical level in Yangjiaping called *Hunanospongia delicata* QIAN & DING, 1988 (figured in DING & QIAN, 1988). Similar isolated spicules have been found also in Middle Cambrian sediments of the Georgina Basin, South Australia (MEHL, in prep.) and in a few clusters they have been observed on plate surfaces of Upper Cretaceous Arnager limestone (MEHL, in prep.).
Material: This specimen is an unicate (San 118 A, sponge Z).

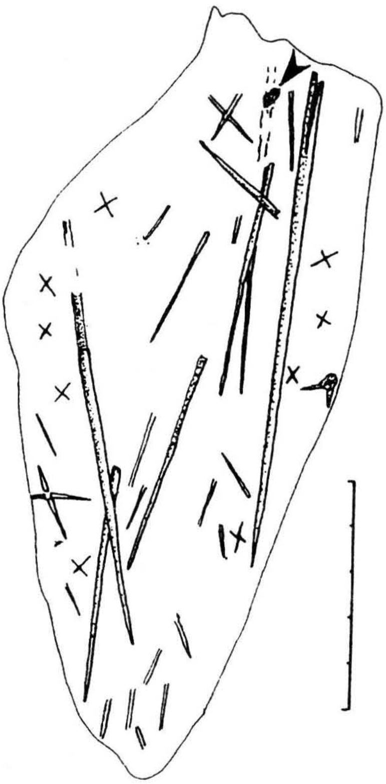


Text-fig. 10: *Hunanospongia* sp. (San 118-z); scale 5 mm.

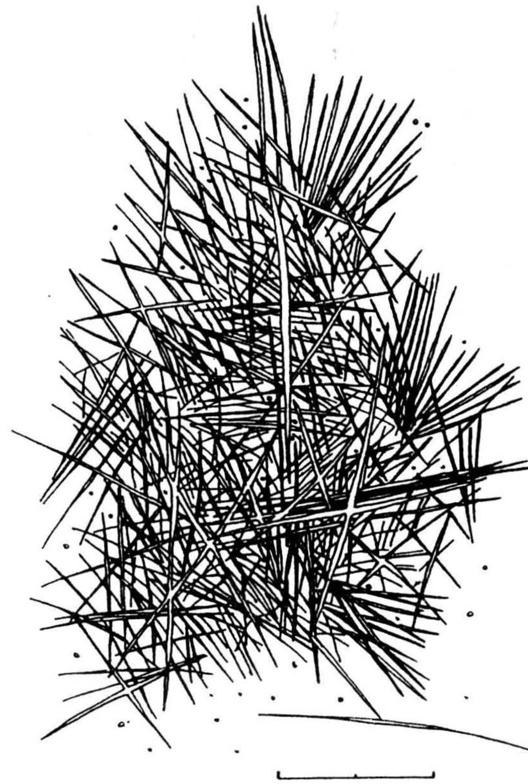
?Hexactinellid sp.
(Pl..3, fig.2; text-fig. 11)

This small sponge fragment, is a dark, limonitic crust which contains some silicified spicules. The fossil shows a subconical outline and measures 22 x 6 mm maximal size. Spicules inside are a few coarse diactins associated with some smaller and very badly preserved relics, partly as impressions only, of monaxons and a few questionable stauractins. The coarse diactins, the largest of which measures 16 mm in length and ca. 200 µm in diameter, more or less follow the direction of the long axis of the subconical body fossil. Their pointed ends lie within the limonitic area and point towards the assumed base of the sponge. Because their opposite ends are all broken, none of the large diactins is complete in its entire length. Close to the margin of the assumed proximal end of the sponge fossil, a short spicular ray points out of the bedding surface (Text-Fig 11, arrow). It seems to belong one of the large spicules, from which it appears to project in a perpendicular direction. If this interpretation holds true, at least some of the apparent diactins would be of true triaxial nature. The smaller spicules are preserved as "ghoasty" impressions only, some of which seem to be triaxones. These are questionable stauractins, which measure about 250-400 µm in total size, they are all in a diagonal orientation to the coarse diactins.

Discussion: Because of the apparent stauractins, as well as the possible triaxial nature of some "diactins" (as discussed above), this sponge most probably belongs to the Hexactinellida. However, the incomplete specimen, which is the only representative of this type within the collection, in a bad preservation state, so no definite systematic assignment can be established. The coarse diactins all seem to end within the outline of the limonitic crust. This implies that they most probably did not project beyond the sponge wall. For this reason, the diactins cannot be interpreted as marginal prostalia or anchoring root spicules, and it is hard to understand their function, except as some kind of main vertical supporting elements stabilizing the sponge. Such coarse spicules that sre completely integrated within the sponge wall are observed in the Devonian hexactinellide *Taleolaspongia* RIGBY & MEHL (in press), in which similar spicules of triaxial origin run through the wall in a longitudinal direction. However, these Devonian sponges are of rather large size and possess round pores in the wall, and they show no further similarities to the sponge here described.
Material: The specimen (San 105) is an unicate.



Text-fig. 11: Hexactinellide sponge *indet.* (San 105); scale 5 mm.



Text-fig. 12: *Solactiniella plumata*, holotype (San 101); scale 10 mm.

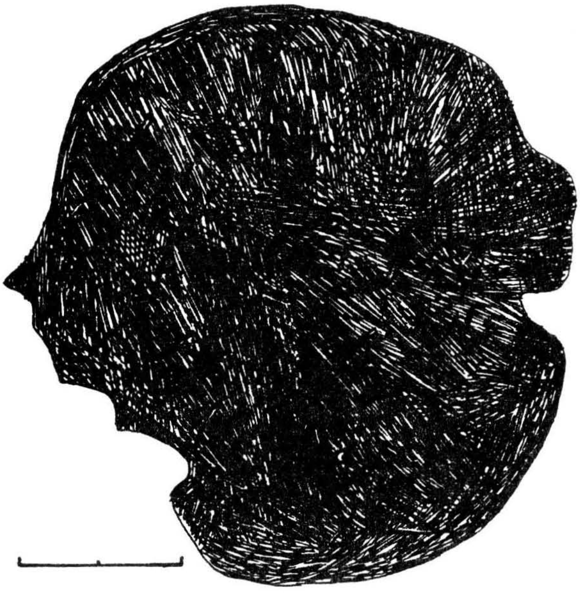
Porifera *incertae sedis*

***Solactiniella* n.g.**
(Pl. 2, fig. 1; text-fig. 12)

Derivatio nominis: *sol* (lat.) = the sun, *actin* (lat.) = ray; refers to the radial sun-like arrangement of diactine spicules.
Type species: ***Solactiniella plumata***.
Diagnosis: Spicules are mainly, or exclusively, coarse diactins, which are organized in bundles and radiate towards and protude beyond the margins of the sponge body.
Description: See the type species.

***Solactiniella plumata* n.g., n. sp.**

Derivatio nominis: *plumos* (lat.) = feather-like, fluffy; refers to the divergence of the spicular bundles towards the margins.
Description: The sponge, which appears to be a fairly complete specimen, measures 3-4 cm in diameter, and shows no oscular cavity. The spicules are mainly impressions, some of which still contain internal moulds of secondarily thickened central canals, probably in limonitic preservation. Only diactins and a few questionable stauractins are observed. The diactins are rather large, up to 20 mm, but mostly 5-10 mm, in total length. The spicule orientation seems fairly accidential, but especially the peripheral diactins tend to radiate towards and project from the margin in a plumose arrangement.
Discussion: At a first view, this fossil looks like an accidential, dense accumulation of spicules in a chaotic arrangement. However, the preferred radial orientation and the fact that only one, maybe two, types of spicules indicate that this spiculation belongs to one and the same sponge body. It is not definitely established whether this sponge belongs to the Hexactinellida or to the Demospongiae, since we cannot determine, whether or not stauractins were also originally present. Even if the spicule impressions were all originally diactins, they may well belong to a lyssacine hexactinellide sponge. On the other hand, Demospongiae of similar outline are known from the Middle Cambrian Burgess Shale. *Choia* WALCOTT possesses large diactins exclusively, which radiate from the center and project from the margin of the sponge body. The plumose, radiating spiculation must be considered as a very ancient pattern of the Demospongiae. However, the radial spicule arrangement of *Choia* is much more regular than in *Solactiniella*, and the large coarse spicules of the latter do point towards an attribution to the Hexactinellida.



Text-fig. 13: *Saetaspongia densa*, holotype (San 102-l); scale 10 mm.

Material: The Holotype, San 101A, B (plate and counterplate) is the only body fossil that is definitely assigned to this species. Diactins of the size documented here seem to be a major component of spicule mats described above (like in San 107, pl. 5, fig. 1).

***Saetaspongia* n. g.**
(Pl. 3, fig. 1; text-fig. 13)

Derivatio nominis: *saeta* (lat.) = bristly hair; refers to the very thin hair-like spicules.
Type species: *Saetaspongia densa*
(Pl. 3, fig. 1; text-fig.13)
Diagnosis: Dense accumulations of very thin hair-like diactins arranged in semiparalles bundles throughout the sponge body. The spicules line, but do not protude beyond the well-defined outer margin of the sponge body.
Description: See the type species.

***Saetaspongia densa* n.g., n. sp.**

Derivatio nominis: *densus* (lat.) = tight; refers to the dense accumulation of spicules, appearently without peripheral apertures.
Description: The holotype, an almost circular, probably fairly complete impression of a sponge body measures about 3 x 4 cm. No oscular cavity is visible, but the dermal margins are partly preserved. The impressions of thin, hair-like diactins (probably originally about 25 μm in diameter) are only 1-2 mm long. The spicule impressions, most of which are pointed in both ends, are arranged in semi-parallel, sometimes also plumose bundles, which generally radiate towards the periphery. However, they do not protude beyond the outer surface of the sponge body, but they line the outer margins as tangential dense bundles. Impressions of thicker-appearing spicules (about 50-100 μm in diameter) occur, and some are in a perpendicular orientation, visible as round holes, scattered among the bundled diactins. These larger spicules appear to be mainly monactins and diactins, but a few of them might be tri-, tetr- or even hexactins.
Discussion: The principalia of this sponge appear to be all diactins, the mode of preservation does not allow any definite statements, as to whether or not spicules with more than one axis were originally present. Thus, the systematic position of this sponge cannot be definitely determined. The radial, sometimes plumose arrangement of diactins indicates a demospongian rather than a hexactinellide affinity. However, sponges with hair-like, mainly diactine spicules in a similar orientation are known also from Palaeozoic hexactinellids, e.g. the Devonian *Rufospongia triporata* RIGBY & MEHL (in press). *Rufospongia*, However, possesses clearly spicule delimited pores in the body wall, and it has definitely hexactinellide spicules as well. The larger spicule impressions may not belong to this sponge, since similar impressions are also common on the surface of the sample (e.g. on the paratype, San 104) outside the outline of the fossils.
Material: Holotype: San 102-L; Paratype: San 104

3.3 Fossil poriferan faunas showing similar taphonomy: Red Hill (Middle Devonian, Nevada) and Arnager limestone (Upper Cretaceous, Denmark)

These sponge fossils from Hunan Province are preserved mainly as spicule impressions on the surface of the dark shale. Although the spicules are unfused, they seem to be more or less in their original position within the sponge bodies. Although most siliceous sponges from the Early Palaeozoic possessed non-rigid skeletons of loose spicules (except the "Lithistida", common in Ordovician and Silurian strata), such good preservation is exceptional in the fossil record of non-rigid sponges. Normally, the small mineralized, siliceous or calcitic spicules will fall out of the decaying soft tissues and can be found as isolated spicules only, scattered within the sediment. For this reason, the fossil record of these non-rigid poriferan groups is poor compared to their from an actualistic viewpoint assumeably worldwide dominance within most sponge faunas. This is true especially to the Hexactinellida, since so-called dictyonal forms with rigid siliceous skeletons of fused spicules did not become an important faunal element until the Late Triassic (e.g. in Northern Sichuan, China; WENDT et al, 1989 and in the

Carnian Cassian beds, Italy; KEUPP et al., 1989). Because of a few fossilization "windows", such as the Cambrian Burgess Shale (WALCOTT, 1920) or the Middle Devonian Red Hill (RIGBY & MEHL, in press) faunas, we know of at least some non-rigid, entirely preserved sponges from the Early Palaeozoic. In such cases, a rapid embedding prior to decay prevented these sponges from falling apart, and thus the exceptional documentation of spicules *in situ* is possible. Even in Mesozoic strata, the hexactinellids are probably generally under-represented within the fossil record due to the fact that the non-rigid, so-called "lyssacines", which are dominant among the Hexactinellida today, normally would not be documented. From the Coniacian Arnager limestone (Bornholm, Denmark), lyssacine hexactinellids known from isolated spicules only, such as the Rossellidae, were documented only recently as body fossils (MEHL, 1992). Common to the Cretaceous Arnager fauna, the Devonian Red Hill sponges, and our Tommotian ones described here is the preservation of non-rigid sponges, especially lyssacine hexactinellids, in fairly large quantities. The sponges do not appear accumulated in certain layers, but occur more or less scattered throughout the sequences. Beds of the Red Hill section (Givetian) are 2-10 cm thick and consist of mainly dolomitized wacke- and packstones with a constant terrigenous input of fine to medium grained quartz sand. Generally, the sponges are preserved as hematite, probably resulting from metasomatosis of the pyritic pseudomorphosis of originally siliceous spicules. Only small sponges, *Teganiella ovata* RIGBY & MEHL, in press, are found as entire body fossils. They commonly accumulated in monospecific clusters (up to 35 specimens were counted on a piece of limestone that measures less than 10 X 10 cm). Sponges larger than about 5 cm, such as dictyospongiids or *Rufospongia* RIGBY & MEHL, in press, are generally fragmental, but occationally occur as large, almost complete specimens up to 10-20 cm size. These large fossils of the fragile sponge walls most probably were subject of rapid burial more or less *in situ*. Common to most samples from the Red Hill-section is the fact that a sponge-bearing bedding surface typically contains only one species of sponge fossils. Interestingly, such "taxonomical sorting" with accumulations of a large number of sponge fossils of one single species, e.g. *Choia ridleyi* WALCOTT, 1920, on shale surfaces are commonly observed also in samples of the Middle Cambrian Burgess Shale collection (MEHL, pers. obs. 1992). This taphonomy can be explained only by assuming that the sponges concerned during their lifetime were already settled in monospecific groupings. Maybe this is due to their often non-sexual mode of reproduction, and/or to the short larval phases of sexual generations. Also, species-specific ecological requirements often cause larvae to settle, where other specimens of the same species are already successfully growing. Another example is the Upper Cretaceous (Coniacian) Arnager limestone (Bornholm, Denmark). The beds of this section consist of 5-15 cm thick lime mud- and wackestones that wedge out over lateral distances of 10-20 m. They contain sponges in large quantities, predominantly lyssacine hexactinellids and common root tufts, often found in living position as documented by MEHL (1992) and preserved as cristobatite silica, pyrite or limonite pseudomorphs, or as hollow impressions of spicules. The extraordinary preservation of non-rigid hexactinellids as entire body fossils with their spicules in place implies a rapid fossilization of these sponges prior to the decay of soft tissues. Presumably, turbidity currents occasionally embedded the living sponges. The lobe deposits of the Arnager beds further confirms the interpretation of these sediments as the result of sudden events.

4. Conclusions

1. According to investigations of the lithology and trace element geochemistry analysis, the Lowermost Cambrian sediments of the Sansha section were deposited under partly anoxic conditions, or in a stagnant basin, respectively.
2. Upper Sinian and Lower Cambrian strata of Hunan and Anhui provinces are bio- and lithostratigraphically correllated with E-Yunnan and Hubei provinces for the first time.
3. During Upper Sinian and Lowermost Cambrian time, within the Yangtze platform following facies types can be distinguished: protected basin, uplift area, deep basin.
4. The "Badaowan" event is diachronous.
5. Exceptionally well-preserved fossils extend the record of entirely preserved Hexactinellida and probably also Demospongiae down to the basal Tommotian.
6. The occurence of derived representatives of the sponges, such as the reticulate Hexactinellida, in strata of the basal Cambrian confirms the phylogenetic assumption that the Porifera are an original and very old group of Metazoa.
7. Isolated, definitely poriferan, hexactinellid, and other types may be with demospongean affinities, spicules are documented from Upper Precambrian (Sinian) strata probably stratigraphically equivalent to the Ediacara Member are documented for the first time.
8. Thus follows that the documentation of entire sponges as body fossils from strata of

the Upper Proterozoic is now merely a question of time and effort.

5. Acknowledgements

The authors thank Prof. Dr. CHEN Junyuan, Dr. ZHANG Yunming, Dr. ZHU Maoyan and Mr. LI Guoxian (all Nanjing) for guidance and assistance in the field.

We are endepted to Prof. Dr. J.K. RIGBY for discussion and for valuable comments and suggestions on the manuscript. Special thanks are due to Hendrik SIEGMUND (Berlin) for valuable discussions and joint field work in 1991 and 1992. Hendrik SIEGMUND and Dr. J. MALETZ (Buffalo) are acknowledged for the critical reading of the manuscript. Hendrik SIEGMUND supplied the photos for pl 6, figs. 2-4. Thanks to Mrs. GROßKOPF and Mr. KLEEBERG (Berlin) for the photographic documentation for the plates. DM. gratefully acknowledges many stimulating discussions with Prof. H. KEUPP (Berlin). MS. thanks Dr. MATTHEIS (Berlin) for RFA analyses, Prof. WANG Xiaofeng (Yichang) for translations from the Chinese and Dr. R. BREWER (Nanjing) and Dr. H. GELDSETZER (Calgary) for discussions and literature assistance. Mrs. DUNKER (Berlin) expertly drew figs. 1-6.

The research was funded by MPG, Munich and DFG under grant no. Er 96/7/1-3 with contributions by NIGPAS. The field trip of MS to China in 1992 was supported by DAAD, Bonn. Further, we thank DFG for financing the investigation on Porifera of REITNER and MEHL (Re 665/1,4; Ke 322/5/1-3).

6. References

Anonymous (1987): Regional Geology of Guizhou Province: 698 p., Beijing (Geological Publishing House).

Anonymous (1988): Regional Geology of Hunan Province: 719 p., Beijing (Geol. Publishing House).

Anonymous (1990): Regional Geology of Hubei Province: 705 p., Beijing (Geol. Publishing House).

Anonymous (1991): Regional Geology of Sichuan Province: 730 p., Beijing (Geol. Publishing House).

BENGTSON, S. (1986): Siliceous microfossils from the Upper Cambrian of Queensland.- Alcheringa, **10**: 195-216.

BENGTSON, S.; CONWAY MORRIS, S. COOPER, B.J.; JELL, P.A. & RUNNEGAR, N.N. (1990): Early Cambrian Fossils from South Australia, 364 pp, Brisbane (Assoc. Austr. Palaeont.).

BRASIER, M.D. (1992): Background to the Cambrian explosion.- Journal of the Geological Society, London, **149:** 585-587.

BRASIER, M.D. (1992): Nutrient-enriched waters and the early skeletal fossil record.- Journal of the Geological Society, London, **149:** 621-629.

BRASIER, M.D., MAGARITZ, M., CORFIELD, R., LUO, H., WU, X., OUYANG, L., JIANG, Z., HAMDI, B., HE, T. & FRASER, A.G. (1990): The carbon- and oxygen-isotope record of the Precambrian-Cambrian boundary interval in China and Iran and their correlation.- Geol. Mag., **127:** 319-332.

BRIGGS, D.E.G. (1977): Bivalved arthropods from the Cambrian Burgess Shale of British Columbia.- Palaeontology, **20**: 595-621.

BRUMSACK, H.J. & THUROW, J. (1986): The geochemical facies of black shales from the Cenomanian/Turonian boundary event (CTBE).- In: WALLISER (ed.), Fifth International Conference on Global Bioevents: 24-25, Göttingen.

BRUMSACK, H.J. (1992): Depositional environment of Cenomanian/Turonian black shales: chemical evidence.- In: O.H. WALLISER (Ed.), Fifth International Conference on Global Bioevents: 24-25,Göttingen.

CHEN, J. & ERDTMANN, B.-D. (1991): Lower Cambrian fossil Lagerstätte from Chengjiang, Yunnan, China: Insights for reconstructing early metazoan life.- In: A.M.SIMONETTA & S.CONWAY MORRIS (Eds.), The early evolution of Metazoa and the significance of problematic taxa: 57-76, Camerino (Cambridge University Press).

CHEN, J., FOLAND, K.A., XING, F., XU, X. & ZHOU, T. (1991): Magmatism along the southeast margin of the Yangtze block: Precambrian collision of the Yangtze and Cathaysia block of China.- Geology, **19:** 815-818, Boulder, Colorado.

CHEN, J., HOU, X. & LU, H. (1989): Early Cambrian netted scale-bearing worm-like sea animal.(in Chinese, with an English abstract)- Acta Palaeontologica Sinica, **28(1):** 1-16.

CHEN, M. & XIAO, Z. (1991): Discovery of the macrofossils in the Upper Sinian Doushantuo Formation at Miaohe, Eastern Yangtze Gorges. (in Chinese, with an English abstract)- Scientia Geologica Sinica, **4**: 317-324.

CHEN, M. & XIAO, Z. (1992): Macrofossil biota from Upper Sinian Doushantuo Formation in Eastern Yangtze Gorges, China. (in Chinese, with an English abstract)- Acta Palaeontologica Sinica, **31(5):** 513-529.

CHEN, N., YANG, X., LIU, D., XIAO, X., FAN, D. &

WANG, L. (1982): Lower Cambrian black argillaceous and arenaceous rock series in South China and its associated stratiform deposits.(in Chinese)- Mineral Dep., **1(2):** 39-51.

CHEN, P. (1984): Discovery of Lower Cambrian small shelly fossils from Jijiapo, Yichang, West Hubei and its significance.(in Chinese)- Professional Papers of Stratigraphy and Palaeontology, **13:** 49-66.

COLLEY, S., THOMSON, J., WILSON, T.R.S. et al. (1984): Post-depositional migration of elements during diagenesis in brown clay and turbidite sequences in the North East Atlantic.- Geochim. Cosmochim. Acta, **48:** 1223-1235.

COMPSTON, W., WILLIAMS, I.S., KIRSCHVINK, J.L., ZHANG, Z. & MA, G. (1992): Zircon U-Pb ages for the Early Cambrian time-scale.- Journal of the Geological Society, London, **149**: 171-184.

COVENEY, R.M., JR. & CHEN, N. (1991): Ni-Mo-PGE-AU-rich ores in Chinese black shales and speculations on possible analogues in the United States.- Mineral Deposita, **26**: 83-88.

COVENEY, R.M., JR., MUROWCHIVK, J.B., GRAUCH, R.I., CHEN, N. & GLASCOCK, M.D. (1992): Field relations, origins, and resource implications for Platiniferous Molybdenum-Nickelores in black shales of South China.- Explor.Mining Geol.,**1(1):** 21-28.

DAWSON, J.W. (1889): Fossil sponges and other organic remains from the Quebec Group at Little Metis.- Trans. Roy. Soc. Can., sect. iv, **7**: 31-55.

DILL, H. (1986): Geochemical facies analyses of Upper Proterozoic metabolites (Bohemian Massif / F. R. Germany) as a guide to metal exploration.- In: E.T. DEGENS, P.A. MEYERS & S.C. BRASSELL (Eds.), Biochemistry of Black Shales: 37-53, Hamburg (Geol. Paläontol. Inst. d. Univ. Hamburg).

DING, Q. & CHEN, Y. (1981): Discovery of soft metazoan from the Sinian System along eastern Yangtze Gorge, Hubei.(in Chinese)- Journal of the Wuhan Geological Institute, 2: 53-57.

DING, Q. & XING, Y. (1988): Soft-bodied metazoans and spongia.(in Chinese)- In: ZHAO, Z. et al. (Eds.), The Sinian System of Hubei: 101-106, Wuhan (China University of Geosciences Press).

DING, W. & QIAN, Y. (1988): Late Sinian to Early Cambrian small shelly fossils from Yangjiaping, Shimen, Hunan.(in Chinese, with an English abstract)- Acta Micropalaeontologica Sinica, **5(1)**: 39-55.

FAN, D. (1983): Polyelements in the Lower Cambrian black shale series in southern China.- In: S.S. AUGUSTITHIS (Ed.), The significance of trace metals in solving petrogenetic problems and controverses: 447-474, Athen (Theophrastus Publications S.A.).

FAN, D., YANG, R. & HUANG, Z. (1984): The Lower Cambrian black shale series and iridium anomaly in South China.- In: Developments in Geoscience, Contributions to the 27th IGC, Moscow, 215-224.

FAN, D., YE, J. & LUI, T. (1992): Black shale series-hosted Silver-Vanadium deposits of the Upper Sinian Doushantuo Formation, Western Hubei Province, China.- Explor. Mining Geol., **1(1)**:29-38.

FINKS, R.M. (1960): Late Palaeozoic sponge faunas of the Texas region. The siliceous sponges.- Bull. Amer. Mus. Nat. Hist., **120** (1): 1-160.

GORJANSKY, V. YU. (1977): First find remains of a sponge in the Lower Cambrian of East Sibiria (in russian).- Ezhegodnik Vsesoyuznyi Palaeontologiya Obshchestva, **20**: 274-276.

GRAY, J.E. (1835): On the coral known as glass plant (*Hyalonema sieboldi*, Gray).- Proc. Zool. Soc. London, **1835**, part 3: 63-65.

GRUBER, G. & REITNER, J. (1991): Isolierte Mikro- und Megaskleren von Poriferen aus dem Untercampan von Höver (Norddeutschland) und Bemerkungen zur Phylogenie der Geodiidae (Demospongiae).- Berliner geowiss. Abh. (A), **134**: 107-117.

HALL, J. (1884): Descriptions of the species of fossil reticulate sponges constituting the family Dictyospongiidae.- 35th Ann. Rept. New York State Mus. Nat. Hist.: 465-471.

HALL, J. & CLARKE, J.M. (1898): A memoir on the Palaeozoic reticulate sponges constituting the family Dictyospongidae.- Part I: 743-984, New York, Albany (Wynkoop Hallenbeck Crawford Co.).

HE, T., YANG, X. (1982): Lower Cambrian Meishucun stage of western Yangtze stratigraphic region and its small shelly fossils.(in Chinese, with an English abstract)- Bull. Chengdu Inst. Geol. M. R., Chinese Acad. Geol. Sci., **3**:69-95.

HENRICH, R.; HARTMANN, M.; REITNER, J.; SCHÄFER, P.; FREIWALD, A.; STEINMETZ, S. DIETRICH, P. & THIEDE, J. (1992): Facies belts and communities of the Arctic Vesterisbanken Seamount (Central Greenland Sea).- Facies, **27**: 71-104.

HOU, X. & BERGSTRÖM, J. (1991): The arthropods of the Lower Cambrian Chengjiang fauna, with relationships and evolutionary significance.- In: A.M.SIMORETTA & S. CONWAY MORRIS (Eds.), The early evolution of Metazoa and the significance of problematic taxa: 179-187, Camerino (Cambridge University Press).

HOU, X. (1987): Two new Arthropods from Lower Cambrian, Chengjiang, Eastern Yunnan.(in Chinese, with an English abstract)- Acta Palaeontologica Sinica, **26(3)**:236-256.

KEUPP, H., REITNER, J. & SALOMON, D. (1989): Kieselschwämme (Hexactinellida und "Lithistida") aus den Cipit-Kalken der Cassianer Schichten (Karn, Südtirol).- Berliner Geowiss. Abh. (A), **106**: 221-241.

KOTT, R. & WUTTKE, M. (1987): Untersuchungen zur Morphologie, Paläökologie und Taphonomie von *Retifungus rudens* RIETSCHEL, 1970 aus dem Hunsrückschiefer (Bundesrepublik Deutschland).- Geol. Jb. Hessen.

KRUSE, P. (1983) Middle Cambrian "Archaeocyathus" from the Georgina Basin is an anthaspidellid sponge.- Alcheringa, 7: 49-58.

KRUSE, P. (1987): Further australian Cambian sphinctozoans.- Geol. Mag., **124**: 543-553.

LUO, H., JIANG, Z., WU, X., SONG, X. OUYANG, L., XING, Y., LIU, G., ZHANG, S. & TAO, Y. (1984): Sinian-Cambrian boundary stratotype section at Meishucun, Jinning, Yunnan, China: 154 p., Yunnan (Peoples Pub. House).

LUO, H., JIANG, Z., WU, X., SONG, X., OUYANG, L. et al. (1982): The Sinian-Cambrian boundary in eastern Yunnan, China.(in Chinese, with an English abstract): 265 p., P.R.China.

MEHL, D. (1991): Are Protospongiidae the stem group of modern Hexactinellida?.- In: REITNER, J. & KEUPP, H. (eds.), Fossil & Recent Sponges, Proc. Int. Porifera Symp. Berlin 1988, **100**: 43-53, Berlin Heidelberg New York (Springer).

MEHL, D. (1992): Die Entwicklung der Hexactinellida seit dem Mesozoikum-Paläobiologie, Phylogenie und Evolutionsökologie.- Berliner Geowiss. Abh., (E) **2**: 1-164.

QIAN, Y. & BENGTSON, S. (1989): Palaeontology and biostratigraphy of the Early Cambrian Meishucunian Stage in Yunnan Province, South China.- Fossils and Strata, **24:** 156 p., Oslo (Universitetsforlaget).

QIAN, Y. (1989): Early Cambrian small shelly fossils of China with special reference to the Precambrian-Cambrian boundary: 341 p., Nanjing (Nanjing University Publishing House).

REITNER, J. & MEHL, D. (1993): Monophyly and systematics of the Porifera.- Verh. Naturwiss. Ver. Hamburg (N.F.), **34**, Hamburg (in press).

REITNER, J. (1992): "Coralline Spongien". Der Versuch einer phylogenetisch-taxonomischen Analyse.- Berliner Geowiss. Abh. (E), **1**: 1-352.

RIETSCHEL, S. (1970): Beiträge zur Sedimentation des Hunsrückschiefers 28. *Retifungus rudens* n.g., n.sp., ein dictyospongiider Kieselschwamm aus dem Hunsrück-schiefer.- Notizbl. hess. L.-Amt Boden-forsch., **88**: 30-35.

RIGBY, J.K. (1966): *Protospongia hicksi* HINDE from the Middle Cambrian of Western Utah.- Jour. Palaeont., **40**: 549-554.

RIGBY, J.K. (1969): A new Middle Cambrian hexactinellid sponge of Western Utah.- Jour. Palaeont., **43**: 125-128.

RIGBY, J.K. (1978): Porifera of the Middle Cambrian Wheeler Shale, from the Wheeler Amphitheater, House Range, in Western Utah.- Jour. Palaeont., **52**: 1325-1845.

RIGBY, J.K. (1983): Sponges of the Middle Cambrian Marjum Limestone fom the House Range and Drum Mountains of Western Millard County, Utah.- Jour. Palaeont, **57** (2): 240-270.

RIGBY, J.K. (1986): Sponges of the Burgess shale (Middle Cambrian), British Columbia.- Pelaeontographica Canadiana, **2**: 105 pp.

RIGBY, J.K. (1987): Early Cambrian sponges from Vermont and Pennsylvania, the only ones described from North America.- Jour. Palaeont., **61**: 451-461.

RIGBY, J.K. (1991): Evolution of Palaeozoic heteracnid calcareous sponges and demosponges - patterns and records.-

RIGBY, J.K. & CHURCH, S.B. (1990): A new Middle Cambrian hexactinellid, *Ratcliffespongia wheeleri*, from Western Utah, and skeletal structure of *Ratcliffespongia*.- Jour. Palaeont., **64** (3): 331-334.

RIGBY, J.K. & MEHL, D. (in press): A Middle Devonian sponge fauna from the Northern Simpson Park Range, Central Nevada.- Brigham Young University Geological Studies.

SCHULZE, F.E. (1887): Über den Bau und das System der Hexactinelliden.- Königl. preuß. Akad. Wiss. Phys. Abh., **1886**: 1-97.

STEINER, M., ERDTMANN, B.-D. & CHEN, Y. (1992): Preliminary assessment of new Late Sinian (Late Proterozoic) large siphonous and filamentous "megaalgae" from eastern Wulingshan, north-central Hunan, China.- Berliner geowiss. Abh. (E), **3:** 305-319.

SUN, W. (1986): Late Precambrian Pennatulids (sea pens) from the Eastern Yangtze Gorge, China: Paracharnia gen. nov.- Precambrian Research, **31**: 361-375.

SUN, W. (1989): Subdivisions and correlations of the Upper Precambrian in China and Australia.- Palaeontologia Cathayana, **4:** 1-22.

TANG, T., ZHANG, J. & JIANG, X. (1978): Discovery and significance of the Late Sinian fauna from Western Hunan and Hubei.(in Chinese)-Acta Stratigraphica Sinica, **2:** 32-45.

TUREKIAN, K.K. & WEDEPOHL, K.H. (1961): Distribution of the elements in some major units of the Earth's crust.- Geol. Soc. America Bull., **72(2):** 175-191.

VINE, J.D. & TOURTELOT, B. (1970): Geochemistry of black shale deposits - a summary report.- Economic Geology, **65:** 253-272.

WALCOTT, C.D. (1920): Middle Cambrian Spongiae.- Smithsonian Misc. Coll., **67**: 261-364.

WEDEPOHL, K.H. (1970): Environmental influences on the chemical composition of shales and clays.- In: L.H.AHRENS et al.(eds.), Physics and chemistry of the earth: 307-333, Oxford and New York (Pergamon Press).

XING, F., XU, X., CHEN, J., ZUOU, T. & FOLAND, K.A. (1992): The late Proterozoic continental accretionary history of the southeastern margin of the Yangtze platform. (in Chinese, with an English abstract)- Acta Geologica Sinica, **66(1)**: 59-72.

XING, M. (1989): The geochemistry of Hg in country rocks of Guizhou Province. (in Chinese, with an English abstract)- In: Geology of Mercury deposits of Guizhou Province, China: 324-343.

XING, Y., DING, Q., LIN, W., YAN, Y. & ZHANG, L. (1985): Metazoans and trace fossils. (in Chinese)- In: Y. XING et al. (Eds.), Late Precambrian Palaeontology of China: 182-188, Beijing (Geol. Publ. House).

YAN, J. & LIU, P. (1989): Geological features and genesis of the Mercury deposits of Guizhou Province. (in Chinese, with an English abstract)- In: Geology of Mercury deposits of Guizhou Province, China: 1-56.

YANG, Z., CHENG, Y. & WANG, H. (1986): The Geology of China: 298p., Oxford (Clarendon Press).

ZHANG W. (1992): Sinian and Early Cambrian floras and biostratigraphy on the South China platform.- Palaeontographica, Abt. B, **224(4-6)**: 75-119.

ZHANG, W. & HOU, X. (1985): Preliminary notes on the occurrence of the unusual trilobite *Naraoia* in Asia.- Acta Palaeontologica Sinica, **24(6):** 591-595.

ZHU, W. & CHEN, M. (1984): On the discovery of macrofossil algae from the Late Sinian in the eastern Yangtze Gorges, South China. (in Chinese, with an English abstract)- Acta Botanica Sinica. **26(5)**: 558-560.

Plate 1

Locality for specimens of plate 1-6 1 km southwest of traffic checkpoint Sansha
Algae from the Niutitang formation of the Louyixi section.

Fig. 1 *Perspicaris* sp., mass accumulation of carapaces
Scale: 5 mm.

Fig.2 *Perspicaris* sp., isolated carapace
Scale: 5 mm

Fig. 3 *Perspicaris* sp., isolated carapace
Scale: 5 mm.

Fig. 4 *Perspicaris* sp., isolated carapace
Scale: 5 mm.

Fig. 5a Damaged *Perspicaris* carapaces one with an injury (arrow)
Scale: 5 mm.

Fig. 5b Enlargement of injury of fig. 5a.
Scale: 500 μm.

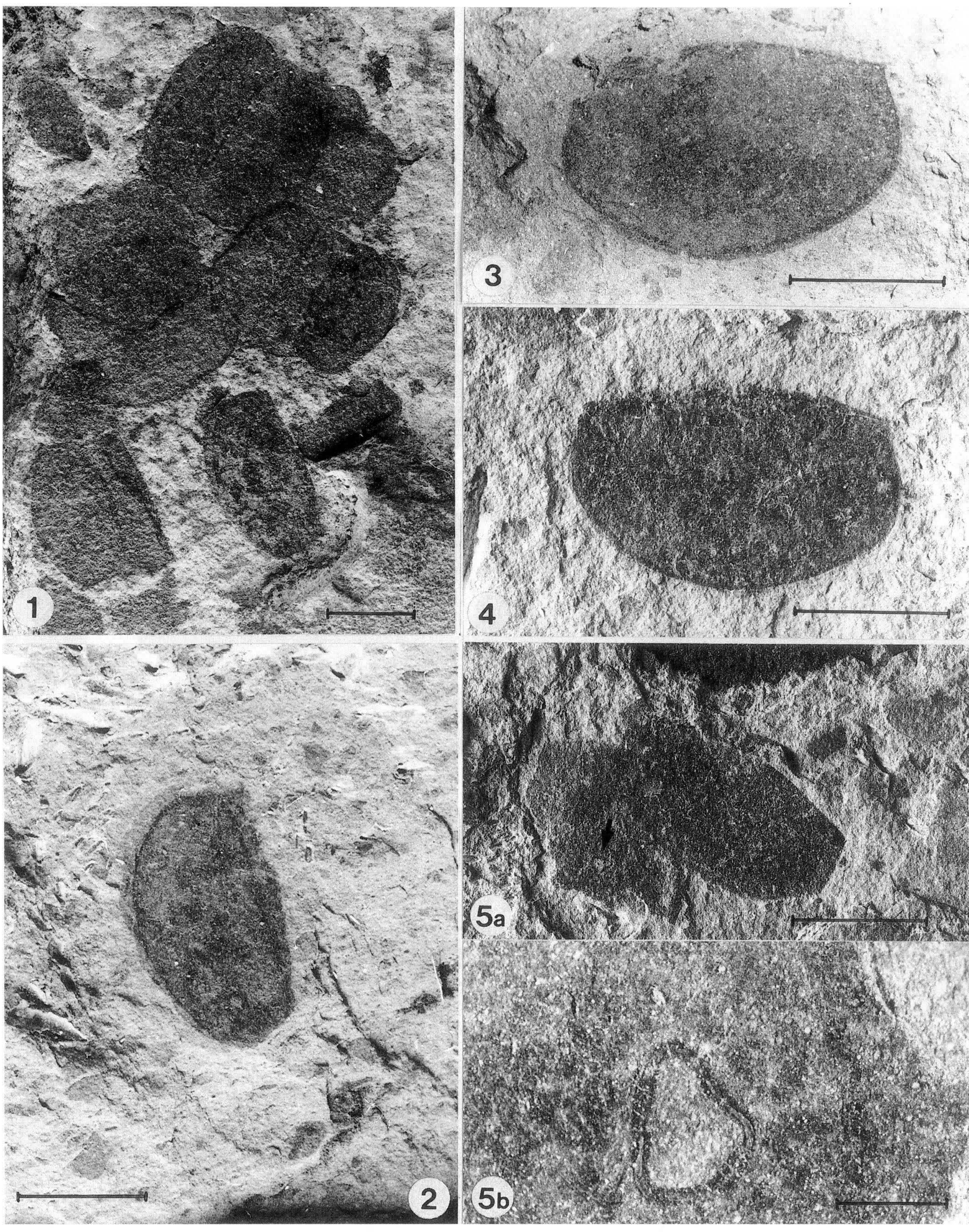

1
2
3
4
5a
5b

Plate 2

Fig.1 *Solactinella plumata* n.gen.n.sp., holotype (SAN 107a,b)
Scale: 1 cm.

Fig.2 *Sanshadictya microreticulata* n.gen.n.sp., holotype (SAN 117a,b)
Scale: 250 µm.

Fig.3a Unnamed alga linked with a sponge spicule (open arrow)
Scale: 1 mm.

Fig.3b Enlargement of fig. 3a close to black arrow with appendages of funnel-shaped extensions
Scale: 300 µm.

Fig.4 Unnamed alga.
Scale: 1 mm.

Fig.5 *Perspicaris* sp., carapace,
Scale: 5 mm.

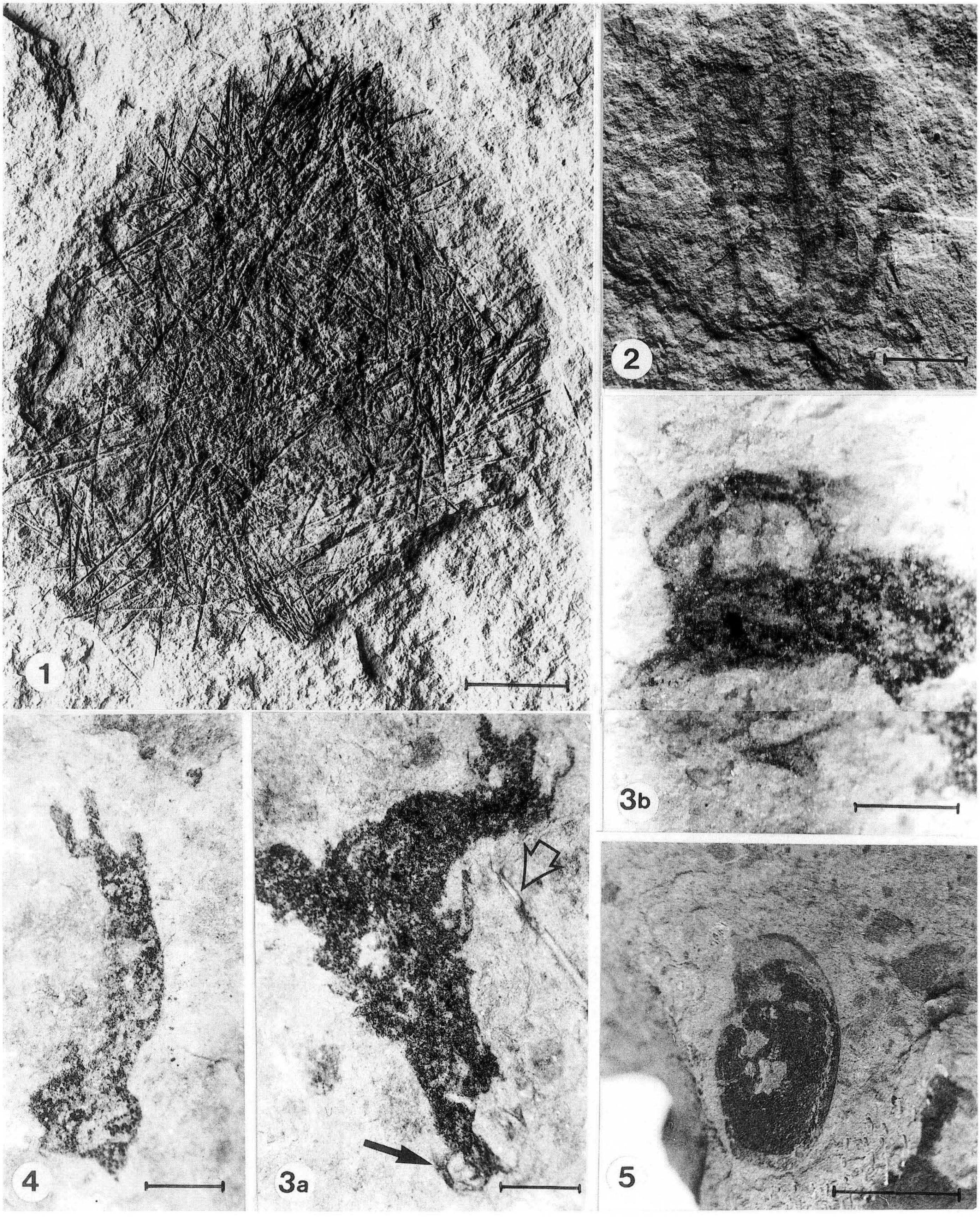

1
2
3b
4
3a
5

Plate 3

Fig.1 *Saetaspongia densa*, n.gen.n.sp., holotype (SAN 102). Taxon with demosponge features.
Scale: 5 mm.

Fig.2 Young hexactinellid with two marginal large monaxonic spicules.
Scale: 1 cm.

Fig.3 *Triticispongia diagonata* n.gen.n.sp., holotype (SAN 143)
Scale. 250 μm.

Fig.4 Damaged and partly decayed *Perspicaris* carapaces.
Scale: 5 mm.

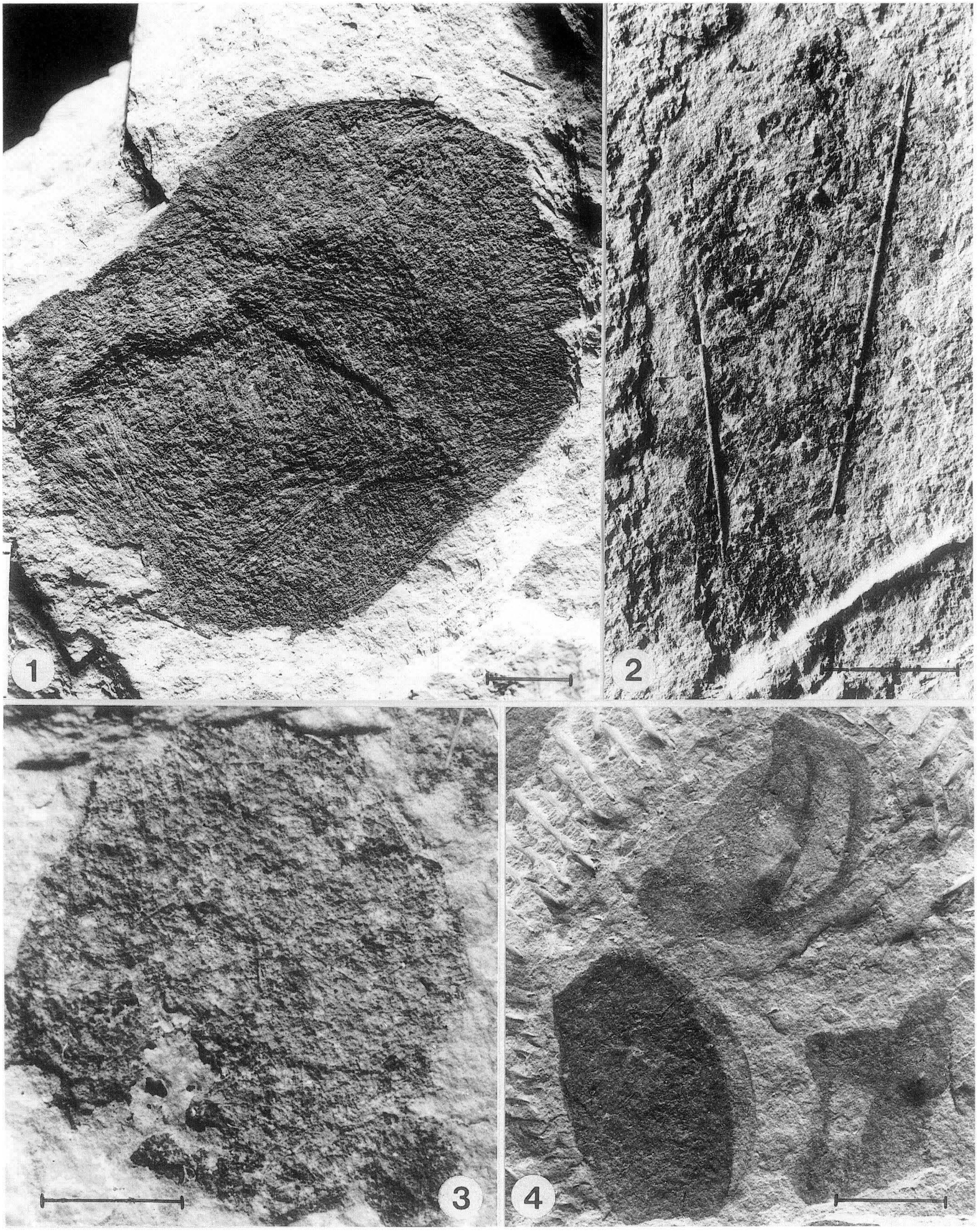

1
2
3
4

Plate 4

Fig. 1a *Hyalosinica archaica* n.gen.n.sp., holotype (SAN 109a,b)
Scale: 5 mm.

Fig. 1b Enlargement of the spicule root tuft of *Hyalosinica archaica*.
Scale: 5 mm.

Fig. 2 *Hunanospongia* sp. (QIAN & DING, 1988). Maybe remains of a dermal spicule layer.
Scale: 5 mm.

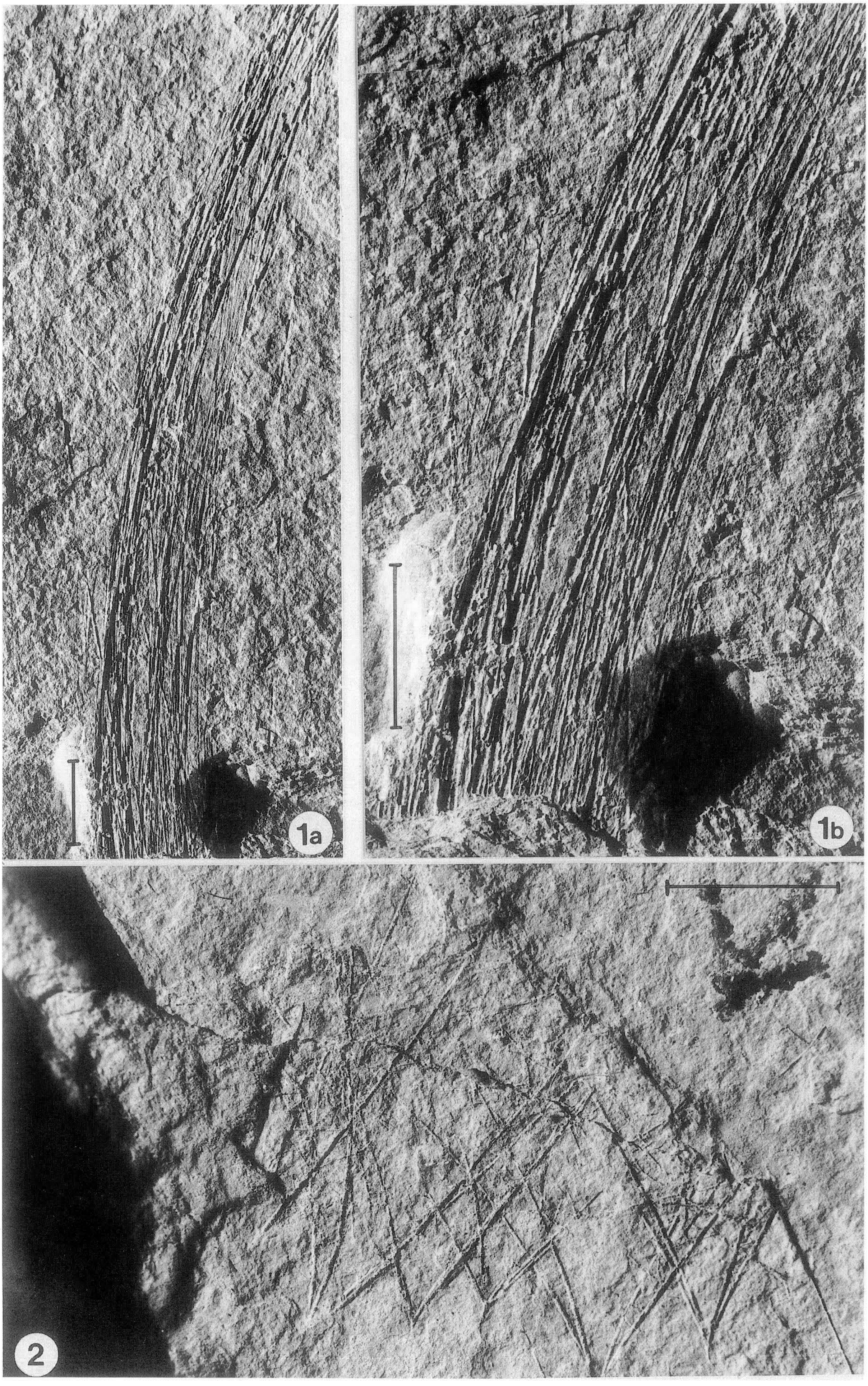


Plate 5

Fig.1 Thin spiculite layer of hexactinellid scleres. these layers may have a lateral extension of some square meters. Young sponges are often settled on these layers (SAN 107)
Scale: 1 mm.

Fig.2 Young hexatinellid sponge with imprints of stauractins (SAN 108)
Scale: 2 mm.

Fig.3 Relatively large rounded black fossils near the base of the Sansha region (SAN 50b). These structures exhibit sometimes remains of small spicules. Therefore they are interpreted as sponge remains, maybe with demosponges affinities.
Scale: 5 mm.

Fig. 4 Very young hexatinellid sponge growing on a large hexactine.
Scale: 250 µm.

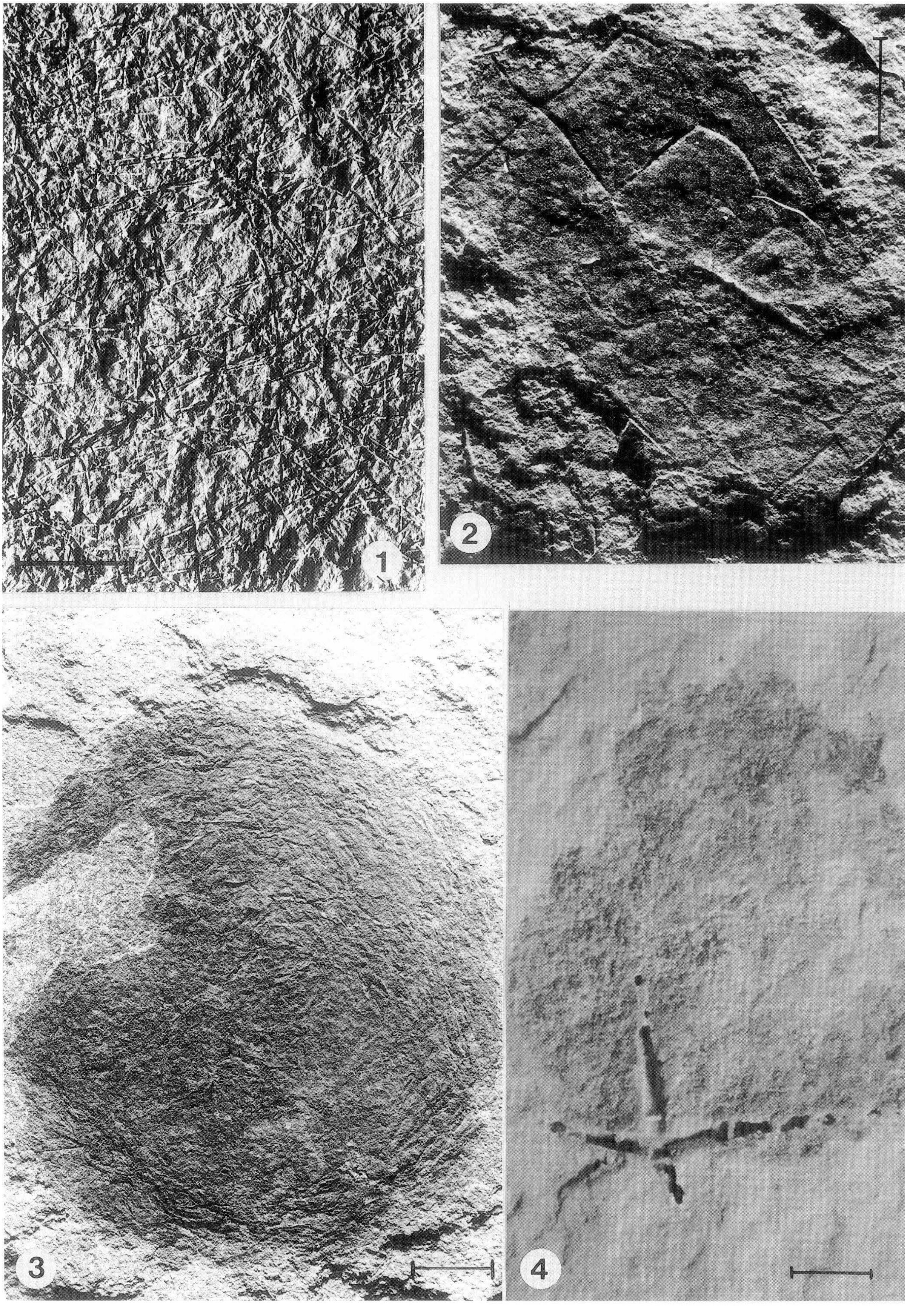

1
2
3
4

Plate 6

Fig.1 Accumulation of young hexactinellids partly growing on large spicules (SAN 143)
Scale: 2 mm.

Fig.2 Cluster of hexactinellid spicules from the basal chert of the Sansha section above samples SAN 1/4 (Lower Tommotian).
Scale: 250 µm.

Fig.3 Isolated monaxonic spicules with remains of spines (acantho-)
Scale: 500 µm.

Fig.4 Spicule cross section with diagenetically enlarged central canal and outer spines.
Scale: 10 µm.

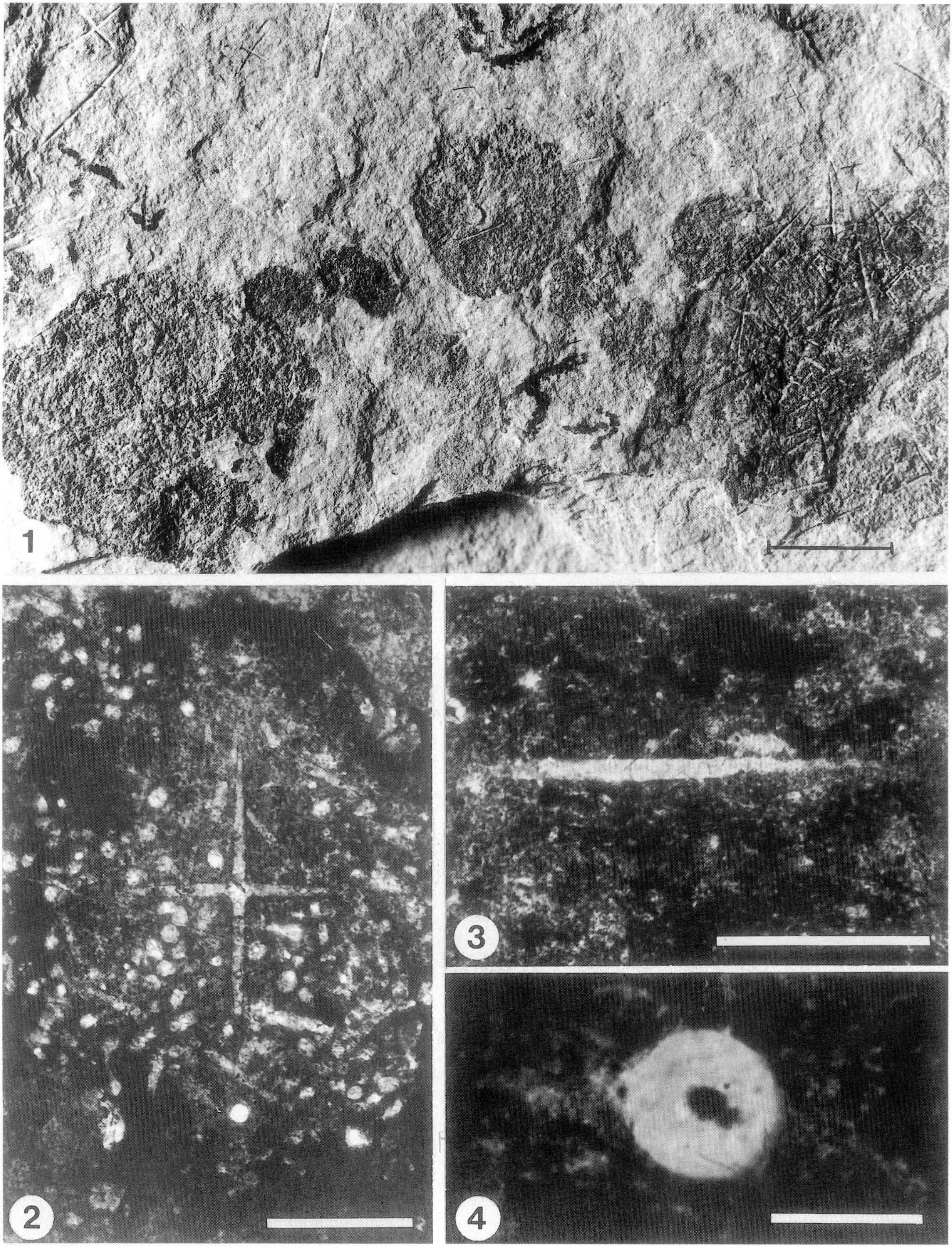
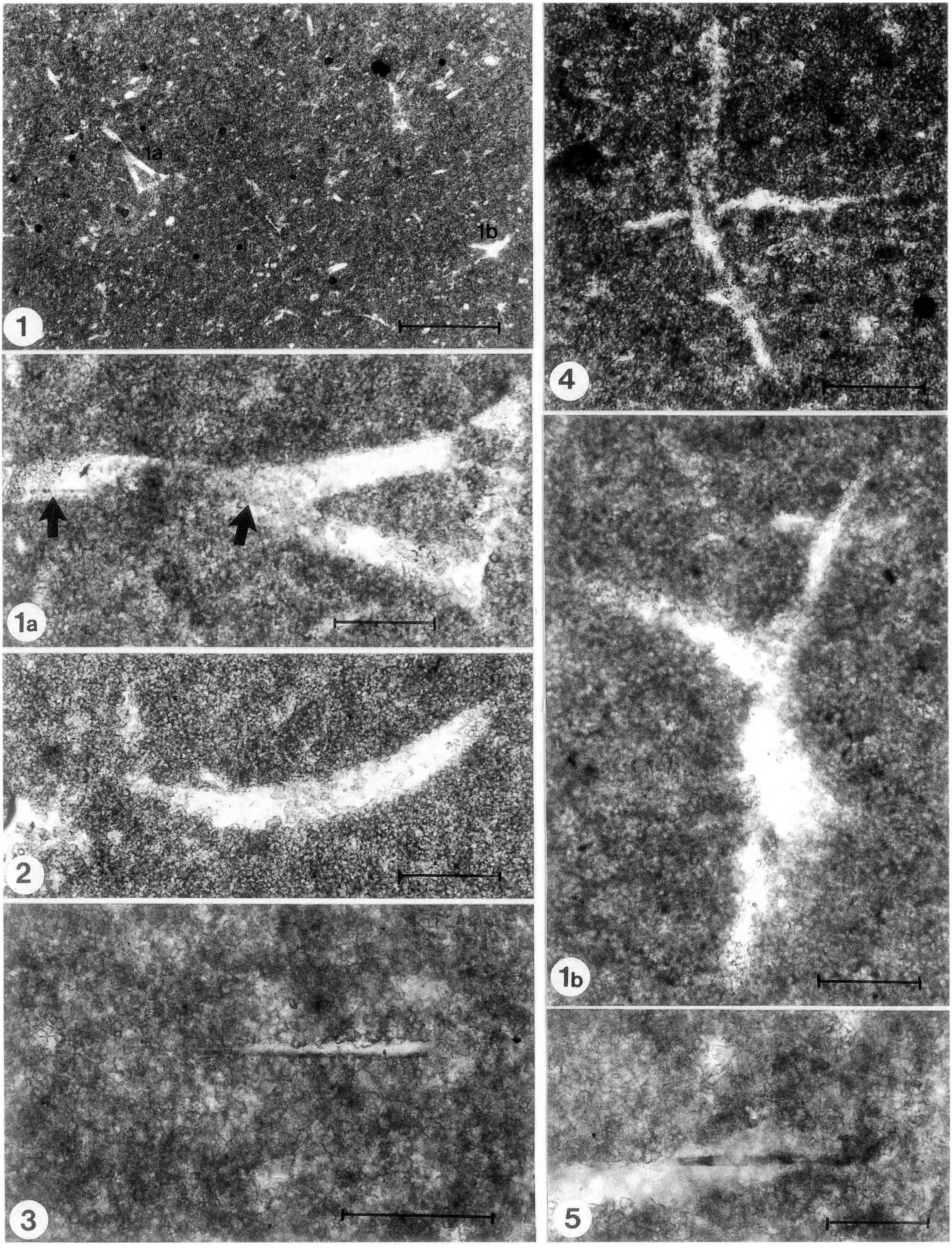

1
2
3
4

Plate 7

Spicules from the Precambrian Shiobantan Member (Dengying Formation) of the road section of Liantuo of sponges.

Fig. 1	Overview of the spicule bearing wackestone. The spicules are secondarily silicified. Scale: 200 µm.
Fig. 1a	Spicule with triane affinities. Arrow marks remains of an axial canal (enlargement of fig. 1) Scale: 50 µm.
Fig. 1b	Diagenetically altered stauractine spicules with affinities to hexactinellids (enlargement of fig. 1) Scale: 20 µm.
Fig. 2	Oxeote spicule (demospnge ?) Scale. 50 µm.
Fig. 3	Style spicule (demosponge ?) Scale: 50 µm.
Fig. 4.	Stauractine spicule (hexactinellid) Scale: 75 µm.
Fig. 5	Remain of a spicule axial canal. Scale: 20 µm.


1
1a
1b
2
3
4
5