

PERMIAN DEEP-WATER OSTRACODS FROM SICILY (ITALY). PART 2: BIOFACIAL EVALUATION AND REMARKS TO THE SILURIAN TO TRIASSIC PALEOPSYCHROSPHERIC OSTRACODS

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Abstract:

The Permian sequence of the Sicilian paleogeographic domain in Western Sicily was deposited under continuous pelagic deep-water conditions with unrestricted connection to the Permian Pacific (Panthalassa). The ostracod faunas of these pelagic deposits indicate an ecotype that is common and characteristic for open pelagic conditions and water-depths below 200–500 m in Silurian to Triassic geosynclinal areas. Because of the very low evolutionary rates these cosmopolitan faunas contain during the Late Paleozoic and Triassic increasing percentages of archaic elements that disappeared suddenly during the Upper Liassic, when thermospheric conditions were established in the world oceans.

The term Thuringian for this ecotype cannot be used, because this term is preoccupied by the Thuringian stage (= Zechstein) of Upper Permian. The term paleopsychrospheric ostracod faunas is introduced here for these above mentioned Silurian to Triassic (Lower Liassic) ostracod faunas. General morphologic characters and distribution patterns of these paleopsychrospheric ostracod faunas show similarities to the Tertiary – Recent psychrospheric ostracod faunas (e.g. total lack of eye tubercles in such groups that have contemporaneous representatives with eye tubercles in shallow-water seas, dominance of smooth and spined forms by absence of the sculpture type with heavy broad ribs, very homogenous faunas over large distances, very high percentage of cosmopolitan species).

Zusammenfassung:

Die permischen Schichtenfolgen der Sicanischen paläogeographischen Einheit Westsiziliens wurden unter kontinuierlichen pelagischen Tiefwasserbedingungen bei uneingeschränkter Verbindung zum permischen Pazifik (Panthalassa) sedimentiert. Die Ostracodenfaunen dieser pelagischen Ablagerungen zeigen einen Ökotyp an, der in silurischen bis triassischen Geosynklinalgebieten weit verbreitet ist und offene pelagische Bedingungen bei Wassertiefen unter 200–500 m charakterisiert. Wegen der sehr geringen Evolutionsraten enthalten diese kosmopolitischen Faunen während des Jungpaläozoikums und der Trias wachsende Anteile von archaischen Elementen, die während des Oberlias plötzlich verschwanden, als sich thermosphärische Bedingungen in den Weltozeanen einstellten.

Die Bezeichnung "Thuringian" für diesen Ökotyp kann nicht verwendet werden, weil diese Bezeichnung für die Thuringian-Stufe (= Zechstein) des Oberperm präokkupiert ist. Die Bezeichnung paläopsychrosphärische Ostracodenfaunen wird hier für diese oben genannten silurischen bis triassischen (unterliassischen) Ostracodenfaunen eingeführt. Allgemeine morphologische Merkmale und Verbreitungsmuster dieser paläopsychrosphärischen Ostracodenfaunen zeigen Ähnlichkeiten mit den tertiären bis rezenten psychrosphärischen Ostracodenfaunen (z.B. totales Fehlen von Augenknoten in solchen Gruppen, die altersgleiche Vertreter mit Augenknoten in Flachmeeren besitzen, Dominanz von glatten und bestachelten Formen bei Abwesenheit des durch grobe, breite Rippen gekennzeichneten Skulpturtypus, sehr homogene Faunen über große Entfernungen, hoher Prozentsatz kosmopolitischer Arten).

1. INTRODUCTION

In part 1 of this paper (this volume) Permian deep-water ostracod faunas from pelagic sequences of the Sosio Valley area and the Lercara-Roccapalumba area (both Western Sicily) were described. The map of the investigated areas, the geological sketch of the Torrente San Calogero section WSW of Pietra die Salomone, where the richest

ostracod faunas have been found, the composed stratigraphic column of pelagic Permian and Triassic in Western Sicily, and the ostracod plates have been presented in part 1 (text-figs. 1-3, pls. 1, 2).

In the present part 2 the paleoecologic importance of the rich deep-water ostracod faunas from the higher Middle Permian to basal Upper Permian and of similar faunas in the Paleozoic and in the Triassic is discussed.

2. REMARKS TO THE PERMIAN BASINAL SEQUENCE IN WESTERN SICILY

CATALANO; DI STEFANO & KOZUR (1988b) recognized for the first time a Permian pelagic deep-water sequence in the Sicanian paleogeographic domain of Western Sicily. According to these authors, it consists of Kungurian (Jachtashian) flysch, a Kubergandinian Olistostrome Unit and a Wordian to Dzhulfian Claystone Unit.

The Kungurian flysch is the oldest well exposed stratigraphic unit in the Sicanian paleogeographic domain. Several 100 m of this unit are exposed, but its thickness may be considerably larger, because its base is never exposed. The flysch consists of reddish or gray sandstones, siltstones and shales. Graded bedding, flut casts and other sedimentary marks are common in these rocks. Resedimented limy sandstones to sandy limestones occur subordinately in the reddish or reddish and gray part of the flysch, whereas in the gray part only few banks of carbonatic sandstones have been found.

Trace fossils of the *Nereites* ichnofacies are common. Especially frequent are *Paleodictyon* and feeding traces with meander patterns, but *Paleodictyon* seems to be restricted to the red flysch. This ichnofacies, especially the common occurrence of *Paleodictyon* (first evidence of this Silurian - Tertiary ichnogenus in the Permian) is known only from deep-water deposits, according to FREY & SEILACHER (1980) from the lower bathyal and abyssal zones in water-depths well below 1000 m.

Except of trace fossils only *Ammodiscus* sp. is frequent in the shales and siltstones, but neither ostracods nor other fossils with calcareous shells occur. Only in the gray flysch occasionally prints of very small (juvenile ?) bivalves and very few ostracods can be found. Conodonts are rare and represented by the pelagic *Mesogondolella intermedia* (IGO) and *M. idahoensis* (YOUNGQUIST; HAWLEY & MILLER) indicating a Jachtashian (Kungurian) age of the flysch. Plant detritus occurs in some layers of the gray flysch. Therefore the coast of a continental area or island arc was not far during the deposition of the flysch.

The few limy sandstones or sandy limestones are rich in resedimented shallow-water fossils (algae, bryozoans, few ostracods and fusulinids). They are often corroded or show other signs of resedimentations. Except of these fossils transported from adjacent shallow-water areals, some well preserved conodonts are present. Like in the shales and siltstones the pelagic *M. intermedia* and *M. idahoensis* occur, but additionally *Neostreptognathodus pequopenensis* BEHNKEN and *Sweetognathus behnkeni* KOZUR are present indicating more marginal and shallower environments.

Quite characteristic for the limy sandstones and sandy limestones of the flysch unit are enigmatic, spine-like microproblematica. Like echinoderms, they consist of high-magnesium calcite, but all are tetroradiate with pores between the 4 ridges. Their paleoecologic significance is unknown, but because they are quite missing in the accompanying shales and siltstones with deep-water fossils, they are rather components transported into the basin together with the algae, bryozoans etc. On the other hand, these microproblematica are also unknown from typical shallow-water carbonates of Lower Permian age. Perhaps they indicate, as *N. pequopenensis* and *S. behnkeni*, outer shelf conditions.

As a whole, the typical Kungurian flysch sequence is a deep-water deposit with strong influx of clastic material and partly also with resedimented shallow-water fossils. Strong terrigenous influx and layers with fine plant detritus indicate the vicinity of a land or island arc. The flysch may indicate last Hercynian compressive movements. The conodonts are slightly altered (CAI = 2), unlike the Chihshian to Rhaetian conodonts of the Sicanian paleogeographic domain that are quite unaltered (CAI = 1), if they are not thermally altered along young faults.

The flysch sequence is overlain by the Olistostrome Unit (see part 1, Unit A in text-fig. 2) of several tens to more than 100 m thickness. Its matrix is a dark-gray, soft, often pyritic clay with sand grains, among it rose quartz. It contains only very few, but partly stratigraphically important fossils. The conodont association with *Mesogondolella phosphoriensis* (YOUNGQUIST; HAWLEY & MILLER) and *Sweetognathus subsymmetricus* WANG; RITTER & CLARK indicates basal Middle Permian (Kubergandinian) age. Like in the flysch, also these conodonts from the matrix of the Olistostrome Unit are typical Circum-Pacific species. Except of conodonts, only a few pyritized radiolarians (mainly Albaillellacea) and very few of the above mentioned microproblematica are present that may be reworked from the underlying flysch sequence. Spormorphs are common, but plant detritus cannot be observed.

The olistoliths consist largely of gray flysch sediments from the underlying sequence. Rocks unknown from sequences are also present among the olistoliths. They consist of dark-gray, hard radiolarian marls, somewhat siliceous, radiolarian-rich calcilutites, resedimented calcarenites, biogenic limestones and dark-gray, marly brachiopod-ammonoid limestones with light-gray limestone interclasts.

All these limestones and marls contain very rich pelagic Circum-Pacific faunas. The radiolarian-bearing olistoliths (marls, calcilutites, see above) contain typical Cir-

cum-Pacific Lower Permian *Pseudoalbaillella* associations, e.g. with *Pseudoalbaillella scalprata scalprata* HOLDSWORTH & JONES, *P. scalprata postscalprata* ISHIGA, *P. (Kitoconus) elongata* ISHIGA & IMOTO. These radiolarians indicate Jachtashian (Kungurian) age. For some faunas latest Artinskian age cannot be excluded. These rocks are therefore lateral equivalents of the flysch deposited in more distal parts of the basin without terrigenous influx.

The calcarenites and biogenic limestones contain very rich Chihsonian pelagic conodont faunas with *Mesogondolella zsuzsanna* KOZUR, rare *M. slovenica* RAMOVŠ and some *Hindeodus* sp. In the biogenic limestones additionally reef-debris occur (reef-slope sediments).

The brachiopod- and ammonoid-bearing limestones contain few conodonts, *M. idahoensis* (YOUNGQUIST; HAWLEY & MILLER) and *Sweetognathus guizhouensis*. BANDO et al. that indicate latest Jachtashian (latest Kungurian) to Chihsonian age. Scolecodonts are common, indicating that these rocks were not deposited in water depth below 100 m, where scolecodonts are rare.

As a whole, the Chihsonian olistoliths indicate a shallowing of the basin after the deposition of the flysch and contemporaneous radiolarian marls and radiolarian-bearing calcilutites during the Jachtashian (Kungurian). Seemingly carbonatic sedimentation prevailed during the Chihsonian. Pelagic limestones prevail, but reefs were present adjacent to the basin.

The Olistostrome Unit indicates the onset of a new sedimentation cycle. During this time a deepening of the basin and a transgression on the foreland began. In the next higher unit, the Claystone Unit (see part 1, Unit B in text-fig. 2), predominantly red, in the lower part also light-gray clays without any sand content have been deposited. Partly they contain only siliceous microfossils (radiolarians, spicules of Silicospongia), partly also ostracods and foraminifers are present. These clays represent a strongly condensed sequence. In a few meters of these clays Wordian, Capitanian, Abadehian and Dzhulfian fossils can be found. The radiolarian fauna consists of Circum-Pacific species, dominated by highly evolved Follicucullidae, e.g. *Pseudoalbaillella eurasiatica* KOZUR; KRAHL & MOSTLER, *Follicucullus monacanthus* ISHIGA & IMOTO, *F. cf. charveti* CARIDROIT & DE WEVER, *Ishigaconus scholasticus* (ORMISTON & BABCOCK). In some samples mass occurrences of radiolarians with several 100,000 specimens per kg material can be observed.

Conodonts are nearly absent in the clays, but extremely frequent in broken, thin beds of calcarenites that

contain more than 1,000 conodonts per kg material. Except of conodonts these calcarenites contain sponge spicules and ostracods, but often also debris of phosphatic fossil remains (redeposited fish remains), partly with bonebed character.

Pelagic sedimentation continued during the Triassic (see part 1, text-figs. 2, 3). In the Lower Ladinian (Unit C in text-fig. 2) gray, greenish-gray and red radiolarites, greenish tuffites, siliceous, partly cherty limestones prevail, whereas the Upper Ladinian is built up by greenish-gray to pink nodular cherty limestones, somewhat marly shales and quite subordinately red radiolarites (Unit D in text-fig. 2). In the Middle Carnian dark-gray, marly, often cherty limestones and marly shales prevail and from the Upper Carnian to Rhaetian a monotonous sequence of bedded, light-gray cherty limestones is present.

3. PALEOECOLOGIC EVALUATION OF THE DEEP-WATER OSTRACOD FAUNAS FROM THE MIDDLE-UPPER PERMIAN CLAYSTONE UNIT OF THE SOSIO VALLEY AREA AND OF PALEOZOIC TO TRIASSIC OSTRACOD FAUNAS FROM SIMILAR ENVIRONMENTS

The ostracod faunas of the Middle-Upper Permian Claystone Unit, both from the red clays and from the calcarenites, are quite different from the well known and rich contemporaneous shallow-water ostracod faunas from the adjacent Western Tethyan shelf. In the red clays, even the genera are different except of some ubiquitous forms, like *Haworthina*, *Roundyella* and doubtful *Bashkirina*. In the calcarenites (reworked subordinately also in the red clays) several genera of kirkbyids are identical with the shallow-water ostracod faunas. *Bairdia* and *Cryptobairdia* are here common and *Parabythocythere* is present. But even in these faunas neither among the kirkbyids nor among *Bairdia*, *Cryptobairdia* and *Parabythocythere* identical species with the shallow-water faunas can be found. Whereas the shallow-water faunas from adjacent areas are quite different, similar ostracod faunas can be found in Lower Permian beds of Timor Island. Both these similarities and the difference against contemporaneous shallow-water faunas from the adjacent shelf are facies-controlled (see below).

The richest ostracod faunas have been found in sample 655 (1 kg red clay) of Upper Capitanian to Abadehian age. The clay disintegrated in cold water and was washed

with a 0.063 mm sieve. The residues (72 g) consist exclusively of fossils. Except of some 100 ostracods, some foraminifera and few siliceous sponge spicules, only radiolarians are present. They are quite identical with species from the highest Middle Permian to basal Upper Permian red deep-sea cherts from Japan and from Oman. They indicate pelagic conditions and a broad, open deep-water connection to the Permian Pacific (Panthalassa). The same is indicated by the pelagic conodont faunas from the calcarenites that consists likewise exclusively of Circum-Pacific species.

The calcarenites consist of biogenic calcareous sands without any terrigenous components. They are diagenetically not much changed and have still many open pores (poorly cemented). Between the biogenous calcareous sand grains many fossils, especially ostracods, sponge spicules and conodonts can be observed on the surface of these rocks. These calcarenites may have been the distal parts of fans of transported material from adjacent reefs. Only few such calcarenites are present. With exception of a more than 10 cm thick bank from the lower part of the sequence, they are only some mm thick. All these calcarenites are broken and randomly distributed in the strongly disturbed red clays.

No macrofossils can be found in these calcarenites (and in the red clays). So, seemingly the reefs were not immediately adjacent to the deposition area of the red clays with some calcarenites. Reef limestones are only known from tectonic blocks in the Sosio Valley.

The ostracods of the calcarenites are white and have white calcareous matrix. Some of so preserved ostracods can be found also quite subordinately in the red clays mostly adjacent to the calcarenites. They seemingly derived from these calcarenites, in which they can be easily moved from their surface. *Amphissites* ? *sosioensis*, *Kellettina reticulata*, *Kirkbya* ? n. sp., *Nodoparaparchites reticulonodosa* and *Parabythocythere siciliensis* could be found only in this preservation and have therefore originally not lived in the red clays, but they are all known from the calcarenites.

The ostracod fauna of the calcarenites consists of *Bairdia/Cryptobairdia* (only 2 species, but many specimens) and of some species that can be also found in the red clay. *Sinocoelonella densistriata* is frequent in both rocks and also *Spinomicrocheilinella dargenioi*, *Microcheilinella* sp., *Paraberounella laterospina* and the *Bashkirina*, *Haworthina* and *Roundyella* species can be found in both facies. On the other hand, *Pseudospinella ruggierii* and *Spinosioella catalanoi*, both frequent in the red clays, could not be found in the calcarenites. Kirkbyids, in

turn, are here more frequent, especially *Kellettina reticulata* is common.

The kirkbyids of the calcarenites (and of the red clays) are all very small forms (mostly 200–300 µm long), in contrary to contemporaneous species (often of the same genera) from adjacent shallow-water seas that are in general 600–1,000 µm long. Part of these forms, especially from the red clays, are seemingly juvenile forms, but also the adults of the most species are very small. There is a possibility that these small forms lived interstitially, like the recent Punciidae.

Even the calcarenites have not yielded any real shallow-water fossil. Seemingly this fauna was transported from shallower, but not shallow seas adjacent to reefs into the deep water basin. From the geological situation can be concluded that the faunas of these calcarenites are mixed and they should contain faunal elements that lived originally in different water depth. But ostracods with eye tubercles and sculpturated bairdiids, frequent in contemporaneous shallow-water sediments of the Western Tethys shelf, are quite missing. The accompanying other faunal elements are pelagic. Therefore also this ostracod fauna is not a shallow-water fauna, but has lived in water depth below 300 m (missing eye tubercles !).

The red clays are real deep-water sediments, indicated by all, mainly siliceous faunal elements (CATALNO; DI STEFANO & KOZUR, 1988 a, b and in press). This is also indicated by the geological development of this area. Already the Kungurian flysch contains very rich deep-sea trace fossil associations with numerous *Paleodictyon*. In the Middle Permian in the whole southern and central part of the Western Tethys sinking tendencies and wide transgressions on the foreland can be observed (e.g. with more than 4,000 m Wordian and Capitanian shallow-water sediments in Tunisia). The time-equivalents of this thick sequence are few meters of red shales in the Sicilian paleogeographic realm of Western Sicily. The sedimentation rate was therefore very low. Input of terrigenous material, like in the Lower Permian cannot be observed anymore.

Some of the red clays contain only siliceous faunal elements (radiolarians, sponge spicules, agglutinated foraminifera), in others also calcareous microfossils (ostracods, calcareous foraminifera, but not fusulinids) occur. The red clays with some calcareous microfaunas beside dominating siliceous microfossils have been surely deposited above the CCD. Those red clay that contain only fossils with siliceous skeleton may indicate deposition below the CCD.

The evaluation of all geological and faunistic data shows that the ostracod-bearing red clays has been deposit-

ed above, but near the CCD. Their deposition depth was surely considerably deeper than 1000 m water-depth. The deep-water connection to the Permian Pacific was broad and unrestricted, because the radiolarian and conodont faunas are even in specific level identical with the Circum-Pacific faunas.

The climate during the Middle and Late Permian was in the Western Tethys area subtropical/tropical (reefs in shallow-water blocks in Sicily, fusulinid-algal limestones on the Western Tethys shallow-water shelves). But in Gondwana and in the Angaride Province cold-water faunas are known throughout the Permian and in the deeper Lower Permian glacial sediments are widespread in Gondwana and some glaciomarine sediments were reported from the higher Permian of northern Siberia. Therefore we can await psychrospheric conditions in the world oceans during the Permian.

The extreme differences between the shallow-water and deep water ostracods in the Western Tethys confirms this opinion. Seemingly a distinct thermocline between the warm surface water and the colder deeper water was present that acted as faunal barrier. Quite the same strong differences between shallow- and deep-water faunas were present during the Triassic. Deeper water faunas from pelagic sediments of areas with free connection to the world ocean contain an archaic ostracod fauna with *Acanthoscapha*, Tricorninacea, strongly spined primitive Bythocytheracea, Healdiacea and other Paleozoic elements. This fauna has a distinct Paleozoic aspect. Contemporaneous shallow-water ostracod faunas have, in turn, typical Meso-/Cenozoic character with many sculpturated bairdiids, heavily sculpturated Cytherocopina etc. Also here no common species can be found between the shallow-water and the open-sea deep-water ostracod faunas and the transition between these faunas is rather fast. In an estimated depth interval from about 100 m to about 500 m the ostracod fauna changed nearly totally.

This situation continued until the lowermost Jurassic. In the Toarcian a drastic world-wide change occur. In deep water sediments, without any change of facies, suddenly all Paleozoic elements (*Acanthoscapha*, Tricorninidae, Healdiacea), still dominant before, disappeared. In the same time a drastic change in the radiolarian faunas can be observed, where nearly all Triassic elements suddenly disappeared and the fauna became dominated by very small forms, especially williriedellids. From this moment the dominance of Entactinaria and Spumellaria against the Nassellaria changed into absolute dominance of Nassellaria. Also among the brachiopod faunas in this level many archaic elements disappeared.

After this faunal event in the deep-water associations, not related to a comparably strong event in the shallow-water faunas, quite transitional changes from the shallow-water into deep-water ostracod assemblages can be observed. Mostly the same groups occur in the shallow- and deep-water, only with other species or partly genera. The morphologic differences between the shallow- and deep-water ostracod faunas are from this time the same as indicated by BENSON (1984) for thermospheric Cretaceous deep-water ostracods against contemporaneous shallow-water ostracods. This situation continued from the Toarcian up to the Late Cretaceous or even Paleocene.

In this time the world oceans were really thermospheric. Because of the missing thermocline, the differences between the shallow-water and deep-water ostracods were not so great and the changes were gradual over a longer depth interval. Moreover, the Jurassic and Cretaceous deep water ostracods were not so cosmopolitan than the Eocene to recent psychrospheric ostracods and the Silurian to basal Jurassic paleopsychrospheric (term explained later) ostracods.

Except of the archaic paleopsychrospheric deep-water ostracods from pelagic sediments with unrestricted broad connection to the world ocean we find in the Triassic (and before) also deep-water ostracod faunas that are not archaic and therefore not so different from the shallow-water associations. In contrary to the shallow-water faunas they do not contain any taxa with eye tubercles, and species with more delicate sculpture and broad ventral wings are more frequent than in shallow-water associations. Almost all typical Paleozoic elements, like *Acanthoscapha*, Tricorninacea, are absent. Only Healdiacea are frequent, but they are not restricted to deep-water environments and common also in shallow-water sediments below the wave-base.

These ostracod faunas occur in restricted basins inside or behind carbonate platforms, which have no open deep-water connection with the world ocean. These are ostracod faunas of low energy environments in water-depths of more than 200 m indicated by microfacial investigations. From the geological situation and the subtropical/tropical warm climate during the Triassic can be concluded that these basins were thermospheric deeper water areas. There are some evidences that at least the westernmost part of the southern branch of Triassic Tethys had also thermospheric conditions, whereas the northern branch was two-layered with distinct thermocline. These two branches were separated by the Krejos Plate sensu TOLLMANN (compare TOLLMANN & KRISTAN-TOLLMANN, 1985) which could be a barrier for cooler bottom

water. The investigations to this problematic are still in progress.

The archaic character of the Triassic (and Permian) deep-water ostracods from areas with open deep-water connection to the world ocean indicates that these ostracods lived in a very stable biotope that has not significantly changed since the latest Ordovician/earliest Silurian. In this very long time interval the oceans were surely psychrospheric during the Late Ordovician and the Late Carboniferous/Early Permian glaciations. No changes in the basic character of the Silurian to Lower Carboniferous open pelagic deep water faunas against Lower Permian or even Late Permian ones can be observed.

If in this long time interval several times thermospheric and psychrospheric conditions had changed in the world oceans, than the observed constancy of the here discussed deep water ostracod faunas would be unexplainable. As clearly observable in recent psychrospheric and thermospheric deep-water ostracod faunas (e.g. from the Atlantic Ocean and from the Mediterranean Sea) the differences between these faunas are drastical. The changes between psychrospheric and thermospheric ostracod faunas in the present day Mediterranean Sea from the Tertiary to recent are likewise drastical. The above mentioned Toarcian break in the deep water ostracod faunas was likewise very strong.

This latter event is especially important for the explanation of the conditions before this event. The Jurassic/Cretaceous oceans were surely thermospheric. The only explanation for the sudden disappearance of all the Paleozoic elements (that had survived in deep water environments even such global events, like the Permian-Triassic boundary) is, that the pre-Toarcian oceans were not thermospheric.

Because no stronger climatic changes can be observed during the higher Liassic, the change from a two-layered psychrospheric world ocean into a thermospheric ocean must be caused by changes in the paleogeography that have changed the oceanic circulation. If, for instance, the transport of warm surface water into polar regions was interrupted, the outflow of cold bottom water from these regions into low latitude oceans would end.

If we trace back the archaic Permian and Triassic deep-water faunas into the Lower Paleozoic then we find this fauna exclusively in such pelagic sediments, for which facial, faunal and geological data indicate free deep water connections to the world ocean or the depositional areas of these sediments were situated on the margin of oceans, e.g. Devonian to Lower Carboniferous Hercynian geosyncline of Europe, Asia and North Africa, Permian Tethys ("Paleotethys") north of Gondwana, Timor Island.

BECKER (in BANDEL & BECKER, 1975) named the here discussed deep water ostracod faunas as "Thuringian Ecotype" following ZAGORA (1968) who discriminated a "Thuringian typus" for these faunas. BECKER regarded this fauna in contrary to the "Eifelian Ecotype" (shallow-water ostracods) as fauna of deeper water. Unfortunately, both Eifelian and Thuringian are stratigraphic stages, so both terms can be misinterpreted. Especially in the Permian, "Thuringian Ecotype" would mean Zechstein ecotype (Thuringian stage = Zechstein).

KOZUR (1972) preferred a genetic designation and he regarded these faunas as psychrospheric faunas, because of their outstanding similarities (both in the mode of distribution, morphology and sharp differences to the shallow-water faunas) to Tertiary - recent psychrospheric ostracods. However, because the Jurassic/Cretaceous oceans were surely thermospheric, it is better to name this fauna paleopsychrospheric, a term introduced here.

According to KOZUR (1972) this fauna is restricted to environments with open deep water connection to the world ocean and water depth below 200–500 m (upper depth boundary of this fauna minimum 150–200 m, maximum 500 m). As pointed out by KOZUR (1972) these data are well established not (only) by comparisons with Tertiary to recent psychrospheric ostracod faunas, but above all by microfacial data that are quite independent from the ostracod data.

According to KOZUR (1972) there are no data to recognize, which water depth below the above mentioned upper limit of the paleopsychrospheric fauna can be attributed to these faunas, but, of course, these faunas have lived in water depth well above the CCD, because they have been solved from pelagic limestones. Most of the paleopsychrospheric ostracod faunas have lived in water depth between 200 and 1,000–2,000 m. Faunas from still greater water depth should be expected from sediments deposited near the CCD. As mentioned above, the Middle/Late Permian red deep water clay from Western Sicily with the ostracod fauna described in part 1 of the present paper may belong to this type of sediments.

Bairdia s.l. (including *Cryptobairdia* SOHN) is missing or extremely rare in this fauna. Quite in the contrary, the ostracod faunas from the few intercalated thin calcarenites yielded many bairdiid specimens (but only one or two species unlike the shallow-water faunas with many specimens and species). This fauna has several species in common with the red deep-water clays, others are missing (see above) and the frequency of common species is partly different. Also this fauna has no representatives of the contemporaneous shallow-water faunas from the Western Tethyan shelves. If this fauna is composed of ostra-

cods from different water depth, transported into the deep basin, so even the ostracods from the shallowest involved environment have lived below the environment of the Western Tethyan shallow-water faunas.

The absence or extreme scarcity of *Bairdia* s.l. in the red clays is surely not caused by different substrates, because bairdiids are frequent in shallow-water clays or micritic limestones. Seemingly paleopsychrospheric ostracod faunas rich in *Bairdia* s.l., represent the upper (depth) fauna of these associations, whereas the fauna without or with quite subordinate *Bairdia* s.l. represent the deeper (depth) fauna of these associations. In the Devonian the "Cypridine Shales" would represent the latter deeper faunas, as already assumed by KOZUR (1972). In the Permian, the ostracod fauna of the Sicilian red deep-water clays would belong to the deeper, the fauna of the Lower Permian "flysch" of Timor to the shallower paleopsychrospheric ostracod faunas. However, also the latter fauna was not a shallow-water fauna, but has lived below 200 m water depth.

A confirmation of the above considerations yielded Triassic ostracod faunas from sediments deposited near the CCD (cherts/cherty limestones above oceanic pillow lavas). These sediments yielded ostracod faunas very poor in species and specimens that have not yielded so far any bairdiids.

The following characteristics for the Triassic paleopsychrospheric ostracods can be established (KOZUR, 1972, p. 633):

- (1) Large part of the fauna is archaic (before only known up to the Lower Carboniferous or even Late Devonian), like Tricorninacea, primitive, heavily spined Bythocytheracea (*Paraberounella*, *Nemoceratina*, *Tuberoceratina*), *Acanthoscapha*, *Acratia*, *Healdia*, *Cavellina*, *Sulcella*, *Discoidella*.
- (2) Compared with Triassic shallow-water faunas, but also compared with Triassic thermospheric deep-water faunas from restricted basins, the phylomorphogenetic changes within the Triassic paleopsychrospheric faunas during the Triassic were only very slow.
- (3) The faunas were homogenous over huge distances (very high percentage of cosmopolitan species).
- (4) The most species are thin-shelled.
- (5) Some of the species are larger than Triassic shallow-water ostracods, e.g. *Acanthoscapha* with more than 2 mm length.
- (6) The surface/volume ratio is in general high.
- (7) Many ostracods are smooth or strongly spined. The sculpture type of strong broad ribs, quite frequent in the contemporaneous shallow-water faunas, is missing.
- (8) Eye tubercles, present among many Triassic shallow-water ostracods, are quite missing.
- (9) The number of species is low.
- (10) The hinges are primitive, mostly adont, rarely lophodont.

As already pointed out by KOZUR (1972) these characters can be only used for recognition of a paleopsychrospheric ostracod fauna, if the whole ostracod fauna of rich associations will be evaluated and if all these characters are regarded together. The characters 4–10 alone can be also found among shallow-water ostracods. For instance, strongly spined species can be also found in some fresh-water ostracod faunas. The deep-water ostracods are in general more thin-shelled, but Cytherellacea are also in paleopsychrospheric deep water ostracod faunas thick-shelled. On the other hand, fresh-water ostracod faunas are generally more thin-shelled than even deep-water faunas. In the case of eye tubercles, only the total absence of this feature in all ostracods of a rich fauna is important, because many ostracods, like Platycopina, Cladocopida and Healdiaceae have never eye tubercles, neither in deep-water nor in shallow-water environments.

The number of species is related to all paleopsychrospheric deep-water associations from different parts of the world against all different shallow-water associations. In a single shallow-water association the number of species is often lower than in a single paleopsychrospheric association. But because of the high facial differentiation in the shallow-water against a rather uniform paleopsychrospheric environment, the shallow-water faunas are by far more differentiated and they comprise about 70% of the known Triassic ostracod species.

With exception of the points 1, 2 the above mentioned characters of the paleopsychrospheric ostracods are the same as BENSON & SYLVESTER-BRADLEY (1971) described for recent psychrospheric ostracods. If we include into the considerations also the Tertiary psychrospheric ostracods, than we can also point 2 recognize in recent psychrospheric ostracods. But even the archaic character for some recent psychrospheric ostracods can be proven. Paleozoic elements are, of course, in general not more present, because they disappeared with the beginning of thermospheric oceans during the Lower Jurassic.

In spite of these obvious similarities between the recent psychrospheric and the Silurian to basal Liassic paleopsychrospheric ostracod faunas, the term paleopsychrospheric refers rather to the existence of a two-layered ocean with distinct thermocline than to the absolute temperature of the lower layer. Of course, this lower layer was relatively considerably cooler than the upper layer, but the temperature must not have been so low than in present day psychrospheric.

rospheric oceans. However, because of the quite different character of the paleopsychrospheric ostracods from the contemporaneous shallow-water (and also from contemporaneous thermospheric deep water) ostracods and because of the cosmopolitic distribution of the paleopsychrospheric ostracods, these differences can be only explained by the presence of a distinct thermocline. Moreover, below this thermocline the temperature of the lower layer must be both regionally and seasonally constant and not regionally and seasonally changing.

The paleopsychrospheric ostracods from the Silurian up to the Permian do not show decisive differences against the Triassic ones, but not all 10 points listed above, can be used for recognition of these faunas. So, the hinge is also among the most shallow-water ostracods primitive and not only among the paleopsychrospheric ostracods. Many shallow-water ostracods are in the Paleozoic very big forms, so that we cannot find real general size differences between shallow-water and paleopsychrospheric ostracods. Rather the paleopsychrospheric ostracods are often smaller than the contemporaneous shallow-water ostracods. Such small forms are also present among the Triassic paleopsychrospheric ostracods, but because here the majority of the shallow-water ostracods is small, the very large representatives of the paleopsychrospheric ostracod faunas are more striking. Eye tubercles are also in Paleozoic paleopsychrospheric ostracod faunas quite missing, but with exception of the Permian shallow-water faunas and the few Silurian/Devonian shallow-water faunas with many Leperditida also in the shallow-water mostly such ostracods occur that have no eye tubercles, because only such groups are present that have never eye tubercles (also not in shallow-water environments).

All these differences show the historical aspects in the development of the paleopsychrospheric faunas. Especially distinct is this aspect regarding the archaic character of the Triassic paleopsychrospheric ostracod faunas. This feature is caused by the slow evolutionary rates in an environment that was nearly stable over the long time span of more than 200 my. In the latest Ordovician, where during the glaciation psychrospheric conditions has been established in the world oceans, the new environment was populated mainly by the more modern podocopids. Therefore the Silurian paleopsychrospheric ostracod faunas are not archaic, but more "modern" (dominated by podocopids) than the contemporaneous shallow-water faunas, dominated by the more primitive Beyrichiida and Leperditida. In the Late Paleozoic, where the paleopsychrospheric ostracod faunas contain the same groups, often the same families and genera than the Silurian and Devonian ones, the

archaic aspect of these faunas is already distinct, because the shallow-water faunas contain in this time already many higher evolved Podocopida, Platycopida and Reticulocopida. On the other hand, among the Metacopina, Punciocopina, Binodicopina and the few Beyrichiida that can be found in Late Paleozoic paleopsychrospheric ostracod faunas, especially such primitive forms can be observed that were not more present in contemporaneous shallow-water faunas.

In spite of the fact that the paleopsychrospheric ostracod faunas have evolved more than 200 my in a very stable environment as discussed above, they cannot be regarded as abyssal faunal elements from ancient oceanic plains that should have had especially stable environments. Rocks from these ancient oceans are today mostly not preserved or they consist of often metamorphic remnants of oceanic crust covered by cherts and deep-sea clays deposited below the CCD. They do not contain any ostracods, because microfossils with calcareous shells cannot be preserved there.

Preserved non-metamorphic ostracod-bearing deep-water sediments are in general limestones from the continental slope or from non-oceanic basins deposited under water-depths of 200 m to 1,000–2,000 m. In these sedimentation areas the nutrient supply, but also the sedimentation rate was surely higher than in oceanic abyssal plains. Therefore the diversity of these ostracod faunas will be surely higher than in abyssal plains.

Compared with the most paleopsychrospheric ostracod faunas that derived from epibathyal (subbathyal) sediments, the few known ostracod faunas of real deep-sea sediments are very poor. In the Meliata-Hallstatt rift, the Middle Triassic suboceanic pillow lavas are overlain by red radiolarites, higher up radiolarites and cherty limestones. The first sediments have been deposited below, the latter one a little above the CCD in water depth probably below 2–3,000 m. Here a very poor ostracod fauna was found, consisting of 2 species of healdiids. Neither spined Cytherocopina nor *Acanthoscapha*, both very typical for Triassic paleopsychrospheric ostracod faunas have been found. These latter typical paleopsychrospheric faunas are widely distributed in distal slope sediments of the Meliata-Hallstatt rift (e.g. in cherty limestones, Hallstatt Limestones). If the scarcity of ostracods in the pillow lava-chert-cherty limestone sequence from central parts of the suboceanic (about 1,000 km wide) Meliata-Hallstatt rift is not preservation controlled, than the fossil abyssal ostracod fauna were at least during the Triassic extraordinary poor and not characterized by the most typical elements of the paleopsychrospheric ostracod fauna.

According to KOZUR (1972) the paleopsychrospheric ostracod faunas can be subdivided into 4 groups, recognizable also in the paleopsychrospheric fauna from the Middle/Late Permian of Western Sicily:

- (a) Genera that are known since the Devonian or still earlier from paleopsychrospheric ostracod faunas ("Thuringian Ecotype") or near related forms that have not changed much since this time, e.g. *Tricorninidae*, *Nemoceratina*, *Paraberounella*, *Acanthoscapha*, *Bohlenatia* etc. In the Permian except of these forms also the *Rectonariidae* belong to this group.
- (b) Genera that lived formerly in shallow-water or in shallow and deep water, later only in paleopsychrospheric deeper water, in the Triassic, e.g. *Microcheilina*, *Acratina*, in the Permian, for instance, *Solleikope*.
- (c) shallow-water faunal elements that immigrated into the paleopsychrospheric faunas, if the population pressure in the shallow-water populations was very high. These elements disappeared, if their frequency in the shallow-water faunas decreased. In the Triassic, for instance, some sculpturated Bairdiidae immigrated into the paleopsychrospheric faunas. They became there strongly spined forms. But with the decline of the sculpturated bairdiids in post-Triassic shallow-water sediments, no sculpturated bairdiids can be observed in post-Triassic deep-water sediments. In the Paleozoic the likewise subordinate paleopsychrospheric Beyrichiida (often spined forms) belong to this group.
- (d) Genera that are both in shallow-water and in deep-water sediments present, but mostly represented by different species, e.g. *Cryptobairdia*, *Cavellina*, *Cytherella*, *Hungarella*. The latter genus is in the Triassic not present in water depth above 30–50 m, but below it is frequent in all water depths.

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Appendix

The data of part 2 of the present paper were presented together with the text-figs. and plates of part 1 in a lecture on the 1st European Ostracodologists' Meeting (EOM '89) at 4.8.1989 in Frankfurt a.M.

Two comments were made by Prof.Dr.G. BECKER, Frankfurt, and Prof.Dr.K.G. MCKENZIE, Melbourne. These comments were presented once more after the lecture in written form to the author for publishing together with the replies by the author. Here the comments and the replies are presented.

Prof. Dr. Becker:

You and Dr. GRÜNDEL are equating faunas of the Hercynian geosyncline (faunas of the Thuringian Ecotype) with modern deep-sea faunas. Allow me to point to three backs:

First, the Thuringian Ecotype (in my delimitation) does not mean automatically deep-sea. It indicates generally low-energy environments.

Second, the Devonian Sea was warm ("Klima stellenweise sogar warm", KLULTAE & KRS, 1967). There were at this time no connections to the polar regions. There were no cold bottom currents. The sea was thermospheric. There were no psychrospheric (ostracod) faunas in the Hercynian Geosyncline.

Third, modern deep-sea faunas are rather unknown (letter of Prof. WHATLEY), only 65–70% of the species have been described. There are, however, at least more differences than similarities between the Thuringian Ecotype and modern deep-sea faunas.

Reply Kozur:

Your discussion does not refer to my present paper, but to publications by KOZUR (1972) and GRÜNDEL & KOZUR (1975). We have not published in these papers that the ostracod faunas of the Hercynian geosyncline (your "Thuringian Ecotype") are deep-sea faunas, but we have regarded these faunas as psychrospheric faunas. According to KOZUR (1972) these faunas indicate a minimum water depth of 150–200 m, for the Triassic psychrospheric faunas of Felsöors water depth of more than 500 m were assumed. This has nothing to do with modern deep-sea faunas that live on abyssal plains in generally 4–6,000 m water depth. GRÜNDEL & KOZUR (1975) referred to the data given by KOZUR (1972).

To your 3 points the following answers:

(1) Your "Thuringian Ecotype" does not only indicate low-energy environments both in shallow-marine and in deep-water areas. Many ostracod faunas are known from low-energy environments in the Triassic and Paleozoic that have not yield the "Thuringian Ecotype" ostracods. Restricted basins are in general characterized by low-energy environments, but independent from their water depth, both the shallower and the deeper restricted basins (the latter below 200 m water-depth) never yielded the ostracod faunas of the "Thuringian Ecotype". These ostracod faunas can be only found, if free unrestricted deep-water connections to the world oceans are present in the time intervals from the Late Ordovician to basal Jurassic and from the Eocene to recent.

I do not know any shallow-water low-energy ostracod assemblage (e.g. back-reef seas) that have yielded during the Paleozoic and Triassic ostracods of the "Thuringian Ecotype". For instance, the Peștiș Shale of the Apuseni Mountains in Romania, a time- and facies-equivalent of the "Grenzbitumenzone" in the Tessin Alps, has yielded a very rich typical shallow-water ostracod fauna with several species possessing eye tubercles, like in other shallow-water faunas. The Peștiș Shale is an extremely low-energy environment, in which even prints of the soft bodies of many animals are preserved.

There is surely a general agreement between the ostracodologists that the persistence of morphologically highly specialized forms, like Tricorninidae, Rectonariidae, *Acanthoscapha* and many others from the Devonian or even Silurian up to the Late Permian and partly even into the Triassic requires an extremely stable environment during these very long time intervals. Shallow-water low-energy environments are very unstable environments, even with strong seasonal temperature differences, but also in time (geologically only shortly existing environments). These unstable environments are quite unsuitable for extremely long persisting faunas with very low evolutionary rate. Moreover, the most important elements of the "Thuringian Ecotype" have even crossed the P/T boundary, the strongest caesure in shallow-marine biota in the whole Phanerozoic time. The "Thuringian Ecotype" persisted across the P/T boundary.

Moreover, in all Paleozoic and Triassic ostracod associations of the "Thuringian Ecotype" never a specimen with eye tubercles was found. Referring to the discussion of McKenzie, we should therefore await water depth below 280 m, what excludes shallow-marine low-energy environments.

(2) There is no evidence for thermospheric Devonian ocean. Warm climate ("Klima stellenweise sogar warm") in the Devonian does not exclude a two-layered oceanic model with a cooler lower layer permanently separated by a thermocline from the upper warmer layer, like in the present day tropical regions of the world oceans. According to all paleogeographic reconstructions the Devonian oceans had broad connections to the Polar regions (compare McKERROW & SCOTese, 1989). Therefore I do not know the base for your paleogeographic considerations.

If the Devonian oceans were thermospheric, then it cannot be explained, why in the surely psychrospheric oceans during the Pennsylvanian/Lower Permian Gondwana glaciation the "Thuringian Ecotype" persisted without any significant change in its character and even in the main generic composition, whereas in the same time-interval the shallow-marine ostracod faunas changed very much. As we know from the Tertiary, the changes between thermospheric and psychrospheric ostracod faunas were drastical. Recent thermospheric and psychrospheric ostracod faunas are different each other, even if a connection between both areas exists (e.g. Atlantic - Mediterranean Sea).

Moreover, the differences between the "Eifelian Ecotype" (shallow-water ostracods) and the "Thuringian Ecotype" (psychrospheric ostracods) were very big, indicating a faunal barrier in form of a thermocline. In the Jurassic and Cretaceous thermospheric oceans the differences between the shallow-water and the deep-water faunas were not so big. The thermospheric deep water ostracods were not basically different from time-equivalent shallow-water ostracod faunas except that they are always blind (no eye tubercle) and some morphological differences can be recognized. But they consist of the same ostracod groups, partly also the same genera with different species. Compared with the shallow-water faunas, they have no archaic character. Quite on the contrary the Triassic psychrospheric faunas have distinct Paleozoic character, whereas the contemporaneous shallow-water faunas have distinct Mesozoic character.

Finally, the Jurassic and Cretaceous thermospheric deep water ostracod faunas are not cosmopolitan, like the "Thuringian Ecotype" (e.g. Devonian psychrospheric ostracods from Europe, North Africa and China have a high percentage of cosmopolitan common species). The high vertical exchange of water masses in thermospheric oceans causes regional differences in the temperature of the oceanic deep water. Therefore the thermospheric deep-water fauna cannot be cosmopolitan.

All these discussed data indicate that the Devonian ocean was not thermally unlayered (thermospheric), but thermally two-layered, like during the whole time-interval, in which the "Thuringian Ecotype" existed. This is confirmed by the fact that the "Thuringian Ecotype" suddenly disappeared with the beginning of the Jurassic/Cretaceous thermospheric ocean. In the Toarcian all archaic elements in open deep water faunas, that have survived from the Devonian (or even earlier) without significant changes until the basal Jurassic, suddenly disappeared. To these faunal elements belong *Acanthoscapa*, *Tricorninacea*, *Healdiacea*. This drastic changes in the deep water faunas, not accompanied by likewise drastic changes in the shallow-water faunas, is the normal effect that can be awaited, if the long existing psychrospheric ocean changed into a thermospheric ocean. Because the Jurassic/Cretaceous oceans were surely thermospheric, the pre-Toarcian oceans were surely not thermospheric (down until the latest Ordovician, where the "Thuringian Ecotype" began).

(3) If 65-70 % of the species of modern deep-sea faunas have been described, than this fauna is by far better known than any fossil fauna and compared with the fossil faunas not "relatively unknown". Therefore we can compare these faunas with fossil assemblages at least so good, like Devonian, Carboniferous, Permian and Triassic faunas of the "Thuringian Ecotype".

It is quite understandable that between the "Thuringian Ecotype" (Silurian or latest Ordovician to Lower Liassic) and the 200 my later existing recent psychrospheric ostracod faunas more differences than similarities can be found. During this long time interval two strong changes in the oceanic deep water faunas can be observed: Within the Liassic the thermospheric ocean began and by this all the long existing archaic (Paleozoic) elements of the pre-Jurassic psychrospheric ostracod faunas ("Thuringian Ecotype") disappeared. During the Eocene, where psychrospheric conditions were re-established in the world oceans, distinct changes in the deep water ostracod faunas were caused again. For this reason, the recent psychrospheric ostracod fauna cannot be so archaic, like the Triassic one, because this archaic character depends on the length of the time-interval, in which psychrospheric conditions existed (Silurian to Triassic against Eocene to recent). For this reason, the Silurian psychrospheric ostracod fauna are not archaic, but rather modern, compared with contemporaneous shallow-water faunas.

The basic morphological and especially also distribution characters between recent psychrospheric ostracod faunas and the "Thuringian Ecotype" are the same as already pointed out by KOZUR (1972): Cosmopolitan distri-

bution, very strong differences against the shallow-water faunas that indicate the presence of an effective ecologic barrier (thermocline), high percentage of smooth and ornate (spined) forms, sculpture more delicate, no forms with broad, heavy ribs or with eye tubercles are present, very slow evolutionary rate indicating a very stable biotope without seasonal and regional temperature differences etc.

Additional reference for the reply, not quoted in the present paper

McKERRON, W.S. & SCOTSE, C.R. (eds.) (1989): Atlas of Paleozoic basemaps. In: Paleozoic paleogeography and biogeography. – Geol. Soc. London, Spec. Publ. (pre-print).

Prof. Dr. McKenzie:

Although a depth of around 500 m (mesobathyal) may seem sufficient for a psychrospheric fauna most workers understand the word "psychrospheric" to define greater than 1,000 m depths and cold temperatures - as in modern oceans. Further, the loss of an eye tubercle in physical terms – cf. recent work by KONTROVITZ – may only require depths greater than 285 m.

I believe that Dr. KOZUR needs to define his interpretation of the term psychrospheric more precisely in the sense in which most workers understand the term (cold not relatively cool; more than 1000 m deep; like modern deep oceans). I feel that the onus of proof still rests with Dr. KOZUR to establish credibly that his Sicilian and Timor faunas are psychrospheric.

Reply Kozur:

In 1972 I have defined the Triassic psychrospheric ostracods in detail. In this paper I have pointed out that the upper limit of this fauna was between 200 and 500 m. These data are confirmed by microfacies data (quite independently from the ostracod data) that indicate for sediments with Triassic psychrospheric ostracods always depositional water depth from more than 200 m (upper limit 200 m, maybe considerably deeper). Maybe that some people have defined psychrospheric ostracods as living in more than 1,000 m water depth, but BENSON & SYLVESTER-BRADLEY (1971) pointed out that recent

psychrospheric ostracods live in water depth below 500 m in two-layered oceans and their margins. In uplifted areas within the oceans and in polar regions psychrospheric ostracods begins already well above 500 m, about in 200–300 m water depth, according to BENSON (1988) the strongest changes are at about 400 m water depth. I do not see any reason that the upper limit of fossil psychrospheric faunas has been lower than today.

The deep water character of the red Middle/Late Permian clays of the Sicanian paleogeographic realm in Western Sicily lies beyond any doubt, because all faunal elements indicate not only deep water, but also unrestricted broad deep water connections to the Permian Pacific, where even the same radiolarian and conodont species occur.

Because of cold climates in the boreal and notal seas, the Permian oceans were surely two-layered with lower psychrospheric layer that should be separated from the upper warm layer in subtropical/tropical areas by a distinct thermocline. The very sharp differences in the contemporaneous Permian shallow and deep water faunas indicate the presence of a thermocline.

The Lower Permian ostracod faunas of Timor Island were regarded by GRÜNDEL & KOZUR (1975) as psychrospheric. According to BLESS (1987), referring to AUDLEY-CHARLES (1965, 1968) these ostracods derived from a shallow-marine flysch that contains dominantly cephalopods, trilobites, conodonts, foraminifers (ammodiscids, attached forms, simple endothyrids). According to AUDLEY-CHARLES (1965, 1968) this "shallow-marine flysch" was deposited immediately adjacent to an ocean in the N. If these sediments are really flysch, than shallow-water deposition can be excluded. Flysch contains often shallow-water fossils and even land-plant detritus, but these fossils are transported from adjacent cordilleras or shallow-water areas.

In the faunal list by BLESS (1987) and van den BOOGAARD (1987) even such resedimented shallow-water fossils are not mentioned. The conodont fauna consists almost exclusively of *Mesogondolella* and *Vjalovognathus*, two typical pelagic conodonts of deeper water. No indicative shallow-water conodonts, like *Stepanovites*, are present. Even *Neostreptognathodus*, dominant in shallow basinal facies of this time, is quite missing, so that the conodont fauna indicate pelagic deeper water facies.

The same is indicated by the foraminifers. Fusulinids, dominating in all Permian shallow-water limestones, are quite missing. Also calcareous algae, very frequent in Permian shallow-water limestones, were not reported. Ostracods with eye tubercles, typical for Permian shallow-

water sediments, are likewise missing. On the contrary, *Pseudospinella*, quite characteristic for the Sicilian deep water ostracod fauna, is also in the ostracod faunas of Timor Island frequent.

Even, if the sediments would be to a large part shallow-water sediments (of course, in this case not a flysch), than psychrospheric ostracods could occur in all beds deposited below 200 m water depth. Timor Island is situated near to the margin of Gondwana, where from the Lower Permian cold water shallow-marine faunas are known. Because the depositional area was immediately at the margin of an ocean, under such climatic conditions already at 200 m water depth psychrospheric conditions would be established. There are no paleontological data that indicate water depth of fewer than 200 m for the ostracod-bearing limestones.

The data of KONTROVITZ & MYERS (1988) that ostracods can use sunlight only to a maximum depth of about 280 m are very important and they fit very well with my opinion about the upper depth limit of the (paleo)psychrospheric ostracods. But – as you have pointed out – this is a boundary in physical terms and the live does not always exactly follow such terms. According to BENSON (1984), ostracods with eye tubercles are present among recent living faunas in some places as low as 600 m water depth, exceptionally even down until 900 m water depth. In any case, ostracod faunas, in which forms with eye tubercles are regularly present, should indicate water depth above 200 m. In those geological times, where in the shallow-water ostracods with eye tubercles are frequent (Permian to recent), rich faunas without representatives with eye tubercles that show also the other character of (paleo)psychrospheric ostracod faunas, indicate water depth below 200 m or even below 300–500 m.

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