Permophiles

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SUBCOMMISSION ON PERMIAN STRATIGRAPHY

INTERNATIONAL COMMISSION ON STRATIGRAPHY

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES (IUGS)

CONTENTS

COVER PAGE

Sphenocodon ferox Marsh. Pelecysaur (mammal-like reptile) from the Cutler Formation, Lower Permian, Arroyo de Agua, Rio Ariba County, New Mexico, USA. Length of skull is approximately 38 cms. Photograph provided by D. Brinkman, Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta, Canada. The specimen is in the collections of the Museum of Paleontology, Berkeley, California, USA.

A SUMMARY OF REPLIES TO THE QUESTIONNAIRE FOR THE PROPOSAL OF THE GUADALUPIAN SERIES

In late February, I distributed 24 sheets of a questionnaire to some members of our subcommission, particularly, those from countries other than the United States and Canada. Thanks to the cooperation of these members, I have received replies almost from all of them. Except of a few of replies that indicate a definite rejection or a full support to the proposal, a majority of them agree that the Guadalupian Series is potentially a global stratotype for the corresponding part of the Permian System, but can not make final decision on the acceptability until more details are provided. For presenting the main view points that were expressed by our colleagues, four replies are introduced here together with the questionnaire.

A. The Questionnaire

Dear Colleague:

I'm sure that you have received a copy of the paper which proposes the Guadalupian Series as the international standard for that time interval (published in the International Geology Review, vol. 34, no. 9, 1992). You might have noted that as the co-authors of the proposal, five Titular Members of our subcommission have expressed their preference. As a Titular Member of the Subcommission, you are requested to present your comments to this proposal, or to provide an alternative proposal. For getting a consensus of our members' reaction on this proposal, you are now invited to fill in the following questionnaire.

i) Do you think the available data base is adequate to use the Guadalupian Series as an intercontinental chronostratigraphic concept. What will you rank it?

fully adequate essentially adequate inadequate

If you think the proposed Guadalupian Series is not eligible to become an international standard chronostratigraphic concept, do you intend to offer an alternative proposal?

yes no

Comments:

ii) The proposed stratigraphic level for the basal boundary, the evolutionary appearance of *Mesogondolella nankingensis* (Ching) is particularly significant because potentially, if approved, it would represent a mid-Permian boundary and also serve as both a series and stage boundary. How do you evaluate its usefulness in Permian palaeoequatorial belt as well as its significance in the Boreal and Gondwana Realms?

useful unrecognizable

Comments:

B. The replies

Dr. A. Baud

i) Inadequate. As long as the basal boundary has not been fully described and illustrated, nor the basal boundary of the overlying series , Guadalupian is inadequate as an inter-continental chronostratigraphic concept. Abadeh area (central Iran) is suggested as an alternative proposal.

ii) More work is needed on this conodont, with illustrations, on accompanying faunas and geographic and stratigraphic distributions.

Prof. Dr. E. Sittig

i) I agree with the Guadalupian as a Series for Middle Permian = Guadalupian and Upper Permian = Lopingian. The Guadalupian Series is excellently defined in the Guadalupe Mountains. No other area in the world has a comparably good and complete section with easy access.

I agree furthermore with the Roadian, Wordian, and Capitanian stages of the Guadalupian Series. The Kubergandinian, Murgabian and Midian are primary defined on fusulinids which are restricted to the Tethys and even there missing in pelagic beds. The stratotypes of these stages are all not accessible (political trouble zones after disintegration of the former Soviet Union), the CAI of conodonts from the Kubergandinian and Murgabian stratotypes is 4-5 which excludes late paleomagnetic and palynologic investigations. The Midian stratotype has extremely shallow deposits. No conodonts are present and even the Midian index genus *Yabeina* is missing. The base of the Midian can be therefore not defined in its stratotype. All these things additionally favour the use of the Guadalupian Series with the Roadian, Wordian, and Capitanian stages.

ii) The first appearance of *Mesogondolella nankingensis* (CHING) (junior synonym: *"G." serrata* CLARK and ETHINGTON) at the base of the Guadalupian is in a phylomorphogenetic line from the unserrated *M. idahoensis* (YOUNGQUIST et al.). It is therefore an excellent marker for the definition of the Guadalupian Series. It is present in the Tethyan warm-water pelagic faunas in western North America, in the Boreal Realm (Arctic Canada). It coincides with the appearance of *Sweetognathus subsymmetricus*. Few conodonts are known so far from the Gondwanide Permian. However, *M. idahoensis* is common in the SE Pamir which belong to the margin of Gondwana. In this area, the first Ceratitids (*Paraceltites*) are known from beds just above beds with *M. idahoensis*. These ammonoids begin in the Guadalupian type area at the base of the Guadalupian together with *M. nankingensis*. Therefore, the Guadalupian base is recognisable world-wide.

Dr. C. B. Foster

i) Essentially adequate: BUT SEE COMMENTS

This question has focused attention on the subjectiveness of such a vote. I would prefer the term *potentially* adequate, rather than essentially adequate.

Having visited the Guadalupe Mountains, and looking at the abundance of sequence stratigraphic studies on the section, there is no doubt that this is an excellent section, in terms of access, and exposure, and fulfils some of the criteria set down by Glenister et al. (1992).

But the only useful fossil groups, it seems, are the conodonts, ammonoids, and fusulinids. Primacy for international ties is accorded to the conodonts; a group which has little application for correlation of the Gondwanan Permian [although some Early Permian forms have recently been found in Australia; R. S. Nicoll, AGSO (pers. comm.)], and the same holds generally true for the other fossil groups mentioned.

A major problem also arises with the use of the type sections in the Glass Mountains (not visited by me); ironically they have become the "paratypes", whereas the "holotype" sections are in the Guadalupe Mountains. If the equivalents of the Word Formation can be demonstrated beyond reasonable doubt in the Pipeline Shale, then these problems will be overcome. But the argument of historical priority should from this evidence alone be abandoned. The purpose of selection of a reference section is to provide useful information, not to rehash earlier concepts, which may or may not be relevant to the present argument.

Conodonts, ammonoids, and fusulinaceans have been discussed as important groups; it is also claimed that as the CAI values are "1" over much of the area, the possibility exists for palynomorph studies. My own sampling through much of the Guadalupes yielded only organic debris and no recognisable spores or pollen, neither am I aware of any published palynological studies from this region, and unpublished, proprietary, palynological studies from subsurface sections show few good assemblages. Again it emphasises the subjective nature of the choice of fossils to define the Series.

It comes to this: if the conodont and ammonoid studies, as is claimed, allow international correlation, and the Glass Mountain faunas can be demonstrated in the Guadalupe area, then the nominated sections have all the potential for an adequate (marine) chronostratigraphic unit.

ii) Unrecognisable

In the Gondwana Realm, the conodont evidence would be of no use in defining any boundary.

Although not a conodont worker, I an puzzled by the use of the species name *nankingensis*. According to Wang and Wang (1981, *Spec. Pap. Geol. Soc. Amer.* 187), and subsequent discussion by Clarke and Wang (1988, *J. Paleont.* 62) the holotype of *nankingensis* is lost, and there is some question as to the different morphology of a single paratype; surely the name should be declared *nomen ambigum*, and *serrata* used.

Prof. M.Kato

I fully agree with the opinion that the Guadalupe mountain area is one of the best studied in the world for the Permian.

Question is, however, how chronological data derived from the Guadalupian are effectively applicable to the world Permian for correlation. Also how fine is the conodont biostratigraphy in terms of chronological resolution.

I am personally in favour of employing the evolution of neoschwagerinid foraminifers for finer zonation of the concerned parts of the Permian in the Tethys. But, of course, this scheme will encounter difficulty when we deal with the Boreal and American provinces.

Stability in the Permian chronology or chronostratigraphy is what we are aiming at. Therefore we ought to have first a detailed correlation chart, for the world "Middle Permian".Thus we are able to choose the Guadalupian as an appropriate stage unit.

We may employ the Guadalupian for the time being, awaiting for more detailed, comprehensive study in the Tethys to be done, perhaps in south China. Or, we may employ both Central Asian scheme as well as American one in parallel at the present moment.

In any case, to me, it is still early to finalize the selection of the Guadalupian as an unified, only stage unit in the "Middle Permian."

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2. SECRETARY'S NOTE

I should like to thank all those who contributed to the issue of "Permophiles". The next issue will be in November 1994; please submit contributions by October 1.

Contributors may send in reports by mail, FAX or E-mail. "Permophiles" is prepared using WordPerfect 5.1 for those wishing to send in 5¼" or 3½" IBM computer discs (please also send printed hard copy). Files can also be sent in their native format with an ASCII version.

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3. THE NEED FOR A BURSUMIAN STAGE, UPPERMOST CARBONIFEROUS, NORTH AMERICA

If, as it seems likely, the base of the Permian is placed at, or near, the first appearance of *Sphaeroschwagerina fusiformis* in bed 19 or at the base of bed 20 of the Aidaralash section in the western Urals region, then the traditional lower boundary of the Permian System as used in the Midcontinent (Moore and others, 1951) and southwestern North America (Thompson, 1954) lies below this base. The first appearance of *S. fusiformis* (or its North American equivalent *Pseudoschwagerina beedei* or associated zonal fossils) marks the base of the Permian Wolfcampian Series (Ross, 1963; Baars and others, 1992).

This succession of uppermost Carboniferous strata between the traditional top of the Pennsylvanian Virgilian Series and the base of the Permian Wolfcampian Series includes the Admire Group and the lower part of the Council Grove in Kansas, as defined by Moore and others (1951). It extends at least as high as the base of the Grenola Limestone (Ross and Ross, 1985) and most probably as high as base of the Neva Limestone Member at the top of the Grenola (with the first appearance of *Paraschwagerina kansasensis*, a species that co-occurs with *Pseudoschwagerina beedei* and *P. uddeni* in other sections in the region) (Baars and others, 1992).

In south central New Mexico, Thompson (1954) used the Bursum Formation to include this interval that lies above the Virgilian and below the first occurrence of inflated fusulinaceans, such as *Pseudoschwagerina uddeni, P. texana*, and *P. beedei* in the lower part of the Hueco Limestone. Thompson (1954) in using Bursum for this stratigraphic unit redefined and restricted both the lower and upper boundaries of the Bursum as originally defined by Wilpolt and others (1946).

Although Thompson sometimes has been criticized for redefining the Bursum as a fossil zone rather than a lithostratigraphic unit, this is not borne out by Thompson's detailed discussion and illustrations of Bursum lithologies (Figures 1 and 2), lateral lithologic facies changes, and stratigraphic relations at the base and top of the Bursum Formation. He clearly recognized that this unit had lithologic continuity from north to south in both the San Andres and Sacramento Mountains of south central New Mexico and that it extended into the northern part of the Hueco Mountains of West Texas. He also clearly established that the Bursum was a rock unit that was consistently the same age across this region.

The Bursum Formation in south central New Mexico is a cyclical succession of sandstones, conglomerates, siltstone- and claystone-red beds, thin marine shales, and limestones. Minor unconformities separate most of the nearly ten thin depositional sequences or parasequences in the formation. Weathering below these unconformities produced shallow, but well developed soil profiles with root casts, soil nodules of various types, local microkarsts, and related features. The Bursum was deposited in a shallow late Pennsylvanian basin on the higher portion of the cratonic shelf. Both to the north and south along the north-south trends of the mountain ranges the Bursum thins internally and by erosion at the top of the formation.

The limestones are nearly all shallow-water, light grey, wackestones and packstone. Echinoderm fragments, algae, gastropods, and fusulinaceans are locally common, but the preserved fossil biota usually has a low diversity with only a few small species and genera. A few darker, some siliceous-rich, 'deeper water' limestone facies are present.

Bursum fusulinaceans are distinctive. *Triticites* species, such as *Triticites creekensis* and *T. cellamagnus*; have thick-walls with well-developed keriotheca, high nearly tabular chomata, large proloculi, and thickly fusiform shape. In addition primitive *Leptotriticites* species with low chambers and strongly folded septa, such as L. *hughensis* and *L. glenensis* (and in Kansas, *L. extenta*, *eoextenta*, *L. americana*, *L. fivensis*) are present. Fusulinaceans in the upper part of the Bursum include *Pseudofusulina*, such as *P. robleda*; that are large, but not very regular in their construction and shape and also primitive *Schwagerina* that commonly have well-developed pseudochomata, such as *S. pinosensis* and *S.* aff. *S. gradensis* (and in Kansas, *S. longissimoidea* and *S. campensis*).

The Bursum Formation and its faunas were used in the sense of a stage or substage in Ross and Ross (1987a, fig. 3 and b). This stage is widely recognizable, because of its distinctive fossil fauna and lithologic relationships, in southwestern and Midcontinent North American and serves to redefine the top of the Pennsylvanian to correspond to the proposed top of the Carboniferous in the western Urals region of the Russian Federation of States.

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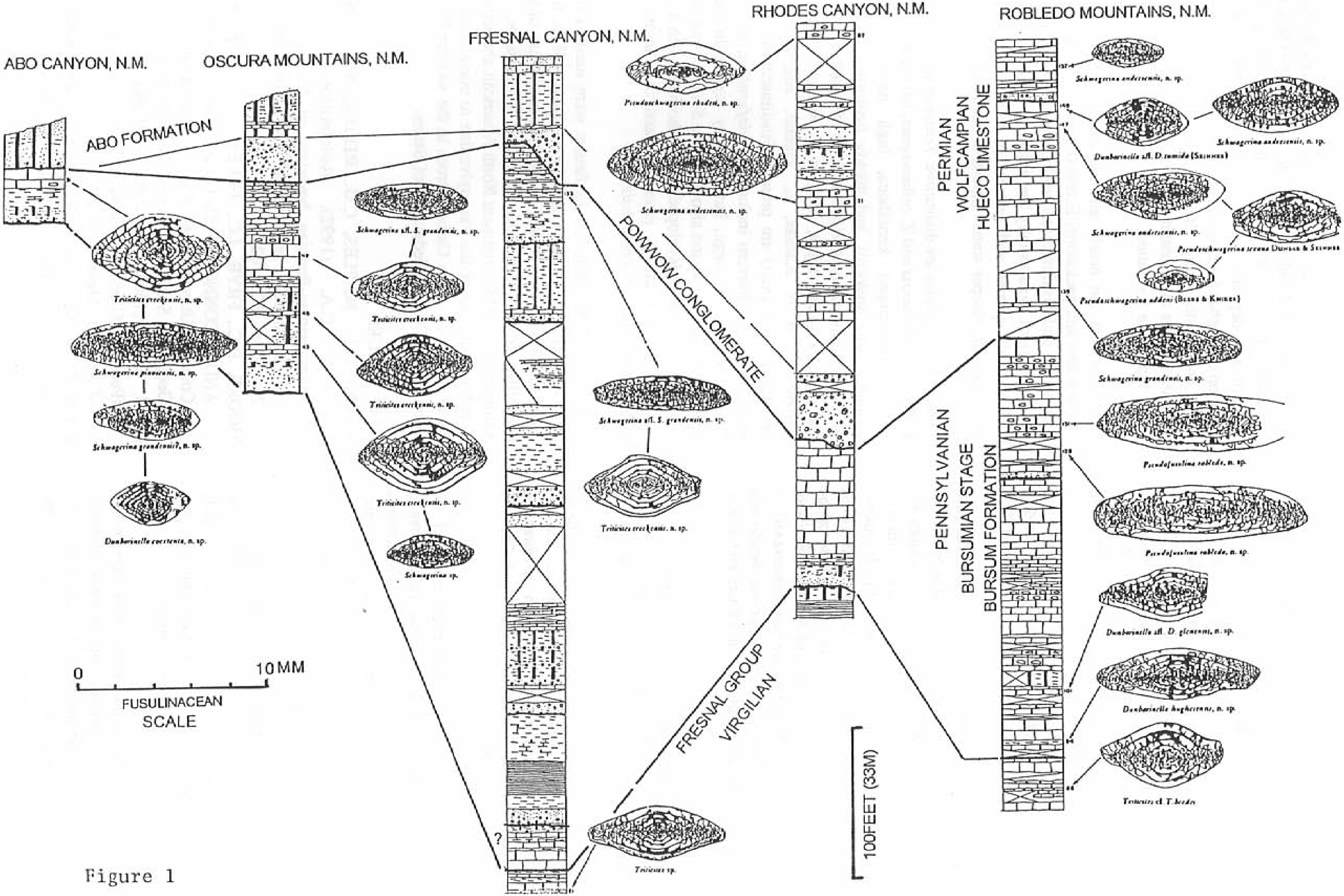

Figure 1

Columnal sections of the Bursum Formation in southern New Mexico and West Texas (modified from Thompson, 1954).

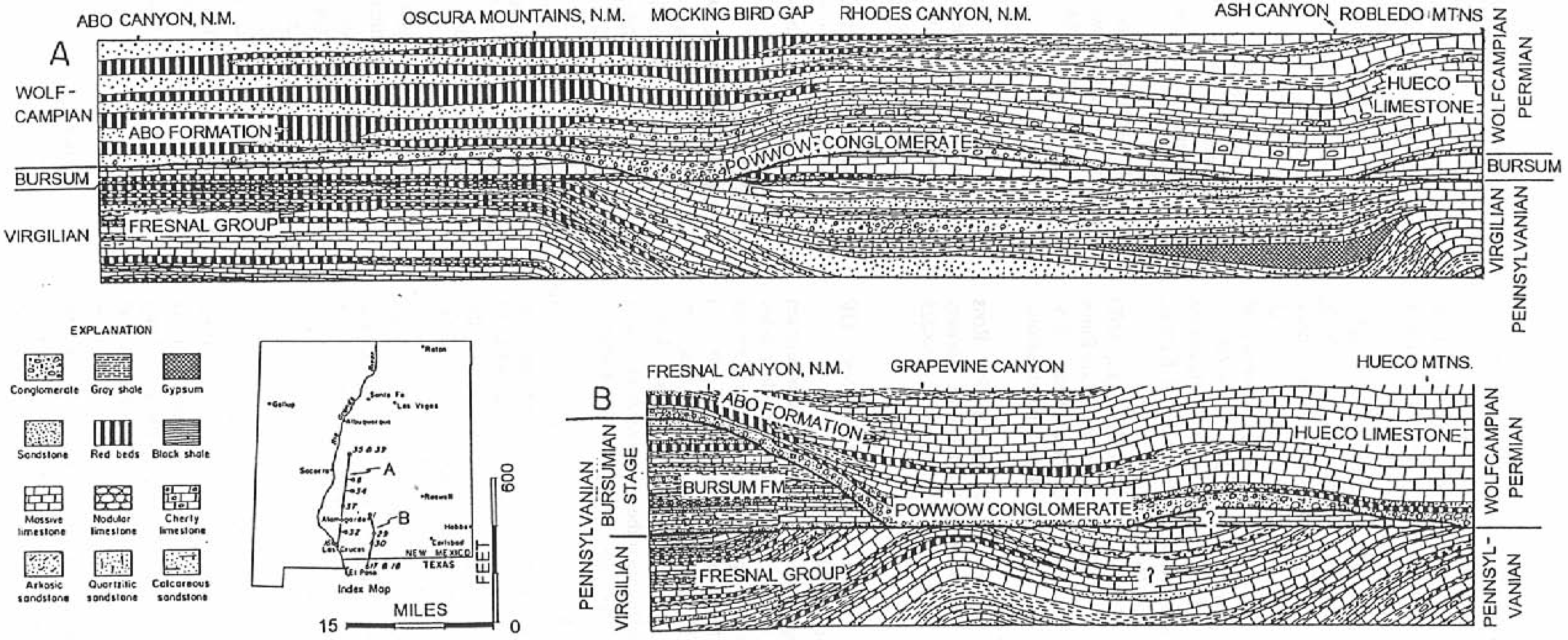

Figure 2

Stratigraphic profiles in southern New Mexico and West Texas showing position of Bursum Formation between beds of Virgilian age and Wolfcampian age.

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4. DESIDERATA FOR DESCRIPTIONS OF PERMIAN CORAL FAUNAS

Corals are among the most obvious fossils in Permian marine limestones of the world and can be excellent index fossils if properly worked up. Many studies of Permian coals are presently being pursued worldwide. It is a sometimes practice for describers of the coral faunas to restrict their works to certain kinds of corals. Some consider only colonial Rugosa, others emphasize cerioid or solitary Rugosa, and some concentrate only on Tabulata.

Three areas with reasonably completely known Lower Permian (Wolfcampian and at least some Leonardian) coral faunas are considered here to determine what the affect of this practice might be on the loss of data to the incompletely described faunas elsewhere: the McCloud limestone of northern California, the stratigraphic sequence including the Riepe Spring Limestone, Riepetown Sandstone, and Arcturus Formation of east-central Nevada, and the Bird Spring Limestone (Permian part) of southern California and southern Nevada.

Northern California has the thickest of the three sequences and probably had the most coral-friendly environment with a consequent large number of genera: 23 (Wilson, 1982, 1985). Of these, 26.3% are fasciculate Rugosa, 30.4% are cerioid Rugosa (and cerioid asteroid), 21.7% are solitary Rugosa, and 21.7% are Tabulata. If only the Rugosa had been reported, then 21.7% of the genera would be unknown. If only the colonial Rugosa had been reported, then 43.4% of the genera would be unknown. If only the cerioid Rugosa had been reported, then 70.2% of the genera would be unknown.

The east-central Nevada area has only 13 genera (Wilson and Langenheim, 1962), perhaps fewer in part because of some missing basal Permian strata and because of thick sandstone units. If only the Rugosa had been reported, then 15.3% of the genera would be unknown. If only the colonial Rugosa had been reported, then 30.6% of the genera would be unknown. If only the cerioid Rugosa had been reported, then 54.4% of the genera would be unknown.

The southern California-southern Nevada area has 13 known genera (Wilson, 1991, in press; Wilson and Langenheim, 1993). If only the Rugosa had been reported, then 30.7% of the genera would be unknown. If only the colonial Rugosa had been reported, then 38.3% of the genera would be unknown. If only the cerioid Rugosa had been reported, then 84.4% of the genera would be unknown.

Clearly, these losses to the faunal numbers would have altered conclusions that have been drawn from the data. Clearly also, such additions to partially described faunas would be assets to the conclusions that have been drawn.

It would be a contribution to the study of Permian paleontology and stratigraphy for workers to collect entire coral faunas and describe them.

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5. NOTES ON THE PERMIAN TECTONICS OF THE CENTRAL SOUTHERN ALPS (ITALY)

In the central Southern Alps of Italy, the Permian structural evolution can be divided into two main sections which correspond to the major depositional cycles of the same system, known in literature (e.g., Italian I.G.C.P., 203 Group, ed., 1986). The former stage reaches up to, or slightly above, the Early-Late Permian boundary, while the latter belongs to younger Permian times. This deformative change deals with (a) the presence of a marked unconformity sealing a hiatus of yet unknown duration; (b) an abrupt lithological and palaeogeographical evolution, generally from terrigenous coarse-fine grained fluvial and lacustrine deposits (Collio, Tregiovo and other units), associated with or replaced by conspicuous volcanic products, to sandy and ruditic fluvial redbeds (Verrucano Lombardo, Val Gardena Sandstone), which record widespread erosion and the end of any extrusive activity; (c) a general plate re-organisation, well attested by a number of subvertical faults which cut the lower cycle deposits and are sutured by the overlying redbeds.

In general terms, the Permian structural history of the central Southern Alps can be summarized as follows:

The early tectonic stage

The siliciclastic and volcanic continental deposits of the lower depositional cycle infilled narrow and elongated intramontane subsiding fault-bounded basins. The Collio, Tione and Tregiovo basins are the most representative examples of the investigated region, as well as the Orobic basin to the northwest. During the Early Permian, the Giudicarie and other associated lines (like the Sabion and Foiana lines) can be interpreted as active crustal signatures. They formed the basin boundaries and gave rise to tectonic scarps, the presence of which strongly influenced the sedimentation into the adjacent lows. Moreover, the Giudicarie and other lines were sites of igneous eruptions.

The connection of these faults with the evolutive context of the above Permian basins, the tectonic structures in some areas, and the sedimentary framework of the basins lead to interpretation of them as strike-slip basins with transitional tectonics regionally controlled by dextral movements of the Permian Giudicarie line (Cassinis and Perotii, 1994; Fig. 1). This transcurrent activity was probably responsible for the opening of the Tione and Tregiovo basins, which are delimited to the east by other lines.

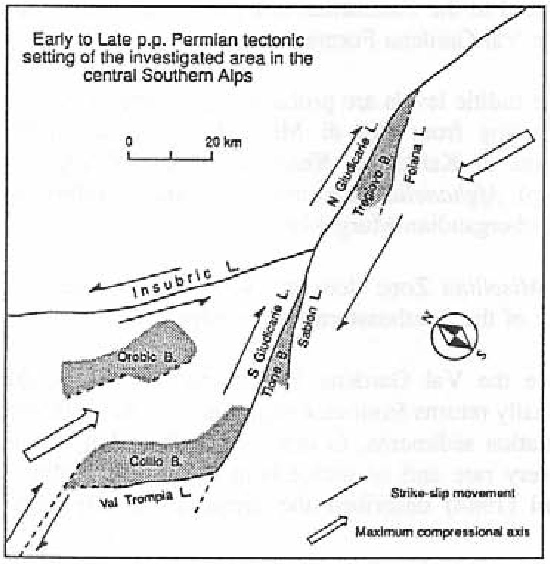

Figure 1

The Val Trompia Collio basin could in turn be interpreted as a pull-apart basin, with the typical "lazy Z" shape (Mann et al., 1983), which is evident in the eastern sector where the basin changes direction. This basin spread within two main dextral faults, that is between the Giudicarie line to the east and another hypothetical parallel line to the west, presumably situated in the Camonica Valley or nearby. Thus, the present Val Trompia line corresponds to the Alpine compressional reactivation of one Permian fault of prevalent extensional character, which southerly delimited the Collio basin.

The late tectonic stage

The Upper Permian redbeds, which are widespread over a vast part of the Southern Alps, unconformably cover the Early Permian basins and the surrounding highs, stepping down onto the Hercynian rock basement. A relative uplift of the South-Alpine region and a progressive levelling of the topography characterized these later Permian times, in association with a general extensional regime probably related to early rifting. The faults established during the first stage were sutured by these redbeds, or subjected to reactivation and at places to tectonic inversion. The main older transcurrent faults probably were also involved themselves into such extensional regime.

Clear examples of this Permian structural re-organization are reported from a number of Southern Alpine areas (e.g., Venturini, 1990; Cassinis and Neri, 1992; Massari et al., in press). In our opinion (Cassinis and Periotti, 1994), the sedimentary and tectonic framework of the Val Trompia Collio basin represents an excellent example of such structural development.

Stress field evolution during the Permian

The palinspastic reconstructions inferred from numerous palaeomagnetic data on Permian rocks (Heller et al., 1989) indicate that the South-Alpine domain underwent a counterclockwise rotation of almost 50° to 60° with respect to a stable Europe, probably about the end of the Mesozoic times. Rotating the present tectonic frame to its position during the Permian, it displays a geometry compatible with the tectonic setting of late-Hercynian Europe. In particular, the Giudicarie line assumes approximately an E-W orientation, fully entering into the extended dextral megashear zone stretching, in the Permo-Carboniferous from the Appalachians to the Urals (Arthaud and Matte, 1977; Fig. 2).

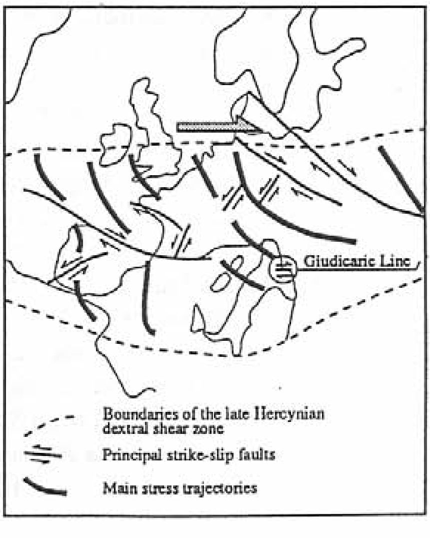

Figure 2

Conclusion

In short, the Permian structural evolution of the central Southern Alps seems to indicate that the final act of the Hercynian orogeny was followed by progressive extensional conditions and early consistent transcurrent movements. Such tectonics were the prelude to the intense Mesozoic rifting, which led to the opening of the Tethys ocean. In particular, inside this geological scenario, the Giudicarie and the Val Trompia lines seem to have played a significant role. Moreover, during the Alpine mountain building, such lines strongly influenced again the structural framework set up by the Late Cretaceous and Neogene compressions.

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6. A SCHEMATIC RECORD OF THE ITALIAN PERMIAN SEDIMENTS WITH FUSULINIDS

In Italy, marine sediments of Permian age can be found in four different areas: a) in the Southeastern Alps; b) in Tuscany; c) in Basilicata; d) in Sicily. They represent, together with those of Tunisia, the most western sediments of the Permian Tethys. In almost all of these rocks fusulinids are present, whereas cephalopods and conodonts important for biostratigraphy have been found only in Sicily. Therefore, I shall give a summary picture of the biostratigraphy of Italian Permian marine sediments based on the fusulines, and for schematic purpose, I shall refer almost exclusively to the generic names.

a) The Southeastern Italian Alps

The Permian succession is one of the best-known in the world. In the past 60 years, it has been examined in great detail and with great passion and competence by Prof. F. & G. Kahler (1937, 1980 and 1989).

At the base of the series, the Rattendorf Group (*Pseudoschwagerina* limestones) includes sediments of the Asselian-Sakmarian stages. The first appearance of *Occidentoschwagerina* indicates the beginning of the Asselian which ends with the Zellia Zone. Above, there is the Trogkofel Group. The name derives from Mount Trogkofel (in Italian "Creta di Aip") on the Italian-Austrian boundary line.

In this group, *Praeparafusulina lutugini* indicates the base of "Artinskian" (=Yachtashian), but all the *Pseudofusulina vulgaris* zone seems to be represented. The Trogkofel Group can appear with two different lithologies, known respectively as 1) Col Mezzod limestone and 2) Goccau limestone. In the former, the presence of *Eoparafuslina* (*Eoparafusulina*) and *E.* (*maccloudia*) can indicate the Late Sakmarian stage. In the latter, *Minojapanella* and *Pamirina* seem to indicate the Bolorian.

In the Adriatic Sea, levels of the Trogkofel Group have been found in the AGIP Oil Co. well "Amanda 1 bis". Above the Trogkofel Group, the "Breccia di Tarvisio", a ruditic deposit, signals the beginning of the new phase that will lead to the continental and paracontinental conditions of the Val Gardena Formation.

These ruditic levels are probably the source of the samples originating from Col di Mezzod (1978) containing the remains of Kahlerina, *Neoschwagerina* (*N. craticulifera* Group), *Afghanella*, *Sumatrina*, etc., and therefore datable as Kurbergandian-Murgabian.

The *Misellina* Zone does not seem to be present in any series of the Southeastern Italian Alps.

Above the Val Gardena Formation, the marine domain gradually returns from east-southeast and the Bellespophon Formation sediments. In this formation in Italy fusulinids are very rare and of scarce help to biostratigraphy. Only Pasini (1984) described the presence of extremely rare

Cadonofusiella and *Reichelina*. The formation should therefore be dated as Dzhulfian-Dorashamian.

The boundary between Permian and Triassic ages is marked by the "Tesero horizon" with some *Nankitella*-levels in the lower part and the only find of a small specimen which is probably a *Palaeofusulina* (Changsinghian age?).

b) Toscana

At about 100 km south of Florence, near Siena, an association of fusulinids of the latest Carboniferous-early Permian age (from Gzhelian to Sakmarian) has been found in small pebbles belonging to the Mt. Quoio Formation of the "Verrucano Group" of Triassic age. The association is made up of the genera *Staffella, Schubertella, Boultonia, Pseudofusulina, Daixina* and *Eoparafusulina* (*Eoparafusulina*) (Engelbrecht et al., 1988).

Praeparafusulina lutugini (early "Artinskian") has been described within a sample from Elba (Tyrrenean Sea near Leghorn). I believe that here too it originates from Triassic levels. Another association of early Permian "Fusulines" has been described in the ENEL well PC 33b at -3.024, 40 m (Pandeli and Pasini, 1990). It includes *Praeparafusulina* cf. *lutugini, Polydiexodina* (*Eopoloydiexodina*?), *Misellina*(?), *Cancellina* and therefore, it probably datable as latest Bolorian to Kubergandian.

Unfortunately, the stratigraphic position of the sample is not clear and perhaps in this case also, it is a reworked rock.

c) Basilicata

Permian "Fusulines" have been found in pebbles of only 50 cm in diameter, in the Mt. Facito Formation of the Triassic age. The fusulinids that have been found and the remains of the microfauna in the pebbles denote the presence of Permian sediments of a Bolorian age (presence of a probably *Pamirina darvasica*) to Upper Murgabian (with *Neoschwagerina "craticulifera"* and *Afghanella*) probably reworked and resedimented before in the late Permian (with *Codonofusiella* and *Dunbarula*) and subsequently in the Triassic, where they are now found (Ciarapica et al., 1988).

d) Sicily

Permian fusulinids can to be found in the Roccapalumba-Lercara area and in the "Sosio Valley" (western Sicily). In these areas, Catalano et al. (1991) described conodonts, radiolarian and ostracodes of early middle and late Permian (up to late Changsinghian) deep water deposits.

The remains of a carbonate platform, such as the celebrated limestones of the Sosio Valley (and some isolated samples of *Roccapalumba* and *Lercara*) with well known fusulinid associated (*Kablerina, Yangkienia, Raeuserella, Eoparafusulina*(?), *Chusenella, C.* (*sosioella*), *Rugososchwagerina, Neoschwagerina, Verbeckian, Dunbarula*, etc.) are referable to the Kubergandian-Murgabian stages. These limestone blocks and the deep water deposits belong to a chaotic pile of Permian-Mesozoic and younger (Miocene) rocks.

Further studies on Italian Permian

From the work previously outlined, it is clear that paleontologic research on the Permian can proceed especially in the Southeastern Alps.

Concerning this region, important studies on the fossils of sediments of the continental environments are being published. In the other areas, research on subsurface geology will be pursued, with which we shall attempt to discover where to find "in situ" the formations from which the allochthonous Permian rocks originate.

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7. PERMIAN BRACHIOPOD BIOGEOGRAPHY OF THE WESTERN PACIFIC IN RELATION TO TERRANE DISPLACEMENT AND CLIMATIC CHANGE

This Australian Research Council funded multi-year project commenced at the beginning of 1992 in an attempt to unravel the changing patterns and timing of Permian marine provincialism in the Western Pacific region in relation to terrane movement and/or climatic change.

It is believed that changes in palaeogeography and palaeoclimates both have profoundly affected the distributional patterns of marine organisms. The timing of these changes is likely to be best revealed if the finest possible time scale is used. In this respect our methodology differs from most previous similar studies. Our approach to this project is threefold, as summarised below.

1. Establishment of Permian stage by stage biostratigraphical/taxonomic data bases

Our initial task is to compile for each Permian stage (occasionally substage or a combination of two stages, depending on the resolution of biostratigraphical dating and correlation) a biostratigraphical data base containing the following information:

A: Locality of each fauna;
B: Present-day geographical coordinates of the locality;
C: Tectonostratigraphical identity;
D: Permian palaeolatitudes of the tectonostratigraphic unit (if available);
E: Stratigraphical unit;
F: Principal lithology/facies of the locality;
G: Associated fusulinid/ammonoid zones (if established);
H: Number of species;
I: Number of genera;
J: Endemicity (Percentage of endemic genera);
K: Sampling efficiency (see Stehli, 1970);
L: Permian ratio (see Stehli and Grant, 1971);
M: Principal references.

Apart from the biostratigraphical data base, a separate taxonomic data base is also compiled for each stage, listing the species as recorded in the references consulted, species as revised by us in the light of modern taxonomy, and the families the revised species belong to. Up to the present we have compiled three data bases for the Asselian/Tastubian, Baigendzhinian/Early Kungurian, Kazanian-Midian time slices respectively (See Shi and Archbold, 1993a, 1993b, 1994a). Compilation of other Permian data bases are also under way. The published data bases are available for purchase from us, either in hard copy or disk format.

2. Quantitative analysis

A data matrix consisting of the presence/absence data of brachiopod genera of each Permian stage (or substage or a combination of stages/substages) is then compiled from the above biostratigraphical and taxonomic data bases. This data matrix is then subjected to multivariate statistical analysis. We employ a wide range of multivariate techniques in order to cross-compare results. These techniques include cluster analysis (using different similarity coefficients and different clustering algorithms), principal coordinate analysis, correspondence analysis, detrended correspondence analysis, nonmetric multidimensional scaling, and discriminant analysis. The purpose of applying these techniques is for manipulating input data more efficiently (at least we hope so) and for generating working hypotheses that have to be tested independently. One of us has recently reviewed all pertinent multivariate methods with respect to palaeobiogeographical data (Shi, 1993a, 1993b, 1994).

3. Interpretation of results from quantitative analyses

The output from the quantitative analysis is either a dendrogram or a two- or three-dimensional scatter plot of faunal stations and/or brachiopod genera. Grouping patterns of faunal stations or genera are usually present in these diagrams. Interpretation of these groups, however, is critical and usually the ultimate goal of a quantitative palaeobiogeographical study. Our approach to this problem is, first, to generate a working hypothesis from the patterns recognised and then to test this hypothesis using other geological (sedimentological or paleomagnetic) or ecological data/theories, including theories of dispersal biogeography, vicariance biogeography and tectonic displacement.

Preliminary results

Up to date, we have published (or in press) results on the Asselian-Tastubian (Shi and Archbold, 1993c) and Baigendzhinian-Early Kungurian (Shi and Archbold, 1994a) distributions of brachiopod faunas, and the results are promising. In the case of the Asselian-Tastubian time interval, we have recognised through the quantitative analysis a new faunal province, called the Indoralian Province, which includes faunas of this age from Australia, Shan-Thai terrane, Peninsular India and much of the Himalayan terrane. This province represents the cold-water fauna of eastern Gondwana developed during the extensive Gondwanan glaciation. For the Baigendzhinian-Early Kungurian data, two very interesting transitional faunal provinces have been identified. The one in the north, named the Sino-Mongolian Transitional Province, is restricted to North China, Mongolia, Russian Far East (Sikhote Alin terrane) and some parts of Japan. The recognition of this province readily conforms to the concept of a Middle Permian Inner Mongolian-Japanese Transitional Zone proposed by Tazawa (1991, 1992). The southern Transitional Province embraces faunas from the Lhasa terrane, Himalayan terrane, Shan-Thai terrane, Timor and western Iran Jaya. In other words, the province largely overlaps with the geographic extent of the Cimmerian Continental Strip or Continent(s) of Sengor (1979). The cause for the development of the two transitional provinces in the western Pacific during the Middle Permian is not clear but we (Archbold and Shi, 1994; Shi and Archbold, 1993d, 1994b, 1994c; Shi et al., 1994) have proposed a scenario involving changes in climatic regimes and terrane dispersal across the Permian Tethys or a combination of both.

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8. PERMIAN PALAEONTOLOGY OF WESTERN AUSTRALIA

Within the region of Gondwana, the marine Permian succession of Western Australia offers one of the most complete marine sequences and the most important for international correlations. While regions peripheral to Gondwana during the Permian offer a few fusulinids and conodonts to add to debates about international stratotypes and boundaries only sporadic ammonoids aid the Permian biostratigraphers of Australia. Other groups such as palynomorphs, foraminifers, brachiopods and molluscs may show links with Himalayan, Uralian and Boreal faunas and floras but questions of timing and the correlation of such links are often complex. Nevertheless, the Western Australian faunas have traditionally been correlated with the Uralian (two-fold) sequence, often with considerable success, on the basis of considering data from a wide range of faunal elements. The principle of considering as much of the total fauna as possible (well espoused by Cooper and Grant, 1973) appears to stand in sharp contrast to recent proposals (Glenister et al., 1992) to define the base of the

Upper, or Late, Permian (Middle Permian in their usage), on the basis of a single conodont that will almost certainly never be found in temperate or cool-water Permian faunas. Such proposals offer little help in the problems of true global correlations but may assist in correlations between tropical faunal provinces of limited extent.

It is appropriate to announce to all Permophiles the appearance of an exhaustive volume on the "Palaeontology of the Permian of Western Australia" (see S.K. Skwarko (editor), 1993 in the reference list). Contributions from 23 scientists cover such topics as Permian geographical and tectonic features, palaeoclimate, correlation and age of Western Australian Permian strata and past studies of Western Australian Permian fossils. Fossil groups covered include foraminifers, sponges, corals, bryozoans, brachiopods, bivalves, ammonoids, nautiloids, gastropods, scaphopods, conulariids, ostrocods, trilobites, asteroids, blastoids, crinoids, conodonts, palynomorphs, plants, fish, annelids and trace fossils. One hundred and two large format international A4 plates illustrate the volume and extensive microfiche supplements provide details of all fossil species described from Western Australia. Nautiloids, scaphopods and the few conodonts are yet to be formally described.

As with all such volumes some manuscripts were completed earlier than others and a minor update is required to mention new work on the Western Australian Permian during the last few years. A preliminary new zonation of the foraminifers of the Australian marine Permian is now available (Palmieri, 1990) and significant contributions to Western Australian Permian palynology have been added to the record (Backhouse, 1991, 1993). Significant additions have been made to the knowledge of the echinoderm faunas (Webster and Jell, 1992). New data is available on fossil floras (McLoughlin, 1992a, 1992b, 1993) and fish (Daymond, 1993). Work has continued on the brachiopod faunas (Archbold, 1993a; Archbold and Shi, 1993; Archbold and Thomas, 1993) and a zonation based on brachiopod assemblage zones has been published (Archbold, 1993b).

The volume is available for $AUST 60 plust postage $AUST 25 from: Mining Information Centre, Mineral House, 100 Plain Street, East Perth, 6004, Western Australia, Australia.

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9. PRELIMINARY REPORT ON THE PERMIAN CONODONT FAUNA OF DARVAS AND SE-PAMIR AND ITS IMPORTANCE FOR THE PERMIAN TIME SCALE

The Darvasian, Murgabian, Pamirian stages (Miklucho-Maklay, 1958), the Kubergandinian stage (Leven, 1963), Bolorian stage (Leven, 1979) and Jachtashian stage (Leven, 1980) have been defined in the Darvas and Pamir with stratotypes in this area. Also the Chihsian stage (Leven, 1975) was defined by a fusulinid succession in the Darvas, but its stratotype lies in South China. Therefore this stage was later re-named as the Bolorian stage to have the stratotype in the Darvas area, where the Chihsian fusulinid zones have been established. Jachtashian, Chihsian or Bolorian, Kubergandinian and Murgabian are often used as regional stages in the Tethys, whereas the other above stages are no longer used in the present Permian literature.

All stages established in the Pamir were fusulinid-defined mostly by Miklucho-Maklay, Leven and Davydov. Also later drastic redefinitions were exclusively made of fusulinid faunas. Thus, the original Murgabian comprised the *Neoschwagerina* faunas above the *N. simplex* Zone and the *Yabeina-Lepidolina* fauna. Later, the *N. simplex* Zone was added to the Murgabian (Miklucho-Maklay, 1963) and still later, the *Yabeina-Lepidolina* fauna was excluded from this regional stage and placed into the Capitanian (Leven, 1967), later into the Midian regional stage. In some horizons ammonoids are present. They have been attributed to the fusulinid-defined stages, but not used for defining the stage boundaries. For this reason, even the correlation between Darvas and SE Pamir is difficult, if ammonoids, but no fusulinids are present. Thus, the assignment of the basal Kochusuj Formation of SE Pamir (containing the Buz-Tere ammonoid complex) to the Bolorian or Jachtashian is not yet clear as stated by Leven et al. (1992), because in the uppermost type Jachtashian of the Darvas no ammonoids are present and in the lower Kochusuj Formation no fusulinids are known.

Because the fusulinids, which have been used for definition of the Jachtashian to Murgabian (and Midian) regional stages are only known in the Eurasian Tethys and in some narrow displaced terranes at the west coast of North America, which have the same Tethyan origin, none of the Tethyan regional stages of the Jachtashian to Midian interval (with exception of the Midian=Abadehian all defined in the Pamir) can be used for the Permian standard scale. This is also clear for other reasons. Because of the geographic isolated position, the Pamirian stratotypes of the Jachtashian, Bolorian, Kubergandinian and Murgabian stages were always hardly accessible. Since the disintegration of the former Soviet Union these stratotypes, as well as the Midian stratotype (Dzhagadzur in Transcaucasia), are totally inaccessible. The conodonts of the Pamirian stratotypes have a CAI of 4-5. Therefore these stratotypes are unsuitable for paleomagnetic and palynological investigations. In the Midian stratotype, in turn, all pelagic fossils (ammonoids and conodonts) are missing. Even the fusulinid *Yabeina*, by which the range of the Midian is defined, is missing in the Midian stratotype. Therefore the base of the Midian cannot be exactly defined in terms of its standard zonation in the Midian stratotype.

However, if we regard the terms Jachtashian etc. for what they really are, fusulinid ages for the Eurasian Tethys, then they are very important for subdivision and correlation of the widespread Permian shallow-water carbonate platform deposits of the Tethys. These carbonates can with some difficulty be correlated with fossils other than fusulinids. For this purpose, additionally the correlation of these fusulinid ages with ammonoids and conodonts are necessary to correlate these fusulinid ages within the proposed Permian standard. Because the Pamirian stratotypes are no longer accessible (see above), only formerly collected material can be investigated. In the pelagic sequences of the SE Pamir (with the Kubergandinian and Murgabian stratotypes Kuberganda Valley and Kutal-Dzhamantal), fusulinids occur only in coarse-grained, often microconglomeratic reworked beds with numerous shell fragments and grains of shallow-water carbonates and magmatic material. Only this material was sampled for fusulinid investigations. It is not very suitable for conodont studies and contains few and often reworked conodonts. The basinal pelagic limestones and cherts, very suitable for conodonts and radiolarians, were not sampled. Some pelagic material was available from ammonoid collections of latest Early Permian. From these rocks rich conodont collections are present for the assumed Bolorian equivalents of the SE Pamir in the collection of Prof. Barskov.

The present report is based on my own collections from SE Pamir and on the material of Prof. Barskov which could be determined by Kozur in 1991 (courtesy of Prof. Barskov, Moscow).

The oldest conodonts from the Pamir are *Mesogondolella bisselli* (Clark and Behnken) and *Sweetognathus inornatus* Ritter from the lower part of the upper Jachtashian at its stratotype Vozgina in the Darvas (Reimers, 1991), where they occur in the lower *Chaleroschwagerina vulgaris* Zone. If they are not reworked, this part would belong to the Early Artinskian. So far the entire *C. vulgaris* Zone was regarded as Late Artinskian.

Two very distinct conodont faunas occur in the Kochusuj Formation of SE Pamir, which is generally placed into the Bolorian. In the lower member *Mesogondolella bisselli*, *M. shindyensis*, Kozur, *M. intermedian* (Igo), *M. gujioensis* (Igo), very rarely *M. asiatica* (Igo), *Neostreptognathodus exsculptus* Igo, *N. ?foliatus* Igo, *N. ?murgabicus* (Reimers), very rarely transitional forms between *N. pequopensis* Behnken and *N. leonovae* Kozur (and at the boundary to the overlying conodont fauna the later species themselves), *Pseudohindeodus nassichuki* (Kozur), *P. oertlii* (Kozur), *Rabeignathus bucuramangus* (Rabe), *R. pamiricus* Reimers, *Sweetognathus guizhouensis* Bando et al., *S. iranicus* Kozur et al. (=*S. flexus* Reimers), *S. venustus* Reimers, *Vjalovognathus shindyensis* (Kozur). *N. exsculptus* have been determined by Kozur (1978) and Reimers (1991) as *N. sulcoplicatus* (Youngquist et al.).

N. exsculptus and *N. ?foliatus* begin in the Skinner Ranch Formation of Texas about the same level as *N. pnevi* Kozur and Movshovich. The first appearance of the latter species was used to define the base of the Kungurian in the Urals (Kozur, 1993). Therefore this fauna corresponds to the lowermost conodont zone of the Cathedralian of Texas and it is younger than the Artinskian of the Urals. Unfortunately, the fusulinid age of this fauna is unknown. Only in the uppermost part of the Kochusuj Formation begin fusulinids of the upper Bolorian which are also present in the overlying Shindy Formation and in the lower part of Kubergand Formation. The fusulinid age of the basal Kochusuj Formation is therefore either early Bolorian or Jachtashian.

A little older is the fauna of the Bitauni ammonoid horizon which contains according to van den Boogaard (1987) only *M. bisselli* and *V. shindyensis*. All the above more advanced *Mesogondolella* are missing, whereas the absence of the *Neostreptognathodus* and *Sweetognathus* is facies controlled (fully pelagic deposits without transported shallow-water elements). The fauna belongs to the late Artinskian. Because this ammonoid fauna was equated with the Buz-Tere ammonoid complex, it was placed into the Bolorian. However, like for the *N. exsculptus* conodont fauna of the basal Kochusuj Formation, it may have uppermost Jachtashian fusulinid age.

By the presence of *Vjalovognathus shindyensis*, this conodont fauna is a typical fauna of the eastern Gondwana conodont province, to which belongs the Pamir, Timor and according to a pers. comm. of Prof. Metcalfe also eastern Australia.

Still within the lower Kochusuj Formation, a distinct change in the conodont fauna can be observed and a rather rich, but monotonous conodont fauna with *Mesogondolella idahoensis* (Youngquist et al.) and *Neostreptognathodus leonovae* Kozur begins. Except of these species only *P. nassichuki*, *S. guizhouensis* and *S. venustus* are rarely present. Leonova and Dmitriev (1989) reported also the very rare occurrence of *M. asiatica*, *N. prayi* Behnken and *S. adjunctus* Behnken in this conodont fauna, but Reimers (1991) did not report these forms in the *M. idahoensis-N. leonovae* Zone and also we could not find these forms in this level. Because *N. leonovae* is not known outside the Pamir and characteristic Cathedralian guideforms are missing, also this fauna belongs probably to the East Gondwana conodont province.

Kozur (1978) separated this conodont fauna as *N. leonovae* Zone from the underlying *V. shindyensis* Zone. Reimers (1991) found the same distinct differences between these two conodont faunas. However, because he reported few specimens of *N. idahoensis* and *N. leonovae* in the uppermost *V. shindyensis* fauna of the Igrimijuz section, he united both very different conodont faunas in the *N. leonovae* Zone. His figured "*Neogondolella*" *idahoensis* from this level is a typical *M. shindyensis* without cusp and with widely separated denticles even in the anterior carina. One of his figured *N. leonovae* from the *V. shindyensis* fauna is a transitional from between *N. pequopensis* Behnken and *N. leonovae*, reported also by Kozur from this level. The other specimen is a *N. leonovae*. The occurrence of a guide form of the overlying fauna near the boundary between both faunas does not justify the uniting of these two very different conodont faunas. Therefore we separate furthermore the *M. intermedia-V. shindyensis* Zone from the *M. idahoensis-N. leonovae* Zone. The boundary between these two zones may coincide with the boundary between the Jachtashian and Bolorian fusulinid ages, but it is surely younger than the Artinskian-Kungurian boundary.

Upper Bolorian conodont faunas are unknown. The conodont faunas from the Kubergandinian and younger beds of SE Pamir have been derived from fusulinid-bearing beds with reworked faunas within fusulinid-free pelagic deposits. For this reason also the conodonts show strong reworking. Movshovich (1986) reported from the upper Kubergandian *M. idahoensis*, *M. intermedia*, *P. nassichuki* and *Gullodus sicilianus* (Bender and Stoppel). Only the later form occurs in the Middle Permian of Sicily. All other species are typical world-wide distributed guide forms for the Cathedralian (*M. idahoensis*) and early Cathedralian (*M. intermedia*) or occur in the lower Bolorian of SE Pamir (*P. nassichuki*). Reimers (1991) reported the lower Bolorian *N. leonovae* from the Early Kubergandinian of Darvaz. Also this form is probably reworked.

Murgabian beds from several localities (including the type section Kutal) yielded beside reworked Early Permian conodonts *Mesogondolella phosphoriensis* (Youngquist et al.) and *M. siciliensis* (Kozur), a typical fauna for cold bottom water, known also from Sicily, Oman and partly from the Phosphoria Formation of western U.S.A. Both species are known from Roadian and Wordian deposits, ammonoid-bearing beds with *M. siciliensis* have always a Wordian age. The strong reworking of older forms and the exclusive occurrence of cold bottom water smooth *Mesogondolella* species which have a longer range than the serrated forms and which are not yet well correlated with any proposed world standard, are a further reason that the type Kubergandinian and type Murgabian are unsuitable as world standards.

Faunas of Midian fusulinid ages (Karasin beds and their equivalents) yielded beside reworked Early Permian conodonts the same above Middle Permian conodont fauna, dominated by *M. siciliensis* and *M. phosphoriensis* and additionally *Iranognathus* n. sp., *Mesogondolella* n. sp. are present. The following explanation can be given for this fact: (1) The *M. phosphoriensis-M. siciliensis* fauna ranges up to the Capitanian; (2) the lower Midian is a time-equivalent of the Upper Wordian; (3) *M. phosphoriensis* and *M. siciliensis* are reworked elements. Very rarely *M. postserrata* (Clark and Behnken) is present in the late Midian.

Post-Midian conodonts faunas from the Takhtabulakh Formation yielded *Clarkina altudensis* Kozur and the stratigraphically youngest faunas contain *Clarkina subcarinata* (Sweet), indicating a Changsingian age.

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10. THE PERMIAN OF CENTRAL AND EASTERN THAILAND (WESTERN MARGIN OF THE INDOCHINA MICROCONTINENT)

The Permian of Peninsular Thailand has been the subject of a short note in Permophiles (1991) and of a more detailed paper in the Journal of Southeast Asian Earth Sciences (1994). The present paper concerns very different Permian sediments and fossils which belong to the western part of the Indochina Microcontinent.

WHAT HAS CHANGED DURING THE LAST FEW YEARS?

The rapid development of agriculture in many areas of Thailand has made easily accessible a great number of Permian exposures. Moreover, the disappearance of the jungle and the construction of new roads have paved the way for better observations. Accordingly, a detailed study of the Permian is presently possible and the "monotonous" stacks of limestone start to reveal a complicated history which was unthought-of in the past.

Sections extending continuously from Carboniferous to Permian have been identified; the best ones range from Middle Carboniferous (Moscovian) to Middle Permian (Murghabian).

The aim of this paper is to give some information on the discoveries made during the last four years.

LOWER PERMIAN

Lower Permian sediments belonging to the *Pseudoschwagerina* Zone are exposed in southeastern, central and northeastern Thailand. Limestone is prominent. However, sandstone and shale are locally well developed and may suggest the presence of ancient estuaries. In addition to the wide areas where limestone is prominent, a band of shales, cherts, allodapic limestones and volcanoclastic rocks (Nam Duc Formation) is well exposed east of Lom Sak and extends southward almost to Saraburi; it is considered a deep elongated basin. The limestones deposited in shallow marine areas are very rich in diverse fossils; foraminifers, corals and brachiopods are widely distributed. Trilobites are very rare. The search for conodonts has been very limited. To date, studies have been focused mainly on fusulinids and brachiopods (Pitakpaivan, 1966; Yanagida, 1967; Igo, 1972; Ingavat et al., 1980; Sugiyama and Toriyama, 1981). Corals which were largely unknown four years ago, have been discovered in Loei Province of northeast Thailand (Fontaine et al., 1994) and in two areas of central Thailand (new data); they consist of solitary (without and more commonly with dissepiments), very rare fasciculate and occasionally abundant massive Rugosa.

The Carboniferous in Loei area consists of interfingering shale, argillaceous limestone and limestone. The boundary between Carboniferous and Permian is located in clastic rocks and elsewhere in poorly fossiliferous or dolomitic limestone; it is very difficult so far to indicate very precisely its position in the field.

PERIOD BETWEEN *PSEUDOSCHWAGERINA* ZONE AND *NEOSCHWAGERINA* ZONE

Very few fossiliferous localities have been assigned to this period and these localities belong mainly to Kubergandian and less commonly to Bolorian; Yakhtashian has not been clearly identified. At the southern end of Khao Somphot in central Thailand, the interval between *Pseudoschwagerina* Zone and *Neoschwagerina* Zone is represented by dolomitic limestone which has not yielded any fossil so far. In Loei area, it corresponds to a limestone which is commonly poor in fossils and contains no compound Rugosa, only a few Tabulata belonging to *Protomichelinia*. Accordingly, the period between *Pseudoschwagerina* Zone and *Neoschwagerina* Zone is characterized by environments which were not favourable to the development of abundant and diverse faunas.

NEOSCHWAGERINA-YABEINA ZONE

In the limestones belonging to this period, fossils are again in abundance and very diverse; they include algae, foraminifera, corals, brachiopods and very large pelecypods (Alatoconchidae). Corals consist of some Tabulata, rich and diverse assemblages of Rugosa; they built small reefs in many places.

During this period, some trends to emergence bringing influx of terrigenous materials are obvious; they interrupted temporarily limestone deposition. In the Saraburi area (central Thailand), an interbed of silty claystone, about 40 cm thick, contains terrestrial plants (Ingavat and Campbell, 1972). In the Takfa area, a horizon of the limestone hill called Khao Tabong Na is made of interfingering thin beds of limestone and red siltstone; it is 1 m thick and the limestone beds display symmetrical ripple-marks at their surface. In the Battambang area in Cambodia near the eastern border of Thailand, bauxite and fossil wood have been found in reddish shale and calcareous mudstone situated between a limestone containing *Sumatrina, Pseudodoliolina* and *Pseudofusulina* and a limestone rich in *Yabeina multiseptata* and *Parawentzelella*.

At the end of this period, a complete emergence started, but not at the same time everywhere. To the north in the Loei area, the Midian and even the uppermost part of the Murghabian appear to be absent; for instance, *Yabeina* has never been found there. On the contrary, this genus has been mentioned to the south in the Kabinburi area (Pitakpaivan and Ingavat, 1980). Emergence apparently started from the north by the end of Murghabian to reach the south by the end of Midian. Dzhulfian and Dorashamian are unknown in central and eastern Thailand.

CONCLUSION

The depositional history of the Permian sediments of central and eastern Thailand may be partially explained by changes in eustatic sea level. It needs tectonics to be fully understood, a conclusion already proposed by some other geologists after different studies. In Cambodia, the Lower Permian is unknown whereas sea covered a large part of this country during Murghabian-Midian; the absence of Lower Permian is difficult to be attributed to changes in eustatic sea level.

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11. PERMIAN PELAGIC AND SHALLOW-WATER CONODONT ZONATION

Conodonts are the most important guide fossils of the Permian. They occur in marine shallow-water and pelagic deposits and are only missing in intratidal carbonate platform and in glaciomarine cold-water facies. In shallow subtidal algae-fusulinid carbonates conodonts are mostly very rare. Like the radiolarians, but unlike the other important Permian guide fossils (ammonoids, brachiopods, fusulinids), the conodonts are not much affected by provincialism. Only in the Eastern Gondwana Province (Pamir, Himalaya, Timor, eastern Australia), the Early Permian conodonts show a distinct provincialism, indicated by the common occurrence of *Vjalovognathus shindyensis* (Kozur) and *Neostreptognathodus leonovae* Kozur, both missing outside this province. However, even in this conodont province the most important world-wide distributed guide forms are present, like *Mesogondolella bisselli* (Clark and Behnken), *M. gujioensis* (Igo), *M. idahoensis* (Youngquist, Hawley and Miller), *M. intermedia* (IGO), *Neostreptognathodus exsculptus* IGO, *N. ?foliatus* IGO.

However the Permian conodonts are strongly facies dependent. In shallow-water and pelagic deposits of the same age totally different conodont faunas may be present. In very shallow water deposits, conodonts are either missing or represented by the genus *Stepanovites*, and in North America by the very similar genus *Sweetina*. Like other fossils from this facies, these conodonts have only little stratigraphic value.

Beside *Stepanovites*, numerous conodont genera occur in Permian shallow-water deposits below the tidal flats, but the typical pelagic gondolellid conodonts are missing in such faunas. The Lower Permian shallow-water conodonts have higher stratigraphic value than the pelagic ones. Also, the shallow-water conodonts of the uppermost Permian are stratigraphically very important.

Stratigraphically important Permian shallow-water conodonts belong to the genera *Gullodus* Kozur (restricted to upper part of reef slopes), *Hindeodus* Rexroad and Furnish [with important guide forms in the Upper Permian and around the Permian-Triassic boundary; especially forms with partly fused carina, such as *H. julfensis* (Sweet), occur also in pelagic deposits], *Iranognathus* Kozur, Mostler and Rahimi-Yazd (Artinskian-Changxingian, some species are also present in pelagic deposits), *Merrillina* Kozur (Capitanian to lower Dzhulfian), *Neostreptognathodus* Clark (with several excellent guide forms of the Late Artinskian-Roadian), *Rabeignathus* Kozur (?latest Artinskian, early Cathedralian, both shallow-water and pelagic), *Streptognathodus* Stauffer and Plummer (common in shallow-water and pelagic Asselian, rarely up to the Early Artinskian), *Sweetognathus* Clark (several Early-Middle Permian guide forms) and *Wardlawella* Kozur.

Gondolellid conodonts (*Mesogondolella* Kozur, *Clarkina* Kozur) are restricted to pelagic deposits. Ribbed *Mesogondolella* are excellent guide forms, restricted to the Middle Permian. Also among the smooth forms are numerous guide forms, but their identification is partly more difficult if they do not have characteristic outlines.

The pelagic conodonts are well studied throughout most of the Permian. Shallow-water conodonts are well studied in the Lower Permian, especially in the Late Artinskian and Cathedralian, where they comprise the most important conodont guideforms. In the Middle Permian, except the Roadian, the succession of shallow-water conodonts is not yet well known, whereas the Upper Permian shallow-water conodont succession is well known and stratigraphically important, especially around the P/T boundary.

Fortunately, the shallow-water and pelagic conodont succession can be easily correlated (Tables 1, 2). In many samples, especially from slope deposits, pelagic and shallow water conodonts occur together and some conodonts occur both in shallow-water and pelagic rocks (see above). Thus, in the marginal parts of the Delaware Basin practically every conodont-rich sample has both the shallow-water and pelagic conodonts, which makes this area extremely important for Permian stratigraphy and a key area for defining world-wide applicable stages. Moreover, in this area also an abundance of other stratigraphically significant fossil groups are present, such as ammonoids, brachiopods, radiolarians and fusulinids. Their zonations can be well correlated with the conodont standard in this area. The same situation is present in the Asselian to Artinskian of the Cis-Urals. However, in many places reworking of older material can be observed. In the Upper Permian several Tethyan sections are known, where the shallow-water and pelagic conodonts occur together. This is a fortunate situation, because at this time there are only few conodonts known from other areas.

In the Delaware Basin and partly in the Cis-Urals and in the Upper Permian of the Tethys in several intervals joint pelagic-shallow water zonations can be established that are partly more detailed than the pelagic or shallow water zonations alone and can be used as standard zonations that are of world-wide applicability (Tables 1, 2). Therefore, the water depth dependence of the conodont faunas mostly does not cause problems for the conodont biostratigraphy. In the Middle Permian Guadalupian Series problems are caused by the temperature dependence of the pelagic gondolellid faunas. Shallow pelagic warm-water faunas are characterized by ribbed *Mesogondolella*. The phylomorphogenetic lineages of these conodonts are well known and well correlated with the ammonoid scale in the Delaware Basin and in South China. The cold bottom water pelagic faunas of the Tethys, of the Gondwanide margin and of the Phosphoria Basin in the western USA are characterized by smooth *Mesogondolella* of the *M. phosphoriensis-M. siciliensis* group. The exact range of the species within this group is not yet known. Problematic are successions, where these two different Middle Permian gondolellid faunas occur in superposition. Then abrupt changes in the gondolellid faunas are present which mask the true range of the pelagic conodont faunas. Similar problems are caused by water depth related differences with not clear relations to temperature differences within pelagic gondolellid faunas. For instance, in the shallow pelagic Altuda Formation of the southern margin of the Delaware Basin a phylomorphogenetic cline *M. postserrata* (Behnken) - *M. shannoni* Wardlaw - *Clarkina altudaensis* Kozur can be observed. The first appearance of the latter species is an excellent marker for definition of the upper boundary of the Capitanian stage. In the deep basin facies of the Delaware Basin the ribbed gondolellids are more rare, but the development from *M. postserrata* to *M. shannoni* can be observed in the basal part of the locally thin Lamar Limestone. Near the top of the Lamar the *M. postserrata* stock disappeared suddenly and it is replaced by *Clarkina crofti* Kozur and Lucas (=*C.* cf. *bitteri* in Kozur, 1992). This species with highly upturned lateral margins and a very long free blade is unrelated to both *M. shannoni* and *C. altudaensis* and has been derived either from *M. praexuanhanensis* Mei and Wardlaw or from *C. bitteri* (Kozur). *C. altudaensis* is missing in the deep basin facies.

Therefore, not every change in the gondolellid fauna of uninterrupted sections marks a phylomorphogenetic line. Partly it indicates an immigration of an other gondolellid stock because of facies changes.

A similar situation can be observed in South China. According Mei et al. (1994), there is a lineage *Mesogondolella postserrata* - "*M.*" *altudaensis*-*M. praexuanhanensis*-*M. xuanhanensis* within the uppermost Guadalupian of China. The figured specimens of "*M. altudaensis*" by Mei et al. (1994) are either distinctly serrated and belong to *M. shannoni* or, if they are unserrated, they have a distinct cusp. These conodonts are typical representatives of the *M. shannoni* Zone of the late Capitanian, and not from the *C. altudaensis* Zone. However, the presence of *C. altudaensis* in China can not be excluded, because all figured forms (belonging to the *M. shannoni* Zone) have been derived from the lower "*altudaensis* Zone". Therefore two different correlations between the conodont faunas of Texas and South China are possible (see Tables 3a, b).

Independent of this question, *M. praexuanhanensis* Mei and Wardlaw has surely not evolved from *C. altudaensis* and also not from *M. shannoni* regarded as "*M.*" *altudaensis* by Mei et al. (1994). *Clarkina altudaensis* displays a broad unserrated platform with rounded posterior end, their primitive forms have an indistinct cusp and slightly to moderately upturned platform margins, their advanced forms have no cusp and a very flat platform. *M. praexuanhanensis* displays a slender platform with pointed posterior end, highly upturned platform margins, a distinct free blade and a distinct cusp. This species is therefore not only very different from *C. altudaensis* (and *M. shannoni*), but its distinctive characters are opposite to the trends in the development from *M. shannoni* to *C. altudaensis* and within *C. altudaensis*.

The conodont successions are discussed in detail by Kozur (in press). The Permian conodont successions are very important for the marine Permian stratigraphy. At the C/P boundary only gradual and unpronounced changes can be observed in the conodont faunas, like in other fossil groups. The first appearance of *Streptognathodus barskovi* (Kozur) and *Wardlawella expansa* (Perlmutter) which coincides roughly with the first appearance of perrinitids and *Pseudoschwagerina*, is regarded as the base of the Permian. The Early/Middle Permian boundary (base of the Guadalupian) is well defined by the first appearance of *M. nankingensis* (CHING) which evolved from *M. idahoensis*. The Guadalupian-Lopingian boundary is defined by the first appearance of *Clarkina altudaensis*, which evolved from *M. shannoni* (Kozur, 1992, Mei et al., 1994). However, there are still problems with the age of the *M. praexuanhanensis* and *M. xuanhanensis* zones (see Figs. 3a, b). The P/T boundary is defined with the first appearance of *H. parvus* (Kozur and Pjatakova) which evolved from *H. latidentatus* (Kozur, Mostler and Rahimi-Yazd).

For definition and correlation of Permian stages the conodont successions are also very important. For instance, the top of the type Artinskian cannot be correlated with any area outside the Cis-Urals by any fossil group with exception of conodonts. For this reasons, it was so far impossible to leave the Cis-Uralian standard to any other standard. Kozur (1993) defined the top of the Artinskian with the first appearance of *Neostreptognathodus pnevi* Kozur and Movshovich which evolved from *N. pequopensis*. This phylogenetic cline is also present in the Skinner Ranch Formation of Texas. There, *N. pnevi* begins about in the same level as *M. intermedia*, *M. gujioensis*, *N. exsculptus* and *N.? foliatus*. With these latter forms the base of the post-Artinskian/pre-Roadian stage can be also defined in the Tethys, where *N. pnevi* is unknown. This stage is here named as Cathedralian (Ross and Ross, 1987), because this stage was defined as stage between the Artinskian and Roadian in Texas, where the cline *N. pequopensis*-*N. pnevi* is known as in the Cis-Uralian. All other stages used for this interval, are not suitable. The base of the Chihsian=Bolorian stage is fusulinid defined (base of the *Misellina dyhrenfurthi* Zone) and the base of this fusulinid zone cannot be exactly correlated with the ammonoid and conodont scale. Moreover, this fusulinid zone is restricted to the Tethys, where *N. pnevi* is unknown. Therefore no direct correlation with the top of the type Artinskian will be possible. Most probably, the Bolorian begins above the lower conodont zone of the post-Artinskian/pre-Roadian interval. The Leonardian, defined like the Cathedralian in Texas, is used in different manner. It includes at least parts of the late Artinskian.

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Table 1. Permian conodont zonations

	Series	Stage	Conodont Zones and Assemblages Zones			Conodont Standard-Zonation	
			Shallow water	Pelagic			
TRIAS.	Lower Triassic -Scythian	Brahmanian ("Induan")	Isarcicella isarcica	Clarkina carinata		Isarcicella isarcica	
			Hindeodus parvus			Hindeodus parvus	
PERMIAN	Upper Permian -Lopingian	Changxingian	H. latidentatus	C. deflecta-C. changxin		H. latident.-C. changxingensis	
			Hindeodus julfensis	Clarkina subcarinata		C. subcarinata-H. julfensis	
		Dzhulfian (Wuchiaping)	Iranognathus tarazi	Clarkina orientalis		Clarkina orientalis	
				Clarkina transcaucasica		Clarkina transcaucasica	
			Merrillina divergens Hindeodus altudaensis	Clarkina leveni		Clarkina leveni	M. divergens M. rosenkrantzi
		new stage?		Clarkina liangshanensis- Clarkina altudaensis		Clarkina liangshanensis- Clarkina altudaensis	
	Middle Permian -Guadalupian	Capitanian		Mesogondolella shannoni		Mesogondolella shannoni	
				M. postserrata		M. postserrata	
		Wordian	Gullodus catalanoi	M.aserrata	Mesogon-dolella siciliensis	Mesogondolella aserrata	
				M. nankingensis		Mesogondolella nankingensis	
		Roadian	S. subsymmetricus Neostreptognathus clinei				Sweetognathus subsymmetricus
	Cathedralian		N. sulcoplicatus	M. idahoensis		M. idahoensis-N. sulcoplicatus	
			Neostreptognathodus prayi	M. zsuzsannae		M. zsuzsannae-N. prayi	
				M. asiatica		M. idahoensis-N. prayi	
			N. exculptus- N. pnevi	M. shindyensis-M-intermedia		M. idahoensis-N. exsculptus	
						M. intermedia-N. exsculptus	
	Artinskian		N. pequopensis-N. ruzh.	Mesogondolella bisselli		M. bisselli-N. pequopensis	
			Sweetognathus whitei			M. bisselli-S. whitei	
			S. whitei-St. artinskiensis	M. bisselli-St. artinskiensis		M. bisselli-St. artinskiensis	
			W. adenticulata- Streptognathodus n. sp. A.	Mesogondolella bisselli- Streptoganthodus n. sp. A.		Mesogondolella bisselli- Wardlawella adenticulata	
	Sakmarian		S. merrilli-Strept. n. sp. B.	M. bisselli-Strept. n. sp. B.		M. bisselli-S. merrilli	
	Asselian		Wardlawella expansa- Streptognathodus postfusus	Mesogondolella foliosa- Streptognathodus postfusus		Wardlawella expansa- Streptognathodus postfusus	
			Wardlawella expansa- Streptognathodus constrictus	Mesogondolella adentata- Streptognathodus constrictus		Wardlawella expansa- Streptognathodus constrictus	
			Wardlawella expansa- Streptognathodus barskovi	Streptognathodus barskovi- Streptognathodus wabaunsensis		Wardlawella expansa- Streptognathodus barskovi	

Table 2. Correlation of the conodont zonation of the Eastern Gondwana province with the standard zonation

Stage	Conodont standard-zonation	Conodont zones of the Eastern Gondwana conodont province		
		shallow-water	pelagic	Eastern Gondwanide standard
Cathedralian		unknown	unknown	unknown
	N. idahoensis-N. sulcoplicatus			
	M. zsuzsannae-N. prayi			
	M. idahoensis-N. prayi	*N. leonovae*	*M. idahoensis*	*N. idahoensis-* *N. leonovae*
	M. idahoensis-N. exsculptus			
	M. intermedia-N. exsculptus	*N. exsculptus-* *R. bucaramangus*	*M. intermedia-* *V. shindyensis*	*N. exsculptus-* *V. shindyensis*
Late Artinskian	*M. bisselli-N. pequopensis*	unknown	*M. bisselli-V. shindyensis*	*M. bisselli-V. shindyensis*
	M. bisselli-S. whitei			

Table 3a. Correlation of the Chinese conodont zonation with the proposed standard zonation around the Guadalupian-Lopingian boundary. Variant a: All "*M.*" *altudaensis* sensu Mei et al. (1994) are *M. shannoni* and near related forms of the *M. shannoni* Zone. *C. crofti* from the uppermost Lamar is the successor of *M. praexuanhanensis*

Series	Stage	Conodont standard-zonation	Subdivision after Mei et al. (1994)		
			Conodont zones	Stages	Series
Upper Permian–Lopingian (pars)	Dzhulfian (Wuchiapingian)	*Clarkina orientalis*	*Clarkina orientalis*	Wuchiapingian	Lopingian (pars)
		Clarkina transcaucasica			
		Clarkina leveni *M. divergens-M. rosenkrantzi*	*Clarkina leveni*		
		Clarkina liangshanensis-Clarkina altudaensis	*C. liangshanensis* ?		
				Unnamed Stage	
Middle Permian–Guadalupian (pars)	Capitanian	*Mesogondolella shannoni*	*M. xuanhanensis*		
			M. praexuanhanensis		
			"*M. altudaensis*"		
		M. postserrata	*M. postserrata*	Capitanian	Guadalupian (pars)

Table 3b: Correlation of the Chinese conodont zonation with the proposed standard zonation around the Guadalupian-Lopingian boundary. Variant b: Only the figured forms of "*M.*" *altudaensis* sensu Mei et al. (1994) from their lower *altudaensis* Zone are *M. shannoni* and near related forms of the *M. shannoni* Zone. Real *C. Altudaensis* is present in the upper *altudaensis* Zone sensu Mei et al. (1994). *C. crofti* from the uppermost Lamar is not the successor of *M. praexuanhanensis*.

Series	Stage	Conodont standard-zonation	Subdivision after Mei et al. (1994)		
			Conodont zones	Stages	Series
Upper Permian–Lopingian (pars)	Dzhulfian (Wuchiapingian)	*Clarkina orientalis*	*Clarkina orientalis*	Wuchiapingian	Lopingian (pars)
		Clarkina transcaucasica			
		Clarkina leveni *M. divergens-M. rosenkrantzi*	*Clarkina leveni*		
		Clarkina liangshanensis	*C. liangshanensis* ?	Unnamed Stage	
disputed	Unnamed Stage	*M. xuanhanensis*	*M. xuanhanensis*		
		M. praexuanhanensis	*M. praexuanhanensis*		
		C. altudaensis	"*M. altudaensis*"		
Middle Permian–Guadalupian (pars)	Capitanian	*M. shannoni*			
		M. postserrata	*M. postserrata*	Capitanian	Guadalupian (pars)

12. *SPHAEROSCHWAGERINA VULGARIS-SS. FUSIFORMIS* ZONE. A RESTUDY OF TYPE FUSULINIDS IN P.I. KROTOV'S (1888) AND D.F. SHAMOV'S (1940) COLLECTIONS

The type-species of *S. vulgaris-S. fusiformis* Zone of the Asselian belong to P.I. Krovtov's fusulinid collection and were described by him from Upper Paleozoic deposits when he was mapping the Middle Urals (Krotov, 1888). Holotypes of both species were established by S.F. Scherbovich (1949) based on illustrations in P.I. Krotov's work (1888). These illustrations show that in thin-sections of both holotypes only outer volutions are stripped; the inner structure and character of the proloculus are not observed. In fact, in Russian micropaleontology varieties of species *S. vulgaris* and *S. fusiformis* are used. They were described by S.F. Scherbovich (1949) from Asselian deposits of the South Urals: *Sphaeroschwagerina vulgaris aktjubensis* (Scherbovich), *S. vulgaris timanica* (Scherbovich), *S. vulgaris ashensis* (Scherbovich), *S. fusiformis crassa* (Scherbovich), *S. fusiformis* var. *plicata* (Scherbovich). They all are established by well-centered axial sections cutting the proloculus. A full description is given, indicating holotype, stratigraphical range and geographical location. The scheme for the zonal subdivision of the Schwagerine Horizon (=Asselian) was first proposed by D.F. Shamov, when he was studying Upper Paleozoic oil-bearing carbonaceous reef deposits of Bashkiria (D.F. Shamov, 1940). All the material is from boreholes.

According to D.F. Shamov, the Pseudofusuline Horizon is characterized by *Schellwienia modesta* (Scherbovich), *Sch. buharchensis* Davydov, *Sch. glandiformis* (Alksne), *Sch. delicata* (Alksne), *Sch. klunnikovi* Davydov, *Zigarella explicata* (Leven and Scherbovich). The Schwagerine Horizon begins with the level of the earliest occurrence of *Sphaeroschwagerina*. The lower fusulinid zone is characterized by *Schwagerina* aff. *netchaevi* (Davydov), *Schw. gracilis* (Sjomina), *Sphaeroschwagerina* aff. *salomatiensis* (Ketat), *S. darvasica* (Leven and Scherbovich), *S. fusiformis* (Krotow sensu Scherbovich, 1949), *S. aktjubensis* (Scherbovich), *S. kumajica* (Scherbovich). The fusulinid assemblage of the middle zone includes *Sphaeroschwagerina constans* (Scherbovich), *Zigarella pseudopointeli* (Rauser), *Pseudofusulina*? *decurta* (Korzhinskyi).

For his scheme D.F. Shamov used species and varieties of species, described by S.F. Sherbovich before World War II.

D.F. Shamov's fusulinid zonal scheme of the Schwagerine Horizon was modernized by D.M. Rauser-Chernousova (1949, 1960), who introduced in practice and into the literature the name *S. vulgaris-S. fusiformis* for the lower fusulinid zone of the Asselian. I have restudied P.I. Krotov's collection, which is kept in the Central Geological Museum in St. Petersburg (CGM, No. 1640) and also D.F. Shamov's collection of thin-sections from borehole 101/1, Bashkiria, which is kept in the Micropaleontological Laboratory of the Geological Institute of Academy of Science, Moscow; on this material the scheme for the zonal subdivison of Schwagerine Horizon was first established. In P.I. Krotov's collection only the paratypes of *S. vulgaris* and accompanying fusulinids are preserved. It turned out that among the paratypes of *S. vulgaris* different groups of fusulinids are present. Some of them are similar to the species *Sphaeroschwagerina lagitima* (Grozdilova), the others to *Schwagerina sphaeroidea* (Rauser). Both species characterize middle Asselian deposits of the Urals and Russian Platform (Rauser-Chernousova, Scherbovich, 1958; Grozdilova, 1966). Also in the assemblage of these species there was found *Pseudoschwagerina intermedia* Rauser, also characterizing the middle fusulinid zone of the Asselian. Identification of *S. vulgaris* (Scherbovich) by means of paratypes from Krotov's collection will result in a big muddle in paleozoological and stratigraphical nomenclature, that is why I suggest that this species should be considered invalid ("nomen delendum") and excluded from taxonomical practice. As the holotype and paratypes of species Sphaeroschwagerina fusiformis (Krotow) disappeared during World War II, specimen No. 119, described by S.F. Scherbovich from the same area can serve as the neotype (Scherbovich, 1949, p. 85-86, pl. 6, gif. 5). This specimen is kept in the Laboratory of Micropaleontology, Geological Institute Ac. Sci., Moscow. In my opinion *Sphaeroschwagerina aktjubensis* (Scherbovich) (="*Schwagerina*" *vulgaris* var. *akjubensis*) and *S. fusiformis*, characterizing this zone in the stratotype borehole No. 101/1 in Bashkiria (by D.F. Shamov), should be considered index-species of the lower fusulinid zone of the Asselian. In accordance with the decisions of the Permian Subcommission of the Interdepartmental Stratigraphical Committee the stratotype of the lower fusulinid zone of Asselian was established in the Aideralash section, beds 19/6-25 (Resolutions . . . 1992; Davydov et al., 1992). Entire results of the investigation of the type materials on *Sphaeroschwagerina aktjubensis-S. fusiformis* fusulinid zone will be published soon.

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13. EARLY PERMIAN DEGLACIATION SEQUENCES REFLECT END OF "ICE HOUSE" CONDITIONS IN NORTHERN GONDWANA

The sedimentary record of the late Paleozoic glaciation ("ice house" sequence) generally may be subdivided into three lithofacies groups. In ascending order they comprise:

1) the glacial facies association
2) periglacial lithotypes reflecting glacial retreat
3) the deglaciation facies

Although varying in detail, this general succession is recognized in both terrestrial and marine environments alike. Of these facies associations the deglaciation facies reflecting the transition from the periglacial conditions to the final climatic amelioration is of utmost importance as it marks the termination of the "ice house" regime. Although this facies may be recognized in most regions where a complete, early Gondwana sequence has been preserved this brief note concerns only a few examples from the Tethyan margin of Gondwana.

The composition of the glacial association (tillites of various kinds, debris flows, slumped masses of ice transported material etc.) and of the periglacial environments (outwash gravels and sands, laminites with or without drop stones, turbidites, debris flows etc. invariably show an "arkosic" composition, consisting of quartz, feldspar, micas and chlorite. Clay minerals are absent or their participation is very low. This composition persists down to the finest lutites of the laminites and changes only where the source area of the glacier was dominated by carbonates or other mono-mineralic suites.

The deglaciation sequence on the other hand is characterized by black or very dark lutites, usually pyritic and with a noticeable kerogen content, often with a dominance of algal kerogen. Clay content is high and consists wholly or dominantly of kaolin. Frequently the lutites contain fist- to head-sized carbonate concretions and the occurrence of sulfates, mainly gypsum, is quite common. This unusual mineral composition of the post-glacial sequence is caused by early diagenetic processes governed by a specific environment typical of that time. Turbidites which may be interspersed with the black lutites at irregular frequencies, indicate high sediment intake and instability near the shore line. Wopfner (1970) who first reported this facies from the Arckaringa Basin in South Australia compared it with mineral associations found in the fjords of New Zealand of today.

The threefold subdivision of an "ice house" sequence formed in an entirely non-marine environment is well demonstrated by the Idusi Formation of the Ruhuhu Basin in SW-Tanzania. It reflects glacial highstands, glacial retreat and deglaciation in a most demonstrative manner (Wopfner, 1989; Wopfner and Diekmann, 1991). Diekmann (1993) who studied the glaciogenic sequence of several Karoo basins of SW-Tanzania in detail, demonstrated the break in the mineralogical composition between the "arkosic" glacial-periglacial Lisimba Member and the postglacial, kaolinitic Lilangu member. He showed convincing evidence that both, carbonate concretions and pyrite formed during early diagenesis, prior to compaction and in a reducing environment, caused by high input of organic material. TOC contents exceeding 5% are commonly associated with aggregates of siderite. The carbonate concretions show quite low δ^{18} O- and δ^{13} C- values, whereby the latter decrease from around -2.0 ‰ near the rim to -44.7 ‰ at the core. According to Diekmann (1993) the negative carbon isotope ratios are indicative for decomposed organic material.

Palynological studies have placed the upper part of the Lilangu Member within the *Granulatisporites confluence* Oppel-zone (Foster and Waterhouse, 1988) which places this deglaciation sequence within the Late Asselian to Early Sakmarian. Similar results were obtained by palynological studies carried out by R. Weiss (pers. comm., 1993). The Lilangu Member is overlain by the coal bearing Mchuchuma Formation. Frequently the contact between the two units is marked by an angular unconformity.

A very similar deglaciation facies is known from southern Oman, where the glacial-periglacial succession of the Al Khlata Formation (Haushi Group) is succeeded by the black, bituminous Rahab Shale. The latter forms the cap-rock of the prolific oil fields of southern Oman. According to palynological data reported by Levell et al. (1988), the Rahab Shale are of Asselian to Sakmarian age, hence roughly time equivalent to the Lilangu Member of the Idusi Formation. The Rahab Shale range from laminites with drop stones near the base to massive dark coloured mudstones with a characteristic gamma-ray peak. Like the lutites of the Lilangu Member, the Rahab Shale were deposited in a large freshwater body without marine influence. In contrast to the Permo-Carboniferous successions of Tanzania and Madagascar, where the glaciogenic sequences are overlain by coal-bearing strata, the Haushi Group of Oman is followed by dolomitic and gypsiferous deposits of the Khuff Group.

Comparable glacial to postglacial sequences also exist in the

Permian basins of northwestern Australia. In the Bonaparte Gulf Basin, the glacial deposits of the Kulshill Formation are topped by the Treachery Shale, again a black lutite, rich in organic matter. The succeeding sequence consists of sandstones with some carbonate interbeds. Except for a few minor lenses, no coal-bearing strata were developed. Foster (1986) assigned the Treachery Shale to the *Granulatisporites confluence* Oppel-Zone, indicating time equivalence with the Lilangu Member in Tanzania and the Rahab Shale of Oman.

These sections from or near the Tethyan margin of Gondwana may be compared with Late Carboniferous-Early Permian glacio-marine deposits of southwestern China. The Kongshuhe Formation of the Tengchong Block in western Yunnan, representing a typical glacial sequence comprising diamictites, slump masses, laminites, etc. is capped by up to 100 m of black, kaolinitic and pyritic mudstone with large carbonate concretions (Wopfner and Jin, 1993). The mudstones contain up to 2% organic carbon, the origin of which cannot be determined due to exposure to high temperatures. The concretions consists mainly of siderite (Jin, in press).

A transition sequence of marls and sandstones of about 20 m leads from the deglaciation mudstones up to massive, coralliferous limestones of Early Permian age. Again, no coal-bearing strata are present. Similar successions were developed on the neighbouring Baoshan Block, but there the deglaciation facies is succeeded by Early Permian basalts with limestone and red bed interbeds.

The deglaciation facies appears to be well represented also in India, both in peninsular and Himalayan successions (Casshyap and Qidwai, 1974; Singh, 1983). However, this author has not studied these occurrences in sufficient detail to make any conclusive comments. Within the Gondwana tectonic window in Sikkim, black massive mudstones overlay tillites and laminates, and are succeeded by thick sandstones and coal-bearing units. The succession which is dated by marine fossils is comparable both in lithology and age with the examples described from Tanzania and Madagascar.

Conclusion

The ubiquitous appearance of the black, kaolinitic, more or less euxinic deglaciation facies in Late Asselian to Sakmarian times suggests an almost synchronous termination of the Late Paleozoic glaciation. Some diachronism may be indicated between western Yunnan and northwest Australia which would be in keeping with the climatic gradient between lower and higher latitudes. Climatic amelioration, particularly along the Tethyan margin of Gondwana must have been very rapid. The change from the Late Carboniferous-Early Permian "ice house" conditions to a climate conducive for the deposition of carbonates and evaporites must have been completed by the end of the Sakmarian along the Tethyan margin (Oman, Yunnan, Bonaparte Gulf) and only shortly thereafter in the more continental basins (Tanzania, Madagascar, India) if the coal-bearing strata are interpreted as products of temperate to warm temperate climates.

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14. ON THE STUDY OF THE BOUNDARY STRATA BETWEEN GUADALUPIAN AND LOPINGIAN SERIES

It is not possible to establish the time scale of the Permian System based on a single section or a single area of the world, because of incomplete development of the normal marine deposits in the classic areas.

Recently, it has become a focus of Permian studies to define the upper boundary of the Guadalupian Series or the Capitanian Stage, since the US Permian group proposed the Guadalupian Series from Guadalupe National Park in West Texas, USA as the stratotype of the Middle Series in their three-fold scheme of the Permian System (Glenister and others, 1992). Some positive efforts on clarifying this definition have also been made by other Permian ammonoid and conodont workers.

Zhou and others (1989) suggested that the Capitanian Stage (in Furnish, 1973 definition) in the United States is at least partially equivalent to the Wujiapingian Stage in South China. It is presumed that a significant stratigraphic overlap is present between these normal marine sequences from the two continents, based on the fact that the ammonoid genus *Timorites*, representative of Capitanian, has been found from Dhulfian Stage in association with Araxoceratids in many localities around the world, including Transcaucasia, Central and North Iran, Kitakami Massif of Japan, Russian Far East, and the Las Delicias area of Mexico.

A latest advance on this view-point has been made by one of the present authors (Gong Yuhong). In at least three localities in Hunan Province, Wujiapingian conodonts have been found from the Guadalupian-aged Upper Member of the Douling Formation (Coal series) (Text-figure 1). In the Xiaoyuanchong section of Jiahe County, this Upper Member comprises 56 meters of mainly calcareous mudstone and contains the Guadalupian ammonoids *Roadoceras roadense* (Böse), *Altudoceras zitteli* (Gemmerallo), *Paraceltites hoeferi* (Gemmerallo) and *Doulingoceras nodosum* Zhou. The lower part of the member has the Wujiapingian conodonts *Hindeodus* sp., *Xaniognathus* sp. and *Clarkina* cf. *bitteri* in a two and half meter thick bioclastic micrite intercalation. In two other localities, *Clarkina bitteri* and *C. liangshanensis* have been found in equivalent strata of the Upper Member of the Douling Formation.

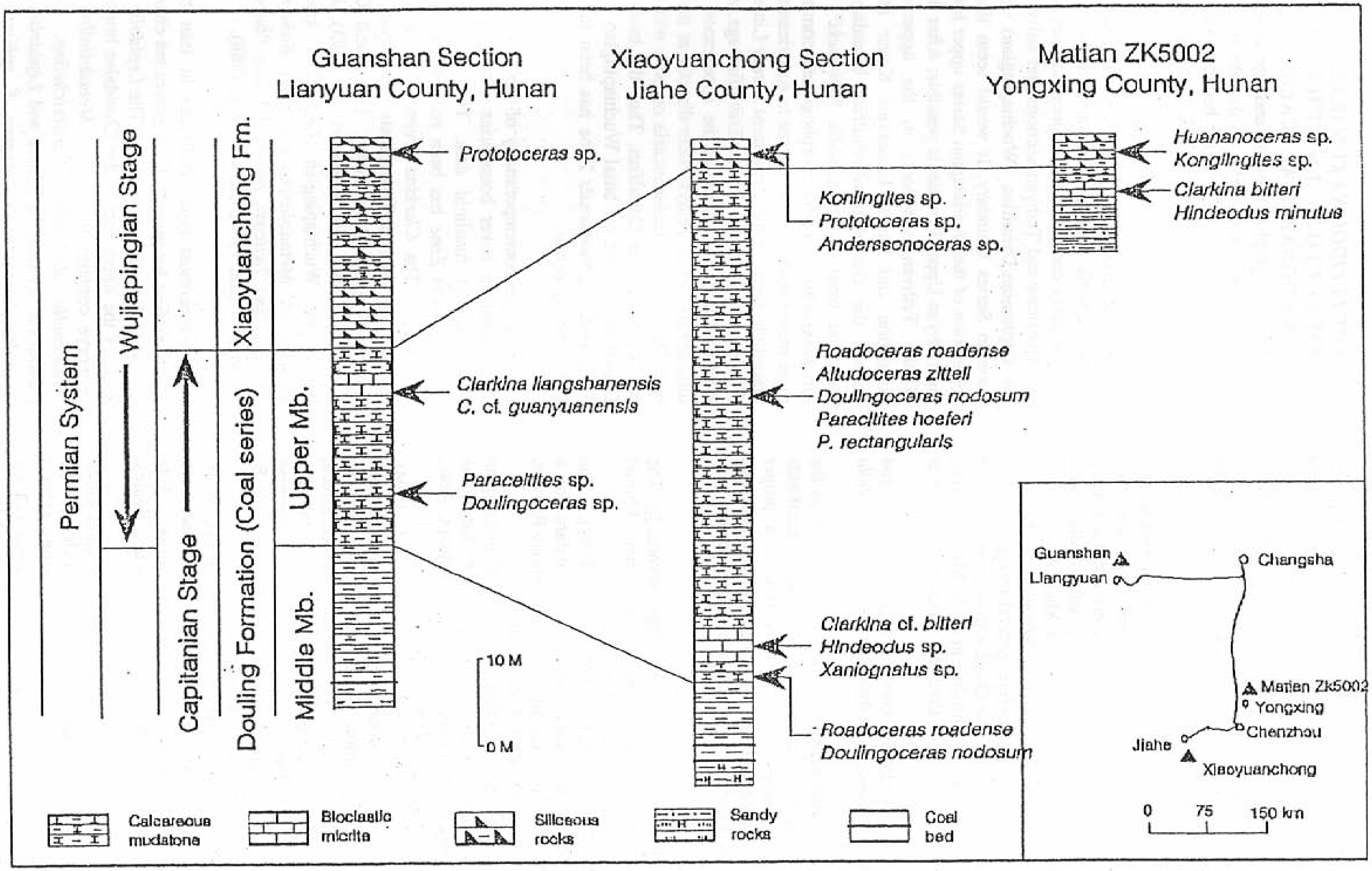
Kozur (1992, p. 108) compared the Texas conodont materials with those from Tethyan areas, and noted as follows: "the uppermost Altuda Formation of the western Glass Mountains comprises the major overlap of the Guadalupian and the Tethyan Late Permian is present in the Glass Mountains" Although we can make no judgement on his conodont taxonomy, based only on his paper, we are impressed by his interesting opinion.

Mei and others (1994), however, has reached a different conclusion on the relationship of Capitanian and Wujiaping Stages. Their study was based on conodonts from a section in Dukou, Xuanhan County, Sichuan and suggested that not only is the overlap absent but a stage-long gap is present between these two stages (Mei and others, 1994, p. 2, 7 and Table 1). There are two totally different answers to the same question.

Before proceeding, we would like to point out that the concepts of Capitanian and Wujiaping Stages in Mei and others (1994, Table 1) were interpreted in a restricted sense. According to Table 1 of Mei and others (1994), the Capitanian is restricted to a single conodont zone - *Mesogondolella postserrata* Zone, while the *Clarkina altudaensis* Zone and *C. subcrinata* Zone in the traditional concept of the Stage were excluded from the upper part, and the Wujiapinginan is restricted to the carbonate deposit - the Wujiaping Limestone, but does not include the Wangpo shale (unexposed in the Dukou section). In fact, the Wangpo shale is commonly treated as a part of the traditional Wujiapingian Stage. In addition, the "Kuhfeng" Formation of Mei and others (1994) is assignable to the Maokouan Stage as indicated on page 2 of their paper (also see Regional Geology of Sichuan, Geol. Mems. ser. 1, no. 23, PR China Ministry Geol., Miner. Res., 1991, p. 187), instead of "unnamed stage" as shown in their Table 1.

As pointed by Mei and others (1994, p. 7), "since the Permian conodonts are not highly diversified in morphology, not as abundant as in other periods, and their stratigraphical and ecological distribution and especially the taxonomy are still poorly understood, we should patiently and carefully gather more materials (such as continuous stratigraphical sequence and abundant specimens) and more objectively study them, in order to avoid further complicating stratigraphical problems in haste". We assume that the above-mentioned contradictory opinions of Kozur (1992) and Mei and others (1994) might be a result of insufficient taxonomic studies of the Permian conodonts. We expect a generally accepted conodont taxonomy and a well-established conodont zonation in the boundary strata to be worked out before we make any decision on the upper boundary of Guadalupian Series.

On the other hand, we think that it is the difference in definition of the base of Wujiapingian Stage in various facies in South China that has led to the different correlations on the boundary strata. Zhou (1986) has pointed out the migration of the depositional facies and biocommunities along with sea-level changes in the Permian South China Restricted-Sea. As one of the index fossil groups, the araxoceratids exclusively contained in the mudstone of the coal series have different first appearances - being controlled by the facies. In addition, we cannot be certain whether the base of the *Clarkina bitteri-C. liangshanensis* conodont Zone is the same as that of the *Anderssonoceras-Prototoceras* ammonoid Zone until we



Text-figure 1 - Guadalupian and Lopingian Series boundary strata in Hunan find them in a single section or clarify the nature of facies changes in the region. A recent discovery from Hunan (Gong, see Text-figure 1) has shown that first appearance of the conodont *Clarkina bitter* is earlier than that of ammonoids *Anderssonoceras, Konglingites* and *Prototoceras* and later than the disappearance of ammonoid *Roadoceras-Paraceltites.*

We do not wish to debate whether there is an overlap or a gap in the boundary strata between Capitanian and Wujiapingian Stages, but believe that there is not a missing "unnamed stage" between Maokouan and Wujiapingian Stages, unless a further subdivision of Maokouan Stage is made (see Mei et al., 1994, page 2). We suppose that there is still much to be learned before general recognition of a precise upper boundary of the Guadalupian Series in South China. To complete the establishment of the Middle Series, i.e., Guadalupina Series, we think the following research is necessary:

1) Establish a specialist consensus on taxonomy and evolutionary lineages of the conodonts *Mesogondolella* and *Clarkina.*
2) Conduct comprehensive collaborative research on the biostratigraphy of ammonoids, conodonts, fusulinids and other groups in a single section at a proper locality in South China to obtain more knowledge about the biochronology of the boundary strata.

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15. THE *LEPIDOLINA KUMAENSIS* ZONE AND ITS POSITION IN THE TETHYAN STRATIGRAPHICAL SCALE

The stratigraphic position and age of the *Lepidolina kumaensis* Zone have been in dispute for a long time. Recently this problem has again become relevant after the proposal from workers in the U.S.A. of the Guadalupian as the International Standard for the Middle Permian Series (Glenister et al., 1992). The Late Permian standard stages can only be established in the Tethyan realm, where the rich and diverse conodonts, ammonoids and fusulinids are present. Only conodonts and ammonoids can help correlate the American and Tethyan sections and solve the problem the Capitanian/Dzhulfian (Wuchiapingian) or the Upper Permian Series boundary. It would seem that the direct correlation of the Guadalupian Series upper boundary with the Tethyan Upper Permian is possible. After the discovery of the Tethyan conodonts in the uppermost Altuda Formation and Lamar Limestone Kozur (1992, 1993) defined the Guadalupian/Dzhulfian boundary "with the transition from *Mesogondolella "babcocki"* to *Clarkina altudaensis* within a phylomorphogenetic continuum" in the uppermost Capitanian. In contrast to American authors, who placed the fauna of the Uppermost Lamar Limestone in the Guadalupian, Kozur assumed a Dzhulfian age. According to Kozur's opinion the level of the appearance of *Clarkina altudaensis* lies in Tethys either directly at the base of the type Dzhulfian in Transcaucasia or even within the lower part of the Lower Dzhulfian. Thus the base of the type Dzhulfian is above the basal Wuchiapingian. On this basis the *Lepidolina kumaensis* Zone has been included in the Dzhulfian by Kozur.

However, the contemporaneity of the type Dzhulfian and Wuchiapingian lower boundaries can be proved by the conodont and fusulinid data. The *Clarkina bitteri-Cl. liangshanensis* Zone has been recognized in the base of both stages. The *Clarkina leveni* Zone was established above these zones in Transcausia (Grigoryan, 1990), Iran (Iranian-Japanese Res. Group, 1981) and China (Tian Shungang, 1993; Jin Yugan et al., 1993). Immediately below the Wuchiapingian *Lepidolina kumaensis, L. multiseptata, Metadoliolina gravitesta, Kahlerina minima* and *Clarkina ?wilcoxi, Mesogondolella "babcocki"* were found (Rui Lin, 1983; Clark, Wang, 1988).

In the uppermost type Abadehian in Iran *Yabeina* and *Metadoliolina* are present. Both genera are characteristic of the *Lepidolina kumaensis* Zone. The *Lepidolina kumaensis* Zone of the upper part of the Chandalaz horizon in South Primorye contains fusulinids - *Metadoliolina, Kahlerina, Sichotenella, Reichelina, Parareichelina, Lantchichites, Dunbarula, Chusenella* genera and *Lepidolina kumaensis, L. multiseptata, Yabeina turgina, Y. sphaerula, Y.* ex gr *globosa* and conodonts - *Mesogondolella postserrata,* *Clarkina bitteri, Cl. rosekrantzi, Cl? wilcoxi, Cl. denticulata* (Kotlyar et al., 1990). In this region the zone is characterized by a rich and diverse fauna. Here it is overlain by the beds with *Parareichelina, Sichotonella, Pseudokahlerina, Rauserella, Codonofusiella parva, C. lipovensis*. The lepidolinid, neoschwagerinid and verbeekinid species are absent. These beds are perhaps equivalent to the *Codonofusiella-Reichelina* fauna of Early Dzhulfian.

A similar assemblage has been reported in the uppermost Maokouan in South China (Rui Lin, 1983). The conodonts from this level have been identified as *Mesogondolella babcocki-clarkina? wilcoxi* Zone (Tian Shungang, 1993). This zone is overlain by the *Clarkina bitteri-Cl. liangshanensis* Zone.

Thus, the Abadehian can surely correlated with the uppermost Maokouan and the upper part of Chandalaz horizon on the basis of fusulinids and conodonts. So far as the *Lepidolina kumaensis* Zone lies below the Dzhulfian or Wuchiapingian it is not of Dzhulfian age.

Besides the analysis of the *Lepidolina kumaensis* fauna there is evidence of a pre-Dzhulfian age for it. Everywhere the assemblage of this zone is constant. It consists of *Lepidolina kumaensis, L. multiseptata, Metadoliolina gravitesta* (or *M. lepida*), *Codonofusiella* spp. (not *C. kwangsiana*), *Kahlerina, Yabeina, Dunbarula, Chusenella, Reichelina* etc. Everywhere (including Japan) the *Lepidolina kumaensis* Zone lies above *L. multiseptata* Zone (or the local correlatives of it) and is overlain by the Dzhulfian *Codonofusiella* beds (=*C. kwangsiana* Zone).

In Japan the *Lepidolina kumaensis* fauna has been identified in the Iwaizaki Formation, from the middle horizon of the Kuma Formation, from the Maizuru Group etc. In its type area the *Lepidolina kumaensis* fauna is identical to the assemblage of the other regions. It is characterized by *Lepidolina kumaensis, L. multiseptata, Metadoliolina gravitesta, Codonofusiella cuniculata, Dunbarula, Rauserella, Reichelina, Parareichelina, Sichotenella, Cylindrocolaniella* etc. In the lowermost horizon of the Kuma Formation has been found *Lepidolina multiseptata* and the upper horizon has yielded *Codonofusiella, Pachyphloia, Robuloides* cf. *lens, Hemigordius*. Japanese workers wrote "it is clear the *Lepidolina kumaensis* occurs later than *L. multiseptata* and that it is followed in turn by the uppermost horizon with *Codonofusiella* fauna" (Minato et al., 1978, p. 29).

The age of the *Lepidolina kumaensis* Zone has been disputed in Japan. Most of the Japanese stratigraphers placed it into the Middle Permian (Choi, 1970, 1984; Minato et al., 1978; Japanese Working Group, 1987; Nakazawa, 1990; Mori et al., 1992). In correlation charts of the Upper Permian the Japanese Working Group showed the *Lepidolina kumaensis* Zone in the Upper part of the Middle Permian. They pointed out the disappearance of *Yabeina* and *Lepidolina* and increase of *Codonofusiella* and *Reichelina* at the base of the Upper Permian Series. For this reason it was shown that most of the Upper Permian Series is consistent with subdivisions that have been recognized using sequence stratigraphy in the continuous sections of the Kitakami Mountains.

As to the joint finds of *Lepidolina kumaensis* and *Codonofusiella, Reichelina* it is known that these genera appear in the Middle Permian. The *Codonofusiella kwangsiana* fauna differs from the *Lepidolina kumaensis* one by the extinction of the highly evolved fusulinids (*Verbeekinacea, Schwagerenidae*) and the mass development of *Codonofusiella*.

The discovery of *Clarkina altudaensis* in the upper part of the Kuhfeng Formation in China confirms a pre-Dzhulfian age for the *Lepidolina kumaensis* Zone, but a new question is raised. If the Upper Permian Series lower boundary will be defined at the base of the Dzhulfian in Transcaucasia or the base of the Wuchiapingian in China then the problem of the interval from the type Capitanian upper boundary to the base of the Upper Permian Series should remain open for further resolution. In this case the *Lepidolina kumaensis* Zone is pre-Dzhulfian as well as type Capitanian. If the base Upper Permian Series lower boundary will be defined with the appearance of the *Clarkina altudaensis*, then the Upper Permian Series lower boundary will be placed within uppermost Maokouan or at the base of the Abadehian.

In my opinion, the base of the *Clarkina bitteri-Cl. liangshanensis* Zone is the best Upper Permian Series lower boundary. The very important biological and geological events take place at this boundary. It is easily recognizable everywhere and can be recommended as the International Standard.

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16. MORPHOMETRIC CONFIRMATION OF THE *MESOGONDOLELLA IDAHOENSIS* TO *M. NANKINGENSIS* TRANSITION

INTRODUCTION

Mesogondolella idahoensis evolved into *M. nankingensis* through a short-lived mosaic paedomorphocline. Because the evolutionary interplay between individual characters was complex, a precise point within the transition can be selected to define the basal Guadalupian boundary. Guadalupian conodont faunas are characterized worldwide by *M. nankingensis* and its direct descendants (Clark and Behnken, 1979; Clark and Wang, 1988), so a cohesive faunal package would thus be established on this conodont clade. The Guadalupian is widely recognized as the best reference standard for an international chronostratigraphic unit to represent that interval of geologic history, whether it is ultimately accepted as a formal Middle Permian Series (Glenister et al., 1992) or as the lower Series of an Upper Permian Subsystem (Leven, 1992). A basal boundary defined on the inception of *M. nankingensis* would meet all criteria necessary to establish a formal chronostratigraphic boundary. Furthermore, it would stabilize the concept of the Guadalupian in its original type area (Girty, 1902), plus stabilize the concurrent lower boundary of the Roadian in its type area of the Glass Mountains (Wardlaw and Grant, 1990; Lambert et al., in press).

A more objective boundary definition than that typically employed to define chronostratigraphic units is possible using detailed morphometric analysis of this complex clinal transition. An extensive quantitative evaluation of sequential populations is currently in progress, and should lead to a relatively rapid consensus for selecting a GSSP in the type Guadalupian. Initial morphometric analysis of the mosaic paedomorphocline confirms the intermediate aspect of characters exhibited by the transitional form (described qualitatively in Lambert and Wardlaw, 1992; Lambert et al., in press). Although at mid-transition it exhibits distinctive morphologic features, this form should not be considered a separate species. Rather, once that distinctive point in the transition is fully characterized numerically, it should be easily ratified to mark the GSSP. The following is an overview of these preliminary morphometric results.

MECHANICS

The database for this preliminary phase of the morphometric analysis was compiled from specimens representing latest *Mesogondolella idahoensis* collected from the Shumard Member of the Cutoff Formation (Guadalupe Mountains), and from the uppermost Cathedral Mountain and basal Road Canyon formations (Glass Mountains). Some specimens from the uppermost Victorio Peak Formation (shelf deposits immediately underlying the

Cutoff) of the Apache Mountains were also included. The collections included representative samples through the Cutoff and Road Canyon Formations (circumscribing the complete record of the transitional form), and extending stratigraphically upward to include not only early *M. nankingensis*, but also topotypes of *M. serrata* from the Pipeline Shale (Brushy Canyon Formation). Recent re-evaluation of types for *M. serrata* and *M. nankingensis* demonstrate that these taxa are synonymous (Wardlaw et al., in review), as numerous specialists have long suspected. Several *M. nankingensis* specimens from the San Andres Formation (shelfward Cutoff equivalent) in Last Chance Canyon (Guadalupe Mountains) complete the faunal database.

One of the most critical (and least objective) steps in morphometric analysis is orienting any given specimen. Orientation must be accurate and consistent from specimen to specimen for individual points in a landmark analysis to be homologous. Specimens in this study were oriented on a universal stage prior to their electronic acquisition. The resulting images were processed for precise control of contrast and brightness to enhance subtle characters. Landmark points were selected with the images in negative mode to further increase accuracy in delimiting subtle relationships. Distances between landmark points were measured in Cartesian coordinates, then exported to a spreadsheet from which mathematical manipulation could proceed.

The three standard conodont views were digitized from a combined total of 67 images for this study. The upper view had 13 landmark data points (Figure 1), the lower view had 12 landmark data points (Figure 2), and the lateral view had 20 landmark points (Figure 3). The lateral view database was larger than the others in part to develop a measure for average height of anterior carina denticles, average height of inter-denticle troughs, and average width of the anterior carina denticles (see Ritter, 1989).

Because the transition is expressed along a paedomorphocline, characters were examined both independently from size, and as a function of size and stratigraphic level. Size (as a proxy for relative maturity) was standardized by reference to a character that exhibits growth in a linear relationship to the remainder of the element. Selection of a standardized reference character is complicated for *Mesogondolella* because of inconsistent allometric fields resulting from variable bowing and arching of individual elements. However, a reliable approximation was achieved by using carina length as a measure of

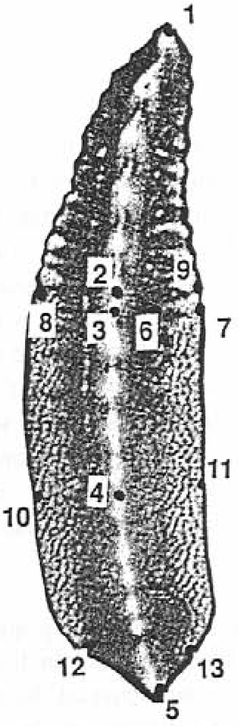

Figure 1. Landmark Points Selected for Analysis: Upper View

Example of *M. serrata* showing landmark points used in morphometric analysis, upper view. Standardization length measured along the carina from 1 to 5.

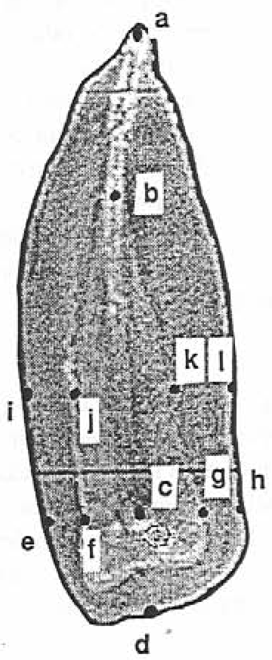

Figure 2. Landmark Points Selected for Analysis: Lower View

Example of *M. idahoensis* showing landmark points used in morphometric analysis, lower view. Standardization length is a-b-c-d.

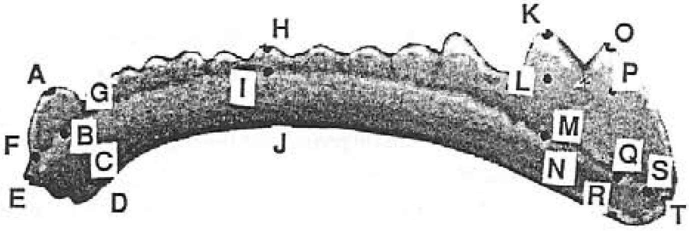

Figure 3. Landmark Points Selected for Analysis: Lateral View

Example of transitional form showing landmark points used in morphometric analysis, lateral view. Standardization length is E-F-B-G-I-M-Q-S-T.

allometric size. To minimize error introduced by warping of the allometric field from bowing, carina length was measured from denticle apex to denticle apex, extending from the anteriormost denticle to the tip of the cusp. These distances were integrated, then standardized to a value of 100 for each element. All landmark distances were scaled to this standard parameter, producing results measured as a percentage of carina length. This method allows for more precise comparisons between juveniles and adults with similar character states. Actual carina length was recorded for subdivision of the three taxon groups into ontogenetically-based components for separate analysis as a function of size.

All lower and lateral views have a corresponding upper view. Distances compiled over landmarks a-d in lower view accurately duplicate the carinal standard length. However, because of considerable differences in the distance between the pit and the posterior tip for *Mesogondolella idahoensis* compared with the other taxon groups in lower view, additional standards were used for lower and lateral views. This enhanced consistency by providing standard measurements that were present in each view. The distance standard for each view is referred to as "arclength". The arclength used in lower view was the length of the attachment surface (a-b-c). The arclength standard used in lateral view was measured along the upper platform surface (E-F-B-G-I-M-Q-S-T).

RESULTS

Although preliminary, the results of this study confirm that the transitional form observed qualitatively can be characterized quantitatively. The means for several selected measures of adult and subadult specimens are discussed below as examples. Table 1 lists the means of selected distances measured from upper views. Standard deviations are listed below each mean. Ratios of selected means comprise the lower part of the table.

The clearest relationships are those dominated by the pattern of increasing serration. Distance 1-8 measures the length of serration along the outer margin of both *Mesogondolella nankingensis* and the transitional form, plus the corresponding tapering portion of *M. idahoensis*. The distance 1-9 represents the same measurement for the inner margin. Point 2 lies along the carina between 8 and 9 such that 1-2 measures the length of the anterior taper for all three forms. Distance 2-4 measures the length of the anterior platform (4 is selected to mark the widest point of the element at mid-platform), to which subdued serrations extend on *M. nankingensis* and some transitional forms. Distance means for the transitional form are intermediate along all portions of the upper surface for these measures. A direct linear relationship of increasing serration through the transition is easily observed. It is noteworthy that when ontogenetic stages are examined as separate entities, small transitional forms fall nearer the overall means for *M. nankingensis*, whereas large transitional forms fall nearer the means for adult *M. idahoensis* (refer to Lambert and Wardlaw, 1992).

Platform width is remarkably consistent for all three taxon groups when standardized for size. Distance 8-9 measures the width of the anteriormost platform (posterior of the taper), and distance 10-11 measures element width at mid-platform. These measures are essentially the same for all three groups (Table 1). However, the maximum width of the platform margin (measured at the point where the adcarinal furrow is widest--distance 6-7) shows a linear relationship through the transition. Note that subadult *Mesogondolella nankingensis* exhibit a greater percentage than adults when treated as a distinct grouping, whereas the adult specimens average between the means for the transitional form and overall *M. nankingensis*.

Basic platform shape can be inferred using the ratios of several distance measures. As a general statistical principle, ratios tend to be more variable than individual measurements. Nevertheless, in this study the standard deviation of each distance in combination with the standard deviation of the ratios show that these parameters are consistent through the transition. The ratio of 1-9:1-8 provides a measure of element bowing along the anterior taper. A measure of 1.00 would indicate a straight anterior carina (zero bowing). The transitional form and *Mesogondolella nankingensis* have identical measures that indicate less bowing than occurs in *M. idahoensis*. This is easily confirmed qualitatively.

The intermediate character morphologies of the transitional form are typically duplicated in measures from other views. Table 2 lists the means of selected distances measured in lower view. The mean of the transitional form lies between that of its ancestor and descendant for the distances e-f and f-c. The former is a measure of the width of the outer margin at the pit, and the latter is a measure of the outer half of the attachment surface width at the pit. The related distance i-j measures the width of the outer margin at mid-platform, where the transitional form matches the mean of *Mesogondolella idahoensis*. Conversely, the mean maximum platform width (also measured at mid-platform) of the transitional form matches that of *M. nankingensis*. Considered together, these widths document how the transition proceeds from the *M. idahoensis*-state to the *M. nankingensis*-state for this lower surface character. This is reflected by the intermediate mean of the transitional form for the distance j-k, which measures the width of the attachment surface at mid-platform. The ratio j-k:i-l measures the amount of the lower surface composed of the attachment scar, which again produces an intermediate mean for the transitional form, as it does at the pit (f-g:e-h). A comparison of these two ratios documents the decreasing relative width of the lower attachment surface through the evolutionary cline.

The distance c-d in lower view is a measure of the lower platform surface posterior of the pit (Table 2). That distance is almost half again as long in *Mesogondolella idahoensis* than in either the transitional form or *M. nankingensis*, which share a similar mean for this measure (the transitional form mean falls between those of its ancestor and descendant when only adult specimens are included). The more expansive surface posterior of the pit in *M. idahoensis* promotes a false impression that the keel is reduced in this species relative to its descendants. However, the ratio of distances a-b:a-c demonstrates that the keel forms a more significant component of the lower attachment surface in *M. idahoensis* than it does in either the transitional form or *M. nankingensis*. Interestingly, this ratio of means for the transitional form falls outside those of *M. idahoensis* and *M. nankingensis*. The relatively high variability of this mean along with an average nearer *M. nankingensis* when only adults are considered (like distance c-d above) suggests that growth fields in the transitional form were interactive through ontogeny, stabilizing only after *M. nankingensis* became a distinct species.

For measures in lateral view (Table 3), cusp dimensions provide an excellent example of a direct linear relationship between all three taxonomic groupings. The distance A-B measures cusp height, whereas the distance F-G measures cusp width (elongation). In both cases, once scaled for size (relative maturity), the mean of the transitional form lies approximately half way between those of *Mesogondolella idahoensis* and *M. nankingensis*. Such data help document the continuity of this morphological cline.

Similarly impressive is an analysis of the relative discreteness of the anterior carina denticles. The distance K-L measures the length of the discrete portion of the penultimate anterior carina denticle. The distance L-M measures the length of the fused portion of the same denticle. The mean for K-L of the transitional form is essentially the same as for *Mesogondolella nankingensis*, and both are larger than that measure for *M. idahoensis*. Conversely, the mean for L-M of the transitional form is approximately the same as that for *M. idahoensis*, both of which are significantly larger than that for *M. nankingensis*. The overall evolutionary pattern for this character, from predominantly fused (*M. idahoensis*) to relatively discrete (*M. nankingensis*), becomes obvious. These coupled characters again produce a mean for the transitional form that is intermediate between the mean measures of its ancestor and descendant. The same relationship holds true for the anteriormost denticle (P-Q:O-Q).

The ratio E-T:arclength relates the direct measure of the anterior to posterior extremities in lateral view to the standard of that view, measured along the upper platform surface. This ratio thus serves to measure relative arching of the element. A perfectly flat element would have a ratio of 1.00. Note that *Mesogondolella idahoensis* is significantly less arched than either the transitional form or *M. nankingensis*, the latter two having an essentially identical mean arch ratio.

An anomalous mean in lateral view is that of the distance measuring the anterior termination of the lateral platform margins (S-T), which can be considered a measure of the average length of the "free blade". The mean distance for *Mesogondolella nankingensis* is more than twice that for *M. idahoensis*, but the mean for the transitional form is very near zero. This reflects a progressive reduction, then re-acquirement, of a "free blade" through the transition. That minimum mean in the S-T distance measurement serves to emphasize a point within the transition at which the anteriormost carina denticle is often completely enclosed by the lateral platform margins. This distinctive morphology in lateral view coincides with the initiation of anterior serrations at adult stages in the transitional form, conspicuous in upper view. It strongly suggests a good marker horizon within the transition where a chronostratigraphic boundary can be easily recognized both qualitatively and quantitatively.

SUMMARY

In summary, the evolution of *Mesogondolella idahoensis* into *M. nankingensis* transpired through a mosaic paedomorphocline. A short-ranging transitional form can be recognized both qualitatively and quantitatively. Numerical characterization of the complex interplay between various features should result in a precise definition of the concurrent basal Guadalupian/Roadian boundary. Once quantitative evaluation of sequential populations is complete, this precision should lead to a rapid consensus for selecting a GSSP defined within the clinal transition to mark the basal Guadalupian Series boundary.

Table 1. Means of Selected Distance Measures:
Upper View

Distance Measure	*M. idahoensis*	Transitional	*M. nankingensis*
1 - 2 (*l* anterior taper)	26.6 6.5	36.9 4.4	41.5 4.4
2 - 4 (*l* anterior platform)	9.1 3.7	10.5 2.5	18.5 8.5
4 - 5 (*l* posterior platform)	63.9 7.4	54.8 4.7	40.3 11.3
6 - 7 (*w* outer margin @ widest pt. of furrow)	4.4 1.8	4.7 1.2	7.3 1.5
8 - 9 (*w* platform @ taper)	29.3 1.5	29.4 1.6	28.9 3.9
10 - 11 (*w* @ mid-platform)	31.5 4.0	31.5 2.7	28.1 3.7
1-9:1-8 (anterior bowing)	.91 .04	.95 .03	.95 .03
8-9:10-11 (platform shape)	.94 .09	.94 .07	1.03 .05

Table 2. Means of Selected Distance Measures: Lower View

Distance Measure	*M. idahoensis*	Transitional	*M. nankingensis*
e - f (*w* outer margin @ pit)	7.1 1.3	5.9 1.7	5.6 2.1
f - c (*w* attachment @ pit)	11.9 2.0	9.7 0.4	8.4 1.4
i - j (*w* outer margin @ mid-platform)	9.2 1.9	9.2 1.3	11.7 1.9
j - k (*w* attachment @ mid-platform)	19.1 2.9	12.9 0.3	10.2 2.4
i - l (maximum platform *w*)	39.0 3.8	32.8 1.5	32.4 3.7
c - d (*l* pit to platform posterior)	18.3 3.4	13.5 1.7	13.5 2.1
a-b:a-c (keel % of attachment)	.59 .04	.26 .10	.31 .04
j-k:i-l (attachment % of lower surface)	.49 .03	.39 .02	.31 .07
f-g:e-h (attachment *w* @ cusp)	.65 .05	.61 .04	.57 .09
[j-k:i-l]: [f-g:e-h] (posterior expansion of attachment)	.76 .05	.65 .04	.55 .07

Table 3. Means of Selected Distance Measures:
Lateral View

Distance Measure	*M. idahoensis*	Transitional	*M. nankingensis*
A - B (*h* cusp)	8.3 1.8	5.5 1.4	5.3 0.8
F - G (*w* cusp)	8.0 1.2	6.0 2.0	3.9 1.6
S - T (*w* "free blade")	2.1 1.4	0.4 .2	4.9 1.8
K - L (discrete denticle)	3.4 .4	4.3 .5	4.2 1.1
L - M (fused denticle)	10.8 .7	10.5 2.0	6.0 1.4
L-M:K-M (% denticle fused)	.85	.79	.65
P-Q:O-Q (% denticle fused)	.85	.78	.67
E-T:arcl (arching)	.83 .02	.77 .03	.78 .02

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17. THE UPPER PERMIAN DEPOSITS OF THE VOLGA-URAL REGION, RUSSIA

The Volga-Ural region is stratigraphically typical of the Permian deposits. Scientists of Kazan University determined groups and stages for the Permian, and gave the most complete faunal descriptions including brachiopods, pelecypods, foraminifers, ostracodes, foliage flora, corals, bryozoans and conodonts of the separate stratigraphic units. The names of the most eminent Russian geologists are connected with the study of the Permian: Noinsky, Nechaev, Nikitin, Cherdinzev, Golovkinsky. Scientists of Kazan University are continuing stratigraphic, facies, mineralogical, petrographic, paleontologic and paleomagnetic investigations.

In spite of all this work there are still many problems that need to be addressed. Complex biostratigraphic, paleomagnetic and lithologic-facies correlation of the reference sections of the USA, Central Europe, Volga-Ural region and China can be considered as one of the most important problems of world stratigraphy of the Late Paleozoic. In order to solve this problem, we need to reconstruct the whole chain of geological events of the Late Permian and Early Triassic. The correlation of red non-marine formations of Europe, China and Northern America with normal-marine Permian deposits of Tethys could serve as the basis for a unified stratigraphic scale.

So in this respect, joint work on investigations of the stratotype sections in different regions as well as the study of lithological and paleontological materials, paleomagnetic investigations and the data interpretation are of great importance.

Geologist of Kazan University would like to draw their colleagues' attention to the Upper Permian deposits of Volga-Ural region of Russia. For this purpose from 3-10 July 1994, we are planning to hold a conference jointly with the Geological Institute of St. Petersburg. The program will include: 1) discussion of the stratigraphy, biostratigraphy, paleomagnetism and correlation of the Upper Permian of Russia and adjacent regions; 2) studying the palynological materials and collection of flora and fauna; 3) studying monographical collections of the geological museum; 4) work at the paleomagnetic laboratory; 5) 4 or 5 days excursion to the stratotypes and cross-sections along the Volga River and the Kama River.

Besides, during the excursion, participants will be acquainted with marine platform sections of the Upper Jurassic and Cretaceous well characterized by fauna.

Duration: 7 days, 3-10 July, 1994 at Kazan University. Cost $90.00 to $100.00 per day. Participants will be accommodated in the hotels while staying in Kazan and in the tents during field excursions.

Dr. G.V. Kotlyar, Dr. V.R. Losovsky, Dr. A.V. Gomankov, Dr. L.A. Fefilova, Dr. B.V. Burov and some others are expected to make reports. We would appreciate it if Dr. Newell, Dr. Visscher, Dr. Foster, Dr. Utting, Dr. Cassinis, Dr. Menning and other participants of the summer 1991 excursion could also make reports about obtained materials.

Leaders: G.V. Kotlyar and N.K. Esaulova. Concerning participation: Dr. G.V. Kotlyar, VSEGEI, Sredniy Prosp., 74, St. Petersburg, V-26, 199026, Russia. Tel.: 21-87-156. Dr. N.K. Esaulova, Geological Faculty, Kazan University, Lenina 18, Kazan, 420008, Russia. Tel.: 54-41-86, 318-427. Fax: 8432-380994, Telex: 224-641 Chair Su.

We would like to invite all interested specialists to take part in this work.

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18. CORRELATION BETWEEN AUSTRALIA AND THE TYPE TATARIAN, RUSSIAN PLATFORM, EVIDENCE FROM PALYNOLOGY AND CONCHOSTRACA: A DISCUSSION

The purpose of this note is to review:

- the palynological criteria for correlation and recognition of the Tatarian in areas outside of the type locality on Russian Platform, in particular Australia
- the marine faunal-equivalent age of the base Tatarian
- palynological criteria for recognition of the Permian /Triassic boundary
- current evidence for correlations with Australia using conchostracans.

INTRODUCTION

The type Tatarian on the Russian Platform is predominantly a non-marine redbed sequence and correlation within Russia and the FSU is achieved using plant macrofossils, spores and pollen, bivalves, ostracod and conchostracan assemblages. Because of the general lack of marine fauna, the Tatarian has been largely abandoned as a world standard, although the name appears as a time correlative on almost all standard chronologies, but often without substantiation. The situation is further complicated by the claim that a significant hiatus exists between the top of upper Tatarian (Vyatsky Horizon) and the overlying Vetlugian Series, considered to be of Early Triassic age (Gomankov 1992, also Gomankov and Meyen 1986).

Various non-palaeontological methods have been applied to correlate between the non-marine and marine sequences, but often circular arguments are involved. From Russian magnetostratigraphic studies, the boundary between the Permo-Carboniferous Reversed Superchron (PCRS) and the Illawarra Superchron is placed at the base of the upper Tatarian (Vyatsky Horizon, see Molostovskiy 1992 for summary). Thus to compare magnetostratigraphic results, and to test the use of reversal patterns for international correlation, independent time control is needed. This constraint also applies to the utilisation of carbon isotope values to define the Permian/Triassic boundary (see summary of Morante et al., 1994, Erwin, 1994). Of critical importance, therefore, is the recognition of the Tatarian, outside of FSU, and it is on this point that we concur fully with Gomankov (1992).

CRITERIA TO CORRELATE THE BASE OF THE TATARIAN- PALYNOLOGY

The first appearances of the pollen *Scutasporites unicus* Klaus 1963, and *Lueckisporites virkkiae* Potonié and Klaus 1954, and of the lycopod spore *Kraeuselisporites papillatus* Jansonius 1962, are, *inter alia*, considered primary keys to the recognition of the base of Russian Tatarian palynofloras (pers. comm. to Foster and Utting 1993 at Kazan State University by Fefilova, Gomankov et al.: see also Molin et al., 1986). Primacy is here given to the first appearance (FA) of *Scutasporites*, together with *L. virkkiae* (Figure 1).

Other quantitative indicators are used to recognise Tatarian palynofloras, such as the increasing abundance of the pollen *Vesicaspora schemeli* Klaus 1963 (for other examples see Varyukhina et al., 1981), but such criteria may be more important locally, rather than for international correlation - they are not used here.

Shared occurrences of *S. unicus* and *L. virrkae* were used by both Balme (1979) and Gomankov (1992) in suggesting correlation between the Tatarian of the Russian Platform and assemblages from Kap Stosch, East Greenland (Balme 1979; Figure 1).

S. unicus was described by Klaus (1963) from the upper part of the Grödner Sandstone [= Gröden Ss = Val Gardena Sandstone- see Wopfner et al., 1983; Italian Research Group (IRG) 1986], and the overlying *Bellerophon* Formation. Further palynological work by Pittau (*in* IRG 1986, *in* Massari et al., 1988) has confirmed the rare occurrences this distinctive pollen.

Correlation between the Russian Tatarian and assemblages from the Salt Range, Pakistan (Balme 1970) and eastern Australia is made via the same Alpine section in which Pittau reported *Playfordiaspora cancellosa* (Playford and Dettmann) Maheshwari and Banerji 1975 [as *P. crenulata* (Wilson) Foster 1979], and other Gondwanan pollen, which allows correlation with the *P. crenulata* Zone (see Foster 1982 for zonal criteria), equivalent to the lower part of the *Protohaploxypinus microcorpus* Zone of Helby et al. (1987).

Figure 1 shows the correlation between East Greenland, Austrian/Italian Alps, Salt Range, eastern Australia, and the Tatarian of the Russian Platform.

AGE OF THE BASE OF THE TATARIAN FROM MARINE EQUIVALENTS

Key sections for independent age determination lie in faunas from the upper Gröden Sandstone/ *Bellerophon* Formation, and the correlative upper Unit 4 of the Chhidru Formation, Salt Range. The age of the *Neogondolella rosenkrantzi* conodont fauna from the *Martinia* Shale, East Greenland, associated with Balme's *Vittatina* Assemblage and *S. unicus*, cannot be accurately determined (Gomankov 1992). *N. rosenkrantzi* has a maximum possible age of late Wordian (Kungurian), and a virtually unknown top range (Bruce Wardlaw pers. comm. 1994).

The age of the upper Gröden Sandstone and *Bellerophon* Formation is difficult determine, without involving circular arguments. Broglio Lorgia et al. (1988) noted that cephalopods, and tetrapod footprints, from 80m above the base of the Val Gardena Sandstone (≡upper Gröden) suggest a "generical Upper Permian age" **and from the palynological work of Pittau, and her correlation to eastern Australia/Salt Range they further inferred a "Lower Dzhulfian age"** (see Figure 1). Broglio Lorgia et al. (1988), and Broglio Lorgia and Cassinis (1992) further discuss the upper *Bellerophon* Formation fauna and from microfaunal evidence conclude a latest Dorashamian age. The evidence seems equivocal with comparisons at generic level. The latter work shows the Permian/Triassic boundary occurring within the overlying Tesero Horizon of the Werfern Formation (see Figure 1 and below, also review by Schönlaub 1991).

The age of Unit 4 of the Chhidru Formation has also undergone revaluation from Punjabian (pre-Dzhulfian of Waterhouse 1976) to Late Dzhulfian [Pakistani-Japanese Research Group (P-JRG) 1985]. Kapoor (1992, table 3.1, p. 22) shows Unit 4 reaching into the lower part of the upper Dzhulfian, but on another figure (3.2, p.24) shows the top of the Chhidru Formation (and by definition Unit 4) of mid Dorashamian age.

It seems that a Late Dzhulfian age for Unit 4 may be reached by consensus, and from the correlation shown in Figure 1, the same age is suggested for the base of the Tatarian.

A DISSENTING VIEW OF THE CORRELATION AND AGE OF THE BASE TATARIAN

Gomankov (1992, fig. 1) correlates only the uppermost Tatarian, the Vyatsky Horizon, with the Balme's East Greenland *Vittatina* Assemblage. His argument is based on negative correlation with the German Zechstein, and gives primacy to the appearance of the pollen *Klausipollenites schaubergerii* (Potonié and Klaus) Jansonius 1962. Gomankov argues that the Tatarian is older than the Zechstein, which in turn, he proposes, occupies a significant time hiatus between the top of the Tatarian of the Russian Platform and the overlying Vetlugian Series [for which an Early Triassic age is accepted, see below]. His conclusion is based on: 1) *K. schaubergeri* **does not occur** in the Tatarian, but is common in the unconformably, overlying Vetlugian Series and 2) on the apparent limited representation of the presumed oldest members of a proposed evolutionary development of *Lueckisporites* (Visscher 1971, 1973 - see discussion below).

In discussing a correlation with the Salt Range, Gomankov argues that the palynoflora from the uppermost Chhidru Formation (equated the *P. crenulata* Zone of eastern Australia - Fig. 1) is younger than that from the Tatarian, because of the lack, in the Tatarian palynofloras, of *Densoisporites* spp., *Ephedripites* spp. and *Lunatisporites* (al. *Taeniasporites*) *noviaulensis*. These taxa, however, a not essential components of the palynoflora from Unit 4 (= white sandstone unit, see Balme 1970).

REMARKS

The apparent absence of *K. schaubergeri*, noted by Gomankov, is interesting, although Klaus (1963, p.335), admittedly working from line drawings, considered that a single specimen from the Russian Early Permian (Kungurian) assigned to *Protocedrus* sp. by Samoilovich (1953, p. 39, pl. 7, fig. 2) belonged to *K. schaubergeri*. Visscher (1971, p. 65) also speculated that a line drawing appearing in Kiuntzel (1965) might be of *K. schaubergeri*, but as this has not been confirmed by Gomankov's re-examination of that material, it remains very tenuous. As *K. schaubergeri* appears throughout the Chhidru Formation (Balme 1970), it seems curious that the entire unit was also not considered younger than the Tatarian by Gomankov.

Through the courtesy of Dr Gomankov, Foster has prepared and examined palynological preparations from the Vyatsky Horizon (uppermost Tatarian), from the Russian Platform. These studies have shown the presence of pollen of the *Lunatisporites noviaulensis/pellucidus* complex, which in the Salt Range are typical of the uppermost Chhidru assemblage (Balme 1970), and the youngest Permian in eastern Australia: for this reason alone Foster considers that any time gap between the Tatarian and the overlying Vetlugian is much shorter than suggested by Gomankov. Moreover, his approach seems not to take into account any localised hiatuses within Tatarian reference sections.

Primacy for correlation is accorded by Foster to the appearance of *Scutasporites* with *L. virkkiae* rather than the apparent evolutionary development shown by *L. virkkiae*. As noted by Visscher (1980), in his discussion of *L. virkkiae*, morphologic criteria used to determine conspecifity need to be very carefully evaluated and understood. We note here that some of the Tatarian specimens of *Scutasporites* are larger that those assigned to *S. unicus* by Klaus (1963) and by Balme (1979), as *S.* sp. cf. *S unicus*; but they are congeneric.

SOME PALYNOLOGICAL INDICATORS OF THE EARLY TRIASSIC

Independently dated palynological events that mark the Early Triassic (here to include Griesbachian/Induan Stages) are: spinose acritarch blooms (Alaska, Canada, Greenland, Europe; Balme 1990, Visscher and Brugman 1981) and, with some notable exceptions (East Greenland, Balme 1979; Norwegian Western Barents Sea, Hochuli et al., 1989), the first appearance of members of *Aratrisporites* Leschik emend. Playford and Dettmann 1965 in, *inter alia*, Australia and Russia (see summaries by Mørk et al., 1992, also Ouyang and Norris 1988, Ottone and Garcia 1991). As shown in Figure 1, the latter is also used to identify the basal Triassic in non-marine sections in Australia (see Foster 1983) and Russia (e.g. Tuzhikova 1985). In Australia, *Aratrisporites* spp. first appear in the ammonoid-bearing, Griesbachian, Kockatea Shale (type locality for the *Kraeuselisporites saeptatus* Zone of Dolby and Balme 1976), and in the non-marine, palynoflora-bearing sections in eastern Australia assigned to the *Protohaploxypinus samoilovichii* Zone (see Foster 1982).

As noted above almost all records of the first appearance of *Aratrisporites* are considered of Triassic age. Kiuntzel (1986, fig. 12), working on upper Permian and lower Triassic palynofloras of the Moscow Syncline, pointed out that members of the genus appear in the top Tatarian. Dr Gomankov and CBF examined some of the original material from this study, but were unable to locate any specimens of *Aratrisporites*. The record, however, remains intriguing and further study is warranted as the same information is presented by Yaroshenko (1993, fig. 1). If correct, it emphasises, at least to CBF, that any gap between the Tatarian and Triassic is of localised importance.

Visscher and Brugman (1986) referred to a 'fungal event' which they considered linked the latest Permian and earliest Triassic, and documented abundances of *Tympanicysta* Balme 1979 from the upper part of the *Bellerophon* Formation and overlying Tesero Horizon of the Werfen Formation in the southern Alps. *Tympanicysta*, and its probable senior cogener *Chordecystia* Foster 1979, are widely known from upper Permian / Triassic (Induan) deposits throughout many parts of the world, Greenland, Canada, Europe, Australia (upper *P.microcorpus* Zone of Helby et al., 1987), China, Africa (Hankel 1992), Israel (Eshet, 1990), and Russia (Induan of Pechora Basin; 1991, 1993 unpublished observations Foster and Yaroshenko). The chronologic range of this form needs to carefully evaluated. In the Alps, Pittau (*in* IRG 1986) first recorded *Tympanicysta* together with *S. unicus* in the Val Gardena Sandstone (= upper Gröden Sandstone) of the Bletterbach-Butterloch section (see Figure 1) and it continues through to the Werfen Formation. As noted above a precise age for this section, perhaps other than Dzhulfian, has yet to be established. The same form also occurs abundantly in a Russian palynological slide, prepared by Dr I. Faddeeva (St. Petersburg), and marked Kazanian, held in the collection of Dr G. Warrington, British Geological Survey. More details are being sought, but the current age spread seems too large to claim that their widespread occurrence resulted from a single event.

TATARIAN CORRELATION BETWEEN AUSTRALIA AND RUSSIA: CONCHOSTRACAN DATA

Kozur (1977), Gomankov (1992) and Briggs (1993) refer to proposed correlations, on the basis of conchostracans, between the upper Tatarian (Vyatsky Horizon) and the Newcastle Coal Measures [NCm] ("Belmont Series" *sic*) of the Sydney Basin, eastern Australia. Of these papers, only Gomankov refers to a primary source (Novozhilov 1970) for this suggested correlation. Novozhilov (1970, p.34) claimed that using mainly conchostracan species of the superfamilies Leaioidea and Limnadioidea in Tatarian deposits of the Volga region, eastern Kazakhstan and the Lower Tungus Basin, correlation was possible with Sydney Basin faunas described by Mitchell (1925). Tasch (1987) placed Mitchell's sample localities in a modern stratigraphic context, and noted that most of his species from the Newcastle Coal Measures came from two localities: (i) near the top of the unit, from the Awaba Tuff Member of the Eleebana Formation (= Belmont Chert Quarries in Mitchell) and (ii) from the near the base of the unit, below the Dudley Coal Seam (see Herbert and Helby 1980 for details). Other localities occur in the Triassic Wianamata Group (Mitchell 1927). Mitchell's collections therefore span almost the entire coal measure section, through the overlying Narrabeen Group, Hawkesbury Sandstone, and Wianamatta Group. No Leaioidea were found by Mitchell above the Newcastle Coal Measures. *Aratrisporites* spp. makes its first appearance in the mid Narrabeen Group (and on this basis is considered early Triassic), while the last two mentioned rock units belong to the Middle Triassic (see Balme 1990).

According to Novozhilov (1970, table 8) the "Belmont Series", in which he included the Belmont Shale (= upper NCm), Narrabeen Shales (≈Group), and the Hawkesbury Shale (≈Group, Middle Triassic), equates with the upper Tatarian Stage. This correlation is based partly on the occurrence of his "Horizon with Leaioidea and *Megasitum harmonicum*" in the Vyatsky of the Volga region, the Bugariktinsk of the Lower Tungus Basin, the Maichatsk and Akkolkinsk Suites of Saikan-Saursk Syncline in eastern Siberia, and in the Belmont Beds and Narrabeen Shales of the Sydney Basin.

Arguments against this correlation are:

1. *Megasitum harmonicum* is so far unknown in Australia, and no leaioids have been recorded from the Narrabeen Group.
2. None of the leaioid species described by Mitchell (1925) from the Newcastle Coal Measures, have been found in Russia, despite their revision by Tasch (1987), and their current revision by Jones and Chen (in preparation). None of Mitchell's leaioid species that appear in Kozur's (1977, p.96) erroneous list, have, to our knowledge, been found in Russia. Some of Mitchell's taxa are recorded, however, in Novozhilov's (1956) monograph on the Leaioidea, as type species for many of the new genera he introduced, many of which are now invalid.
3. Again, from the Russian literature available to us, we know of only one leaioid species in the Russian Tatarian (*Triedrolophus tverdochlebovi* Molin 1968), whereas there are at least seven in the Kazanian, and at least another four near the Kazanian-Kungurian boundary (Novozhilov 1956, Molin 1968), many of which are referrable to *Hemicycloleaia.*

An argument to consider in favour of the correlation:
Five of the non-leaioid taxa described by Mitchell (1927) from the Newcastle Coal Measures, have been reported from the Upper Permian sequences of presumed Tatarian age in the FSU (Novozhilov 1958, 1970). They are *Palaeolimnadia glabra* [recorded as *L. (Limnadia) glabra*] from the Bugariktinsk Suite of the Lower Tungus Basin (Novozhilov 1970). *Pseudestheria novocastrensis** from the same unit (Novozhilov 1958), and from the Arctic Nordvik Basin in the subsurface Misailapsk Series, where they occur with *P. obliqua**, *Glyptoasmussia belmontensis* and *Concherisma bellambiensis**. From preliminary comparisons of figures of the Russian specimens, taxa marked with an asterisk (*) are accepted, tentatively, as conspecific. *C. bellambiensis* is probably a small bivalve, as Mitchell (1927) suggested.

Lev (1957) studied the fresh-water ostracods (mostly new species of *Darwinula*) from the Misailapsk and the overlying Effusive-Tuff Suite. Palynomorphs were studied from the same deposits by Dibner (1958), who identified the assemblage as a Tatarian, but the data needs to be re-evaluated, to confirm correlation with other Tatarian assemblages.

COMMENTS AND CONCLUSIONS

Figure 1 shows our suggested correlation of the Russian Tatarian, based on the appearance of *Scutasporites* together with *Lueckisporites*, and recognition of palynological correlatives of the upper Chhidru Formation, but more detailed information is required for confirmation. For example, are the key spore-pollen species from the upper Chhidru Formation at Wargal confined to this level? The Salt Range sections have been subjected to intense study but the Wargal section, from which Balme (1970) recovered the distinctive suite of plant microfossils, does not appear to have been re-examined as part of subsequent palaeontologic/palaeomagnetic/ carbon isotopic studies (e.g. P-JRG 1985, Baud et al., 1989, Haag and Heller 1991). The Wargal section was mapped as the 'white sandstone unit' (Kummel and Teichert 1970, ≡ Unit 4 of later workers), but from the general lithologic description of Unit 4 (e.g. at Zaluch Nala, "weathered very soft, thinly laminated sandstone and sandy shale" P-JRG 1985, p.237) it seems unlikely that plant microfossils could be preserved in this lithotype. This may not affect the late Dzhulfian age assigned to the Chhidru Formation *in toto*, but further sampling is required. Similarly there are problems in dating precisely the Alpine and East Greenland sections, resulting from either poor preservation of fossils, or geographically restricted/long ranging faunas, and complex lithological relationships.

At present too little is known about the ranges of the above conchostracan species to assess their usefulness for age determination. Whether the Newcastle Coal Measures should be correlated with the Tatarian or with the Kazanian *on the basis of conchostracan evidence*, remains an open question. We do, however, find it very interesting that shared species from another marine microfossil group (Foraminiferida), and also from the Nordvik Basin, do occur in eastern Australian assemblages, allowing correlation with the early Late Permian (Kazanian; Foster, Palmieri and Bondareva in prep.). Correlation potential with Russian sections might also exist in the rich fossil insect faunas of the Newcastle Coal Measures, and needs to be evaluated.

Despite problems in establishing ties with the Tatarian of the Russian Platform, it is premature to claim that alternative methods of correlation, e.g. palaeomagnetism and carbon isotopes, are more precise. These alternative methods must themselves be calibrated independently, using palaeontologic data. What is highlighted by this review is that much more primary analysis of both marine and non-marine fossils is required.

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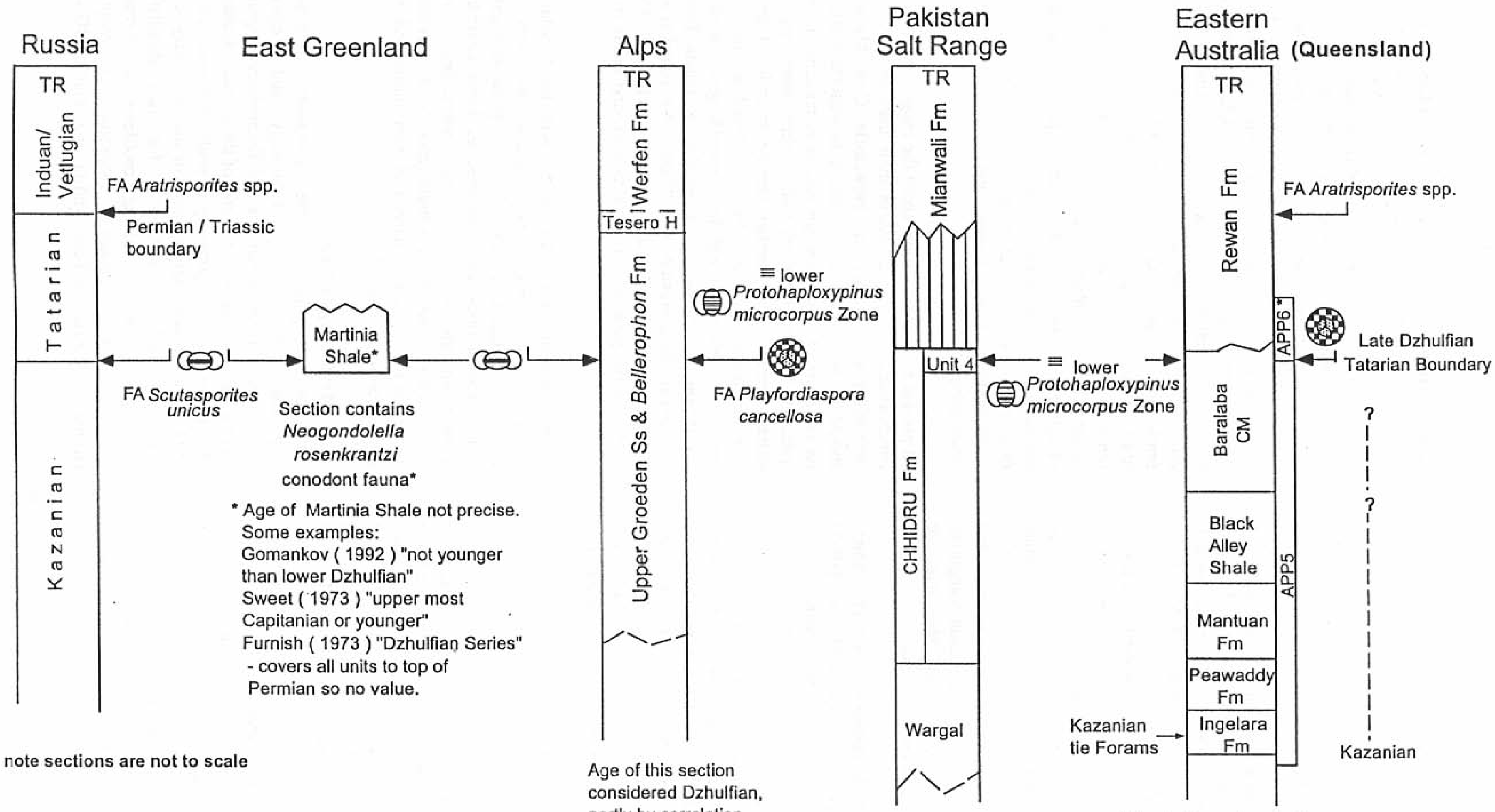

* Age of Martinia Shale not precise.
Some examples:
Gomankov (1992) "not younger than lower Dzhulfian"
Sweet (1973) "upper most Capitanian or younger"
Furnish (1973) "Dzhulfian Series" - covers all units to top of Permian so no value.

Age of this section considered Dzhulfian, partly by correlation with Australia and Salt Range.

* Age of Unit 4

. Pakistani - Japanese Working Group (1985)
"Late Dzhulfian for all Chhidru.
Wargal - upper Murgabian to lower Djulfian.

. Gomankov (1992) lower Djulfian (for Unit 4) and Russian Tatarian older.

· Kapoor (1992) Unit 4 going into the Dorashamian.

* Australian palynologic zones (Draper *et al.* 1990)

Figure 1

SUGGESTED CORRELATION OF THE TATARIAN WITH EASTERN AUSTRALIAN SECTIONS via SALT RANGE, AUSTRIA AND GREENLAND. EVIDENCE FROM PALYNOMORPHS.

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19. UPPER PERMIAN OCHOA GROUP OF WEST TEXAS AND SOUTHEASTERN NEW MEXICO

INTRODUCTION

In North America, strata of Late Permian age are confined to the southern High Plains of the western United States. In west Texas and southeastern New Mexico, these strata are an evaporate-dominated succession as much as 1700 m thick long referred to as the Ochoan Series. Ochoan rocks are mostly nonfossiliferous and may include strata of Middle Permian (Guadalupian) and Early Triassic age. Therefore, use of Ochoan as a Late Permian stage can be rejected. Instead, we view these strata as a lithostratigraphic unit, the Ochoa Group. Here we briefly summarize Ochoa Group stratigraphy and age relationships based on recently published, more extensive reviews by Lucas and Anderson (1993, 1994).

STRATIGRAPHY

The Ochoa Group consists of four formations (in ascending order): Castile, Salado, Rustler, and Quartermaster (Figs. 1, 2). The Castile Formation has a maximum thickness of 700 m and consists of anhydrite, calcite-banded anhydrite, halite, limestone and minor amounts of other evaporites and clastics. It conformably overlies the uppermost Bell Canyon Formation and equivalents and has a conformable and intertonguing contact with the overlying Salado Formation.

The Salado Formation is mostly halite with thin beds of anhydrite, polyhalite, shale and potash-bearing salts. Maximum thickness is about 725 m, and there are no known outcrops of the Salado Formation. In the Delaware basin (Fig. 1), the Salado is conformably underlain by the Castile Formation and conformably overlain by the Rustler Formation. However, beyond the Delaware basin to the north and northwest, the Salado rests unconformably on the Guadalupian Artesia Group (Tansill Formation), and in some areas the Rustler truncates the Salado.

The Rustler Formation has an extensive outcrop area in the Rustler Hills of West Texas where it is as much as 114 m thick. The maximum reported subsurface thickness is 150 m. Lithologically, the Rustler Formation can be divided into two parts, a lower portion of dolomite, anhydrite, sandstone and shale and an upper 45-53 m thick bed of anhydrite or gypsum. Five members of the Rustler Formation have been formally proposed (ascending order): Virginia Draw, Culebra, Tamarisk, Magenta and Forty-Niner members. The Quartermast Formation unconformably? overlies the Rustler Formation.

The youngest Ochoa Group strata belong to the Quartermaster Formation (Dewey Lake Formation and Pierce Canyon Redbeds are synonymous terms). As much as 115 m thick, the Quartermaster Formation is red beds of fine- to medium-grained sandstones, siltstones and gypsum in laterally persistent beds intercalated to give the appearance of cyclical deposition. Upper Triassic (Upper Carnian) strata of the Dockum Formation of the Chinle Group disconformably overlie the Quartermaster Formation.

OCHOA GROUP AGE RELATIONSHIPS

The Castile Formation contains no fossils or other evidence such as volcanic-ash beds by which its age could be directly estimated. Because it overlies Capitanian strata (Lamar Limestone Member of the Bell Canyon Formation and its equivalents) its late Guadalupian maximum age is established. Several post-Lamar limestone beds in the basal

Castile may contain evidence of Guadalupian age. Thin laminae in the Castile suggest that deposition was in relatively deep water, well below wave base, and spanned approximately 200,000-300,000 years. The end of the Capitanian is estimated to have preceded the end of the Permian by 5 million years on most numerical time scales. This indicates that Catile deposition consumed approximately 5% of Late Permian time, if the cyclostratigraphic estimate is correct. Therefore, the entire Castile Formation is Permian, and it represents a tiny fraction of Permian time very close to the Middle-Late Permian boundary.

No fossils or other age indicators are known from the Salado Formation or are likely to be found. Its conformable and interfingering lower contact with the Castile Formation and position below Rustler Formation strata with Late Permian fossils indicate that the Salado must be of Late Permian ge. However, the duration of Salado deposition is impossible to estimate.

The Rustler Formation offers the best time constraints of the entire Ochoan section. An extensive marine invertebrate fauna from the Virginia Draw Member in the Rustler Hill is of Permian age. This fauna is dominated by brachiopods (especially *Derbya sulcata* Walter), with lesser numbers of bivalves and gastropods. It co-occurs with an extensive conodont fauna that has been assigned a Changxingian (Late Permian) age. The post-Virginia Draw Member strata of the Rustler lack an invertebrate macrofauna, although in their lowest part (Culebra Dolomite Member, basal Tamarisk Member) they contain conodonts like those lower in the Rustler section. Therefore, it is probable that the entire Rustler Formation is of Late Permian age, though there is no direct age control for the upper part of the formation.

Three lines of evidence bear directly on the age of the Quartermaster Formation:

1. Three molluscan taxa from Quartermaster outcrops in Briscoe County, Texas - *Naticopsis transversus* (Beede), *Schizodus oklahomensis* Beede and *Myalina acutirostratus* Newell and Burma - may suggest a Permian age.
2. Magnetostratigraphy of the Quartermaster Formation in Palo Duro Canyon, Texas, has been correlated to the Late Permian Illawara magnetozone at the end of the Kiaman superchron.
3. Fracasso and Kolker sampled and dated a volcanic-ash bed in the Quartermaster Formation that lies 4 to 20 m above the base of the formation in Caprock Canyon State Park, Texas. K-Ar dates of 251±4 and 261±9 Ma were obtained by Fracasso and Kolker. The Permian-Triassic boundary is very close to 251 Ma, so the Quartermaster radiometric ages are either latest Permian or earliest Triassic.

All evidence either directly indicates, or is consistent with, a Late Permian age assignment for the Quartermaster Formation. None of these lines of evidence, however, is incontrovertible, and the possibility that some or most of the Quartermaster Formation is of Triassic age needs to be considered, though no evidence currently supports such an age assignment.

DISCUSSION

Although originally proposed as a series, Ochoan has been treated as a stage equivalent to Late Permian time. As the stratotype of a stage, Ochoan strata have been well studied and described and are very accessible, thus meeting two of the key requirements of stratotype for a chronostratigraphic unit. Nevertheless, the Ochoan strata fall far short of an ideal stratotype for a Late Permian stage because they generally lack fossils, radiometric-age data and geomagnetic-polarity data with which to correlate. Furthermore, estimates of the duration of early Ochoan evaporite deposition and intra-Ochoan unconformities suggest that Ochoan strata present only a very incomplete record of Later Permian time. It is even possible, though currently not demonstrable, that some of the youngest Ochoan strata are of Triassic age.

We thus conclude that the Ochoan strata do not provide a suitable stratotype for a stage in the SGCS (standard global chronostratigraphic scale). The use of Ochoan as a regional stage also is problematic because outside of the southern High Plains of eastern New Mexico, west Texas, Oklahoma and parts of Colorado and Kansas there are no known Late Permian rocks in North America. Thus, as a chronostratigraphic unit, Ochoan has very limited utility. Therefore, we recommend that it be dropped from the chronostratigraphic hierarchy and be referred to as a lithostratigraphic unit, the Ochoa Group. The Ochoa Group thus consists of the Castile, Salado, Rustler and Quartermaster Formations, an evaporite-dominated sequence of mostly anhydrite and halite. Available data suggest that the Ochoa Group was deposited during the Late Permian in the southwestern United States. Strata of the Ochoa Group are largely unfossiliferous and do not provide a suitable basis for global correlation of Upper Permian strata.

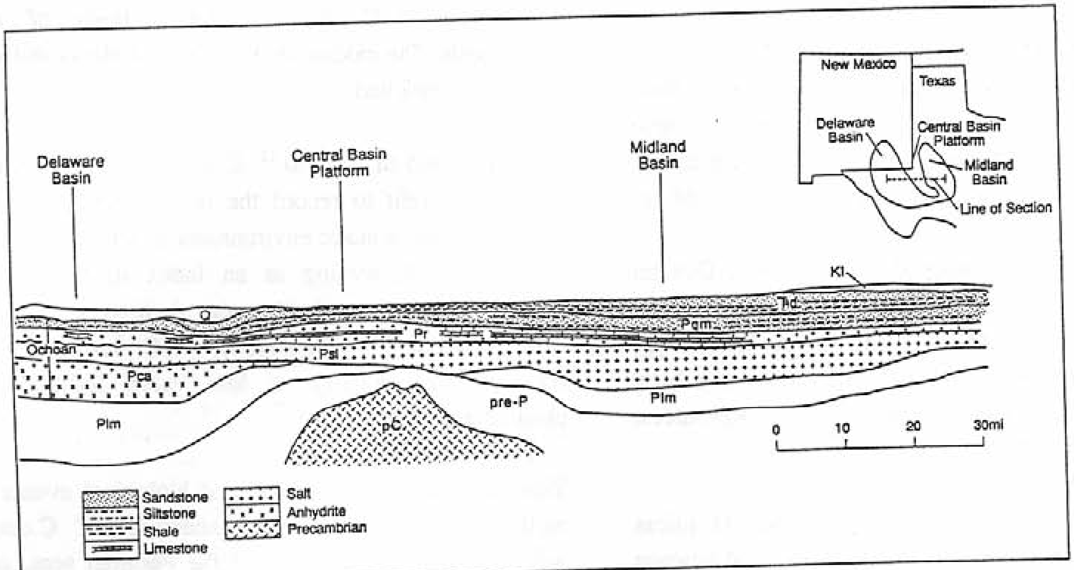

Figure 1. Generalized cross section through Delaware and Midland basins showing regional extent of Ochoan strata. Pe=Precambrian, pre-P=pre-Permian rocks, Plm=Lower and Middle Permian rocks, Pcz=Castile Formation, Psl=Salado Formation, Pr=Rustler Formation, Pqm=Quartermaster Formation, Trd=Dockum Formation, Kl=Lower Cretaceous rocks, Q=Quaternary deposits. Modified from King (1942).

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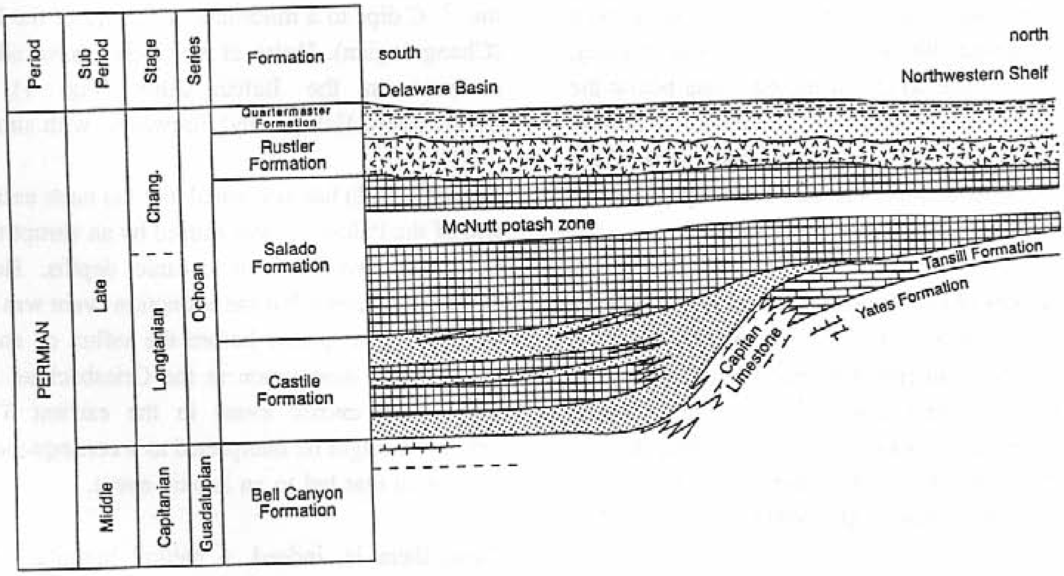

Figure 2. Generalized stratigraphy and age relationships of Ochoan strata in southeastern New Mexico and west Texas.

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20. IS THERE A PRECISE PERMIAN-TRIASSIC BOUNDARY?

In the Rocky Mountains of Western America (Newell and Kummel, 1942) and Western Tethys (e.g., Broglio Loriga et al., 1986 and Posenato, 1988) the lower Griesbachian contains a sparse and peculiar fauna, with *Lingula* and *Claraia* below and with some mixing, *Eumorphotis* above. The so called mixed fauna below the *Lingula* zone (Tesero) we regard as Paleozoic. A normal Triassic fauna gradually recovers with the Nammalian. This includes echinoderms, ammonoids, and brachiopods, as the *Lingula-Claraia* association drops out.

Geochemical studies of stable carbon isotope ratios seem to record variations in the composition of the marine waters in which the boundary sediments were deposited. In addition to minor variations in percentage of ^{13} C in the carbonate fraction of the boundary rocks, there is a dramatic drop in the ratio $_{13}$ C/^{12} C (δ^{13} C, fig. 1) at the culmination of the P/Tr extinction level (Holser et al., 1991).

We may ask, what bearing do the stable isotopes of carbon have on the mass extinctions? The argument is simple (Magaritz, 1989). It is well established that plants favour ^{12} C over ^{13} C in the photosynthesis of organic compounds. The calcareous skeletons of plants and animals are not so enriched.

Thus, the ratio of ^{13} C to ^{12} C in a particular sedimentary layer is thought to record the relative levels of the two isotopes in the aquatic environment in which the sediment was deposited, serving as an index to fluctuations of organic productivity in the sea. A high value of ^{13} C reflects massive withdrawal of ^{12} C into the biomass, increased productivity; a low value indicates lower productivity.

This association of chemical and biological events seems well established. The negative excursion of ^{13} C correlates with the marine regression of the Permian seas, and the following positive excursion closely agrees with the Griesbachian transgression.

In the Permo-Triassic extinction event the isotope ratio of ^{13} C reaches a high level in the mid-Permian (early Guadalupian) with its rich and diverse faunas, followed by a dwindling of taxa and, finally, by a near total extinction of the Permian fauna at the top of the Changxingian (Dorashamian).

Recently Baud et al. (1989) sampled twenty Late Permian-Early Triassic Tethyan sections in Yugoslavia, Turkey, Greece, Armenia, Iran, Pakistan, India and Nepal. In these places and in SE South China (Gruszcyznyski et al., 1990) the ^{13} C dips to a minimum at the top of the Dorashamian (Changxingian). Holse et al. (1991), have added detailed analyses in the Italian Alps (Fig. 1), Greenland, northwestern Europe, and elsewhere, with similar results.

Hallam (1991) has suggested that the mass extinction at the end of the Paleozoic was caused by an abrupt transgression of anoxic waters from oceanic depths. However, our evidence suggests that the extinction event was gradual, and essentially completed before the influx of anoxic waters. The *Lingula* association in the Griesbachian supports the idea of an anoxic event in the earliest Triassic. The extinction might be interpreted as a consequence of a major regression that led to an anoxic event.

Thus, there is, indeed, a natural boundary between the Permian and Triassic erathems with the coincidence of facies boundaries, minimum of δ^{13} C, and biological diversity.

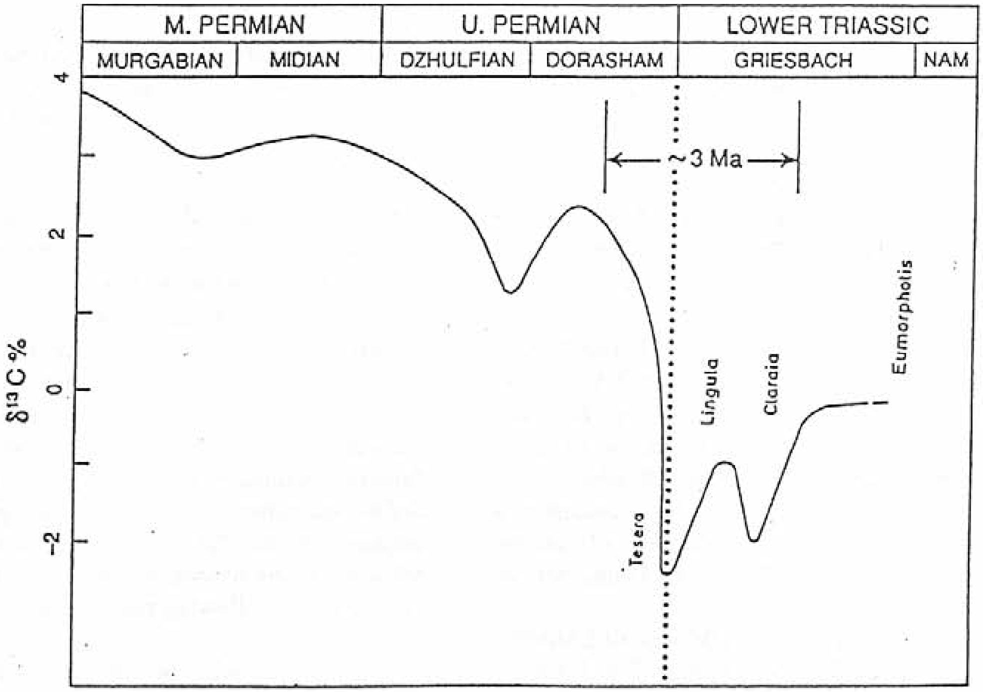

Figure 1
Regional trend in stable carbon isotopes near the Permo-Triassic boundary throughout Tethys. Adapted from Baud et al. (1989) and Holser et al. (1991).

Inferred decline in diversity and biomass accompanied a persistent marine regression to the top of the Tesero Member, followed sharply by unfavourable *Lingula* transgression and slow recovery.

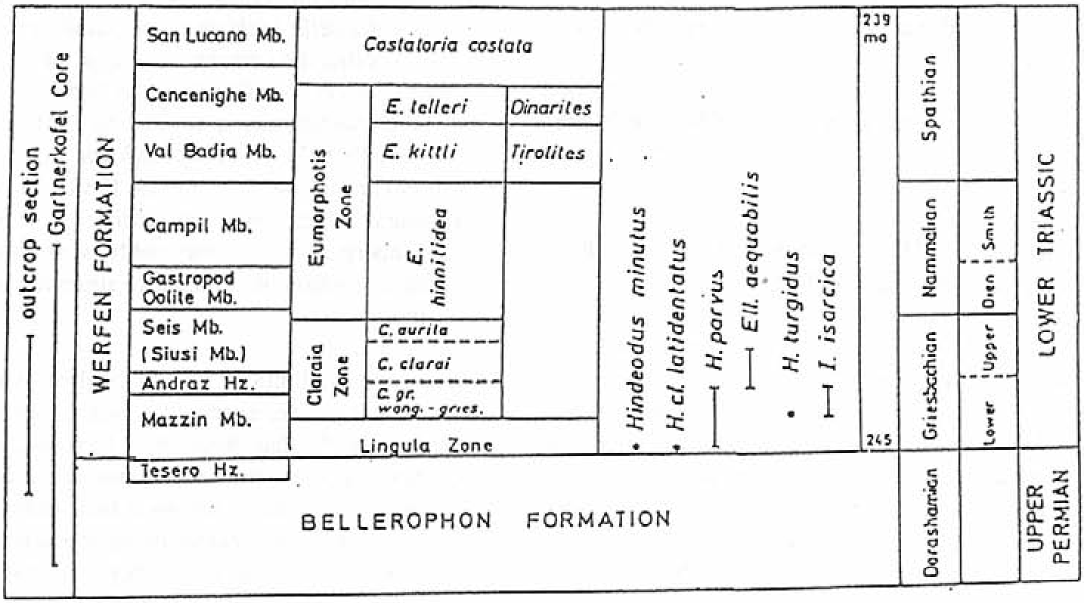

Figure 2
Stratigraphic subdivisions of the Triassic in the Southern Alps. Adapted from Holser et al. (1991) and Broglio Loriga et al. (1986).

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21. CONSIDER THE "UNNATURAL" - FOR CORRELATION POTENTIAL

I write in response to the preceding article by Norman Newell, and as part of a friendly correspondence we have enjoyed over the years. Unlike many of our colleagues, we both recognize gradual trends in organic diversity from a high in the Guadalupian through decline to a minimum near the Paleozoic/Mesozoic boundary, and progressive increase into the Triassic. These trends in community structure can be related in turn to the Late Paleozoic regression and succeeding early Triassic transgression (e.g., Ross and Ross, 1987).

The continuing challenge is achievement of international consensus on <u>definition</u> of the Permian/Triassic boundary GSSP. Impressive advances in understanding geological relationships near the boundary were made in 1993, many of them summarized and evaluated by Yin (Albertiana 11, 1993) and further amplified in the PANGEA Abstracts and those of the Boston GSA meeting. Most important were attempts to appraise the roles in definition and correlation of biostratigraphic, lithostratigraphic, geochemical, paleomagnetic and climatologic data. Results include a trend to adopt the stratotype appearance of the conodont *Isarcicella*? *parva* for definition of the base of the Triassic, in place of the ammonoid *Otoceras* (Yin, 1993), as well as the suggestion of some workers (P/T BWG Newsletter, no. 2, p. 3, 1993) ". . . set the boundary at the world-wide anoxic event in connection with maximum transgression, mass extinction and anomalous geochemical spike . . .", the "natural" boundary. I continue to favor a biostratigraphic definition, rather than one based on geochemical signals, because of the far greater precision achievable with reference to the former. Amplification of this preference is offered in the following paragraphs.

The search should be for an "unnatural" boundary definition, one that is based upon a precisely but arbitrarily chosen point within an evolutionary morphocline. Such clines are common when the biologic group is chosen wisely and the stratigraphic record is devoid of significant gaps. Conodont clines appear to be the best choice for the P/T boundary, and a suitable phylomorphogenetic lineage, including *Isarcicella*? *parva*, has been recognized (e.g., Kozur, 1989) although not yet adequately documented. Many of the Permian stage boundaries are susceptible to similar definition. Lambert (1992, and herein), for example, has an elegant conodont "mosaic paedomorphocline" (*Mesogondolella idahoensis>M. nankingensis*) that will be used to define the coincident base of the Roadian Stage and the Middle Permian Guadalupian Series. Similarly, the base of the Carboniferous is defined by the first appearance of the conodont *Siphonodella sulcata* in the cline from *S. praesulcata* (Flajs and Feist, 1988). [Interestingly, this boundary event was immediately preceded by the Hangenberg anoxia, recognizable world-wide by brief but drastic disruption of community structure and modification of lithofacies.]

Once the definition is established within a single evolutionary cline, every other venue can be employed to correlate with that boundary: biologic, sedimentologic, geochemical, paleomagnetic, climatologic, and tectonic. The "housekeeping" phase will have been terminated, affording the opportunity to concentrate on the science. Rather than being content to relate to a 3 m.y. "natural" event, we will have the possibility of correlation with a resolution of perhaps one hundred thousand years, or even a few tens of thousands (interpolated from Sweet, 1992, p. 128). A precise benchmark will have been provided, against which to chronicle numerous other biological and physical events.

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22. CONODONTS FROM OTOCERAS BEDS: ARE THEY PERMIAN?

Of course, the answer to this question depends entirely on the final definition for the base of the Triassic. The *Otoceras* beds have long been regarded as basal Triassic (Tozer, 1988). However, recently it has been claimed that *Otoceras*-bearing beds at several localities contain conodont fauna like that of the Changhsingian, and are therefore at least partly Permian under proposed conodont-based definitions (Sweet, 1979, 1992; Yin et al., 1988). Below, I summarize new data recently compiled by Orchard, Nassichuk and Lin (in press) from Selong, Tibet, and review other published data bearing on this question. As a complement to this, I have studied conodont collections from Meishan (Wang and Wang, in Zhao et al., 1981), type section of the Changhsingian; from *Paratirolites* beds in northwest Iran (Sweet in Teichert et al., 1976), equivalent to the higher Dorashamian; type material of *Neogondolella carinata* and its associates from the Lower Triassic Dinwoody Formation in western USA (Clark, 1959); and Upper Griesbachian conodonts from the *Proptychites strigatus* Zone of Ellesmere Island in the Canadian Arctic (Mosher, 1973).

The localities where *Otoceras* and conodonts are reported to co-occur are Selong in Tibet, the Guryul Ravine in Kashmir, sections in the central Himalaya (Spiti, Lalung), and in the Arctic. Additional reports of *Otoceras* from South China are unconfirmed, and therefore are not considered here.

Recently, the conodont fauna of the Lower Griesbachian *Otoceras latilobatum* bed at Selong, Tibet has been described by Orchard et al. (in press). The basal Triassic at Selong includes two horizons with *Otoceras*: the *O. latilobatum* horizon below and the *O. woodwardi* horizon above. These might be equivalent to, respectively, the *O. concavum* zone and the *O. boreale* zone in the Canadian Arctic Archipelago (Wang et al., 1989). Conodonts from Selong have formerly been the subject of studies by Rao and Zhang (1985); Yao and Li (1987); Wang et al. (1989); Xia and Zhang (1992); and Wang et al. (1993). Yin (1993, p. 45-47) has recently summarized the section too and highlighted the divergence of views on the conodonts from the *Otoceras* beds. The fauna described by Orchard et al. (op. cit.) comprises *Hindeodus typicalis*, *Isarcicella? parva*, *N.* aff. *N. carinata*, *Neogondolella* aff. *N. changxingensis*, *N.* n. sp., and *N. tulongensis*. A single *I. isarcica* is reported from the top of the bed. These results differ in detail from those of previous workers, but also partly duplicate records that have been contentious. In summary:

1) The concurrent appearance of *Isarcicella? parva* and *Otoceras* reported by Wang et al. (1989) is confirmed. These taxa might therefore provide complementary indices for definition of basal Triassic.
2) The recovery of *Isarcicella isarcica* confirms the occurrence reported previously only by Rao and Zhang (1985). Selong is the only reported locality where *Otoceras* and *I. isarcica* co-occur.
3) Contrary to reports of authors other than Xia and Zhang (1992), the Changhsingian *Neogondolella changxingensis-N. deflecta* assemblage is not recognized within the *Otoceras latilobatum* bed at Selong.

Conodonts described from the *Otoceras* beds at Guryul Ravine by Bhatt et al. (1981) and Bhatt and Arora (1984) included the Changhsingian species *Neogondolella changxingensis*, *N. deflecta* subsp., and *Hindeodus* cf. *latidentatus*, in addition to the long ranging *H. typicalis* and *N. carinata*, and the potential Triassic index *Isarcicella? parva*. Poor illustration of these conodonts precludes confident assignment but, significantly, the occurrence of the Permian species was not acknowledged in subsequent syntheses. In fact, Matsuda (1984) recorded only a single species of *Neogondolella*, that is *N. carinata*, from the Lower Triassic of Kashmir. He illustrated variants that resemble the Selong species *N. tulongensis* and *N.* n. sp., which may have been formerly misidentified as, respectively, the Permian species *N. deflecta* and *N. orientalis* by other authors (see below).

Conodonts from *Otoceras*-bearing strata in the Kumuan, Spiti, and Zanskar sections of the Himalayan region were also described and illustrated by Bhatt and his colleagues. The first report by Bhatt and Joshi (1978) listed the species from the Spiti River section, but provided no illustrations. As discussed by Nakazawa et al. (1980, p. 83), the listed fauna was almost identical with the fauna of the *Otoceras* beds of the Guryul Ravine. Subsequently, Bhatt et al. (1981) and Bhatt and Arora (1984) listed and illustrated conodont faunas from *Otoceras* localities in the central Himalayas, namely Kumuan, Spiti, and Zanskar, as well as at Guryul Ravine (see above). From these faunas they identified *Neogondolella subcarinata*, *N. changxingensis*, *N. carinata*, *N. orientalis*, *N. planata*, *N. deflecta* subspp., *N. behnkeni*, and *N.* sp. A (Bhatt and Arora, 1984, p. 724). Illustrations of these conodonts, mostly from Lalung in the Spiti Valley, are difficult to assess confidently, but, as with the Guryul Ravine material, examples of *N. tulongensis* and *N.* n. sp. appear to be present whereas typical Permian conodont species are not apparent. This is in agreement with Matsuda (1984, p. 120, 122) who, having examined Spiti collections, explicitly rejected the presence of the Permian "*N. subcarinata* group" in the *Otoceras* beds of Spiti.

In the Arctic, Sweet (in Teichert and Kummel, 1976) reported *Hindeodus typicalis* and *Neogondolella carinata* from the *Otoceras boreale* beds in the Kap Stosch area of east Greenland. Recently, Kozur (1993) reported having seen in the Greenland conodont material of W.C. Sweet, *Neogondolella subcarinata* and *N. orientalis* from the "lower *Hypophiceras* Bed"; *Hindeodus latidentatus* from the "*O. boreale* Bed", and *Isarcicella? parva* from the "*Ophiceras* Bed". These data, which are difficult to reconcile with published data in Teichert and Kummel (1976), are crucial because they represent an exceptional record of *H. latidentatus* with *Otoceras*, a situation that Kozur (1989, p. 390) cites to demonstrate that "..the lower *O. woodwardi* Zone and ..the older *O. concavum* Zone..corresponds to the late Changhsingian..". No further details or illustrations of Greenland conodont material have been provided since Sweet's work.

Dagis and Korchinskaya (1987, 1989) also reported the association of *Otoceras boreale* and *Neogondolella carinata* in Spitsbergen. Attempts to extract conodonts from the limy matrix of *Otoceras* specimens collected by E.T. Tozer in the Canadian Arctic have not been successful. However, Henderson (1993) reported Changhsingian conodonts from shales at the base of the *Otoceras*-bearing Blind Fiord Formation in the Sverdrup Basin, but the conodonts remain undescribed and their relationship to *Otoceras*-bearing beds is unclear.

Late Permian sections in Transcaucasia (Dorashamian) and south China (Changhsingian) contain a conodont fauna dominated by *Neogondolella subcarinata*, *N. changxingensis*, *N. deflecta*, and *Hindeodus typicalis*. *Hindeodus latidentatus* occurs in the uppermost parts of the Permian in both regions. Reports of the Griesbachian species *N. carinata* throughout the Ali Bashi and Changhsing formations is, in my view, incorrect. Rather, these elements should be assigned to one or more new species. As alluded to above, many reports of the latest Permian *Neogondolella* species in Griesbachian strata are also judged to be incorrect.

This brief review suggests that there is little, if any, unambiguous conodont data that demonstrates contemporaneity of Lower Griesbachian *Otoceras* and uppermost Permian Changhsingian and Dorashamian stages. A more exhaustive review is given by Orchard et al. (in press). Reports of uppermost Permian conodonts in the Griesbachian, and of Griesbachian conodonts in the uppermost Permian, are refuted or remain unverified. Clearly, further taxonomic revision of *Neogondolella* species from the P-T boundary interval is needed. This is particularly true of *N. carinata* and related species. These revisions will impact significantly on conclusions reached through both traditional and graphic correlation techniques.

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23. THE PERMIAN/TRIASSIC BOUNDARY AND POSSIBLE CAUSES OF THE FAUNAL CHANGE NEAR THE P/T BOUNDARY

Any discussion about the possible causes of the faunal change near the P/T boundary must be based on the question what happened with the faunas in world-wide correlatable horizons near the P/T boundary. It has to be clearly distinguished between local effects on the fauna which may be dramatic because of local facies changes, and world-wide effects on the fauna which happened independently from local facies changes. World-wide faunal changes may be unrelated to facies changes or related to global facies changes. Most important is the correct world-wide correlation of investigated horizons in the Permian-Triassic boundary interval.

During the entire Permian the Boreal (and Notal) ammonoid faunas are very different from the tropical-subtropical Tethyan ones. Bipolarity in distribution of the ammonoid taxa is common for this entire time interval. For instance, the perrinitids are the most important Early Permian guideforms of the tropical-subtropical Tethyan faunal realm including the Eurasiatic Tethys and SW North America. These guideforms are totally missing in the Boreal realm, including also the Cis-Uralian Permian type area, and in the Notal faunal realm. Mixed Boreal-Tethyan faunas are during this long interval either very rare and restricted to small areas or for the most part of this time interval even unknown.

The same picture of ammonoid faunal provincialism can be observed up to the Changxingian. The Tethyan Changxingian ammonoid faunas are different from the Boreal and Notal cool- and cold-water *Otoceras* faunas. Because of the widespread interpretation of the *Otoceras* faunas as Triassic, this situation was explained by a world-wide gap in the ammonoid-bearing pelagic beds around the P/T boundary. Where the latest Permian Changxingian ammonoid faunas are present, there the assumed earliest Triassic *Otoceras* faunas are said to be missing because of a gap and where the assumed earliest Triassic *Otoceras* faunas are present, there the latest Permian Changxingian ammonoid faunas are said to be missing because of a gap. In the same time it was recognized that even in some very shallow-water environments, like in the Southern Alps, no gap is present around the P/T boundary. The provincialism of the fusulinids is even larger than that of the ammonoids. There are not only differences between the fusulinid faunas of the Boreal and Tethyan realms, but also within the Tethyan realm (Eurasian Tethys-Texas).

The only stratigraphically fossil group which is not much affected by the strong Permian provincialism, are the conodonts. The conodont-defined P/T boundary differs not much by different authors. Kozur (1977 and later papers) defined the P/T boundary with the assumed first appearance of the genus *Isarcicella* at the base of the *I. isarcica* Zone. The base of this zone was also preferred as P/T boundary by Sweet (e.g. 1992) and Kotylar (1991). Yin (1985) preferred the first appearance of *H. parvus* (Kozur & Pjatakova) (base of the *H. parvus* Zone). Both boundaries are already by definition very near to or identical with each other. In south China, the best area for a Permian-Triassic boundary stratotype, the first appearance of *H. parvus* is within the transitional bed 2, only few cm below the first appearance of *I. isarcica* (Huckriede). Moreover, Sweet included for long time *H. parvus* into *I. isarcica*. Therefore, the base of his *I. isarcica* Zone was in reality identical with the base of the *H. parvus* Zone. The genus *Isarcicella* (*I. turgida, I.* n. sp.) begins rarely already at or nearly at the base of the *H. parvus* Zone. Therefore also the boundary defined by Kozur coincides with the base of the *H. parvus* Zone. Moreover, Sweet, who now separates *H. parvus* from *I. isarcica*, places *H. parvus* into *Isarcicella*. Kozur (in prep.) found the apparatus of *H. parvus* which is in its general character identical with that of *H. typicalis* (Sweet). However, the single ramiform elements can be distinguished in form species level. If *I. isarcica* would have the same apparatus, then *H. parvus* should be placed into *Isarcicella*.

For the above reasons, there is now general agreement among the conodont workers to place the P/T boundary at the base of the *H. parvus* Zone. This level is world-wide recognizable, whereas the only a little younger *I. isarcica* could not yet found in the Boreal realm and in Sicily. The first appearance of *H. parvus* which evolved in a phylomorphogenetic lineage from *H. latidentatus* (Kozur, Mostler & Rahimi-Yazd), is a world-wide traceable reference horizon. The first appearance of *H. parvus* is, for instance, within the transitional bed 2 in South China (type area of the Changxingian stage), in a red clay horizon somewhat below the top of the Dorashamian stage as redefined by Zacharov (1985) in the Dorashamian type area of Transcaucasia, within the Mazzin Member of Southern Alps, just above the top of the *Otoceras* faunas of Greenland and in the middle part of the *O. woodwardi* Zone of Kashmir. In the Southern Alps, Greenland and Kashmir all transitions between the forerunner *H. latidentatus* and *H. parvus* can be observed, but also in South China and Transcaucasia *H. parvus* begins with most primitive specimens transitional to *H. latidentatus*, which are known from Greenland, Kashmir and Southern Alps just in the level of the first appearance of *H. parvus*.

The contradiction that *H. parvus* begins in Greenland just above the *Otoceras* faunas, but in Kashmir in the middle part of the *O. woodwardi* Zone can be explained by the fact that in both areas *H. parvus* begins contemporaneously with the first ophiceratids. In the Arctic, the first ophiceratids begin above the *O. boreale* Zone, in the Gondwanide margin of the Tethys the first ophiceratids begin within the *O. woodwardi* Zone. Therefore, on the gondwanide margin of the Tethys *Otoceras* begins not only later than in the Arctic (equivalents of the *O. concavum* Zone are so far unknown), but it ranges also somewhat into the *Ophiceras* faunas. Exceptionally, this can be also observed in the Arctic. Nakazawa et al. (1987) found in Spitzbergen a slab with *O. boreale* Spath together with *Claraia stachei* Bittner. The latter species is a guide form of the Arctic *Ophiceras* faunas.

Often the faunal change at the P/T boundary directly or indirectly coincides with a cycle of rapid regression and transgression. The base of the Triassic should be marked by a rapid transgression at or a little below the P/T boundary. It is not probably that the faunal change at the P/T boundary is connected with world-wide regressions and transgressions. The most pronounced, world-wide distributed and rapid transgressions and regressions of the Paleozoic and Mesozoic times can be found in the Gzhelian and early Asselian (Auernigg cycles and similar regression-transgression cycles in USA, China and other parts of the world, connected with the Gondwana glaciation). Despite this fact, at the C/P boundary the most gradual and insignificant faunal and floral changes in the whole Phanerozoic can be observed. At the P/T boundary no global regressions and transgressions can be observed. Transgressions in different stratigraphic levels have been mixed together into world-wide transgressions. Thus, regional transgressions near the P/T boundary in the Tethys were united with the transgression at the base of the *Otoceras* faunas in the Arctic and at the Gondwanide margin of the Tethys into a world-wide big transgression. However, the conodont studies in the basal *Otoceras* beds of Greenland have shown that there occur conodonts of the *Paratirolites* level of the Changxingian (Kozur, lecture in

Calgary, 1993, Kozur & Sweet, in prep.). The same was observed in the Arctic Canada (Henderson, lecture in Calgary, 1993). This transgression in the *Paratirolies* level of the Changxingian is really world-wide recognizable, but it is not connected with any world-wide faunal change and it lies considerably below the P/T boundary. Regressions and transgressions near the P/T boundary above these levels all have regional or local character as may be recognized by the position of these events to the reference level of the first appearance of *H. parvus*. This event happened in Sicily during a maximum regression, in the Southern Alps within the Mazzin Member distinctly above a regression and somewhat above a following transgression (in the level of the first appearance of *H. parvus* no regression or transgression took place), in Transcaucasia somewhat before the maximum of a regression, in Greenland and in Kashmir in a level without regression or transgression, like in the Southern Alps.

In all areas, where both the conodonts and the changes in the Carbon isotope ratio have been investigated, the minimum in the C^{13} curve lies exactly at the base of the *H. parvus* Zone. This indicates that this level coincides with a minimum in organic carbon production which is in favour for the final definition of the P/T boundary with the first appearance of *H. parvus*.

The faunal change at the P/T boundary has been often overestimated. The disappearance of about 96% of the fauna at this boundary (Raup, 1979) is summary estimation about a longer time interval. Bed by bed investigations show that the disappearance of faunal elements occurred over a certain interval with maximum extinction at the base of the *H. parvus* Zone in the Tethyan realm. Nevertheless, the faunal changes were very strong.

As pointed out by Kozur (1977, 1989), mainly shallow-water warm-water benthos was affected. In the deep-water faunas and among the cold-water faunas the changes were rather low. Thus, in the paleopsychrospheric ostracod fauna (cold deep-water fauna of oceans and their marginal parts), such important elements as *Acanthoscapha, Paraberounella* and other primitive Bythocytheracea, Tricorninidae, healdiids range from the early Paleozoic until the Liassic. They disappeared only with the change from psychrospheric to thermospheric oceans in the lowermost Toarcian. The drop in the diversity at the base of the *H. parvus* Zone is rather strong in the whole Tethyan realm, but insignificant in the Boreal and Notal cold-water faunas.

The disappearance of some groups which are very rare in the Permian has been overestimated. Thus, the disappearance of the trilobites marks the disappearance of a class at the P/T boundary. But trilobites were very rare throughout the Permian and in the Changxingian only one species with few specimens is known from South China and Transcaucasia and even that not in the uppermost layers of the Changxingian. The disappearance of the fusulinids is more important, because they are still rather common in the Changxingian. However, fusulinids disappeared in the Boreal realm already before the Roadian, connected with the cooling of this area. They are in the Late Permian restricted to the Eurasian Tethys. This fact is also often overlooked.

Moreover, most of the fossil groups which disappeared near the P/T boundary (e.g. dasycladacen algae, bryozoans, corals, crinoids, holothurian sclerites, scolecodonts, nautilids) re-appeared later. The same is true for several groups of bivalves and gastropods. Related forms, partly the same genera or even species of the above groups re-appeared in the Olenekian, Anisian or even Ladinian. Also this has to be taken into consideration. There must be a relict area, in which most of these groups survived. Because all re-colonization started from the margin of the Pacific, the central tropical part of Panthalassa was seemingly this relict area.

Similar cases are known for extinct Triassic reef communities. Whereas less than 1% of all Triassic coral species survived into Jurassic time, Sinemurian reefs from Cordilleran volcanic terranes have Triassic reef-building corals (Stanley, 1993).

The mode of disappearance of the different faunal elements, the especially strong faunal change in warm-water, shallow-water fossils, and the presence of relict areas in the tropical part of Panthalassa, from which the later re-colonization with Lazarus taxa take part, can be best explained by extinction due to short, but drastic and world-wide temperature drop, like in the calculated nuclear winter. Some month to few years of strong world-wide temperature drop (also in tropical-subtropical areas) would be lethal for the majority of warm-water, shallow-water taxa which lived in the shelf areas. This is quite different from an ice-age, where the tropical belts were reduced in their width, but suffered no distinct temperature drop. The only place, where shallow-water warm-water taxa could survive, are around insular areas in the central tropical part of Panthalassa, because the huge water masses of this ocean will cool only very slowly and in a time span of some months to a few years with cool air temperatures, the water masses in the central tropical Panathalassa will not cool below a point, lethal for warm-water shallow-water faunas.

As shown by Wignall & Hallam (1993), a wide-spread anoxic event was present in the Early Scythian (Brahmanian). This anoxic event could be found by the present author also in Japan, Russian Far East and Sicily. Where its beginning is conodont-controlled, it coincides with the base of the *H. parvus* Zone. This anoxic event may be caused by decreasing oceanic water circulation due to the cooling near the P/T boundary. The very widespread anoxia was surely an effective barrier against re-colonization of the Tethyan shelves from the Central Panthalassan relict area. This is also indicated by the fact that the reappearance of faunal groups which disappeared near the P/T boundary began in the Olenekian, just after the end of the widespread anoxia in Early Scythian basinal deposits. The still later re-appearance (Anisian, Ladinian) of several fossil groups which disappeared near the P/T boundary can be explained by plate tectonic processes. Subduction along the Panthalassa margin brought the relict areas in the central tropical Panthalassa nearer to the continental shelves.

The causes for a short lasting temperature drop also in tropical areas could be dense aerosols caused by an impact of an extra-terrestrial body or by huge volcanic activities. No pronounced iridium peak is present around the P/T boundary. Where such a peak was formerly reported, it has been by later re-investigations refused. According to Kozur (1989), the dense aerosols, which caused the short-lasting temperature drop, where caused by the Siberian Trapp. According to the palynological data, the production of the Siberian trapp began in the Late Dzhulfian and ended during the Early Triassic with a distinct peak at the P/T boundary (Kozur, 1989). These data have been meanwhile confirmed by radiometric data which have shown the main volcanic activity around 250 my (discussion at the Pangea Symposium in Calgary). The presence of these aerosols is also indicated by the huge amount of spores of marine fungi in the Changxingian shallow-water seas, indicating reduced input of sunlight. The marine fungi themselves have been now found (Kozur, in prep.). It may be that the largest eruption of the Siberian Trapp has largely destroyed the ozone layer. The resulting strong UV radiation was lethal for the marine fungi which disappeared very suddenly just at the base of the *H. parvus* Zone. The Siberian Trapp as a cause for dense aerosols would also explain some gradual changes in the fauna which occurred before the P/T boundary. Moreover, it would explain a gradual cooling of the climate which preceded the drastic short-lasting temperature drop in the tropical areas. By this gradual cooling the Boreal cold-water *Otoceras-Hypophicersas* fauna penetrated at first to the gondwanide margin of the Tethys (at base of the *O. woodwardi* Zone) and just before the end of the Permian, in the level of transitional bed 1, this fauna penetrated even parts of the central Tethys (South China).

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24. THE PERMIAN/TRIASSIC BOUNDARY IN THE CONTINENTAL SERIES OF THE MOSCOW SYNECLISE: RECENT ACHIEVEMENTS

The continental Upper Permian and Lower Triassic redbeds are widely developed in the Moscow syneclise, East European platform (Lozovsky, 1991, 1992). The Tatarian stage is the youngest part of the Upper Permian of Murchison's stratotype area. It is divided into three horizons: Urzhumskian (consisting of Nizneustyinskian and Sukhonskian suites), Severodvinskian and Vjatskian.

Let us consider in detail the structure of the latter. The more complete sections of the Vjatskian horizon are in the Vetluga river basin, where Borozdina and Olferiev (1970) divide it into three members, which were recently named. The lower (Zamoshnikovskian) member consists of variegated clay and marls with a lens of polymict cross-bedded fluvial sands and sandstones (51 m). The middle (Luptjugskian) member is characterized by typically thin-bedded grey clay, intercalated within tan-brown and white marls. A lens of fluvial sand is usually present (42 m). The upper (Molomskian) member is composed of pale-brown clay and light-grey marls, sometimes brecciated, with the thin layers of siltstone and sandstone (36 m).

The Vjatskian horizon contains a varied fauna (Tetrapods, Ostracods, Conchostracans, Molluscs), flora and palynomorph associations (Borozdina, Olferiev, 1970; Olferiev, 1974; Strok et al., 1984). It is characterized by the *Pareiasaurus-Gorgonopsian* tetrapod fauna, as well as the underlying Severodvinskian one. The localities of Vjatskian tetrapod fauna are connected with those of the lower and middle members. This fauna includes the *Labirinthodontia* (*Dvinosaurus primus* Amal.), *Batrachosauria* (*Chroniosuchus, Yugosuchus, Kotlassia*), *Diadectosauria* (*Scutosaurus*), *Theriodontia* (*Inostrancevia, Annatherapsidus, Nanocynodon, Dvinia*), *Anomodontia* (*Dicynodon*) (Tverdochlebova, 1991). The stratigraphic position of the famous tetrapod localities on the Vetluga-Vjatka watershed (XV on the Fig. 1) and Vjazniki, Klazma River (XIII) corresponds to the Molomskian member. This fauna contains progressive species of *Dvinosaurus* (*D. purlensis* Shishkin and *D. egregius* Shishkin, chroniosuchid *Bystrowiana, Elgiiniidae* (known from the youngest Permian beds of Scotland) and proterosuchid *Archosaurus rossicus* Tatar. The Archosauria is the typical element of Triassic tetrapod associations, it makes its first appearance in the Late Permian (Sennikov, 1988; Sshishkin, 1990; Ivachnenko, 1992). Shishkin considers this fauna which characterize the upper-Vjaznikovskian (+Molomskian, V.L.) member of Vjatskian horizon as independent. Recently the full cranium of *Daptocephalus* was discovered from the same (?) member in the Vetluga River, Voskresenskoje locality (XIV).

The ostracods of the lower and middle members corresponds to "*Suchonella cornuta, S. typica*" association and the ostracods from the upper members corresponds to "*Darwinuloides tatarica, D-s swijazhica*" one (Mishina, 1969). The numerous gastropods (*Surella, Gorkiella, Vetlugaia, Maturipupa*) and pelecypods (*Palaeomutella, Palaeonodonta*) were found throughout the Vjatskian horizon, especially in the two lower members. It is interesting to emphasize the presence in the middle member of conchostracans (definition of N.I. Novojilov), closed to forms described by Mitchell from the insect-bearing schists of the Belmont Formation, New South Wales, Australia (Olferiev, 1974; Strok et al., 1984).

From many localities of the middle member the Tatarian flora was described (Gomonkov, Meyen, 1986). In these floristic beds the sporomorph associations (S.A.) were studied for the first time by Kuntzel (1965). The reinvestigation by O.P. Yaroshenko of the samples from the Luptjugskian member (borehole cores 514 (VIII), v. Dor, depth 157.5-158 m, borehole core 529 (VII), v. Luptjug, depth 108. 1-113. 7 m) enable us to establish the rich sporomorph association. It is characterized by domination of Gymnosperm pollen of which the *Costati* group is dominant (more 50%): *Vittatina costabilis* Wilson, *V.* sp., *Ventralvittatina vittifera* (Lub.) Koloda and *Weylandites* sp. (last taxa compose 30% of S.A. or more). The second in importance is the *Striatiti* group (more than 30%), which includes *Protohaploxypinus latissimus* (Luber, Waltz) Samoil., *P. diagonalis* Balme, *P. varius* (Bharadwaj) Balme, *Striatopodocarpites* sp., *Striatoabieites* sp., *Scutasporites* sp. cf. *S. unicus* Klaus, *Lunatisporites* spp. and single grains of *Lueckisporites virkkiae* Pot. and Klaus. Non-taeniate pollen (about 10%) are represented by *Alisporites* spp., *Scheuringipollenites ovatus* (Balme and Hennelly) Foster, *Cedripites priscus* Balme. Pteridophyte spores (10%) include the genera *Calamospora, Apiculatisporites, Punctatosporites, Polipodiidites, Indotriradites*. Besides the miospores there are numerous acritarchs *Leiosphaeridia* sp. and a small quantity of *Inaperturopollenites nebulosus* Balme.

This S.A. is very similar to the ones described from the Upper Tatarian in the northern part of East-European platform (Varyukhina, 1971, Molin, Koloda, 1972), as well as with the *Vittatina* Association of East Greenland (Balme, 1979).

The S.A. from the third (Molomskian) member was described from the borehole cores 504 (IX), v. Pavinskyi, depth 166. 8 m. Here the quantity of *Costati* group is sharply reduced, although the *Striatiti* stay numerous. The quantity of spores markedly rises (up to 30%) thanks to the taxa *Brevitriletes* sp., *Apiculatisporites* sp., *Anaplanisporites stipulatus* Jans. The characteristic feature of this S.A. is the appearance of *Ephedripites* spp. (more than 20%), *Klausipollenites schaubergeri* Klaus, single grains of *Densoisporites complicatus* Balme and microfossils of fungal origin *Tympanicysta stoschiana* Balme. *Indotriradites* sp. and *Lunbladispora* sp. continue to be present in a small quantity. The appearance of the taxa *Ephedripites* spp., *K. schaubergeri* and *T. stoschiana*, which persist to play an important role in the Early Triassic S.A., suggests that this association is **transitional** from the Tatarian to the Vokhmian.

The different parts of the Tatarian are overlapped by the Lower Triassic Vetlugian series (see Fig. 1). The latter is divided into four horizons, the lower of them (Vokhmian) is subdivided in turn into Astaschichian, Ryabinskian and

Krasnobakovskian members. In the majority of cases the Astaschichian member comprises the basal part of the Vokhmian, but sometimes the Ryabinskian lies directly on Tatarian beds. Lithologically the Vetlugian rocks are very different from the Vjatskian ones. The colours of the Vetlugian clays are richer than the Vjatskian ones, but the carbonate contents are considerably less. The composition of the detrital minerals is diverse, being greater in the Triassic rocks for epidote (50-60% against 30%) and less in garnet and zircon content (3 and 30% respectively).

Both Astachichian and Ryabinskian members are constructed in its lower parts by the thin layers of polymict fluvial sands, sandstones and conglomerates, usually cross-bedded. Its principal parts are composed of thin-bedded variegated, sometimes black, clays and siltstones.

The Krasnobakovskian member starts with the polymict cross-bedded fluvial sands, sandstones or conglomerates. The principal part of this member is constructed by the brown or red-brown clays, thick-bedded or massive, with a small carbonate concretions. Sometimes the layers of thin-bedded clays occur in the lower part of the member higher than the basal sands. The lens of fluvial sands are often found within the clays (see Fig. 1).

The Astashichian member contains the dicynodont *Lystrosaurus georgi* Kalan., a typical genus for Gondwanan Zone of the same name, as well as for some regions of Asia (China, Mongolia, Siberia). *Lystrosaurus* (?) sp. was recently discovered by V.G. Otchev in the basal sandstones of Ryabynskian member in the locality of Vetluga River (Znamenskoie) with *Tupilakosaurus*, a typical Lower Triassic amphibian, known from the East Greenland and East European platform.

The Astashichian and Ryabinskian members contain the ostracod associations "*Darwinula mera, Gerdalia variabilis*" (Mishina, 1969). Sometimes in these associations rare typical Upper Tatarian ostracods were observed, persisting to the P/T boundary. The conchostracan *Falsisca* cf. *verchojanica* Molin was found by V. Lozovsky in the Astashichian member. It is interesting to point out the presence of species of this genus (*F. eotriassica* Kozur and Saidel in the basal part of Germanic Lower Triassic (Buntsandstein) (Kozur, 1993). In the basal part of the Lower Triassic of western China the same new species of *Falsisca* were found, although the first *Falsisca* sp. appears in the youngest Permian part of the same sections (Zheng-Wu Cheng, 1993).

Based on the faunal and paleomagnetic data, the senior author made the correlation of two lower Vokhmian members (Astashichian and Ryabinskian) with the *Otoceras* zone s.l. of the Lower Triassic marine scale (Lozovsky, 1992). The new data received by O.P. Yaroshenko after the investigation of S.A. confirms this conclusion.

The rich S.A. were obtained from the Astashichian Member (borehole cores 185 (II), v. Okatovo, depth 132 m; borehole cores 5 (IV), v. Anjug, depth 160 m; borehole cores 86 (VI), v. Ryabinovtzy, depth 90-94 m; borehole cores 115 (I), v. Djakonovka, depth 129. 6 m), from the Ryabinskian Member (exposure 42 (XII), v. Sholga, River Yug) and from the Krasnobakovskian Member (borehole cores 16 (XI), v. Permas, depth 91. 5 m). These S.A. are characterized by the dominant role of Gymnosperm pollen, represented by *Striatiti* (20-62%), *Ephedripites* (12-30%) and also the non-taeniate *Disaccites* (3. 5-22%) and *Cycadopites* (up to 10%). The *Striatiti* group includes: *Protohaploxypinus jacobii* (Jans.) Hart, *P. pantii* (Jans.) Orl.-Zwol., *P. samoilovichii* (Jans.) Hart, *Striatoabieites richteri* (Klaus) Hart, *S. multistriatus* (Balme and Hennelly) Hart, *Striatopodocarpites* spp., *Lunatisporites hexagonalis* (Jans.) Fisher, *L. pellucidus* (Goubin) Balme, *L. noviaulensis* (Jans.) Fisher, *L. transversundatus* (Jans.) Fisher, *Crustaesporites* sp.

The *Ephedripites* are represented by *E. extensus* (Jans.) de Jersey, Hamilton, *E. multistriatus* (Jans.) de Jersey, Hamilton, *E. scotti* (Jans.) de Jersey, Hamilton, *E. steevesi* (Jans.) de Jersey, Hamilton. It is characterized by the constant presence of *Klausipollenites schaubergeri*. Among the spores (about 40%) the cavate lycopsids prevails (*Densoisporites complicatus*) Balme (30%), *Pechorosporites disertus* Yarosh., Golub. (up to 7%), in a smaller quantity *Densoisporites playfordi* (Balme) Dettman and *Lundbladispora* spp. are present. Besides it, the *Anaplanisporites stipulatus* Jans., *Leptolepidites jonkeri* (Jans.) Tuzhikova, *Lycospora imperialis* Jans., *Proprisporites pocockii* Jans., *Nevesisporites limatulus* Playf., *Naumovaspora striata* Jans., and rare *Aratrisporites* sp. and *Rewanispora* sp. were found. Numerous *Tympanicysta stoschiana*, *Inapertupollenites nebulosus* and *Leiosphaeridia* sp. were found in all of the samples.

In spite of the unity of these S.A., it is necessary to indicate the distinctions between the different members. The quantity of such Permian elements as *Striatoabieites richteri* and *Klausipollenites schaubergeri* (characteristic taxa for Zechstein of West Europe) is relatively high (up to 16%) in

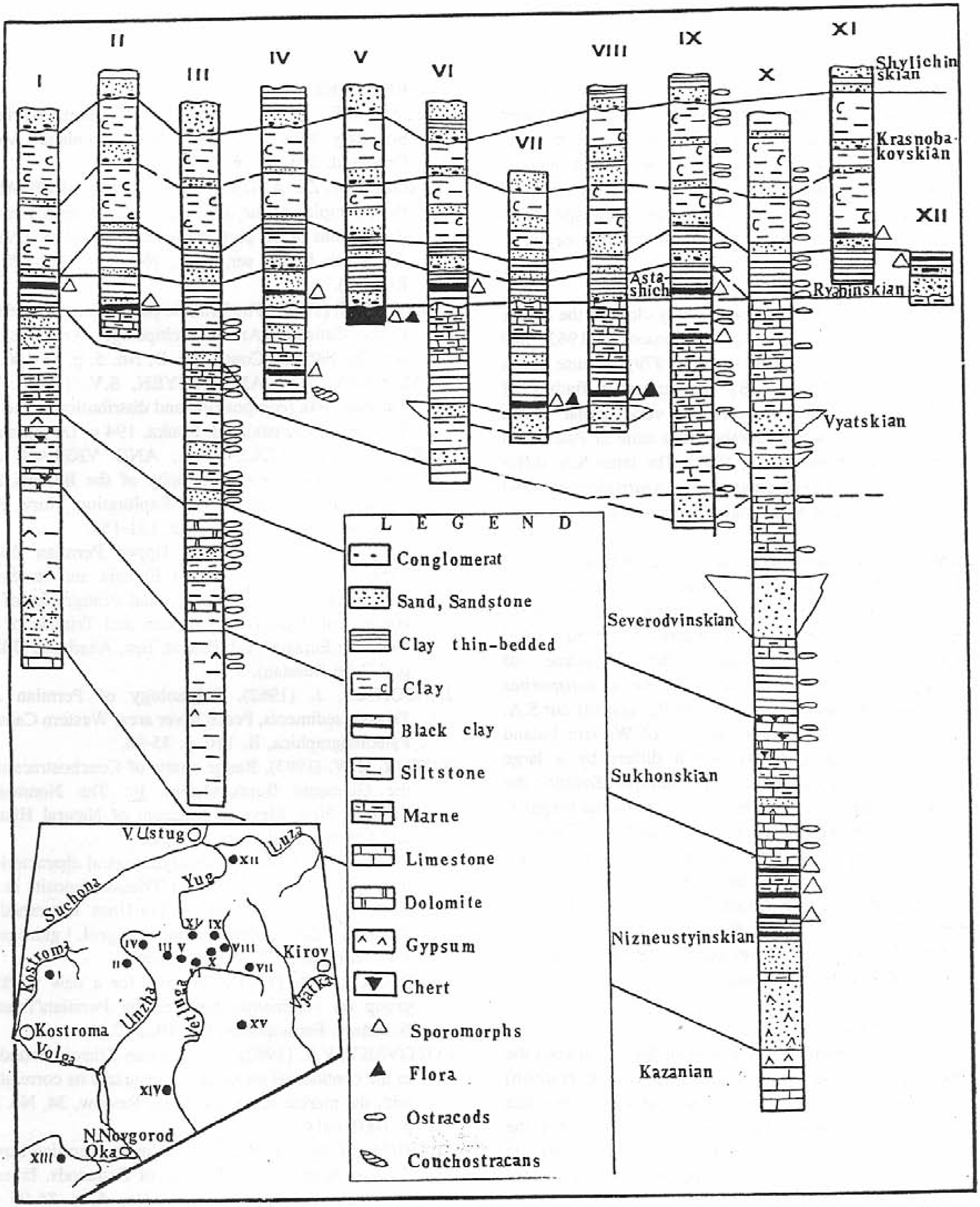

Figure 1 Relationship between the Upper Permian and Lower Triassic beds in the Moscow syneclise.

the Astashichisan member, where *Vittatina* (2.5%) still persists, but in the overlying members it is less. The epibole of *Ephedripites* and *D. complicatus* (about 30%) is observed in the two lower members. In Krasnobakovskian member the above mentioned species of *Ephedripites* and *D. complicatus* are rare, but instead of them new species of *Ephedripites* (up to 18%) and *Densoisporites nejburgii* appear.

The S.A. of Moscow syneclise are very close to the Lower Griesbachian of western Canada (Jansonius, 1962) and Canadian Arctic Archipelago (Fisher, 1979), because its has many common elements. By the numerous finding of *Striatiti* and lycopsids our S.A. are very similar to the assemblages of Lower Charkabozskaia suite of Petchorian syneclise (Yaroshenko et al., 1991). The latter S.A. differ by the wide development of *Aratrisporites* and *Pechorosporites* and by a small quantity of *Ephedripites*.

There are many resemblances and good correlation with the *Protohaploxypinus* and *Taeniaesporites* Associations from the *Otoceras* beds of East Greenland (Balme, 1979), especially with the former, where *S. richteri* and *Ephedripites* are abundant. The presence of *Protohaploxypinus pantii, P. samoilovichii, Lunatisporites pellucidus, L. noviaulensis* and lycopsids connects our S.A. with the one of Lower Buntsandstein of Western Poland (Orlowska-Zwolinska, 1984), which differs by a large development of *Cycadopites*. The multiple *Striatiti*, the constant finding of *P. pocockii* and especially the fungal *T. stoschiana* is marked in the Griesbachian S.A. of Barents Sea (Hochuli et al., 1989). *Klausipollenites schaubergeri* and *T. stochiana* are constantly represented in the P/T boundary beds of South China (Ouyang Shu and Utting, 1990). The Lower Triassic S.A. from the Jincaiyuan of Western China is differ from ours by the domination of non-taeniate pollen (Qu, Wang, 1986).

CONCLUSION

Before we supposed that there was an hiatus between the Upper Permian (Vjatskian) and Lower Triassic (Vetlugian) (Lozovsky, 1991, 1992). The detailed analysis of new data shows that the duration of that hiatus was different in the various parts of the Moscow syneclise, being the minimum in the Vetluga River basin and adjacent areas, where the Astashichian member overlies the Molomskian. The transitional character of the vertebrate fauna and S.A. proves this conclusion. The paleontological data received in the Upper Permian and Lower Triassic continental redbeds of the region of Vetluga River are more complete and varied than similar sections in other regions of the world. It will be possible to select here the best section within interrupted continental sedimentation at the P/T boundary.

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25. SOME COMMENTS AND SUGGESTIONS: DEFINITION OF THE PERMIAN-TRIASSIC BOUNDARY

This boundary has been subject to intensive study, perhaps as intensive as any boundary in the Phanerozoic with possibly the exception of the Cretaceous-Tertiary. After protracted, frustrating and inclusive discussion over many years, this study now leaves workers in a quandary on how the boundary should be defined. This may point to the need to abandon some perhaps oversimplified principles which have often come to be accepted as a method for defining the major boundaries of the Phanerozoic.

Chinese colleagues as a result of a request from a meeting of the Triassic Subcommission, have prepared a comprehensive report, which is both dispassionate and non-partisan, setting out the data available for deciding a boundary (Albertiana, 11, April 1993, 4-30).

In this case a continuous marine section and the use of a single species, be it conodont or otherwise, can be seen as little more than a mirage. Continuity is, I believe, arguable in all known sections associated with the boundary as historically understood. In sections which may be considered to be continuous there are marked breaks, although not necessarily either long or with a thick sequence and in detail there is a lack of faunal continuity, as for example in China. But even if a sequence approaching continuity were to be found in for example "deep water" it would likely be unrepresentative and of limited practical value. I use the term approaching continuity as I would suggest that continuity is only relative in stratigraphy which is characterized on the other hand by discontinuity - bedding itself represents a discontinuity. To depart significantly from the historically understood boundary just for the purpose of finding an "ideal biostratigraphical boundary" would, I believe, be fraught with practical problems. For such a boundary to have a biostratigraphical boundary departing significantly from such a major and important boundary according to the geological events, including the biological development, extinctions and so on, could lead only to confusion and frustration.

It was no doubt for such reasons as these that Tozer proposed and received widespread support for placing a boundary at the base of the *Otoceras* beds. This support has tended to wane because, at least for the present, the correlation of *Otoceras* is not as clear as it once seemed. On the other hand it has long been known that *parvus* appears at different places and times in the developing transgression, which I would assign to the basal Triassic, according to the development of the marine environment after the unusually great and yet still poorly understood regressive phase associated with the historical boundary. Although I do not wish to argue the matter here, I would also contend that to base such a major boundary on a single species, conodont or other, has major practical difficulties for understanding except generally for not more than a regional scale if that.

What seem best to me, would be to place the boundary at the top of the clay at Meishan, China. This would be close to the incoming of *parvus* if this would be a comfort to some. We could then put aside what seems interminable arguments on the boundary and get on with understanding the biological developments, the correlation, the environmental changes and other events. Later according to what we find, we could go back and revise this boundary if it becomes desirable.

(Note: I have put aside the Kashmir and the Selong sections. The Permian is poorly developed — a definite hindrance to their value, the boundary sequences do not seem easy to elaborate and Kashmir for the present is not accessible.)

MAJOR DIVISIONS OF THE PERMIAN AND "MIDDLE PERMIAN"

Most commonly the Permian has been divided into two series, the Lower and Upper Permian following the practice in the historical type area in Russia. In general this has represented a best fit situation for the sequences in many countries of the world and their faunas. From the complexity of the biological and geological development the two series can be regarded as more or less equal.

Middle Permian has been used especially for the Tethyan Region but with the exception of Japan, there has been little consistency in its usage and for the present it is a term to which much confusion attaches. It could well be abandoned except perhaps for Japan where it has a more definite meaning. The Japanese Lower Permian corresponds closely to the Lower Permian of the Russian sequence and as used in many parts of the world. This may offer a way out of the dilemma. The Lower and Upper Permian might be retained as in present usage as series in a twofold major subdivision of the Permian with the Upper Permian having two subseries with geographically based names. These might correspond to the fairly generally accepted subdivisions already in use, i.e., Ufimian or Kubergandian to Midian for the lower and Djulfian and Changhsingian or Dorashamian for the upper. These would correspond to the traditional Middle and Upper Permian of Japan and probably the traditional Lower and Upper Permian of China (see Yang Zunyi et al., 1986 and Dickins, 1991). In this regard there is some problem with regard to the definition of the Chihsia, for which there are different usages, perhaps departing considerably from the original. Perhaps it is worth some mention here that the use of Kungurian in the international scale has been disparaged without good basis — for an assessment (see Dickins et al., 1989).

Recently use of the Guadalupian has been strongly argued as the type for the Middle Permian (Glenister et al., 1992; Glenister, 1993). No doubt the sequences in the type area of the Guadalupian are good. More work especially on the palaeontology, however, is needed before these would be suitable for an international standard — see for example Glenister et al. (1992, p. 863) on stage definitions. In addition a serious problem is that the Guadalupian is not sufficiently representative. Major groups such as the ammonoids and fusulinids are sufficiently distinct to inhibit correlation even with other warm water regions. This seems to lead to undue reliance on too few species or a single species as in the case of the conodont *serrata*. It is noteworthy that the base of the Road Canyon Formation is associated with a major unconformity and that *serrata* may appear at various places and times for all we would know above the regressive-transgressive unconformity according to the information provided by Wardlaw and Grant (1990).

Designation of the Guadalupian as a type for the world standard scale, in my opinion, would be premature. Consideration might be given to the sequence in South China where Yangshinian and Lopingian are already recognized and which appears more representative, although considerable work is required before any decision. Perhaps there are other sequences which might be worthy of attention. I hope my comments will open up some discussion, as I believe dispassionate discussion at this time would be more useful than trying to force the issue.

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26. PERMIAN AND TRIASSIC OF TURPAN-HAMI BASIN, NORTHWEST CHINA

The Turpan-Hami Basin is one of the three large oil and gas bearing basins within the border of Xinjiang, NW China. Since the eighties, very sigificant industrial oil and gas flows have been discovered from the basin, with the major reservoir horizons located in the Middle-Lower Jurassic.

In the Turpan-Hami Basin, the Permian and Triassic are extensively distributed and well-developed, containing abundant fossils, various types of deposits, and rich petroleum and natural gas resources. Therefore, to make a study of the characteristics of these strata including sequence stratigraphy, biota, paleogeography, palaeomagnetism and organic geochemistry, is essential in establishing the regional stratotype section expounding the origin, structural development and organic evolution of the Turpan-Hami Basin. These data will prove of value for the exploration of oil and gas.

The Turpan-Hami Basin began to take its primitive embryonic form in the Early Permian, with the extensive distribution of Early Permian volcanic molasse formation. In the large amounts of medium-basic to medium-acidic volcanic rocks and volcanic tuff intercalations, there are often well-developed deposits of lacustrine mudstone, while the middle part of the basin is developed with carbonatite deposits of the relict seas which were persisting from the Late Carboniferous.

In the Turpan-Hami Basin, the Late Permian-Early Triassic deposits are dominated by limnic and lacustrine facies, with well-developed oil shales in local areas. The continuous sequences of the Upper Permian and Lower Triassic serve as an important area for studying the continental Permian-Triassic boundary. In all the sections, there exist abundant fossils including mammal-like reptiles, bivalves, gastropods, conchostracans, etc., which are all preserved perfectly intact. Of these fossils, the bivalves of the Uppermost Permian are still preserved with primitive aragonite on their shell.

In this basin, the well-developed Late Triassic shallow-water lacustrine deposits are mainly composed of dark-coloured mudstone and carbonaceous mudstone rich in organic matter, representing the important oil source rock of the basin. Developed in this period was a special fauna composed of conchostracans, dhasakthora, insects and ostracodes, which was formed and distributed within a area confined to Kazakhstan, the Junggar and Turpan-Hami basins, and western Mongolia palaeozoogeographical province.

Based on studying the floras and organic geochemistry, in the Turpan-Hami Basin the Permian to Triassic climate shows a tendency towards becoming gradually warmer. According the palaeomagnetic determination, during the Late Permian, this basin was roughly located at 50°N latitude. At that time, there were obvious seasonal changes in the climate with water freezing in the winter and melting in the spring, while structures of annual growth rings may be found on all fossil woods.

Our stratigraphical investigations will be carried on continuously for geological exploration of petroleum and natural gas.

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