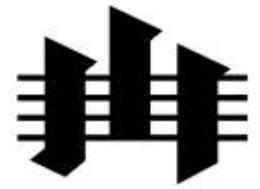


Permophiles

Newsletter of the Subcommittee on Permian Stratigraphy



Number 32
June 1998



Aktastinian and Baigendzhinian section in the Aktasty hills, southern Urals. Aktyubinsk, Kazakhstan



The Sakmarian stratotype section, Sakmara River basin, southern Urals. Kondurovka, Russia

International Commission on Stratigraphy
International Union of Geological Sciences

Table of Contents

Notes from the SPS Secretary	1
Claude Spinoso	
Chairman's Notes	1
Bruce R. Wardlaw	
Stratigraphy and Sequence Stratigraphy of Kondurovka and Novogafarovo, the Potential Sakmarian Boundary Stratotype, Southern Ural Mountains, Russia.	2
Tamra A. Schiappa and Walter S. Snyder	
Conodont-Based Refinement of the Aktastinian - Baigendzhinian (Artinskian) Substage Boundary at the Aktasty Hills Section, Southern Ural Mountains, Kazakhstan	7
D. A. Kerner, V. I. Davydov, W. S. Snyder, and C. Spinoso	
Permian Stratigraphic Units of the Western Verkhoyansk Mountains and their Correlation	8
Aleksandr G. Klets, Igor V. Budnikov, Ruslan V. Kutygin, and Vitaly S. Grinenko	
<i>Hindeodus parvus</i> : Advantages and Problems	8
Wang Cheng-yuan	
Permian Brachiopods from the Selong Xishan Section, Southern Xizang (Tibet): Preliminary Assemblages and Stratigraphical Implications.....	14
Shuzhong Shen, N.W. Archbold, G.R. Shi and Z.Q. Chen	
Permian Tetrapod Biochronology	17
Spencer G. Lucas	
Graphic Correlation Applied to Lower Permian Stratigraphic Sections of the Glass Mountains, West Texas	24
Stephen L. Benoist	
Graphic Correlation of Upper Carboniferous- Lower Permian Strata of Spitsbergen and the Loppa High, Barents Sea Shelf	32
R. M. Anisimov, V. I. Davydov, and I. Nilsson	
Carboniferous and Permian Stratigraphy of the Baoshan Block, West Yunnan, Southwest China.....	38
Wang Xiang-dong, Tetsuo Sugiyama and Katsumi Ueno	
Announcements	41

COVER PHOTOS

Upper photo

Type section of Aktastinian substage in Aktasty Hills area first studied and described by V. E. Ruzhenzev (1956). From this section and from additional localities in the southern Urals, Ruzhenzev described the most abundant and diverse Artinskian ammonoid faunas in the world. Based on this section Ruzhenzev (1956) established the Aktastinian and Baigendzhinian substages of Artinskian Stage. Recent re-examination of this section by VSEGEI (St. Petersburg), the Palaeontological Institute (Moscow), and the Permian Research Institute (Boise, Idaho) reaffirms the potential for this section to serve as a global standard for definition of the Sakmarian-Artinskian and the Aktastinian-Baigendzhinian boundaries. Rich conodont assemblages, occurring throughout this section, have been recovered (D. A. Kerner, et al., this issue) and potentially can provide boundary and body definitions for the Artinskian and its substages.

The photo, looking to the south, was taken approximately from the location of the classic Aktastinian ammonoid locality (Ruzhenzev, 1956, pages 40, 41, photos 1-5). The slope on the right, almost to the crest of the hill, is underlain by Baigendzhinian strata. The foreground and the small hills on a left are underlain by Aktastinian strata. In the center of the valley is the location of the Aktastinian-Baigendzhinian boundary as originally defined by V. E. Ruzhenzev (Photo by D. A. Kerner, 1997).

Lower photo

Type section of Sakmarian on Kurmaya Mountain, on a right bank of the Sakmara river, near the village of Kondurovka, southern Urals. This section, has been cited in the literature since the original work by Murchison, and was described (Murchison, Verneuil and Keyserling, 1845) as one of the best sections of "Upper Carboniferous" strata in the southern Urals. This section became widely known after the investigations by A. P. Karpinsky (1874, 1891) who described ammonoids from strata of the "lower belt of Artinskian", later named by Ruzhenzev (1938, 1950, 1951) as the Sakmarian Stage (substage). A lower boundary definition and detailed description of the Sakmarian in the type section were first presented by V. E. Ruzhenzev (1950, 1951). D. M. Rauser-Chernousova (1965) later provided details of the fusulinicaean distribution. In the 1980s conodonts were first discovered from the Kondurovka section (Movshovich et al., 1979; Isakova, 1987). The Kondurovka section was studied again in 1989-1991 (Chuvashov et al., 1991) in preparation for the field excursion to the Lower Permian of southern Urals in conjunction with the International Congress on the Permian in the World. Artinskian fusulinicaean were first recovered from the upper portions of the section by Chuvashov et al. (1991). In the last several years the Kondurovka section has been re-examined by VSEGEI (St. Petersburg), the Palaeontological Institute (Moscow), the Institute of Geology and Geophysics (Ekaterinburg), and the Permian Research Institute (Boise, Idaho) for the purpose of developing precise, global scale, body and boundary definitions for the Sakmarian Stage. Preliminary data are presented herein (T. A. Schiappa, et. al., this volume).

Photo taken from the flood plain of the Sakmara River, at the southern end of the Karamurantau Ridge. Cliffy portion of section, on the right, is the Kurmaininskaya Formation (Asselian); the gentle slope on a left is the Karamuranskaya Formation, at the base of which, Ruzhenzev (1950) defined Asselian-Sakmarian boundary (Photo by W.S. Snyder, 1994)

Фото на обложке

Фото наверху

Типовой разрез актастинского подъяруса в районе актастинских холмов. Впервые описан и изучен В.Е.Руженцевым (1956), открывшим здесь и в близлежащих разрезах на Южном Урале самые богатые в мире местонахождения артинских аммоноидей, и установившим на основе этих разрезов актастинский и байгенджинский подъярусы. В последние годы после переизучения разреза Пермским Исследовательским Институтом (Бойсе, Айдахо), ВСЕГЕИ (С.-Петербург), Палеонтологического Института (Москва) вновь привлек к себе внимание (Snyder et al., 1997; Kerner, Davydov, 1997). В разрезе помимо аммоноидей установлено наличие богатых комплексов конodontов (см. статью Д. Кернера и др. в этом номере), позволяющих обосновать объем и границы артинского яруса и его подъярусов в глобальной шкале.

Фото сделано примерно от классического местонахождения актастинских аммоноидей в направлении на юг. Склон справа сложен отложениями байгенджинского подъяруса. Небольшие холмы слева - отложения актастинского подъяруса. Примерно в средней части долины находится граница байгенджинского-актастинского подъярусов как она была установлена В.Е.Руженцевым. (Фото Д. А. Кернера, 1997).

Фото внизу

Типовой разрез сакмарского яруса горы Курмая, на правом берегу р. Сакмары, в районе пос. Кондуровка на Южном Урале. Упоминается в литературе начиная со времен Мурчисона (Murchison, Verneuil and Keyserling, 1845), отметившим его как один из лучших разрезов "верхнего карбона" на Южном Урале. Особую известность этот разрез получил после исследований А.П.Карпинского (1874,1891) открывшего и описавшего аммоноидей из отложений "нижнего пояса артинского яруса", позже названных В.Е.Руженцевым сакмарским ярусом (подъярусом) (1938, 1950, 1951). Обоснование границ яруса в стратотипе и его характеристика были впервые даны в работах В.Е.Руженцева (1950; 1951). Позже Д.М.Раузер-Черноусова (1965) предложила детальную фузулинидовую характеристику и впервые описала фузулинид из этого разреза. В 80-х годах в кондуровском разрезе впервые обнаружены конodontы (Movshovich и др., 1984; Исакова, 1987). Разрез переизучен в 1989-1991 гг. при подготовке к показу к международному конгрессу "Пермские отложения мира". В самой верхней части разреза были обнаружены артинские фузулиниды (Чувашов и др., 1991). В последние годы разрез изучался большим коллективом исследователей из Пермского Исследовательского института (Бойсе, Айдахо), ВСЕГЕИ (С.-Петербург), Палеонтологического Института (Москва) и Института геологии и геофизики (Екатеринбург) с целью установления точного объема и границ сакмарского яруса в глобальной шкале. Некоторые аспекты этого изучения отражены в данном номере *Petromorphiles* (см. статью Т. Скиппа и др. в данном номере).

Фото сделано из поймы реки Сакмары на север в направлении горы Курмая. На фото представлена нижняя треть типового разреза Сакмарского яруса (слои 8-13) на южном окончании хребта Карамурantau. Скалистая часть разреза - курмаинская свита ассельского яруса, пологий склон слева - карамуранская свита, основание которой, по определению В.Е.Руженцева, совпадает с границей ассельского-сакмарского ярусов (Фото В.С. Снайтера, 1994).

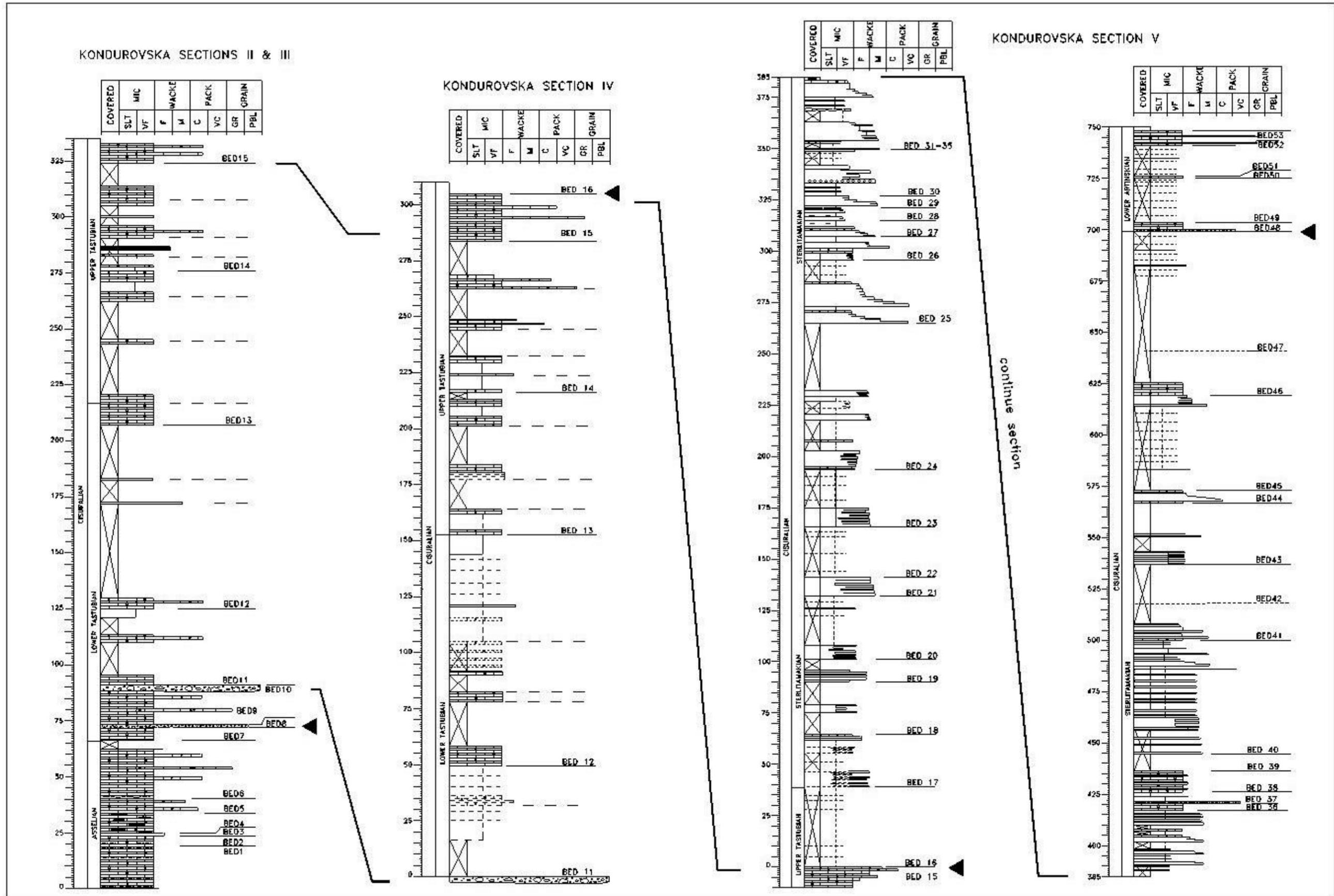


Figure 2. Stratigraphic columns of Kondurovka section, Sakmara River Basin, southern Ural Mountains, Russia. Possible sequence boundaries indicated by dark triangles.

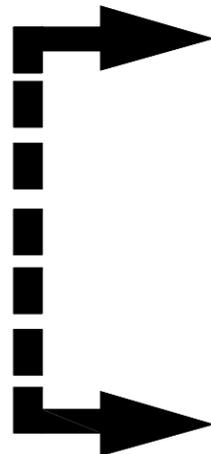
Artinskian Biostratigraphy, Aktasty Hills

Figure 1a

Summary of data collected by PRI in 1994, 1997

 Ammonoid sample locations
 Conodont sample locations

Current location of Aktastinian/Baigendzhinian substage boundary based on V.E. Ruzhencev (1956) ammonoid data



Possible new location for substage boundary based on first appearance of *Neostreptognathodus pequopensis*

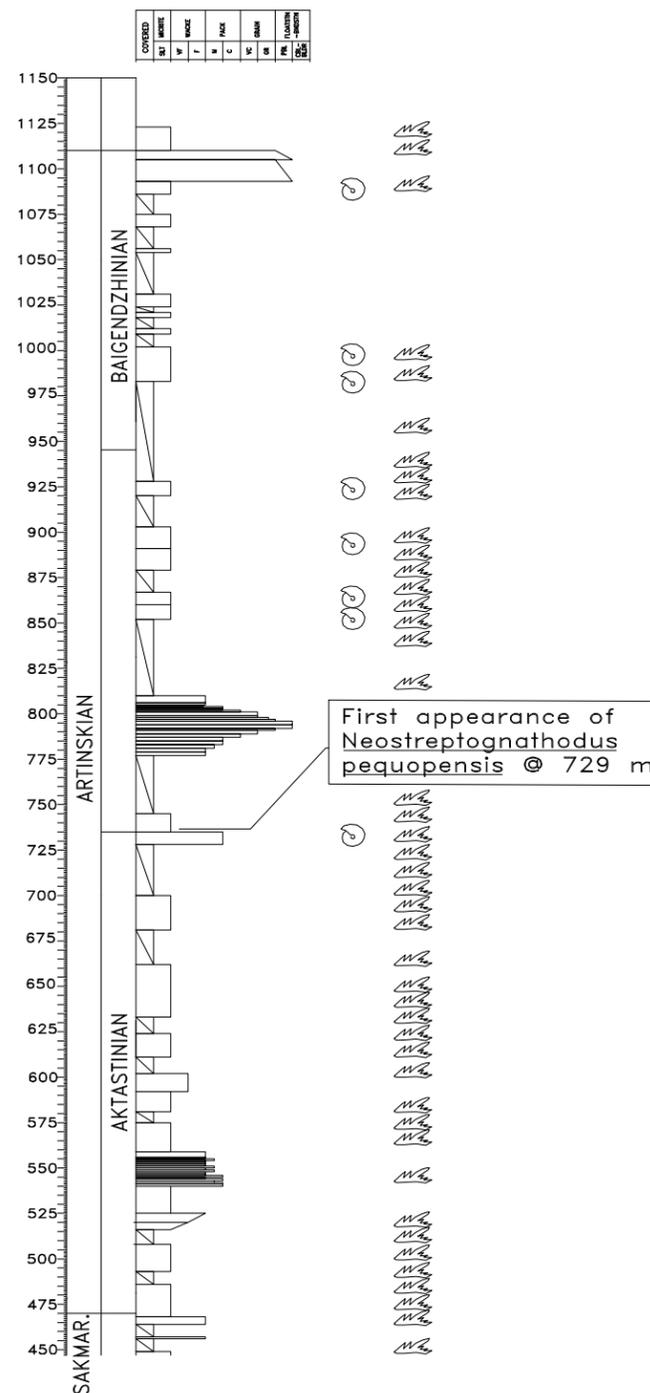
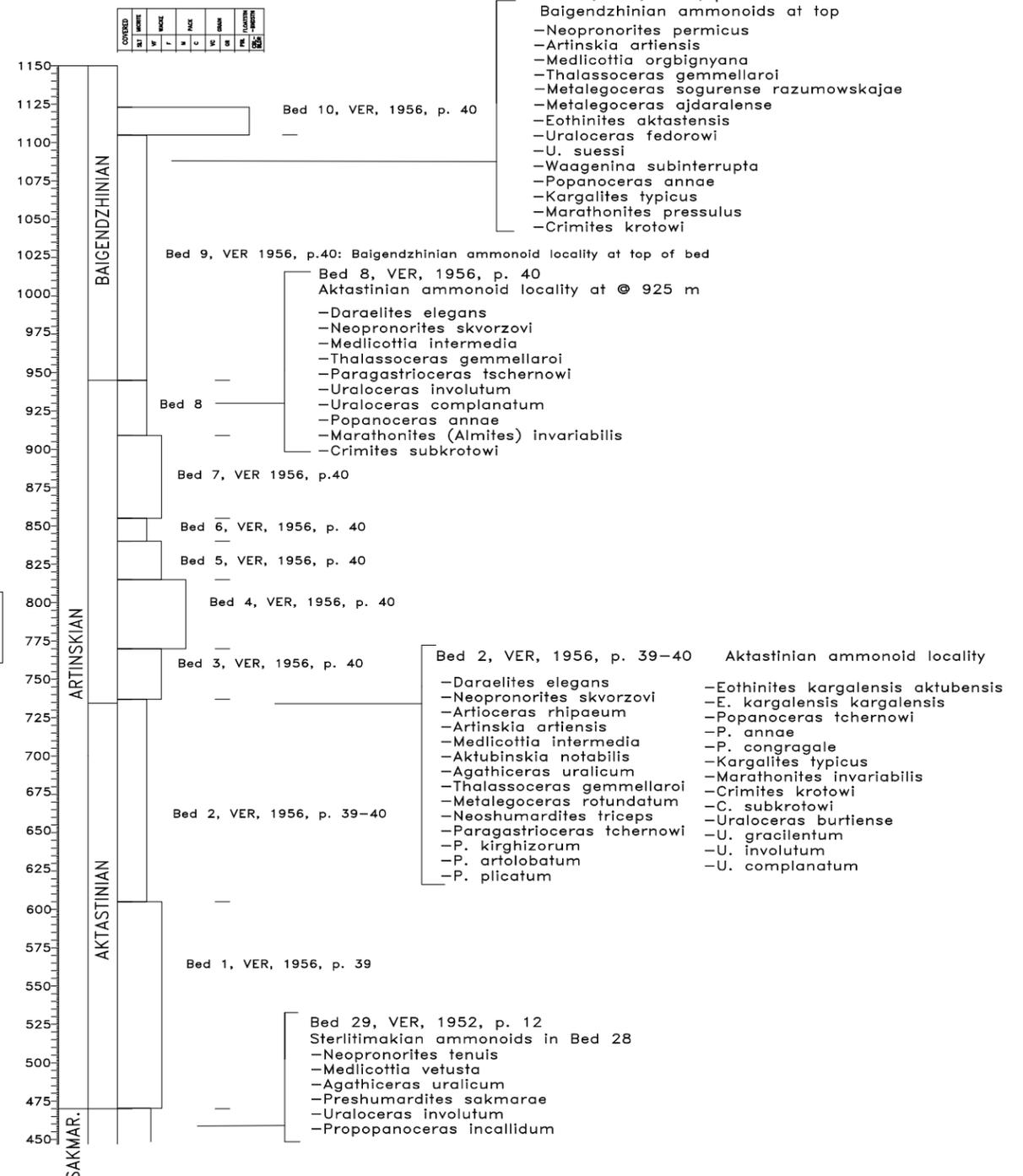


Figure 1b

Summary of data from V.E. Ruzhencev, 1951, 1952, 1956



EXECUTIVE NOTES

Notes from the SPS Secretary

Claude Spinosa

I want to thank all who contributed to the 32nd issue of *Permophiles* and those who assisted in its preparation. We are indebted to Bruce R. Wardlaw and Brian F. Glenister for editorial contributions and to Joan White for coordinating the compilation of this issue. The next issue of *Permophiles* is scheduled for December 15, 1998; readers are encouraged to send contributions for inclusion. Contributions should arrive before December 1, 1998. It is best to submit manuscripts as attachments to E-mail messages. Please send messages and manuscripts to my e-mail address (see bottom of this note). Please note that this is a new E-mail address; those who have been using my old one are asked to discard it and begin using the new address.

Manuscripts may also be sent on diskettes prepared with WordPerfect or MSWord; printed hard copies should accompany the diskettes. Word processing files should have no personalized fonts or other code. Specific and generic terms should be *italicized*. Please refer to recent issues of *Permophiles* (numbers 30 or 31) for reference style, format, etc. Maps and other illustrations are acceptable in tif, jpeg, bitmap or other electronic picture format. If only hard copies are sent, these must be camera-ready, i.e., clean copies, ready for publication. Typewritten contributions may be submitted by mail as clean paper copies; these must arrive well ahead of the deadline as they require greater processing time. We can also receive contributions via E-mail, Fax or through FTP.

We are indebted to Marc Durand, Mima Stojanovic, Hisayoshi Igo, Henri Fontaine, W. M. Furnish, Manfred Menning, Yin Hongfu, Jurgen Kullmann, Inger Nilssen, Ernest H. Gilmour, Corrado Venturini and six additional donors who wished to remain anonymous for contributing a total of \$475 to the *Permophiles* publication fund.

Claude Spinosa
Secretary, SPS
Permian Research Institute
Dept. of Geosciences
Boise State University
Boise, Idaho 83725, USA
fax: 208-385-4061
voice: 208-385-1581
cspinosa@bsu.idbsu.edu

Chairman's Report

Bruce R. Wardlaw

The SPS plans to conduct its formal annual meeting for 1999 at the XIV International Congress on the Carboniferous and Permian (August 17-21, 1999) and for 2000 at the 31st International Congress (August 7-16, 2000) where it will conduct a symposium (1-6, see announcement). However, in preparation for the 2000 meeting, in an attempt to complete the subcommission's mandate, there will be several meetings sponsored by the SPS in which formal meetings will be held. These include:

The International Conference on Pangea and the Paleozoic-Mesozoic transition (March 9-11, 1999) in conjunction with the Permian-Triassic boundary working group of the Subcommission on Triassic Stratigraphy and the SPS working group on the Lopingian.

The International Field Conference on: The continental Permian of the southern Alps and Sardinia (Italy). Regional reports and general correlations (September 16-25, 1999) in conjunction with the SPS working group on continental-marine correlation.

This year the SPS held its annual meeting at the International Symposium of Upper Permian stratotypes of the Volga Region (July 28-August 3, 1998, minutes to be included in the next issue). The SPS also participated in the Guadalupe Mountains Symposium, a symposium celebrating the 25th anniversary of Guadalupe Mountains National Park and presented a poster to the park on the Guadalupian Stratotype.

The Carboniferous-Permian boundary working group completed its task with the publication "Proposal of Aidaralash as Global Stratotype Section and Point (GSSP) for base of the Permian System" in *Episodes* (v. 21, no. 1). The SPS would like to thank the extraordinary efforts of the past two chairs of the working group, Wu Wangshi and Brian Glenister, for guiding and cajoling the group to consensus. The working group members also deserve a hearty thanks for a job well done. The working group is now officially disbanded.

Bruce R. Wardlaw
Chair, SPS
Chief Paleontologist
U.S. Geological Survey
926A National Center
Reston, VA, 20192-0001 USA
bwardlaw@usgs.gov

International Commission on Stratigraphy Bureau

ICS Chairman

Prof. Jürgen Remane
Institut de Géologie
Université de Neuchâtel
Rue Emile-Argand, 11
CH-2007 Neuchâtel,
Switzerland

ICS 1st Vice Chair

Dr. H. Richard Lane
6542 Auden
Houston, TX 77005, USA
voice: (713) 432-1243
fax: (713) 432-0139

ICS Secretary General

Prof. Olaf Michelson
Dept. of Earth Sciences
University of Aarhus
DK-8000 Aarhus C, Denmark

Subcommission on Triassic Stratigraphy

STS Chairman

Prof. Maurizio Gaetani
Dip. di Scienze della Terra
Università di Milano
Via Mangiagalli 34
20133 Milano, Italy
fax: +39 2 70638261
voice: +39 2 23698229
maurizio.gaetani@unimi.it

STS Secretary General

Geoffrey Warrington, STS
Secretary
British Geological Survey
Kingsley Dunham Centre,
Keyworth
Nottingham NG 12 5GG
Great Britain
gwar@wpo.nerc.ac.uk

Subcommission on Permian Stratigraphy

SPS Chairman

Dr. Bruce R. Wardlaw
U.S. Geological Survey
926A National Center
Reston, VA 22092-0001, USA
fax: 703-648-5420
voice: 703-648-5288
bwardlaw@usgs.gov

SPS 1st Vice Chairman

Prof. Ernst Ya. Leven
Geol. Inst. RAS 10917
Pyjevskiy per 7
Moscow, Russia
voice: 095-230-8121
iloewen@uniinc.msk.ru

SPS 2nd Vice Chairman

Dr. C. B. Foster
Australian Geol. Surv. Org.
GPO Box 378
Canberra 2601, Australia
cfoster@agso.gov.au

SPS Secretary

Prof. Claude Spinosa
Dept. of Geosciences
Boise State University
Boise, Idaho 83725, USA
fax: 208-385-4061
voice: 208-385-1581
cspinosa@trex.idbsu.edu

REPORTS

Stratigraphy and Sequence Stratigraphy of Kondurovka and Novogafarovo, the Potential Sakmarian Boundary Stratotype, Southern Ural Mountains, Russia.

Tamra A. Schiappa, Walter S. Snyder

Upper Carboniferous through Lower Permian strata at Kondurovka and Novogafarovo, southern Ural Mountains, Russia (Fig. 1) were deposited on a storm dominated, open, outer to middle mixed carbonate siliciclastic ramp (Fig. 2) that formed the eastern boundary of the Pre-Uralian Foredeep and Ural sub-basin. Our detailed measurement of these stratigraphic sections and lithostratigraphy build on the work completed by Murchison et al. (1845), Karpinsky (1874), Ruzhencev (1936, 1950, 1951), Rauser-Chernousova (1965) and Chuvashov et al. (1993). The Cisuralian stages will be defined formally in the southern Urals of Russia and therefore, detailed documentation of the lithostratigraphy and sequence stratigraphy is necessary.

The strata from these sections have been divided into several major facies (Table 1) which represent a middle and outer ramp depositional environment consisting of fine to coarse-grained limestones with occasional rudstones and floatstones (Fig. 3 (fold out)). The fine grained micrite (M), silty micrite (sM) and mudstone (MS) facies lack any evidence of scouring which suggests deposition from suspension in an offshore, low energy environment. Wackestone-packstone (WP) facies occur as centimeter to meter scale beds, often irregular in thickness and are comprised of varying amounts of skeletal grains, carbonate mud clasts, micrite and siliciclastic silt. The bioclasts consist of whole fusulinaceans and other small foraminifera, fragmentary bryozoans, crinoids and

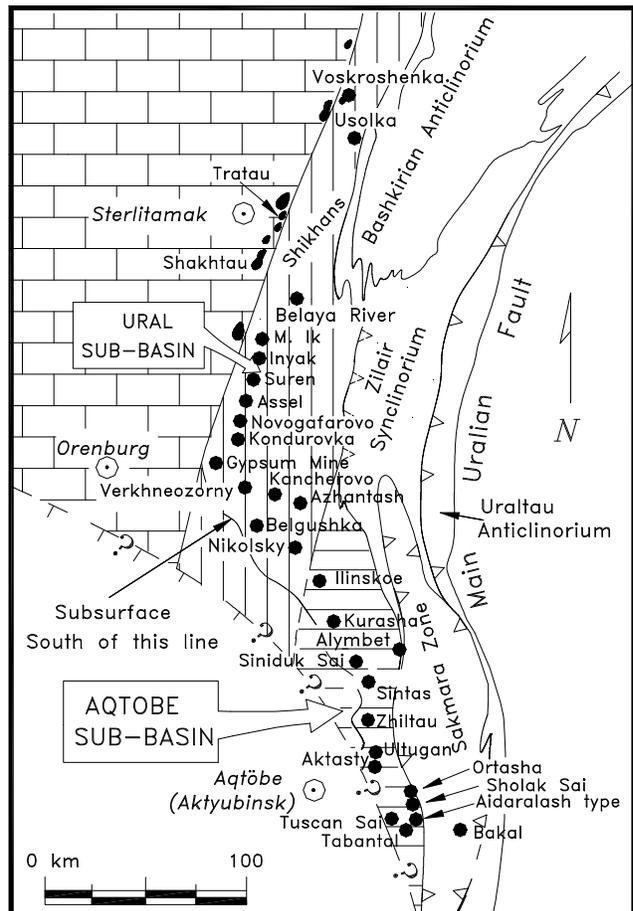


Figure 1. Location map of sections studies within the Pre-Uralian Foredeep, Southern Ural Mountains, Russia. Kazakhstan, Novogafarova and Kandurovka Sections are located within the Ural Sub-basin and Aktasty Hills Section located within the Aqt'be Sub-basin.

URAL SUB-BASIN PALEOGEOGRAPHIC MODEL

NOVOGAFAROVO &
KONDUROVKA / B16+

RUSSIAN
CARBONATE
PLATFORM

USOLKA

KONDUROVKA / B1-B10

KONDUROVKA / B11-B15

???

SHIKAN

BASIN

OUTER RAMP

MIDDLE RAMP

INNER RAMP

BEACH

SHORFACES & BEACH
SILICICLASTIC SANDSTONE

MUD-DOMINATED WITH EVENT BEDS /
TEMPERITES.
MICRITIC MICRITIC SILTSTONE & FINE
SANDSTONE WITH
WACKERSTONE WITH
WACKERSTONE PACKSTONE, AND SOME
GRANULESTONE TEMPERITES + ISOLATED
SLUD-LIPS;
(greenish-brown to yellow-brownish-brown to olive-spongy)

MOSTLY MUD WITH SOME
EVENT BEDS / TEMPERITES.
MICRITIC / SILTSTONE.
WACKERSTONE PACKSTONE
TEMPERITES WITH BRECCIA,
BURRS, TURBIDITES

MICRITIC SILTSTONE
WITH FINE-GRAINED
TURBIDITES

0
-40
-80
METERS

200

100

0

KILOMETERS

Figure 2. Paleogeographic model for the Ural Sub-basin, including the approximate positions of Kondurovka and Novogafarovo along the mixed carbonate-siliciclastic ramp

**TABLE 1
KONDUROVKA AND NOVOGAFAROVO LITHOFACIES**

FACIES	DESCRIPTION
Siliciclastics	
MS	Siltstone-claystone-mudstone
SS1	Very fine, structureless sandstone, interbedded with siltstone-mudstone.
SS2	Fine sandstone beds; grading apparent in some beds with medium to coarse bases; parallel laminations common in most beds, ripple tops occur abundantly; lenticular beds with lateral dimensions of a few to 30 meters and thickness of a few centimeters, typically 15 to 30 cm, and up to 1.5 meters in amalgamated beds.
SS3	Medium (coarse to fine) sandstone; typically graded and parallel laminations; with rippled tops common, but not ubiquitous; erosive bases with flutes, tool marks, load structures; local hummocky cross stratification.
SS4	Gravelites; coarse-grained to granulite sandstones of very fine pebble conglomerates; erosive bases.
CG1	Polymictic pebble to cobble conglomerate; matrix and clast-supported; disorganized to indistinctly stratified beds; some weakly aligned elongate clasts; local slump structures and channels; some outsized clasts 1 to 4 m in diameter; poorly cemented. Limestone and well indurated sandstone clasts predominate, but also include metamorphic, granitic, rhyolite to andesitic volcanic, greenstone clasts. Basal contact is typically scoured into underlying shelf sandstone successions. Fining upward successions 10 to 100 m thick that may contain variable thickness of lenticular sandstone.
Carbonates	
M	Light brown to brown micrite; silt content up to approximately 20%.
WP	Fossiliferous wackestone - packstone, fine- to medium-grained with variable amounts of silt and fine sands, fusulinaceans, small foraminifers, bryozoans, crinoids fragments, pelloids, and carbonate mud intraclasts.
G1	Fine-grained fusulinacean grainstone, with bryozoan, crinoid, and brachiopod fragments (allochems), pelloids, carbonate mud intraclasts, and variable amounts of extraclasts. Alignment of grains is visible in most samples. Laminar beds with lateral dimensions of a few centimeters to 0.75 meter in thickness.
WPGe	Wackestone-packstone-grainstone event beds ("e"); medium- to coarse-grained, locally graded and scoured bases with rare flute casts and load structure and rippled tops. Constituents same as WP and G1. Beds vary from a few centimeters to 0.75 meter thick.
RFL	Gray black and brown limestone pebble rudstone and floatstone, with minor fossiliferous debris (fusulinacean, crinoid and bryozoan fragments) and carbonate mud clasts. Fine-grained micrite matrix. Carbonate mud clasts vary in size from 1 mm to several tens of cm, tend to be well-rounded and oblate. Some of the clasts appear to have been bioturbated and silicified and some contain fusulinacean, small foraminifers and crinoid fragments. Bed varies in thickness from 30 centimeters to several meters.

Modifiers:

- d = dolomitic; a modifier as appropriate for either siliciclastics/carbonates
- m = micritic; applied to siliciclastics with < 50% carbonate
- s/ss = silty/sandy; applied to carbonates with < 50% sand/silt
- a = allochemic; carbonate bioclasts

minor amounts of brachiopod and cephalopod shell fragments. The WP facies represents deposition on a middle ramp with relatively moderate energy conditions (Fig 2). The Wackestone-Packstone-Grainstone event bed (WPG_e) facies is similar in character to the WP facies with the addition of grainstone. The grainstone varies from fine to coarse and is comprised of both whole and fragmentary bioclasts, carbonate mud intraclasts and variable amounts of extraclasts including siliciclastic detritus. The mixture of the bioclastic material, rounded carbonate mud intraclasts and extraclasts indicate event deposition. The deposits tend to be graded and may display horizontal laminations at the top of the beds. Some alignment of grains can be recognized resulting from currents, however current direction has not yet been determined. This facies tends to occur as packages of strata that fine upward; overall character of this facies is consistent with either turbidite or tempestite origins. However, with the lack of observed basal lags, hummocky cross stratification and wave ripple laminations, an accurate and positive distinction between the two depositional mechanisms (wave generated versus current generated) can not be made (Gawthorpe, 1986; Seilacher, 1982). Because of this a generic term "event bed" is used. The fine-grained fusulinacean grainstone (G1) consists of varying amounts of fragmentary and whole bioclasts, rounded carbonate mud clasts and extraclasts. The mixture of well-rounded terrigenous and skeletal debris suggests deposition from submarine currents with mixing of materials derived from two sources (Gawthorpe, 1986). The G1 facies could be part of the WPG_e facies, however, it may reflect winnowing by submarine currents and waves without significant transport. The rudstone and floatstone facies (RFL) are oligomictic and consist of rounded to tabular, slightly silicified WP and M carbonate mud clasts varying in size, from one millimeter to tens of centimeters to meters, within a micritic matrix. The poorly sorted, chaotic matrix-supported fabrics of this facies are typical characteristics of submarine mass gravity flows. Our interpretation is that intraclasts were probably derived from upslope bioturbated hardgrounds formed during a sea level lowstand that occurred along a distally stepped outer ramp. Above Bed 15 (Fig. 3 (fold out)), the remainder of the Sakmarian and lower Aktastinian portion of the section changes from a carbonate rich to siliciclastic dominated system and the facies shift to very fine sandstone (SS1), fine sandstone (SS2), medium-grained sandstone (SS3), gravelite, coarse-grained sandstone (SS4) and micritic siltstone (MS) (Table 1). These changes in facies associations are interpreted to be the result of a change in water depth possibly due to a change in sea level.

Depositional Environment & Sequence Stratigraphy

The Kondurovka and Novogafarovo sequences appear to reflect deposition on a storm dominated, open, outer to middle mixed carbonate siliciclastic ramp which is consistent with the stratigraphic nature of the sections and the biota which is dominated by crinoids, bryozoans and fusulinaceans. Despite fluctuating sea levels (e.g., Ross and Ross, 1988) there is no evidence of sub-aerial exposure in these sections. Lowstand deposits are recognized by a higher frequency of event beds and with the rudstone-floatstone units (RFL) identified as a transgressive systems tract.

The stratification types and facies occurrences are the likely result of relative sea level changes, episodic, storm-related processes and possibly tectonism. Sporadic distribution of event beds occur throughout these sections but lack observed sedimentary

structures such as sole marks, hummocky cross stratification and wave ripples, which make reconstruction of sedimentary dynamics difficult. The most plausible interpretation is that the event beds were storm induced and deposited below storm wave base. The model followed is that on a storm-dominated ramp; nearshore storm set-up water is compensated by offshore-directed bottom return flows (Kreisa and Bambach, 1982, Aigner, 1985; Hobday and Morton, 1984; Walker, 1984). These bottom currents consequently erode storm surge channels through which near shore sediment is funneled offshore and deposited as tempestites (Aigner, 1985, Seilacher, 1982). Wind drift currents mix bioclastic and siliciclastic material into shallow skeletal banks. The offshore bottom currents transport the pelmatozoan ossicles, bryozoan fragments, fusulinaceans, carbonate mud clasts and siliciclastics from the nearshore and deposit them as WPG_e beds.

Silty micrite and micritic siltstone dominated successions are interpreted as highstand systems tract deposits. The maximum flooding surface (MFS) is associated with condensed successions of silty micrites and preservation of abundant ammonoids, conodonts and radiolaria. However, some of the ammonoid bearing units are interpreted as possible sediment gravity flows resulting from storm related processes. Submarine cementation appears to have been minor and the WPe beds derived from the middle ramp during the highstand, reflect the uncemented, mud and bioclastic-rich and siliciclastic-poor lithofacies. The outer ramp condensed successions are overlain by a regressive sequence and are recognized by a gradual shallowing, culminating in a seaward outbuilding of middle ramp horizons, which include wackestones and packstones. Gradation from silty micrite (sM) to silty-sandy wackestone-packstone (s/ssWP) usually occurs within a stratigraphic thickness of a few to 10 meters (for example @ 30 to 40 meters above section II & III, Fig. 3). The s/ssWP represent deposition on the middle ramp and contain crinoid, bryozoan, small foraminifera and fusulinaceans, carbonate mud clasts and siliciclastic debris. Renewed transgressions are documented by the sudden appearance of new silty micrite units.

Throughout the Novogafarovo and Kondurovka sections, packages of event beds are present. These packages of relatively abundant beds are interpreted as lowstand systems tracts. The unique RFL beds are interpreted as a transgressive systems tract and mark the top of a lowstand systems tract at Kondurovka (90 meters above base section II & III, Fig. 3) and Novogafarovo. These deposits suggest that, during lowered sea level, the exposed inner ramp was weakened by physical and chemical processes. As sea level began to rise, flooding of the inner ramp saturated these units, causing collapse and accumulation as sediment gravity flows on the middle ramp (Walker, 1984). The succession that contains the RFL beds at Novogafarovo (550-610 meters above base) and Kondurovka (70-90 meters above base, sections II & III, Fig. 3) is laterally extensive, typically 0.5 to a tens of meters thick and 10-30 km long along strike. The RFL beds contain well-rounded to oblate carbonate mud clasts varying in size from 1 mm to several tens of cm to meters, with minor fossiliferous debris (fusulinacean, crinoid and bryozoan fragments) in a fine-grained micrite matrix. This succession is capped by a floatstone bed that contains WP and M carbonate mud clasts that have been slightly silicified. Interpretations for the origin of this floatstone bed are that it was deposited during the transgressive systems tract as a sediment gravity flow during flooding of the inner ramp.

Overall, the strata at Kondurovka and Novogafarovo sections

represent deposition on a mixed carbonate-siliciclastic storm-dominated ramp during the Late Carboniferous and Early Permian. Lowstand deposits are recognized by an increase in event bed frequency. Beds 8 and 10 at Kondurovka (section II & III, IV, Fig. 3) are interpreted as RFL beds representing a transgressive system tract placing the sequence boundary or sea level lowstand with no subaral exposure below these units. The sequence stratigraphic framework (i.e., sedimentologic continuity and no unconformity) of Kondurovka and Novogafarovo supports placement of the Asselian-Sakmarian boundary as defined by fusulinaceans below Bed 8.

References

- Aigner, Thomas, 1985, Storm Depositional Systems: Dynamic Stratigraphy in Modern and Ancient Shallow-Marine Sequences, *in* Friedman, G. M., Neugebauer, H. J., and Seilacher, (eds.), A., Lecture Notes in Earth Sciences, No.3., Springer Verlag, 174 p.
- Chuvashov, B. I., Chernykh, V. V., Davydov, V. I., and Pnev, P., 1993, Kondurovsky Section, *in* Chuvashov, B. I., Chermynkh, V. A., Chernykh, V. A., Kipnin, V. J., Molin, V. A., Ozhgibesov, V. P., and Sofronitsky, P. A., (eds.), Permian System: Guides to Geological Excursions in the Uralian Type Localities, jointly published by Uralian Branch Russian Academy of Sciences, Ekaterinburg, Russia and ESRI, Occasional Publications ESRI, University of South Carolina, New Series No. 10, pg. 102 - 119.
- Gawthorpe, R.L., 1986, Sedimentation during Carbonate Ramp-to-Slope Evolution in a Tectonically Active Area: Bowland Basin (Dinantian), Northern England, *Sedimentology*, v. 33, pg. 185-206.
- Hobway, D.K., and Morton, R.A., 1984, Lower Cretaceous Shelf Storm Deposits, Northeast Texas, *in* R.W. Tillman, and C. T. Seimers, (eds.), *Siliciclastic Shelf Sediments*, SEPM no. 34, p. 205-213.
- Karpinsky, A. P., 1874, Geological investigations in Orenburgian area. Notes of Mineralogical Soc. Ser. 2, part 9, p. 212-310.
- Kreisa, R. D., and Bambach, R. K., 1982, The Role of Storm Processes in Generating Shell Beds *in* Paleozoic Shelf Environments, *in* G. Einsele and A. Seilacher, (eds.), *Cyclic and Event Stratification*, Springer-Verlag, p. 200-201.
- Murchison, R., Verneuil, E., Kayserling, A., 1845, The geology of Russian in Europe and the Ural Mountains, vol. 1, The Geology, London.
- Rauser-Chernousova, D. M., 1965, Foraminifers in the Stratotypical Section of the Sakmarian Stage (Sakmara River, Southern Ural), Academy of Sciences of the USSR, vol. 135, 80 p.
- Ruzhencev, V. E., 1936, Upper Carboniferous and Lower Permian stratigraphy in Orenburgian area: Bulletin of Moscow Society of Natural History, Geological series, v. 14, no. 3., p. 187-214 (in Russian).
- Ruzhencev, V. E. 1950, Type section and biostratigraphy of the Sakmarian stage. Doklady Academy of Sci. of USSR, v. 71, p. 1101-1104.
- Ruzhencev, V. E., 1951, Nizhnepermian ammonites of the Southern Urals. I. Ammonoids of the Sakmarian Stage): Akademiia Nauk SSSR, Paleontologicheskogo Instituta Trudy, v. 33, 188 pp. (in Russian).
- Seilacher, A., 1982, Distinctive Features of Sandy Tempestites, *in* G. Einsele and A. Seilacher, (eds.), *Cyclic and Event Stratification*, Springer-Verlag, p. 161-174.
- Walker, R. G., 1984, Shelf and Shallow Marine Sands, *in* R.G. Walker ed., *Facies Models*, 2nd ed., Geosciences of Canada, p.141-170.

Tamra A. Schiappa
Permian Research Institute
Geosciences Department
Boise State University
1910 University Dr
Boise ID 83725
USA
tschiapp@bsu.idbsu.edu

Walter S. Snyder
Permian Research Institute
Department of Geosciences
Boise State University
1910 University Dr
Boise ID 83725
USA
wsnyder@bsu.idbsu.edu

Conodont-Based Refinement of the Aktastinian - Baigendzhinian (Artinskian) Substage Boundary at the Aktasty Hills Section, Southern Ural Mountains, Kazakhstan

D. A. Kerner, V. I. Davydov,
W. S. Snyder, C. Spinosa

Upper Paleozoic strata of the Pre-Uralian foredeep in the southern Ural Mountain region of Russia and Kazakhstan comprise the type area of the Cisuralian Series (Lower Permian), consisting of Asselian, Sakmarian, Artinskian, and Kungurian stages. Current studies in the region will attempt to establish stratotypes and precise chronostratigraphic stage and substage boundaries of the Cisuralian based on biostratigraphic and sequence stratigraphic data. Both serve as powerful tools for correlating Cisuralian stages worldwide via recognition of widely distributed fauna and eustatic sequence boundaries.

The Aktasty Hills section, located near Aqtöbe (formerly Aktyubinsk), Kazakhstan (see location map: Schiappa, this issue, page 2, Fig. 1) consists of 1120 m of Lower Permian marine strata of Upper Asselian through Artinskian (Aktastinian and Baigendzhinian) age. The section is a logical choice to serve as the stratotype for a modern definition of the base of the Baigendzhinian substage (and concurrently, the top of the Aktastinian) because it was employed by V. E. Ruzhencev (1956) for the definition of the two Artinskian substages.

Ammonoids, conodonts, and radiolarians are abundantly preserved throughout the section, and fusulinaceans occur in the lower 175 m. Detailed studies of the biostratigraphy and sequence stratigraphy of the Aktasty Hills section are currently underway by Russian colleagues (Chuvashov, 1996) and members of PRI. These studies could serve as the basis for a proposal to establish the Aktasty Hills section as stratotype for the Aktastinian - Baigendzhinian substage boundary of the Artinskian stage. Current definition of Global Standard Stratotype Section and Point (GSSP), regarding bases of chronostratigraphic units, as set forth by the International Commission on Stratigraphy (Salvador, 1997; Remane, 1996) require them to be established within continuous evolutionary lineages and depositional sequences, i.e., bases can not be defined at sequence boundaries (unconformities).

Lower Permian (Cisuralian) strata at Aktasty Hills were first described by V. E. Ruzhencev (1951, 1952, 1956). Chronostratigraphic units were defined based on ammonoids, nautiloids and fusulinaceans from 8 locations. Substages of the Artinskian stage (Aktastinian/Baigendzhinian) were defined at Aktasty Hills based on diverse ammonoid and nautiloid assemblages at three locations. Data are summarized in Figure 1b (fold out).

We remeasured and resampled the section in 1993, 1994 and 1997. Additional ammonoid localities were identified and collected, and the section was also sampled for conodonts and palynomorphs. Within the Artinskian (based on Ruzhencev's divisions) 71 conodont samples were collected and 7 ammonoid locations were sampled. Preliminary biostratigraphic data and stratigraphy are summarized in the fold out facing this page.

New ammonoid and conodont data suggest that the Aktastinian - Baigendzhinian substage boundary be located approximately 220

meters below its present position. The boundary is currently located at 945 m above the base of the section at the top of Ruzhencev's Bed 8 which contains primarily Artinskian ammonoids and one Aktastinian form; *Paragastrioceras tschernowi*. Several additional ammonoid localities containing possible Baigendzhinian forms such as *Metalegoceras klimovi (evolutum?)* and *Eothinites aktastensis* have been sampled below Ruzhencev's Bed 8 at 856 and 867 meters above base. In addition, neostreptognathoid conodonts, possibly *Neostreptognathodus pequopensis*, exist from a sample from 729 meters above base. Conodont zonations by Kozur (1995) and Ritter (1986) indicate *N. pequopensis* ranges throughout the Baigendzhinian.

References

- Chuvashov, B., 1996, Report from the working group of the Asselian, Sakmarian and Artinskian stratotypes, Permophiles, no. 29, p. 2-3.
- Kozur, H., 1995, Permian conodont zonation and its importance for the Permian stratigraphic standard scale, Festschrift zum 60. Geburtstag von Helfried Mostler, Geol. Palaont. Mitt. Innsbruck, ISSN 0378-6870. Bd.20.S. 165-205
- Remane, J., M.G. Bassett, J.W. Cowie, K.H. Gohrbandt, H.R. Lane, O. Michelsen and Wang Naiwen, 1996, Guidelines for the establishment of global chronostratigraphic standards by the International Commission on Stratigraphy (ICS) (Revised), Permophiles, no. 29, p. 25-30.
- Ritter, S.M., 1986, Taxonomic revision and phylogeny of post-Early Permian crisis *bisselli-whitei* zone conodonts with comments on Late Paleozoic diversity.- *Geologica et Palaeontologica*, 20, 139-165.
- Ruzhencev, V. E., 1951. Lower Permian ammonoids of Southern Urals. I. Ammonoids of Sakmarian stage. *Transactions of Paleontol. Inst.; Ac. Sci. USSR*, 33, 1-188.
- Ruzhencev, V. E., 1952. Biostratigraphy of Sakmarian Stage in Aktiubinsk province, Kazakhstan SSR. *Transactions of Paleontol. Inst.; Ac. Sci. USSR*, 42, 1-87.
- Ruzhencev, V. E. 1956. Lower Permian ammonoids of Southern Urals. Ammonoids of Artinskian Stage. *Transactions of Paleontol.; Inst.; Ac. Sci. USSR*, 60: 1-274.
- Salvador, A., 1997, Proposed new chronostratigraphic units for the Upper Permian, Permophiles, no. 30, p. 3-4.

D. A. Kerner.
V. I. Davydov
W. S. Snyder
C. Spinosa
Permian Research Institute
Department of Geosciences,
Boise State University
Boise, ID 83725, USA

Aleksandr G. Klets, Igor V. Budnikov, Ruslan V. Kutugin, Vitaly S. Grinenko

The Permian of the western Verkhoyansk Mountains is characterized predominantly by marine strata exposed in continuous sections with dominantly boreal type faunas. The Verkhoyansk region is geographically intermediate and as such, has important significance for interregional correlation (Budnikov and others, 1997). The history of the formation of Permian deposits of the Verkhoyansk region is characterized by certain packages of strata, each of which is initially predominantly marine, and which later becomes less marine and more nearshore. These sedimentologic cycles can be directly correlated with transgressive-regressive cycles associated with eustatic fluctuations of worldwide ocean level. Each cycle is characterized by a regular distribution of faunal complexes (Permophiles, 28, 30). In Permian strata of the western Verkhoyansk Mountains six sedimentologic cycles are associated with faunal and floral developmental stages. These are the Khorokitsky, Echiisky, Tumarinsky, Delenzhinsky, Dulgalakhsy and Khalpirsky stratohorizons. These strata contain faunal complexes with affinities to the Uralian and to North-American provinces. Regional complexes of the western Verkhoyansk Mountains are correlated with stratigraphic units of Ural region and with the Permian chronostratigraphic scale accepted by Guadalupian Symposium (Guadalupe II) (Table 1). The study was supported by The Russian Fund for Fundamental Investigations, grant N 97-05-65209 and 97-05-64847.

References

- I.V. Budnikov, A. G. Klets, V.S. Grinenko, R.V. Kutugin. 1996. Permian of East Yakutiya. Permophiles No. 28, p. 27-29.
I.V. Budnikov, A. G. Klets, V. S. Grinenko, R. V. Kutugin. 1997. Permian of Barai River (West Verchoyanie). Permophiles No. 30, p. 26-27.
I.V. Budnikov, A. G. Klets, V. S. Grinenko. 1997. West Verkhoyanye is the key region to solve the main stratigraphic problems of Upper Paleozoic of Siberia. Proceedings of The XIII International Congress on The Carboniferous and Permian. Krakow, Poland. Part 1. Warszawa. p. 105-108.

Aleksandr G. Klets
Institute of Geology of Oil and Gas, Siberian Branch of
Russian Academy of Sciences
Novosibirsk, Russia

Igor V. Budnikov
Siberian Research Institute of Geology
Geophysics and Mineral Resources
Novosibirsk, Russia

Ruslan V. Kutugin
Institute of Geology
Yakutsk, Russia

***Hindeodus parvus*: Advantages and Problems**

Wang Cheng-yuan

Conodonts as a leading fossil group for Permian and Triassic biostratigraphy are commonly accepted by nearly all palaeontologists and geologists. *Hindeodus parvus*, as an index species for defining the base of the Triassic, is also commonly accepted by the majority of the members of the International Working Group on the Permian-Triassic Boundary (PTBWG) since 1988. The Permian-Triassic boundary beds and their conodonts have been intensively studied in the recent years. Much progress and achievements have been obtained in the study of conodonts. *Hindeodus parvus* possesses the many advantages for defining the base of the Triassic: wide distribution, occurring in low and high latitudes and in shallow and deep-water facies, it is easy to identify, and therefore it is much better than gondolellid conodonts. But there are still many discrepancies in the conodont study, especially the problems concerning *Hindeodus parvus*: the definition (the definition of *Hindeodus parvus* and the biostratigraphic definition for the base of the Triassic), taxonomy (at the genus, species, subspecies and morphotype levels), evolutionary lineage, zonation, the position of the P/T boundary and the contact relationship of the P/T boundary beds at the Meishan sections which are ranked as the first candidate section for the GSSP of the base of the Triassic. We must face the realities and admit the discrepancies, instead of avoiding the problems. It is not workable to select a GSSP for the base of Triassic before these problems have been solved.

The purpose of this paper is not to evaluate the different viewpoints around *Hindeodus parvus*, but to arouse the members of PTBWG to notice the existing problems, and try to pave a way to solve the problems.

The Advantages of using *H. parvus* as the marker for the P/T Boundary

Hindeodus parvus as a biostratigraphic marker for the base of the Triassic is generally accepted by the majority members of the PTBWG. It is really an excellent species for defining the base of the Triassic. Its advantages are obvious:

1. *Hindeodus parvus* has a world-wide distribution. It has been found at least in 20 localities in China, and also in Kashmir, Salt Range, Transcaucasia, Iran, Italy, Austria, Hungary, United States, Greenland and British Columbia. It occurs in low and high latitudes. Some people (Baud, 1996, and others) consider that the *H. parvus* occurs only in shallow water facies, and because nearly all conodont zonal species were selected from the deep water facies, they concluded that the *H. parvus* was not suitable to be an index fossil for defining the base of the Triassic. But *H. parvus* is also present in deep water facies (Gullo & Kozur, 1993). It has a

Permian of West Verkhoyanye: faunal complexes

System		Ural scale		West Verkhoyaniye regional scale		II Guadalupian symposium, 1996		
Series	Stage	Stratohorizon	Strato-horizon	Provincial brachiopod zone	Ammoid complex	Loplin		
P e r m i a n	U p p e r	Vyatsky	Strato-horizon	Khalpirskaya suite	Ammoid complex	Loplin	Changhsingian	
							Wuchiapingian	
		Tatarian	Severodvinsky	Dulga-lakhsy	Cancrinelloides obrutchevi	Kingoceras ? sp.	Guadalupian	Capitanian
			Urzhumsky					
		Kazanian	Sheshumsky	Delenzhinsky	Olgerdia zavodovskiy	Sverdrupites harkeri (Ruzh.), Sv. baraiensis Kut., Pseudosverdrupites budnikovi Kut., Popaioceras subtimarensis Andr., Daubichutes aff. goochi (Leichert), Ammites kosyinski Andr., Timaroceras kaschirzevi Andr., Beraioceras stepanovi Andr.	Guadalupian	Wordian
					Terrakea korkodonensis			
		Ufimian	Solikamsky	Delenzhinsky	Mongolusia russtensis	Timaroceras kaschirzevi Andr., Beraioceras stepanovi Andr.	Guadalupian	Roadian
					Kolymaella ogonerensis			
		L o w e r	Kungurian	Irensky	Tumarinsky	Megousia kuliki	Timaroceras yakutorum Ruzh., T. bogoslovskayae Andr., T. volkodavi Andr., Epjuresanites kolymaense Andr., E. misalini Popov, Neouddenites andrianovi Ruzh., N. caurus N., F. et G., Popaioceras timarensis Ruzh.	Kungurian
				Philippovsky				
Artinskian	Saransky		Echitsky	Jakutoproductus ex gr. verkhoyanicus	Paragastrioceras spp., Uraloceras popowi Andr., U. evencoriani Andr., Timaroceras subyakutorum Andr., Uraloceras "simense" Ruzh., Metapronorites sp., Neoshumardites triceps hyperboreas Ruzh., Metalegoceras crenatum N., F. et G., Preshumardites sp., Bulumites juferevi Andr., Somoholites sp., Neopronorites milleri Ruzh.	Cisuralian	Artinskian	
	Sarginsky							
	Iginsky							
Sakm.	Burtsevsky	Khorolitsky	Jakutoproductus verkhoyanicus	Bulumites juferevi Andr., Somoholites sp., Neopronorites milleri Ruzh.	Cisuralian	Sakmarian		
	Sterlitamaksky							
Assel	Kholodnolozhsky	Tastubsky	Jakutoproductus protoverkhoyanicus	Bulumites juferevi Andr., Somoholites sp., Neopronorites milleri Ruzh.	Cisuralian	Asselian		
		Shukhansky						

world-wide distribution both in ammonoid-bearing pelagic facies (rare) and in ammonoid-free shallow water facies (common). As a free-swimming animal, the conodonts lived in different depth zones. *Hindeodus* lived in shallow euphotic zone, the *Hindeodus* biofacies was mostly deposited in shallow water facies and rarely in deep water facies. *Clarkina* lived in deep euphotic zone and below the storm wave base. The *Clarkina* biofacies was mostly deposited in basinal and slope facies, and partly in outershelf facies. Moreover, *H. parvus* exists not only in the Tethys realm but also in the Boreal realm and in the Perigondwana area. It is very important for the correlation of the Boreal faunas with the Tethyan standard. On the contrary, the gondolellid species such as *Clarkina meishanensis* that was suggested as an index fossil for the base of the Triassic (Orchard et al., 1994 and Orchard & Tozer, 1997) is not present in the Perigondwana and Arctic regions. So far, nowhere in the world has been found a section from which only the pelagic gondolellid conodonts are present. We have to recognise that true pelagic facies that accumulated during the time interval covering the Permian-Triassic boundary is very rare and very limited. Not any *Clarkina* species as Wardlaw & Mei (1998) suggested could be found both in the Boreal and Tethyan realms and could be index fossil for the base of the Triassic

2. Only the *Hindeodus* lineage can be traced bed by bed from the Permian-Triassic boundary beds, the *Hindeodus* evolutionary lineage at the Meishan sections has revealed a high-resolution conodont zonation. This conodont lineage can be recognised in many sections in the world; even so there are still problems to be solved. On the contrary, so far nowhere in the world has a succession from *Pseudotiroliotes* (or *Paratiroliotes*) Zone-to-*Otoceras* Zone been established in the same section.

3. The first appearance of *H. parvus* is a unique biostratigraphic horizon and it is the level that is close to the event stratigraphic boundary. This biostratigraphic boundary lies, in the Meishan section, 15 cm above the event boundary, and about 5 cm above the dC13 minimum. It nearly coincides with the beginning of the distinct anoxic event that can be observed in most basinal facies in the world (Wignall & Hallam, 1991).

4. The *H. parvus* boundary has several biostratigraphic criteria and other criteria which can be used as auxiliary markers for the base of the Triassic:

A. Biostratigraphic auxiliary markers:

a. The extinction of *Clarkina deflecta*, *C. dicerocarinata*, *C. changxingensis*, *C. meishanensis*, *Hindeodus latidentatus*, *H. changxingensis* and *H. typicalis*.

b. The first appearance of *Isarcicella staeschei*, *I. isarcica*, *Claraia wangi* and *Ophiceras commune*.

B. Other auxiliary criteria:

a. Lithostratigraphic event boundary, the base of the boundary clay at the Meishan section (Boundary bed 1, or bed 25).

b. The boundary of the minimum in dC13 value at the P/T boundary beds.

c. Anoxic event, the base of the upper part of the boundary clay bed 1 or the bed 26 at the Meishan section;

These auxiliary criteria are very helpful and useful for the recognition of the base of the Triassic.

Problems of the *H. parvus* Boundary

As mentioned above, there are still many discrepancies in the conodont study, especially the taxonomical problems and the understanding of *Hindeodus parvus*. Following problems are noted:

The definition for the base of Triassic:

Six different conodont-based definitions for the base of the Triassic have been proposed by conodont workers in the recent years:

1. The First Appearance Datum (FAD) of *Hindeodus parvus*. It was first proposed by Yin et al. in 1988;

2. The FAD of *Hindeodus parvus* Morphotype 1. It was first proposed by Wang in 1994 based on the study of the conodonts from the Meishan sections;

3. The FAD of *Hindeodus parvus erectus*. It was first proposed by Kozur in 1996. He named the *Hindeodus parvus* Morphotype 1 as a new subspecies: *H. parvus erectus*.

4. The FAD of *Clarkina meishanensis*. It was first proposed by Mei in 1996 (MS).

5. The FAD of *Hindeodus parvus proparvus*. Zhu et al. (1997) named six new subspecies of *Hindeodus parvus* based on the eight conodont specimens illustrated in the previous publications. They proposed the so-called typical *Hindeodus parvus*, that is his *Hindeodus parvus proparvus*, for defining the base of Triassic. Zhu et al. (1997) also use *Hindeodus parvus* Morphotype 2 and their own new subspecies *H. parvus lepingensis*, *H. parvus yangouensis*, *H. parvus meishaensis*, *H. parvus baoqingensis* and *Hindeodus dingi* as well as their four morphotypes (morphotype 3 to morphotype 6) of *Hindeodus parvus* to define the base of Triassic;

6. The FAD of one species of a gondolellid element (or *Clarkina* species). It was proposed by Orchard et al. (1996) and Wardlaw & Mei (1998, p.4), but they did not select a discrete gondolellid (*Clarkina*) species as an index fossil.

Which definition is the best for the base of Triassic? There is no agreement among the conodont workers. They have to discuss and to get an agreement for the definition for the base of the Triassic. To select a reliable biostratigraphic definition is very important for the defining the GSSP for the base of the Triassic. The non-conodont specialists of PTBWG should know the importance solving the existing discrepancies. The present author is in favour of using the *Hindeodus parvus* Morphotype 1 or *H. parvus erectus* to define biostratigraphically the base of the Triassic.

Taxonomy (discrepancies on generic level):

1. Most conodont workers have assigned the conodont species *parvus* to the conodont genus *Hindeodus* Rexroad et Furnish, 1964 (Kozur et al., 1995, 1996, 1997; Wang, 1994, 1995; Wang et al., 1996, 1997);

2. Ding et al. (1995) insisted that the species *parvus* should be assigned to conodont genus *Icarcicella* Kozur, 1975

Taxonomy (species, subspecies and morphotype):

Following morphotypes and subspecies of *Hindeodus parvus* have been proposed:

1. *Hindeodus parvus* (Kozur & Pjatakova, 1976). It should be pointed out that Kozur & Pjatakova have selected two holotypes for *Hindeodus parvus*. In 1976 they appointed one holotype (1976, fig.1b) and in 1977 they selected another holotype for same species (1977, pl.1, fig.17, as same as their 1976 fig.1a). Obviously the first holotype (1976, fig.1b) is valid. The two selected holotypes both come from the *Ophiceras commune* Zone, and *Hindeodus parvus* sensu Kozur & Pjatakova (1976, 1977) is different from *Hindeodus parvus* recorded from the *Otoceras* Zone and described by Matsuda (1981);

2. In 1990 Kozur formally named two morphotypes for his two

holotypes *Hindeodus parvus*, Morphotype 1 is his second holotype, Morphotype 2 is his first holotype respectively. He considered that the Morphotype 1 was more typical and had stable characters.

3. In 1996, Kozur named two subspecies for *Hindeodus parvus*. *Hindeodus parvus* Morphotype 1 was renamed *Hindeodus parvus erectus*, *Hindeodus parvus* Morphotype 2 was renamed *Hindeodus parvus parvus*. In the meantime he accepted *Hindeodus parvus anterodentatus* (Dai et al., 1989).

4. Zhu et al. (1996) named four morphotypes for *Hindeodus parvus* based on the illustrated specimens in the literature. The specimen of Matsuda (1981, pl.5, fig.2) was named by them as *H. parvus* Morphotype 3, the specimen of Matsuda (1981, pl.5, fig.1) was named *H. parvus* Morphotype 4 at the same time. The Chinese specimens that are illustrated in Zhu et al (1994) and deposited in Nanjing Institute of Geology and Palaeontology, Academia Sinica, were named another two morphotypes. The specimen of Zhu et al. (1994, pl.1, fig.1) was named *H. parvus* Morphotype 5, while the specimen (Zhu et al., 1994, pl.1, fig.6) was named *H. parvus* Morphotype 6.

5. Zhu et al. (1997) named six new subspecies for *Hindeodus parvus* based on eight specimens illustrated in previous papers, i.e. *Hindeodus parvus baoqingensis* (The specimen of Ding et al., 1995, pl. 1, fig. 1a), *H. p. meishanensis* (the specimen of Wang, C. Y., 1995, pl. III, fig. 6), *H. p. proparvus* (the specimen of Zhu et al., 1994, pl.1, fig.1, and 6), *H. p. lepingensis* (the specimen of Zhu et al., 1994, pl. 1, fig. 3 and the specimen of Ding et al., 1995, pl. 1 fig. 4), *H. p. dingi* (the specimen of Ding et al., 1995, pl. I, fig. 5), *H. p. yangouensis* (the specimen of Zhu et al., 1994, pl. I, fig. 2), they also keep the two morphotypes of *Hindeodus parvus* named by Kozur (1989) and their other four morphotypes named in 1996. They “appointed” that the three specimens described by Matsuda (1981, pl. 5, figs. 1-3) should be *Hindeodus parvus parvus*. Their *H. parvus parvus* is different from the *H. parvus parvus* named by Kozur (1996). It has to be pointed out that Zhu et al. (1997) did not have their own conodont specimens on which they created new subspecies and morphotypes. In addition, they never selected the holotypes for their new taxa, they also never gave a formal description for their new subspecies. They only mentioned in their papers that they “propose” some specimen as new subspecies and give a new name. Based on above hardly anybody can accept these six proposed subspecies and four new morphotypes. It is impossible that the *Hindeodus parvus* has so many morphotypes and so many subspecies as named by Zhu et al. (1996,1997). Zhu et al’s papers are characterised by oversplitting of subspecies or morphotypes; it makes no sense; the numerous so-called morphotypes or subspecies are stratigraphically not relevant, only represent variation within one species or subspecies.

Anyway, the taxonomical situation of *Hindeodus parvus* is very confusing, especially at the subspecies or morphotype level. The *Hindeodus parvus* really has a few morphotypes or subspecies. These morphotypes or subspecies have different ranges and their FADs are also different. If we use *Hindeodus parvus* to define the base of the Triassic, we can not precisely fix the position of GSSP, because the *Hindeodus parvus* has different subspecies or morphotypes with different ranges and FADs. It is reasonable to select one morphotype or one subspecies to define the base of the Triassic. Conodont workers should discuss the problems and get an agreement on the taxonomy of *Hindeodus parvus*. The present

author still considers that the best selection is to use the *Hindeodus parvus* Morphotype 1 or *Hindeodus parvus erectus* or even *Hindeodus erectus* as the definition for the base of Triassic.

Evolutionary lineage:

Following four different evolutionary lineages of *Hindeodus parvus* have been proposed in the recent years:

1. Zhang et al. (1995, in Yin, 1996), Ding et al. (1996) proposed a evolutionary lineage for *Hindeodus parvus*, i.e., *Hindeodus latidentatus* @*Isarcicella parva* @*I. turgidus* @*I. isarcica*;

2. Wang (1996) proposed a evolutionary lineage for the *Hindeodus parvus*, i.e. *Hindeodus latidentatus* @*H. parvus* @*Isarcicella staechei* @*I. isarcica*;

3. Kozur (1996) proposed an evolutionary lineage for the *Hindeodus parvus*, i.e. *Hindeodus latidentatus preparvus* @*H. parvus erectus* @*Isarcicella isarcica*;

4. Zhu et al. (1996) proposed their own evolutionary lineage for the different morphotypes of the *Hindeodus parvus*, that is, *Hindeodus parvus* Morphotype 5@*H. parvus* Morphotype 2 @*H. parvus* Morphotype 3 @*H. parvus* Morphotype 4 @*H. parvus* Morphotype 1 @*H. parvus* Morphotype 6. This is an inferred evolutionary lineage (Zhu et al., 1996,p. 3).

It is a common rule that a species or subspecies, if its forerunner and descendent is not clear, should not be selected as the index fossil for defining the base of a Period or a Stage. Conodont workers have to have a common agreement on the evolutionary lineage of the *Hindeodus parvus*. The present author is in favour of the *Hindeodus latidentatus preparvus* @*H. parvus erectus*—*I. staechei* @ *I. isarcica* lineage.

Conodont zonation for the Earliest Triassic:

Four different successions of conodont zones for the earliest Triassic have been proposed:

1. Zhang et al. (1995) proposed the following conodont zones for the earliest Triassic, in ascending order:

Isarcicella parva Zone @*I. isarcica* Zone @*Clarkina carinata-C. planata* Zone;

2. Ding (1996, p. 69) cited the *parvus* Zone and *isarcica* Zone as the earliest Triassic of the Meishan section.

3. Kozur (1995, 1996) proposed the conodont zones for the earliest Triassic as follows:

Shallow water facies:

Hindeodus parvus Zone @*I. isarcica* Zone;

Pelagic facies:

Clarkina carinata-C. planata Zone (Kozur, 1995, 1996).

4. Wang (1996, 1997) proposed the earliest Triassic conodont zones:

Shallow water facies (*Hindeodus* biofacies):

Hindeodus parvus Zone @*Isarcicella staechei* Zone @*I. isarcica* Zone @*H. postparvus* Zone.

Deep water facies (*Clarkina* biofacies):

Clarkina carinata Zone @*C. planata* Zone.

There is no agreement among the conodont workers about the conodont zones for the earliest Triassic. The present author still considers that the fourth scheme (Wang, 1996, 1997) is acceptable.

The position of the P/T boundary:

At least 13 different definitions of the P/T biostratigraphic boundary have been presented by various different authors as

summarised by Wang (1994b, p. 236-237). The concrete positions of the base of Triassic at the Meishan sections have at least four different schemes (Wang, 1994b, p. 241):

1. the base of bed 25 (boundary clay bed, Sheng et al., 1984; Yin, 1988, 1994; Mei, 1996; Zhu et al., 1997);
2. the base of bed 26 (Zhang, 1984; Sheng et al., 1987);
3. the base of bed 27 (Clark et al., 1986);
4. within the boundary bed 2 (= bed 27, or at the base of AEL882-3, Wang, 1994, 1995, 1996, 1998, Wang et al., 1997, Metcalfe et al., 1997; or at the base of bed 27c, Yin et al., 1995, 1996).

At present most of the members of PTBWG have accepted the fourth scheme, but Mei (1996) and Zhu et al. (1997) still insist to use the first scheme. The present author placed the P/T biostratigraphic boundary with considerable confidence within the boundary bed 2 (the fourth scheme).

Contact relationships at the P/T boundary beds:

Chinese specialists have quite different opinions about the contact relationships of the P/T boundary beds at the Meishan sections:

1. Most peoples consider that the P/T boundary beds at the Meishan sections are continuous marine deposits (Wang, 1994, 1995, 1998; Wang et al. 1996; Kozur et al., 1996; Yin et al, 1996). Wang (1994) especially emphasised that the boundary beds at the Meishan sections are continuous marine deposits that accumulated below storm wave base;
2. Jin et al. (1994) and Sheng et al. (1994) stressed with the same sentence in their two papers that: "The so-called boundary clay at the top of the Changhsingian is in fact a residual bed on the non-depositional surface", which means, the P/T boundary beds at the Meishan sections do not represent continuous sedimentation. Zhu et al. (1997) even proposed that there is a sedimentary gap at the top of the Changhsing Limestone, they called it an "empty area".

If there is a sedimentary gap between the P/T Systems, the Meishan sections can not be selected as stratotype for the GSSP of the base of the Triassic. This is a very important problem on which we have to have a common agreement. The present author still insists that the P/T boundary beds at the Meishan sections are indeed continuous marine deposits that accumulated below storm wave base. There are no sedimentary gap in the boundary beds.

So many discrepancies about the *Hindeodus parvus* are present: its definition, taxonomy, evolutionary lineage, and zonation as well as the level of the base of the Triassic and the contact relationships of P/T boundary beds at the Meishan sections, all of these, we have not gain international agreement. The conodonts are absolutely important for the P/T boundary beds and the GSSP of the base of the Triassic. The conodont workers must discuss and clarify all the crucial problems about *Hindeodus parvus*, especially the following problems are crucial:

1. The conodont definition of the base of Triassic: *Hindeodus parvus* or *H. parvus erectus* (or *H. parvus* Morphotype 1)? The different subspecies of *Hindeodus parvus* have different FADs or not?
2. The forerunner and descendent of the *Hindeodus parvus* or *H. parvus erectus*.
3. The conodont zonation for the earliest Triassic.
4. The contact relationships of the P/T boundary beds at the Meishan sections.

The present author has orally proposed to the Chairman of

PTBWG, Prof. Yin, H. F., to have a meeting to discuss these problems. The present author here again calls to convene an international meeting in China, all of the conodont workers who have studied the conodonts of the P/T boundary beds should be invited to attend this meeting. Prof. Yin, H. F as a Chairman of PTBWG should preside over this meeting. We must be clearly aware that we can not finally vote to the GSSP of the base of Triassic before we gain an international common agreement about the *Hindeodus parvus*.

Acknowledgements

The author thanks very much the Nanjing Institute of Geology and Palaeontology, Academia Sinica for financial support from the special funds for this study.

References

- Baud A., 1996: The Permian-Triassic boundary: recent developments, discussion and proposals. *Albertiana*, 18:6-9.
- Bottjer, D. J., Droser, M. L., & Wang Cheng-yuan, 1988: Fine-scale resolution of mass extinction events: Trace fossil evidence from the Permian-Triassic boundary in South China. *Geological Society of America, Abstract with Programs*, v.20, p.A106.
- Claoue-long, J. C., Zhang, Z. C., Ma, G. G., & Du, S. H., 1991: The age of the Permian-Triassic boundary. *Earth Planet.Sci. Letters*, 105:182-190.
- Clark, D. L., Wang Cheng-yuan, Orth, J., & Gilmore, J. S., 1986: Conodont survival and low Iridium abundances across the Permian-Triassic boundary in South China. *Science*, 233:984-986.
- Ding Mei-hua, Zhang Ke-xing & Lai Xun-long, 1995: Discussion on *Isarcicella parva* of the Early Triassic. *Palaeoworld*, 6: 56-63.
- Gupta, V. J. & Yin Hong-fu., 1987: *Otoceras* and the Permian-Triassic boundary. *Jour. Geol. Soc. of India*, 30: 132-142.
- Jin Yu-gang, Glenister, B. F., Kotlyar, G. V., & Sheng Jin-zhang, 1994: An operational scheme of Permian chronostratigraphy. *Palaeoworld*, 4: 1-13.
- Kozur, H., 1980: The main events in the Upper Permian and Triassic conodont evolution and its bearing to the Upper Permian and Triassic stratigraphy. *Rev. Ital. Palaeont.*, 85(3-4): 741-766.
- Kozur, H., 1994a: Permian pelagic and shallow water conodont zonation. *Permophiles*, 24: 16-20.
- Kozur, H., 1994b: The Permian/Triassic boundary and possible causes of the faunal change near the P/T boundary. *Permophiles*, 24:51-54.
- Kozur, H., 1995a: Permian conodont zonation and its importance for the Permian stratigraphic standard scale. *Geol.-Palaeont. Mitt. Innsbruck*, 20:165-205. *Festschrift zum 60. geburtstag von Helfried Mostler*.
- Kozur, H., 1995b: Some remarks to the conodonts *Hindeodus* and *Isarcicella* in the latest Permian and earliest Triassic. *Palaeoworld*, 6: 64-77.
- Kozur, H., 1996: The conodonts *Hindeodus*, *Isarcicella* and *Sweetohindeodus* in the Uppermost Permian and lowermost Triassic. *Geol. Croat.*, 49/1:81-115.
- Kozur, H., Ramovs, A., Wang Cheng-yuan & Zakharov, Y. D., 1996: The importance of *Hindeodus parvus* (Conodontia) for the definition of the Permian-Triassic boundary and

- evaluation of the proposed sections for a global stratotype section and point (GSSP) for the base of the Triassic. *Geologija*, 37/38: 173-213.
- Lai Xulong, 1998: Discussion on Permian-Triassic conodont study. *Permophiles*, 31:32-35.
- Mei Shi-long, 1996: Restudy of conodonts from the Permian-Triassic boundary beds at Selong and Meishan and the natural Permian-Triassic boundary. In: Wang, H. Z. & Wang, X. L. (eds.): Centennial Memorial Volume of Prof. Sun Yun-zhu: Palaeontology and Stratigraphy, 141-147, Beijing, China University of Geosciences Press.
- Sheng Jin-zhang, Chen Chu-zhen, Wang Yi-gang, Rui lin, Liao Zhou-ting, Bando, Y., Ishi, K., Nakazawa, K., & Nakamura, K., 1984: Permian - Triassic boundary in middle and eastern Tethys. *Journal of the Faculty of Science, Hokkaido University, Series 4*, 21 (1):133-181.
- Sheng Jin-zhang & Jin Yu-gang, 1994: Correlation of Permian deposits in China. *Palaeoworld*, 4:14-113.
- Tozer, E. T., 1986: Definition of the Permian- Triassic boundary; the question of the age of the *Otoceras* beds. *Memorie della Societa Geologica Italiana*, 36:291-302.
- Wang Cheng-yuan, 1990: Some problems on the Guryul Ravine section of Kashmir as Permian- Triassic boundary stratotype. *Palaeontologica Cathayana*, 5: 532- 266.
- Wang Cheng-yuan, 1994: A conodont-based high-resolution eventostratigraphy and biostratigraphy for the Permian-Triassic boundaries in South China. *Palaeoworld*, 4: 234-248.
- Wang Cheng-yuan, 1995: Conodonts of Permian -Triassic boundary beds and biostratigraphic boundary. *Acta Palaeontologica Sinica*, 34 (2):129-151.
- Wang Cheng-yuan, 1996: Conodont evolutionary lineage and zonation for the Latest Permian and the Earliest Triassic. *Permophiles* ,29:30-37.
- Wang Cheng-yuan, 1998: Conodont mass extinction and recovery from the Permian-Triassic boundary beds at Meishan sections, Zhejiang, China (in press).
- Wang Cheng-yuan, Kozur, H., Ishiga, H., Kotlyar, G.V., Ramovs, A., Wang Zhi-hao & Zacharov, Y., 1966: Permian-Triassic boundary at Meishan of Changxing County, Zhejiang Province, China.— A proposal on the global stratotype section and point (GSSP) for the base of the Triassic. In: First Asian Conodont Symposium. *Acta Micropaleont. Sinica*, 13(2):109-124.
- Wardlaw, B. R. & Mei Shilong, 1998: Evolution in the *Hindeodus* apparatus in the uppermost Permian and lowermost Triassic. *Permophiles*, 31:5.
- Wardlaw, B. R. & Mei Shilong, 1998: *Clarkina* (conodont) zonation for the Upper Permian of China. *Permophiles*, 31:3-4.
- Yin Hong-fu, 1993: A proposal for the global stratotype section and point (GSSP) of the Permian-Triassic boundary. *Albertiana*, 11:4-30.
- Yin Hong-fu, 1996: Permian-Triassic Boundary Working Group Newsletter, No.5 (March 8, 1996).
- Yin Hong-fu, Sweet, W. C., Glenister, B. F., Kotlyar, G., Kozur, H., Newell, N. D., Sheng Jin-zhang, Yang Zun-yi, & Zakharov, Y. D., 1996: Recommendation of the Meishan section as Global Stratotype Section and Point for basal boundary of Triassic System. *Newsl. Stratigr.*, 34(2):81-108.
- Yin Hong-fu, Yang Feng-ging, Zhang Ke-xing et al., 1988: A proposal to the biostratigraphic criterion of Permian-Triassic boundary. *Mem. Soc. Geol. Ital.*, 34:329-344.
- Zhang Ke-xin, Ding Mei-hua, Lai Xu-long & Liu Jin-hua, 1996: Conodont sequences of the Permian- Triassic boundary strata at Meishan section, South China. In Yin Hong-fu (ed.):NSFC project: The Palaeozoic- Mesozoic boundary candidates of Global stratotype section and point of the Permian- Triassic boundary. 57-64. China University of Geosciences Press.
- Zhu Xiang-shui, Lin Lian-sheng & Lu Hua, 1996: Recommend a reference section of GSSP. *Journal of Jiangxi Normal University*, 20(3):264-268.
- Zhu Xiang-shui & Lin Lian-sheng, 1997: Typical *Hindeodus parvus* and its significance and discussion on P/T boundary. *Journal of Jiangxi Normal University*, 21(1):88-95.
- Zhu Xiang-shui, Lin Lian-sheng & Zhong Ye-xi, 1997: The further of *Hindeodus parvus* in P/T boundary bed in Northern Jiangxi, and rediscussion of P/T boundary. *Journal of Jiangxi Normal University*, 21(2):1-5.
- Zhu Xiang-shui, Zhong Ye-xi & Lu Hua, 1997: The correlation of the P/T boundaries sections between Dongling, Yangou and Meishan regions in the eastern Tethys. *Journal of Jiangxi Normal University*, 21(1):1-5.
- Zhu Xiang-shui, Lin Lian-sheng & Hu Zhong, 1997: The discovery of the Longtanic conodonts from Qibaoshan, Shanggao County, Jiangxi, and discussion on *Gallowayinella* Time. *Journal of Jiangxi Normal University*, 21(2):174-177.

Wang Cheng-yuan
Nanjing Institute of Geology and Palaeontology
Academia Sinica
Nanjing, 210008
China

Reviewer Comment:

Wardlaw and Mei (1998) did not select a discrete gondolellid (Clarkina) species as an index fossil because they were not proposing an alternative definition of the Permian-Triassic boundary. They fully agree with using the first appearance datum of Hindeodus parvus as the boundary definition. They were pointing out that Clarkina species are useful throughout the Lopingian and C. meishanensis characterises the boundary interval at the Meishan section and implied it would be a good accessory identifier not the boundary definer.

(B. R. Wardlaw)

Permian Brachiopods from the Selong Xishan Section, Southern Xizang (Tibet): Preliminary Assemblages and Stratigraphical Implications

Shuzhong Shen, N.W. Archbold, G.R. Shi and Z.Q. Chen

Different opinions about the taxonomy and biostratigraphy of conodonts and brachiopods from the boundary beds at the Selong Xishan section have been previously presented by Zhang (1974), Yin and Guo (1975), Rao and Zhang (1985), Wang et al. (1989), Xia and Zhang (1992), Wang et al. (1993), Shen and Jin (1994) and Orchard et al. (1994). Recently, some detailed lithostratigraphical, biostratigraphical and geochemical studies on the collections and new results on the Permian-Triassic boundary have been studied and subsequently reported by Jin et al. (1996), Mei (1996), Wang et al., (1997), and Shi and Shen (1997). However, neither detailed biostratigraphy nor systematic study of brachiopods, despite its unique abundance in this section, has been carried out for the sequence of the Selong Group. Moreover, the debate about the correlation of the Selong Group between Xizang and other regions has continued for tens of years.

More than 600 specimens, some 42 brachiopod species belonging to 30 identifiable genera and 2 unidentifiable genera from the Selong Group of the Selong Xishan section are collected and identified. Brachiopods from the Selong Group suggest an age possibly ranging from late Capitanian (Midian) to Changhsingian in terms of the framework of the newly proposed three-fold Permian timescale (Jin et al., 1997). Brachiopods in the uppermost Selong Group demonstrate a clear relationship with those found lower in the Group. They are characteristically dominated by Gondwanan and bipolar elements. *Spiriferella rajah* (Salter) and *S. nepalensis* Lagrand-Blain exist through the whole Selong Group. *Taeniothaerus densipustulatus* sp. nov., *Marginalosia kalikotei* (Waterhouse), *Trigonotreta lightjacki* Archbold and Thomas, *Neospirifer* (*Neospirifer*) *kubeiensis* Ting range up to about 1 metre below the *Otoceras* Bed. The brachiopods in the Selong Group may be roughly divided into two stages. In the lower and middle parts of the Selong Group in the Selong Xishan section brachiopods are relatively low in diversity but high in abundance and predominated by large spiriferids with thick shells such as *Neospirifer* (*Neospirifer*) *kubeiensis* Ting, *Spiriferella rajah* (Salter) and an aulostegoid *Taeniothaerus densipustulatus* sp. nov.; but in the upper part (about 5 m thick) of the Selong Group brachiopods are more diversified and predominated by elements attached by the pedicle with relatively small size although most species in the lower stage are still present. Three brachiopod assemblages are recognised. The *Marginalosia-Composita* Assemblage in the lower part of the Selong Group is considered to be of late Capitanian (Midian) to early Wuchiapingian (Djulfian) age. The overlying *Chonetella nasuta* Zone (Zhang and Jin, 1976; Jin, 1985) is well recognizable in the Selong Xishan section, which could be further divided into *Costatumulus tazawai-Retimarginifera xizangensis* Assemblage and *Stenosisma gigantea-Nakimusiella selongensis* Assemblage in ascending order, and brachiopods in this zone closely resemble those from the Senja Formation in the Dolpo district of Nepal, the Kalabagh Member and the Chhidru Formation in the Salt Range, Pakistan and the middle part of the

Zewan Formation in Kashmir, and be considered to be largely Wuchiapingian (Djulfian). The age of the Coral Bed of Jin et al. (1996) cannot be determined from brachiopods. But a Changhsingian age assignment of the *Martinia*-*Waagenites* Bed (= *Waagenites* Bed of Jin et al., 1996) is preferred (Table 1). It appears that there is no major hiatus present in the whole Selong Group in terms of brachiopod assemblages. A statistical analysis at the generic level shows that the Selong fauna has a strong affinity with those from Nepal and Western Australia, as well as Timor, Kashmir, the Salt Range and the Karakorum Range of Pakistan, and no substantial relationship with South China, Transcaucasia and the eastern Qiangtang terrane.

Acknowledgements

This paper is supported by the Australian Research Council (Grant No. A0503617156).

References

- Archbold, N.W., 1987. South Western Pacific Permian and Triassic Marine Faunas: Their Distribution and Implications for Terrane Identification. In *Terrane Accretion and Orogenic Belts*. Leitch, E.C., and Scheibner, E. (eds.), *Geodynamic Series 19*:119-127.
- Archbold, N.W., 1993. A zonation of the Permian Brachiopod faunas of western Australia. In *Gondwana Eight-Assembly, Evolution and Dispersal*. Findlay, R.H., Unrug, R., Banks, M.R., and Veevers, J.J. (eds.), 313-321. Rotterdam: A.A. Balkema.
- Archbold, N.W., and Bird, P.R., 1989. Permian Brachiopoda from near Kasliu Village, West Timor. *Alcheringa 13*(1-2):103-123.
- Broili, F., 1916. Die Permischen Brachiopoden von Timor. In *Palaeontologie von Timor*. Wanner J. (ed.), 7:1-104. Stuttgart.
- Diener, C., 1897. Himalayan Fossils. The Permocarboniferous Fauna of Chitichun No.1. *Geological Survey of India, Memoirs, Palaeontologia Indica, Ser. 15, 1*(3):1-105.
- Diener, C., 1903. Permian Fossils of the Central Himalayas. *Geological Survey of India, Memoirs, Palaeontologia Indica, Ser. 15, 1*(5):1-204.
- Furnish, W.M., 1973. Permian Stage Names. In *Stratigraphic Boundary Problems: Permian and Triassic of West Pakistan*. Kummel, B., and Teichert, C. (ed.), 522-548. Kansas University Press.
- Grant, R.E., 1970. Brachiopods from Permian-Triassic Boundary Beds and Age of Chhidru Formation, West Pakistan. In *Stratigraphic Boundary Problems: Permian and Triassic of West Pakistan*. Kummel, B., and Teichert, C. (eds.), University of Kansas, Department of Geology, Special Publication 4:117-151.
- Hamlet, B., 1928. Permische Brachiopoden, Lamellibranchiaten und Gastropoden von Timor. *Jaarboek van het Mijneuzen in Nederlandsch Oost-Indie, Gravenhage 56*(2):1-115.
- Jin Yugan, 1985. Permian Brachiopoda and Paleogeography of the Qinghai-Xizang Plateau. *Palaeontologica Cathayana 2*:19-71.
- Jin Yugan, Liang Xiluo, and Wen Shixuan, 1977. Additional material of animal fossils from the Permian deposits on the northern slope of mount Qimolangma Feng. *Scientia Geologica Sinica 3*:236-249.

Series	Stage	Lopingian		Series
Lower Triassic	Griesbachian	Otoceras Bed	Kashmir Nakazawa et al., 1975	Salt Range Pakistan Waagen (1883-1885) Reed (1944) Grant (1970) Wardlaw & Pogue, (1995)
		Hindeodus parvus Zone		Otoceras Bed
Changhsingian	Changhsingian	continuous	Khunamuh Formation	Nepal Waterhouse (1978); Waterhouse & Shi (1990)
		Martinia- "Waagenites" Bed		Unit E ₂
	Caliche Bed	Unit E ₁	Southern Tibet Diener (1897, 1903); Zhang (1974); Jin et al. (1977); Sheng & Wang (1981)	
	Coral Bed	Division IV	Western Australia Archbold (1987, 1993)	
Wuchiapingian	Wuchiapingian	Stenoscisma gigantea-Nakimusiella selongensis Assemblage	Zewan Formation	Mittiwali Member
		Chonelella nasuta Zone		Division III
Capitanian	Capitanian	Costatumulus tazawai-Retimarginifera xizangensis Assemblage	Division II	Marsyangdi Formation ?
		Marginalosia-Composita Assemblage		Division I
Guadalupian	Capitanian	Wargal Formation	Division I	Senja Formation
		Kalabagh Member	Chhidru Formation	Senja Formation
			Lammimargus himalayaensis Zone	Senja Formation
			Lammimargus himalayaensis Zone	Senja Formation
			Lammimargus himalayaensis Zone	Senja Formation
			Amarassi fauna	Senja Formation
			Basleo Fauna	Senja Formation
			Chitichun No. 1 Limestone	Senja Formation
			Balingpu Limestone	Senja Formation
			Lasaitia Limestone	Senja Formation
			Waagenoconcha imperfecta Zone	Senja Formation
			Liveringia magnifica Zone	Senja Formation

Table 1. Brachiopod assemblages in the Selong Xishan section and their correlation with other faunas in the Peri-Gondwanan region.

- Jin Yugan, Shen Shuzhong, Zhu Zhili, Mei Shilong and Wang Wei, 1996. The Selong Xishan section, candidate of the global stratotype section and point of the Permian-Triassic boundary. In *The Palaeozoic- Mesozoic Boundary Candidates of the Global Stratotype Section and Point of the Permian-Triassic Boundary*, Yin Hongfu (ed.), 127-137. China University of Geosciences Press, Wuhan, China.
- Jin Yugan, Wardlaw, B.R., Glenister, B.F., and Kotlyar, G.V., 1997. Permian chronostratigraphic subdivisions. *Episodes* 20(1):10-15.
- Mei Shilong, 1996. Restudy of conodonts from the Permian-Triassic boundary beds at Selong and Meishan and the natural Permian-Triassic boundary. In *Centennial Memorial Volume of Prof. Sun Yunzhu: Palaeontology and Stratigraphy*, Wang, Hongzhen, and Wang Xunlian (eds.), 141-148, China University of Geoscience Press
- Nakazawa, K., Kapoor, H.M., Ishii, K., Bando, Y., Okimura, Y., and Tokuoka, T., 1975. The Upper Permian and the Lower Triassic in Kashmir, India. *Kyoto University, Faculty of Science (Geology and Mineralogy), Memoirs* 42(1):1-106.
- Orchard, M.J., Nassichuk, W.W., and Rui Lin, 1994. Conodonts from the lower Griesbachian *Otoceras latilobatum* Bed of Selong, Xizang and the position of the Permian-Triassic boundary. *Canadian Society of Petroleum Geologists, Memoir* 17:823-843.
- Rao Rongbiao, and Zhang Zhenggui, 1985. A discovery of Permo-Triassic transitional fauna in the Qomolangma Feng area: its implications for the Permo-Triassic boundary. *Xizang Geology* 1:19-31.
- Reed, F.R.C., 1944. Brachiopoda and Mollusca from the *Productus* Limestones of the Salt Range. *Geological Survey of India, Memoirs, Palaeontologia Indica* 23(2):1-678.
- Shen Shuzhong, and Jin Yugan, 1994. Brachiopods from Permian-Triassic boundary beds of the Selong Xishan section. *Abstracts of International Symposium on Permian stratigraphy, Environments and Resources, Guiyang, China*, 27-28.
- Sheng Jinzhang, and Wang Yujing, 1981. Permian fusulinids from Xizang with reference to their geographical provincialism. *Acta Palaeontologica Sinica* 20(6):546-551.
- Shi, G.R., and Shen Shuzhong, 1997. A Late Permian brachiopod fauna from Selong, Southern Xizang (Tibet), China. *Proceedings of the Royal Society of Victoria* 109(1):37-56.
- Waagen, W., 1883-1885. Salt Range Fossils. I. *Productus*-Limestone Fossils. *Geological Survey of India, Memoirs, Palaeontologia Indica, Ser. 13*, 4(2-5):391- 770.
- Wang Wei, Shen Shuzhong and Zhu Zhili, 1997. Carbon isotope characters of the Permian Triassic boundary section at Selong, Xizang (Tibet), China and their significance. *Chinese Science Bulletin* 4:406-408.
- Wang Yugang, Chen Chuzhen, Rui Lin, Wang, Zhihao, Liao Zhuo-Ting, and He Jinwen, 1989. A potential global stratotype of Permian-Triassic boundary. *Chinese Academy of Sciences, Developments in Geoscience. Contribution to 28th International Geological Congress*, 1989, Washington, D.C. USA. 221-229. Science Press, Beijing.
- Wang Zhihao, Chen Chuzhen, and Liao Zhuoting, 1993. Some queries about the paper "Age of the Selong Formation in Xishan, Selong of Xizang (Tibet) and the Permian-Triassic boundary". *Journal of Stratigraphy* 17(3), 223, 237-239.
- Wardlaw, B.R., and Pogue, K.R., 1995. The Permian of Pakistan. In *The Permian of Northern Pangea 2, Sedimentary Basins and Economic Resources*, 215-224, Springer-Verlag, Berlin.
- Waterhouse, J.B., 1978. Permian Brachiopoda and Mollusca from North-West Nepal. *Palaeontographica, Abt. A*, 160(1-6):1-175.
- Waterhouse, J.B., and Gupta, V.J., 1983. A Faunule from the *Lamnimargus himalayensis* Zone in the Upper Shyok Valley, Southern Karakorum Range. In *Stratigraphy and Structure of Kashmir and Ladakh Himalaya. Contributions to Himalayan Geology*, Gupta V.J., (ed.) 2:234-245.
- Waterhouse, J.B., and Shi, Guang R., 1990. Late Permian Brachiopod Faunules from the Marsyangdi Formation, North Central Nepal, and the Implications for the Permian-Triassic Boundary. In *Brachiopods Through Time*, MacKinnon, D.I., Lee, D.E., and Campbell, J.D. (eds.), 381-387. Rotterdam: A.A. Balkema.
- Xia Fengsheng, and Zhang Binggao, 1992. Age of the Selong Formation in Xishan, Selong of Xizang (Tibet) and the Permian-Triassic boundary. *Journal of Stratigraphy* 16(4):256-363.
- Yin Jixiang, and Guo Shizeng, 1975. Stratigraphy of the Mt Jolmolangma and its northern slope, with a discussion about correlation of Sinian-Cambrian and Carboniferous-Permian with adjacent areas. In *A report of the Scientific expedition in the Mt. Jolmolangma region (1975) (Geology)*, 1-71, Science Press, Beijing.
- Zhang Binggao, 1974. The Permian System. In *A report of Scientific expedition in the Mt. Jolmolangma Region (Geology)*, 66-68, Science Press, Beijing, China.
- Zhang Shouxin, and Jin Yugan, 1976. Late Paleozoic Brachiopods from the Mount Jolmo Lungma Region. In *A Report of Scientific Expedition in the Mount Jolmo Lungma Region (1966-1968) 2*, 159-271, Science Press, Beijing.

Shuzhong Shen
N. W. Archbold
G. R. Shi
Z. Q. Chen

School of Ecology and Environment,
Deakin University, Rusden Campus,
662 Blackburn Road, Clayton,
Victoria 3168, Australia
zshen@deakin.edu.au
narchie@deakin.edu.au
grshi@deakin.edu.au
zhongqia@deakin.edu.au

Permian Tetrapod Biochronology

Spencer G. Lucas

Introduction

Permian tetrapod (amphibian and reptile) fossils are broadly distributed across Pangea (fig. 1) and have long provided a basis for nonmarine biostratigraphy and biochronology. Here, I assess the current status of Permian tetrapod biostratigraphy and biochronology.

Previously proposed subdivisions

Relatively few attempts have been made to delineate a global tetrapod biostratigraphy or biochronology of the Permian (fig. 2). Romer (1966, 1973) divided the Permian tetrapod record into three “stages” that essentially correspond to a threefold subdivision of the Permian into Early (Asselian-Artinskian), Middle (Kungurian-Kazanian) and Late (Tatarian) (fig. 2). As Romer noted, cotylosaurs and pelycosaurs dominate the early stage, best known from North America and the western European Rotliegendes. The intermediate stage is dominated by primitive synapsids and known mostly from South Africa and the Russian Urals. The third stage (Romer also called it the “final phase”) is dominated by advanced therapsids known mostly from South Africa.

Anderson and Cruickshank (1978) recognized the same global divisions as Romer, but they recast them as “empires” (essentially the same concept as “chronofaunas” of Olson, 1952). Anderson and Cruickshank (1978, charts 2.1-2.2) also listed 17 Permian tetrapod zones, but did not explicitly define them (fig. 2). However, from their chart 2.1 it is clear that zones 1 through 12 are based on Texas stratigraphic units (1 = Pueblo Formation; 2 = Moran Formation; 3 = Putnam Formation; 4 = Admiral Formation; 5 = Belle Plains Formation; 6 = Clyde Formation; 7 = Leuders Formation; 8 = Arroyo Formation; 9 = Vale Formation; 10 = Choza Formation; 11 = San Angelo Formation; and 12 = Flowerpot Formation), zones 13 and 14 are equivalent to Russian zones proposed by Efremov (13 = Zone I; 14 = Zones II and III) and the youngest zones are those of the South African Karoo basin (15 = *Tapinocephalus* Zone; 16 = *Cistecephalus* Zone; 17 = *Daptocephalus* [= *Dicynodon*] Zone).

Cooper (1982) published a Middle to Late Permian tetrapod biostratigraphy very similar to Zones 11-17 of Anderson and Cruickshank (1978), but with different terminology (fig. 2). Thus, Cooper’s (1982) *Dimacrodon* Zone is based on the vertebrate fossil assemblages of the San Angelo and Flowerpot Formations of Texas (Olson, 1962); his *Otsheria* Zone = Russian Zone I; his *Venyukovia* Zone = Russian Zone II; and his *Robertia* Zone = the *Tapinocephalus* Zone. Cooper (1982) assigned the *Lystrosaurus* Zone to the Permian, though most workers consider it to be Triassic.

There have been no other explicit attempts to develop a global biostratigraphy or biochronology of Permian tetrapods, though correlation charts of the Permian tetrapod record are numerous (e.g., Romer, 1966; Olson, 1989; Olson and Chudinov, 1992). Nevertheless, two regional schemes of Permian tetrapod biostratigraphy have been extremely important (fig. 2). Efremov (e.g., 1937, 1940) proposed a succession of four tetrapod “zones” for the Permian of the Russian Urals. Olson (1957) provided a useful, English-language review of this record (also see Olson, 1962; Olson

and Chudinov, 1992). Zone I is also called the Ocherian dinocephalian complex, and Zone II is the Isheevan dinocephalian complex. Zone III is now known to lack tetrapods, and Zone IV has been called the pareiasaurian faunal complex.

Rubidge et al. (1995) reviewed the development of the South African succession of Permian tetrapod assemblage zones originally proposed by Broom (1906, 1907, 1909) and Watson (1914a, b). The current succession recognizes six assemblage zones of Middle-Late Permian age (fig. 2).

Thus, the current status of Permian global tetrapod biochronology is that Romer’s scheme provides a threefold division of the Permian at the epoch level. Provincial tetrapod biochronologies in Russia and South Africa provide a more detailed temporal subdivision of the Middle and Late Permian, but no such provincial biochronology exists for the Early Permian. However, an Early Permian tetrapod biochronology can be developed based on the record in the western USA

Early Permian: Western USA

The most extensive Lower Permian tetrapod record is from the western United States, especially from Texas, Oklahoma and New Mexico (e.g., Olson, 1967; Hook, 1989; Berman, 1993; Berman et al., 1997). Recent stratigraphic revision of the Texas section (Hentz, 1988, 1989) considerably alters the stratigraphic nomenclature long used here in the vertebrate paleontological literature. Hook (1989) placed the Texas Lower Permian tetrapod record into this revised lithostratigraphy but developed no biozonation (fig. 3). However, this record can be used to delineate three zones (fig. 3), though as Hook (1989) noted, some of the biostratigraphic data here are weak because they rely on rare taxa or taxa of problematic taxonomic status.

Records to the west from the Abo/Cutler/Sangre de Cristo formations of New Mexico and the Four Corners include Pennsylvanian assemblages but mostly correlate to the lower Wolfcampian Bowie Group (Berman, 1993; Sumida et al., 1996). Younger records in the western USA are of Leonardian age (Clear Fork Group of Texas) and range to as young as early Guadalupian—Pease River Group of Texas and Duncan-Chikasha Formations of Oklahoma (e.g., Olson, 1962).

The tetrapod fossils from the Lower Permian of the western USA are the most complete record known. They should provide the basis for subdividing Early Permian time into at least three biochronological units.

Middle-Late Permian: Russia

The vast majority of the Russian Permian tetrapod localities are between Kazan and the Ural Mountains in the drainage basins of the Kama and Belaya Rivers. Efremov (1937) first systematized this record, identifying four successive tetrapod “zones,” which are of Middle-Late Permian age. However, Efremov’s (1937) third “zone,” his “pelycosaurian zone,” was later shown to not be based on a fossil vertebrate assemblage between his second and fourth zones, so there no longer is a “Zone III.” Also, note that each of Efremov’s “zones” are not actually zones (bodies of rock identified by distinctive fossils) in the strict sense, but instead were conceived by him to be “a comparatively long period of existence of a given fauna” (Efremov, 1937, p. 124). Therefore, the Russian “zones” really are biochronologic units that I would term faunachrons or land-vertebrate “ages.”

“Zones” I and II are of Kazanian age and are separated from

“Zone” IV, of Tatarian age, by a substantial unconformity. The “Zone I” tetrapod assemblages include archegosaurids (*Platyops*, *Melosaurus* and *Collidosuchus*), the caseid pelycosaur *Phreatophasma*, several eotitanosuchians (*Biarmosuchus*, *Eotitanosuchus*, etc.), dinocephalians (*Phreatosuchus*, *Estemmenosuchus*) and the dicynodont *Otsheria*. “Zone II” assemblages include archegosaurus (*Platyops*, *Melosaurus*, etc.), seymouriamorphs, captorhinomorphs (*Hecatotomphus*, *Riphaeosaurus*), pelycosaurus (*Mesenosaurus* and the caseid *Ennatosaurus*), theriodonts (*Phthinosaurus*, *Titanophoneus*, etc.), the dinocephalian *Ulemosaurus* and the dicynodont *Venyukovia*. The “Zone IV” assemblages are characterized by the dicynodont *Dicynodon* and include the temnospondyls *Dvinosaurus* and *Chroniosuchus*, the seymouriamorph *Kotlassia*, the pareiasaur *Scutosaurus*, gorgonopsians, a therocephalian and a cynodont.

The Russian Middle to Late Permian record in large part parallels the South African record. However, the Russian record only delineates three zones, so its biostratigraphic resolution is only half that of the South African record, which includes six zones.

Middle-Late Permian: South Africa

The Permian vertebrate record and its biostratigraphy in the Karoo basin of South Africa has long provided the classic succession of Middle to Late Permian tetrapod faunas. Recent reviews by Rubidge (1995), Smith and Keyser (1995a, b, c, d) and Kitching (1995) recognize six successive zones based on tetrapods (fig. 4). These zones are characterized as assemblage zones, but their boundaries lack explicit and consistent definition. This problem is best seen in the case of the *Pristerognathus* Assemblage Zone, stated by Smith and Keyser (1995b, p. 13) to be “an assemblage zone characterized by a therapsid fauna of low diversity dominated by *Diictodon* in association with *Pristerognathus* and the absence of dinocephalian fossils that are a prominent component of the fauna in the underlying zone.” However, only the lowest occurrence of *Ictidosuchoides* corresponds to the base of the zone and is not used to define its base. Precise definition of the South African Permian assemblage zones is needed. Despite this problem, the South African zonation provides the best global standard for the subdivision of Middle and Late Permian time based on tetrapods.

Permian footprint biostratigraphy

Tetrapod footprints of Permian age are broadly distributed, being best known from the Lower Permian of western Europe and the western USA (Haubold, 1971, 1984, 1996; Hunt et al., 1995; Lucas and Heckert, 1995). Other records include Russia (Tverdokhlebov et al., 1997; Lucas et al., 1998), the eastern USA-Canada (Cotton et al., 1995) and South America (Leonardi, 1994). Biostratigraphic zonation and correlation using the Permian footprint record have only been developed in Western Europe (e.g., Boy and Fichter, 1988; Ellenberger, 1983a, b, 1984). In North America, the tracks have almost exclusively been used for paleoecological and paleoethological analyses (e.g., Lockley and Hunt, 1995), and in other areas the track record is so limited as to be of little use for interpretive work.

Two problems hinder the use of Permian tetrapod footprints for biostratigraphy and biochronology:

1. Ichnogenera of tetrapod footprints usually correspond to much broader taxonomic categories than do genera based on body fos-

sils. For example, the Late Carboniferous-Early Permian ichnogenus *Dimetropus* corresponds to the body-fossil family Sphenacodontidae. No particular sphenacodontid genus can be identified by *Dimetropus*, so the temporal range of the ichnogenus = the temporal range of the Sphenacodontidae = Late Carboniferous-Early Permian. Therefore, the ichnogenus only provides biochronologic resolution on the order of epochs.

This is true of most, if not all, Permian tetrapod ichnogenera. For example, the ichnogenera *Batrachichnus* and *Limnopus* = Eryopoidea, *Amphisauropus* = Diadectidae, *Dromopus* = Araeoscelida, *Tambachichnium* = Diapsida, *Dimetropus* = Sphenacodontidae, *Gilmoreichnus* = Ophiacodontidae?, *Ichniotherium* = Edaphosauridae and *Chelichnus* = Synapsida (Haubold, 1996, table 3). These orders, superfamilies and families of body-fossil taxa have stratigraphic ranges on the magnitude of series, so ichnobiostigraphy based on the ichnotaxa can only discriminate correlations at the series level.

2. The shape of a footprint is determined not only by the structure of the foot skeleton of the trackmaker, but also by the interaction of the foot with the substratum. Much of this interaction and the nature of the substratum affects footprint shape, and this has been called extramorphological variation (Peabody, 1948). As Haubold (1996, p. 23) succinctly observed:

Fragmentary tracks, incomplete trackways and other preservational variations of optimal track morphology and trackway pattern are of restricted taxonomic value. These are extramorphological features, mainly controlled by facies and sedimentological influences, and in comparison to the foot-morphology of the trackmakers they are like chimeras. Taxa based on such material are called phantom-taxa. Many of the formerly described Permian footprints are problematic in this regard.

Indeed, vastly oversplit ichnotaxonomies of Permian tetrapod footprints (examples are Holub and Kozur, 1981; Ellenberger, 1983a, b, 1984) have been used to develop biostratigraphic zonations, but these zonations lack a valid taxonomic basis and should be abandoned.

The prospects for a detailed Permian biostratigraphy and biochronology based on tetrapod footprints are poor. In local areas, ichnotaxa may provide a local biostratigraphy that reflects local facies changes (e.g., Conti et al., 1997), but this will only be a biostratigraphy as detailed as the facies changes.

Conclusions

Tetrapods support the division of the Permian Period into three epochs. The most extensive Permian tetrapod records are from the western U.S.A., the Russian Urals, and South Africa, and only these records are of global biostratigraphic and biochronologic significance at present. Tetrapod ichnogenera only provide a series-level Permian biostratigraphy. A more precise global Permian tetrapod biochronology should be developed using a North American standard for the Early Permian and a South African standard for the Middle-Late Permian.

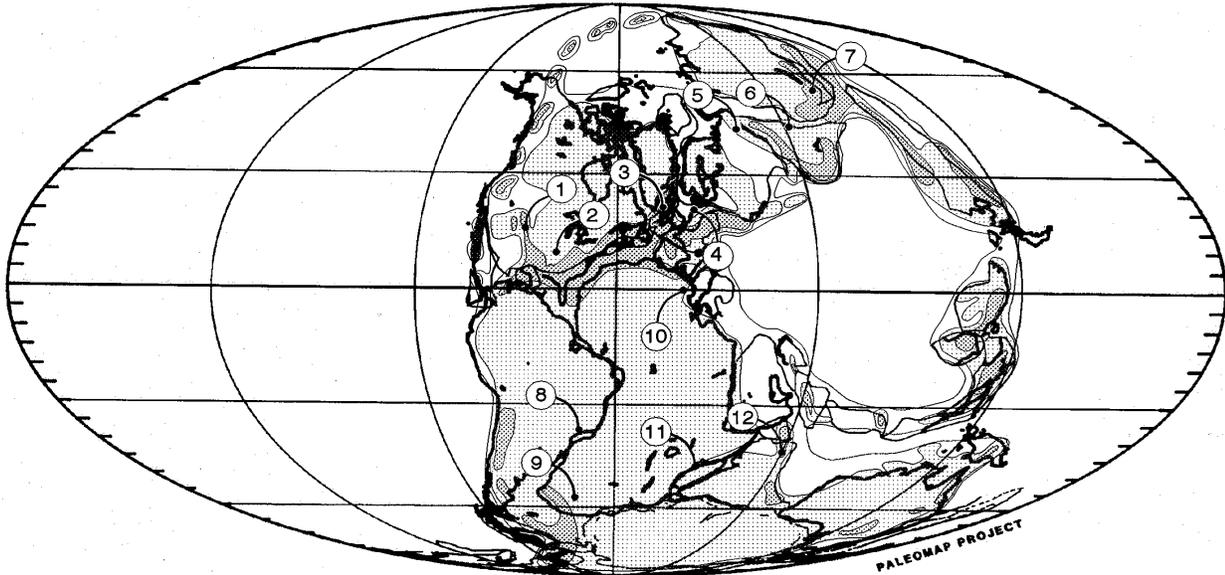


Figure 1. Map of Pangea showing principal Permian tetrapod localities. 1 = western USA; 2 = eastern USA (Dunkard); 3 = Scotland; 4 = Western Europe (Rotliegende); 5 = Russian Urals; 6 = Junggur basin, China; 7 = Ordos basin, China; 8 = Paraná basin, Brazil; 9 = Karoo basin, South Africa; 10 = Morocco; 11 = southern Madagascar; 12 = Kashmir.

Romer (1966, 1973)	Anderson & Cruickshank (1978)	Cooper (1982)	Efremov (1937, 1952) Russia	Rubidge et al. (1995) South Africa
final stage (Upper Permian)	endothiodontid/dicynodontid empire	Lystrosaurus Zone	Zone IV	Dicynodon Assemblage Zone
		Dicynodon Zone		
		17 Cistecephalus Zone		Cistecephalus AZ
intermediate stage (Middle Permian)	tapinocephalid empire	16	Zone II	Tropidostoma AZ
		15 Robertia Zone		Pristerognathus AZ
		14 Venyukovia Zone		Tapinocephalus AZ
		13 Otsheria Zone	Zone I	
		12 Dimacrodon Zone		Eodicynodon AZ
early stage (Lower Permian)	edaphosaurid empire	11		
		10		
		9		
		8		
		7		
		6		
		5		
		4		
3				
2				
1				

Figure 2. Previously proposed biostratigraphic/biochronologic schemes for Permian tetrapods. Note that this is not an exact correlation chart because of different workers' perceptions of the relative age of some intervals.

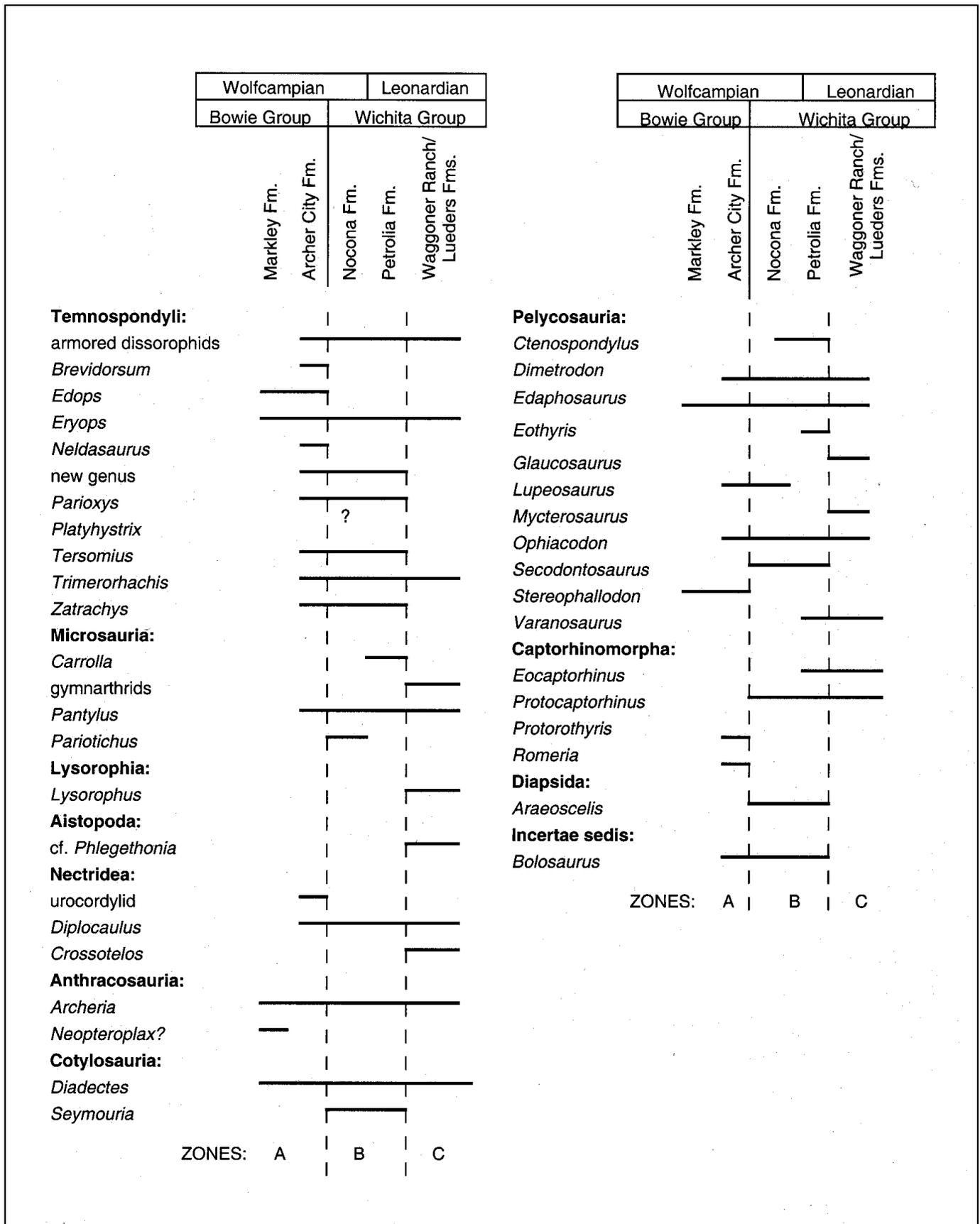


Table 1. Brachiopod assemblages in the Selong Xishan section and their correlation with other faunas in the Peri-Gondwanan region.

References

- Anderson, J. M. and Cruickshank, A. R. I. 1978. The biostratigraphy of the Permian and the Triassic. Part 5. A review of the classification and distribution of Permo-Triassic tetrapods. *Palaeontologica Africana* 21: 15-44.
- Berman, D. S. 1993. Lower Permian vertebrate localities of New Mexico and their assemblages. *New Mexico Museum of Natural History and Science Bulletin* 2: 11-21.
- Berman, D. S., Sumida, S. S. and Lombard, R. E. 1997. Biogeography of primitive amniotes; in Sumida, S. S. and Martin, K. L. M., eds., *Amniote origins*. San Diego, Academic Press, p. 85-139.
- Boy, J. and Fichter, J. 1988. Zur Stratigraphie des höheren Rotliegend im Saar-Nahe-Becken (Unter-Perm; SW-Deutschland) und seiner Korrelation mit anderen Gebieten. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* 176: 331-394.
- Broom, R. 1906. On the Permian and Triassic faunas of South Africa. *Geological Magazine* (5) 3: 29-30.
- Broom, R. 1907. On the geological horizons of the vertebrate genera of the Karoo formation. *Records of the Albany Museum* 2: 156-163.
- Broom, R. 1909. An attempt to determine the horizons of the fossil vertebrates of the Karoo. *Annals of the South African Museum* 7: 285-289.
- Conti, M. A., Mariotti, N., Nicosia, V. and Pittau, P. 1997. Succession of selected bioevents in the continental Permian of the southern Alps (Italy). Improvements in intrabasinal and interregional correlations; in Dickins, J. M., Yang, Z., Yin, H., Lucas, S. G. and Acharrya, S. K., eds, *Late Paleozoic and early Mesozoic circum-Pacific events and their global correlation*. Cambridge, Cambridge University Press, p. 51-65.
- Cooper, M. R. 1982. A mid-Permian to earliest Jurassic tetrapod biostratigraphy and its significance. *Arnoldia Zimbabwe* 9: 77-103.
- Cotton, W. D., Hunt, A. P. and Cotton, J. E. 1995. Paleozoic vertebrate tracksites in eastern North America. *New Mexico Museum of Natural History and Science, Bulletin* 6: 189-211.
- Efremov, I. A. 1937. On the stratigraphic subdivision of the continental Permian and Triassic of the USSR on the basis of the fauna of early Tetrapoda. *Doklady Akademii Nauk SSSR* 16: 121-126.
- Efremov, I. A. 1940. Preliminary description of new Permian and Triassic terrestrial vertebrates from the USSR. *Trudy Paleontologicheskaya Instituta* 10: 1-140.
- Ellenberger, P. 1983a. Sur la zonation icnologique du Permien moyen (Saxonien) du bassin de Lodève (Hérault). *Compte Rendus de l'Académie Science Paris Série II* 297: 553-558.
- Ellenberger, P. 1983b. Sur la zonation icnologique du Permien inférieur (Autunien) du bassin de Lodève (Hérault). *Compte Rendus de l'Académie Science Paris Série II* 297: 631-636.
- Ellenberger, P. 1984. Données complémentaires sur la zonation icnologique du Permien du Midi de la France (bassins de Lodève, Saint Affrique et Rodez). *Compte Rendus de l'Académie Science Paris Série II* 299: 581-586.
- Haubold, H. 1971. *Ichnia Amphibiorum et Reptiliorum fossilium*. *Encyclopedia of Paleoherpetology* 18: 1-124.
- Haubold, H. 1984. *Saurierfährten*. Wittenberg, Ziemsen-Verlag, 231 pp.
- Haubold, H.. 1996. *Ichnotaxonomie und Klassifikation von Tetrapodenfährten aus dem Perm*. *Hallesches Jahrbuch Geowissenschaft* 18: 23-88.
- Hentz, T. F. 1988. Lithostratigraphy and paleoenvironments of upper Paleozoic continental red beds, north-central Texas. Bowie (new) and Wichita (revised) Groups. The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations 170, 55 pp.
- Hentz, T. F. 1989. Permo-Carboniferous lithostratigraphy of the vertebrate-bearing Bowie and Wichita Groups, north-central Texas; in Hook, R. W., ed., *Permo-Carboniferous vertebrate paleontology, lithostratigraphy and depositional environments of north-central Texas*. Austin, Society of Vertebrate Paleontology, p. 1-21.
- Holub, V. and Kozur, H. 1981. Revision einiger Tetrapodenfährten des Rotliegenden und biostratigraphische Auswertung der Tetrapodenfährten des obersten Karbon und Perm. *Geologische Paläontologische Mitteilungen* 11: 149-193.
- Hook, R. W. 1989. Stratigraphic distribution of tetrapods in the Bowie and Wichita Groups, Permo-Carboniferous of north-central Texas; in Hook, R. W., ed., *Permo-Carboniferous vertebrate paleontology, lithostratigraphy and depositional environments of north-central Texas*. Austin, Society of Vertebrate Paleontology, p. 47-53.
- Hunt, A. P., Lucas, S. G. and Lockley, M. G. 1995. Paleozoic tracksites of the western United States. *New Mexico Museum of Natural History and Science, Bulletin* 6: 213-217.
- Kitching, J. W. 1995. Biostratigraphy of the *Dicynodon* assemblage zone. *South African Committee for Stratigraphy Biostratigraphic Series* 1: 29-34.
- Leonardi, G. 1994. *Annotated atlas of South America tetrapod footprints (Devonian to Holocene)*. Brasilia, Servico Geológico do Brasil, 247 pp.
- Lockley, M. G. and Hunt, A. P. 1995. *Dinosaur tracks and other fossil footprints of the western United States*. New York, Columbia University Press, 338 pp.
- Lucas, S. G. and Heckert, A. B., eds. 1995. *Early Permian footprints and facies*. *New Mexico Museum of Natural History and Science, Bulletin* 6, 301 pp.
- Lucas, S. G., Lozovsky, V. R. and Shishkin, M. A. 1998. Tetrapod footprints from Early Permian redbeds of the northern Caucasus, Russia. *Ichnos*, in press.
- Olson, E. C. 1952. The evolution of a Permian vertebrate chronofauna. *Evolution* 6: 181-196.
- Olson, E. C. 1957. Catalogue of localities of Permian and Triassic terrestrial vertebrates of the territories of the U. S. S. R. *Journal of Geology* 65: 196-226.
- Olson, E. C. 1962. Late Permian terrestrial vertebrates, U.S.A. and U.S.S.R.. *Transactions of the American Philosophical Society, New Series* 52: 1-223.
- Olson, E. C. 1967. Early Permian vertebrates of Oklahoma. *Oklahoma Geological Survey Circular* 74: 1-111.
- Olson, E. C. 1989. Problems of Permo-Triassic terrestrial extinctions. *Historical Biology* 2: 17-35.
- Olson, E. C. and Chudinov, P. 1992. Upper Permian terrestrial vertebrates of the USA and Russia, 1991. *International Geology Review* 34: 1143-1160.

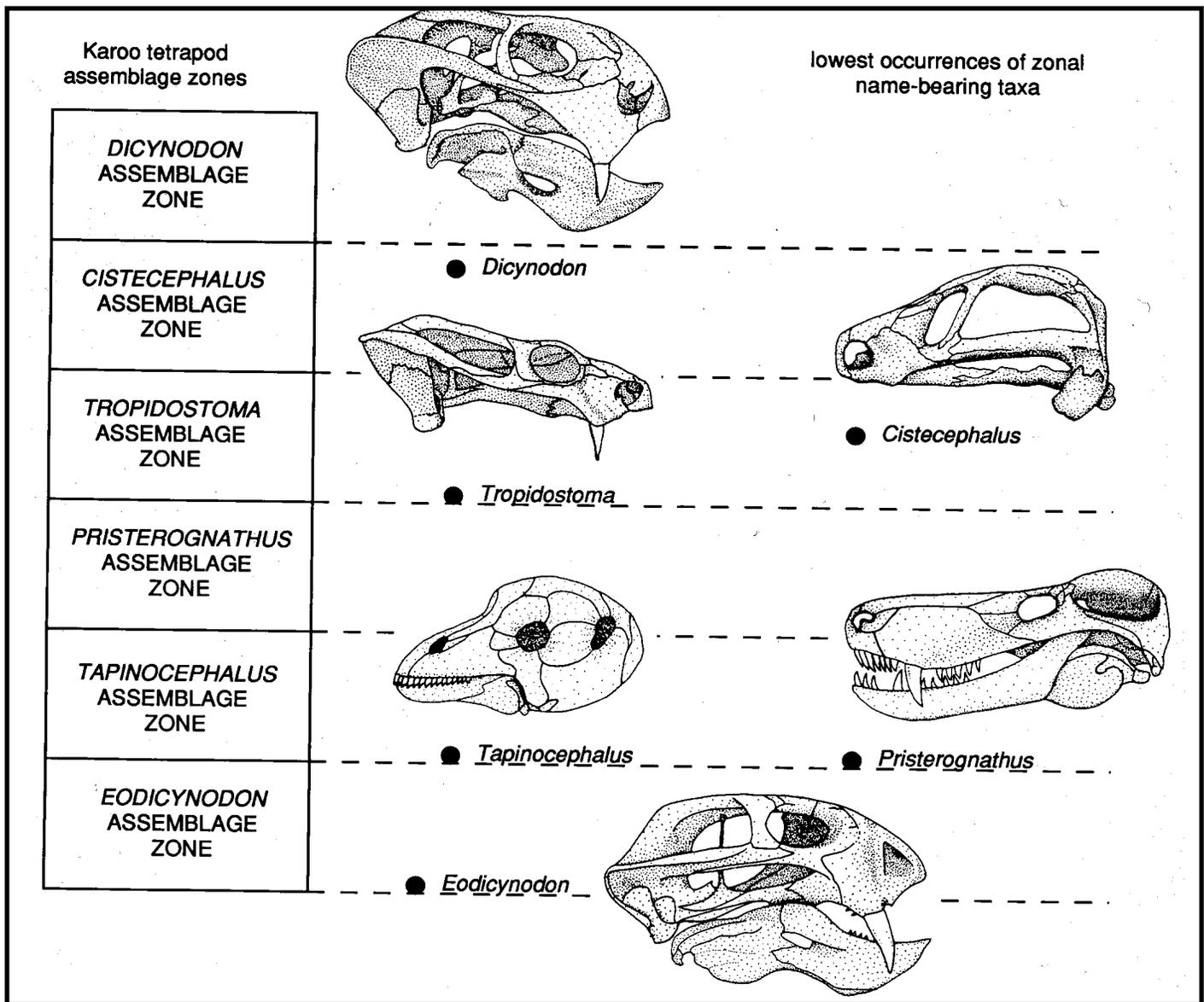


Figure 4. South African assemblage zones of Middle-Late Permian tetrapods (after Rubidge et al., 1995) showing lowest stratigraphic occurrences of genera for which the zones are named.

Peabody, F. E. 1948. Reptile and amphibian trackways from the Moenkopi Formation of Arizona and Utah. University of California Publications, Bulletin Department of Geological Sciences 27: 295-468.

Romer, A. S. 1966. Vertebrate paleontology. Third edition. Chicago, University of Chicago Press, 468 pp.

Romer, A. S. 1973. Permian reptiles; in Hallam, A., ed., Atlas of palaeobiogeography. Amsterdam, Elsevier, p. 159-167.

Rubidge, B. S. 1995. Biostratigraphy of the *Eodicynodon* assemblage zone. South African Committee for Stratigraphy Biostratigraphic Series 1: 3-7.

Rubidge, B. S., Johnson, M. R., Kitching, J. W., Smith, R. M. H., Keyser, A. W. and Groenewald, G. H. 1995. An introduction to the biozonation of the Beaufort Group. Geological Survey of South Africa, Biostratigraphic Series 1: 1-2.

Smith, R. M. H. and Keyser, A. W. 1995a. Biostratigraphy of the *Tapinocephalus* assemblage zone. South African Committee for Stratigraphy Biostratigraphic Series 1: 8-12.

Smith, R. M. H. and Keyser, A. W. 1995b. Biostratigraphy of the *Pristerognathus* assemblage zone. South African Committee for Stratigraphy Biostratigraphic Series 1: 13-17.

Smith, R. M. H. and Keyser, A. W. 1995c. Biostratigraphy of the *Tropidostoma* assemblage zone. South African Committee for Stratigraphy Biostratigraphic Series 1: 18-22.

Smith, R. M. H. and Keyser, A. W. 1995d. Biostratigraphy of the *Cistecephalus* assemblage zone. South African Committee for Stratigraphy Biostratigraphic Series 1: 23-28.

Sumida, S. S., Berman, D. S. and Martens, T. 1996. Biostratigraphic correlations between the Lower Permian of North America and central Europe using the first record of an assemblage of terrestrial tetrapods from Germany. *PaleoBios* 17: 1-12.

Tverdokhlebov, V. P., Tverdokhlebova, G. I., Benton, M. J. and Storrs, G. W. 1997. First record of footprints of terrestrial vertebrates from the Upper Permian of the Cis-Urals,

Russia. *Palaeontology* 40: 157-166.

Watson, D. M. S., 1914a, The zones of the Beaufort Beds of the Karroo System in South Africa. *Geological Magazine, New Series* (6) 1: 203-208.

Watson, D. M. S. 1914b. On the nomenclature of the South African pareiasaurians. *Annals and Magazine of Natural History* 14: 98-102.

Spencer G. Lucas
New Mexico Museum of Natural History
1801 Mountain Road N. W.
Albuquerque, New Mexico 87104 USA

Graphic Correlation Applied to Lower Permian Stratigraphic Sections of the Glass Mountains, West Texas

Stephen L. Benoist

Introduction

The Wolfcampian through Leonardian stratigraphic interval of the Glass Mountains, West Texas (Figs. 1, 2) historically has been considered a standard of reference for Lower Permian strata of North America (Ross, 1963b). Several researchers have suggested that the Leonardian Series, which is characterized by abundant and diverse marine fossils, would make a better international standard of reference relative to the Artinskian and Kungurian stages of the Russian platform, which have fewer well documented faunal elements. Although interest in the Lower Permian biostratigraphy of the Glass Mountains continues, previous researchers have made no attempt to objectively composite this biostratigraphic data. Graphic correlation is a commonly used stratigraphic tool that produces composite sections with a relatively high degree of objectivity (Edwards, 1982; Mann and Lane, 1995), and the purpose of the present paper is to briefly review an application of graphic correlation employing the existing Lower Permian biostratigraphic data of the Glass Mountains. Details of the graphic correlation process are given in Figure 4.

Graphic Correlation of Lower Permian Sections of the Glass Mountains

In the Glass Mountains, graphic correlation is facilitated by the fact that, although each biostratigraphic researcher has tended to concentrate on a single taxon, in many cases they have recorded their taxon appearance data in sections measured along approximately the same transect. Therefore, it has been possible to graphically correlate these equivalent sections using lithologic horizons as tie points. The sections thus composited include: 1) section 3 of Ross (1960, 1962, 1963a), and the Split Tank sections of Cooper and Grant (1972) and Wardlaw and Grant (1987); 2) Section 24 of King (1931), which served as the standard reference section (SRS), and Section 4 of Ross (1960, 1962, 1963a); 3) Section 5 of Ross (1962, 1963a), the Leonardian Lectostratotype of Cys (1977, 1981), and the Road Canyon Stratotype of Wardlaw and Grant (1987, 1989); and 4) Section 12 of King (1931) and Section 6 of Ross (1962, 1963a). For brevity, the process of lithologic correlation of the above sections will not be discussed, although a detailed discussion of the process can be found in Benoist (1997). The locations of study sections are given in Figure 5.

After lithologic correlation, five rounds of graphic correlation were applied to the study sections based on common first and last faunal appearance data among the sections (Fig. 6). Multiple rounds of correlation were necessary so that lines of correlation (LOCS) for each graphic correlation could be adjusted to fit data additions and adjustments produced by subsequent graphic correlations. The recorrelation process ceased after five rounds when the positions of LOCS stabilized.

In general, LOCs were placed to bisect the scatter of points in each graph so that a maximum number of first appearances (FAs- white squares in Figure 6) lie along or below the LOC, and a maximum number of last appearances (LAs- black squares in Figure 6) lie along or above the LOC. In addition, although biostrati-

graphic data from conodont, ammonoid, and brachiopod research were included in this study, the placement of LOCs was weighted to conform with fusulinacean appearances. This decision was based on the fact that, among the study taxa, fusulinaceans: 1) occur in all the study sections, 2) exhibit multiple levels of appearance and a consistent stratigraphic order within sections, and 3) display a level of taxonomic consistency because the majority of fusulinacean taxa in this study were described by a single researcher (Ross 1960, 1962, 1963a, 1964).

Apparent anomalies in data point distribution occur in the graphs of the CS versus the Section 3 and the Leonard Mountain composite sections (Fig. 6- A and D respectively). In the graph of the CS versus the Section 3 composite, numerous brachiopod LAs (unlabelled black squares in the vertical x-axis interval between 514 to 525 units) occur well below the LOC, which has been positioned to parallel the linear trend in fusulinacean appearances; therefore, during compositing, these LAs will undergo large upward range extensions to the level of the LOC. The lack of conformity between the brachiopod and fusulinacean data patterns reflects the relatively sporadic appearance of brachiopods among the study sections, with the LAs of these taxa tending to be truncated in the CS relative to the Section 3 composite. Conversely, the vertical alignment of brachiopod FAs (unlabelled white squares at approximately 492 on the x-axis) below the LOC indicates that the FAs of these taxa are truncated in the Section 3 composite relative to the CS. In the graph of the CS versus the Leonard Mountain composite, several taxon FAs occur well above the LOC (x-axis interval between 0 to 400 units) and do not conform to the fusulinacean data pattern; therefore, during compositing, these FAs will undergo large downward range adjustments to the LOC level. This anomaly results from the fact that CS FAs of these taxa were first established by studies (Cooper and Grant, 1972; Wardlaw and Grant, 1987) in which sampling was limited to the relatively thin Cathedral Mountain Formation in the Split Tank area (Fig. 7); therefore, the LOC suggests that these anomalous CS FAs are highly truncated.

Results

The end product of this study is a Glass Mountains composite standard (CS) that contains the complete biostratigraphic data set (795 taxa) for Wolfcampian through Roadian strata of the Glass Mountains study sections. Also, the CS contains any extensions of taxon ranges that occurred during graphic correlation (See Figure 4 for details of the range extension process). Listed in order of decreasing numbers of species in the CS, the CS taxa belong primarily to four groups: brachiopods, fusulinaceans, conodonts, and ammonoids. Within these groups, taxon range limits have an inherent level of uncertainty; and, among the study sections, individual taxa exhibiting the largest number of appearances should have ranges closer to true stratigraphic ranges (Shaw, 1964). Also, many taxon ranges in the CS are probably underestimates. This probability derives primarily from two factors: 1) the facies-controlled distribution of most species employed in this study, and 2) the restriction of data recovery to measured stratigraphic sections. In the case of ammonoid and brachiopod appearance data, the second factor is accentuated because many of the existing appearance data are recorded at map localities and are not placed in measured stratigraphic sections (A comprehensive summary of Permian biostratigraphic data of the Glass Mountains, inclusive of appearances not placed in measured stratigraphic sections, is

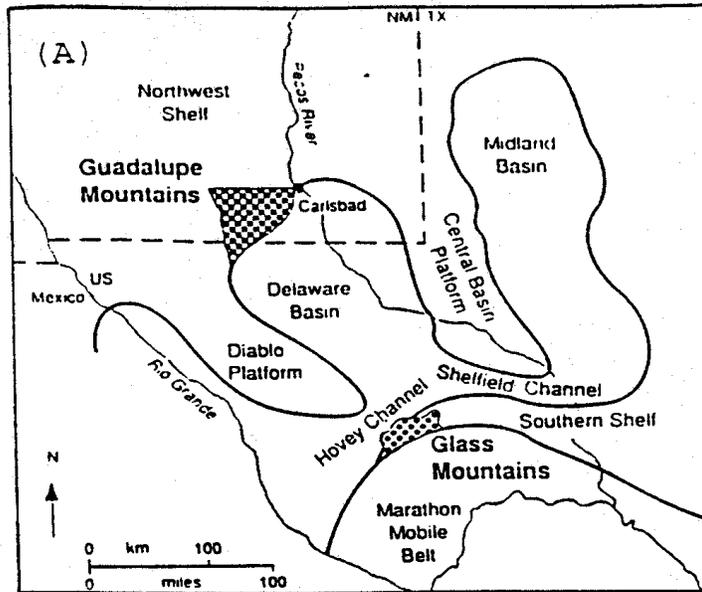


Figure 1. Location of the Glass Mountains, West Texas (from Kozur and Mostler, 1995)

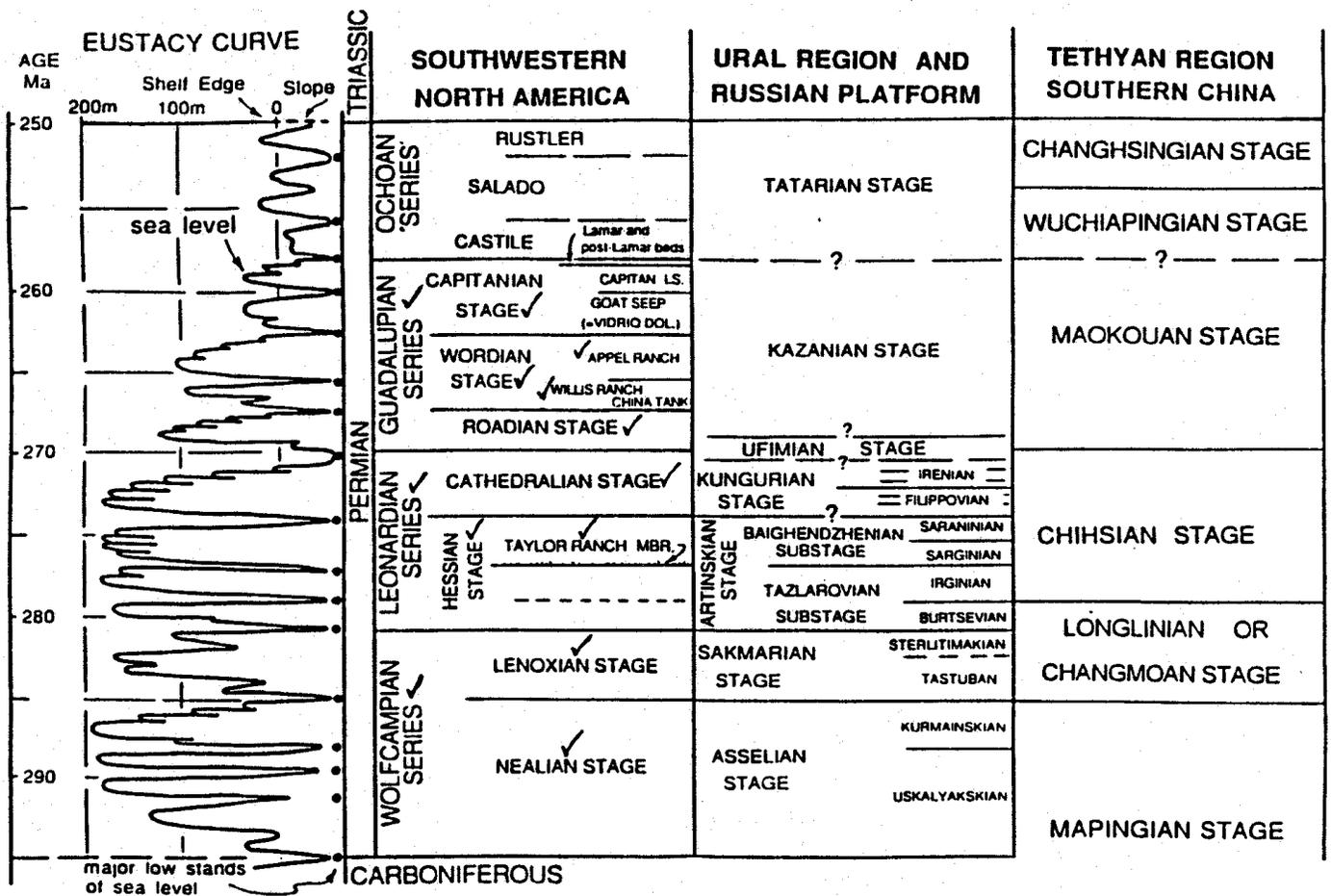


Figure 2. Permian eustasy curve with series and stages for southwestern North America, Ural region and Tethyan region. Checks indicate units present in the Glass Mountains (modified after Ross, 1964).

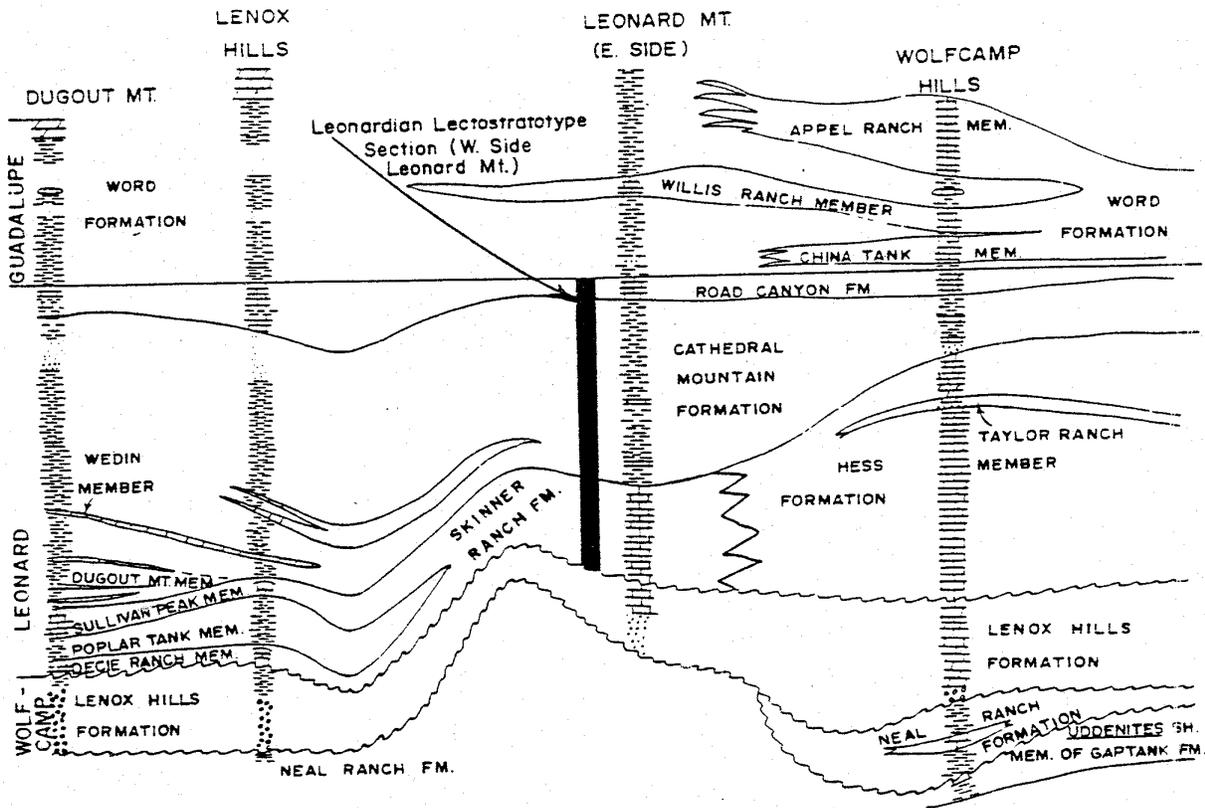


Figure 3. Lateral stratigraphic relationships in the Glass Mountains (from Cys, 1981).

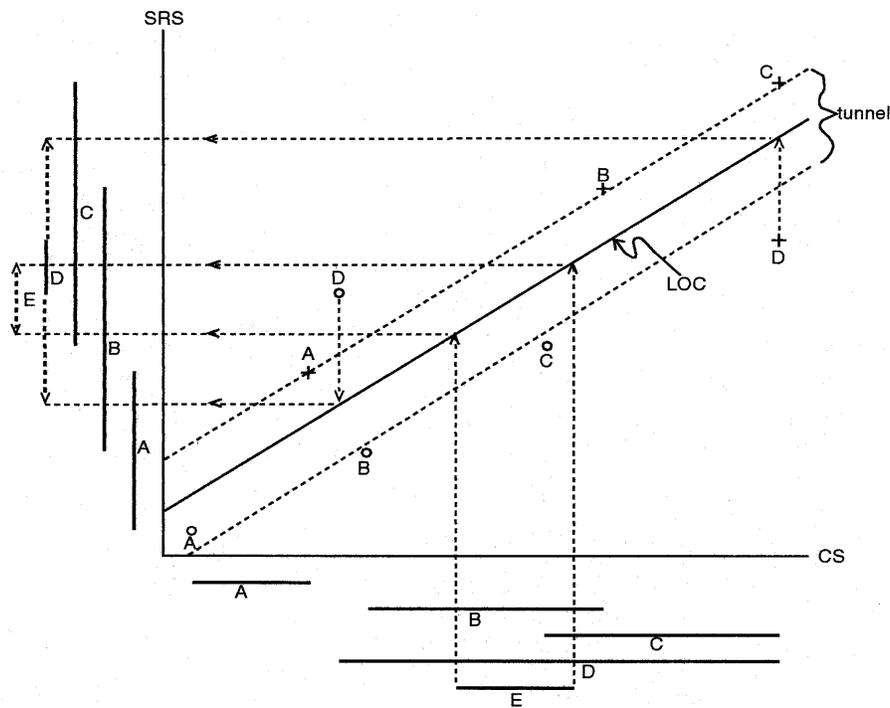


Figure 4. Graphical comparison between a hypothetical standard reference section (SRS) and a temporally comparable (CS). Taxa A, B, C, and D are common to both sections and their bases (O) and tops (+) plot as points on the graph. The line of correlation (LOC) fits the scatter of points so that the line follows the "tunnel" created among the bases and tops of A, B, and C. In the case of taxon D, the position of its base above and its top below the LOC indicates that both the base and top of taxon D's range need adjustment in the SRS. The adjustment of range is achieved by projecting the base and top of D's range on the graph into the LOC. The horizontal projections of the LOC intersection points become taxon D's new range limits in the SRS. Taxon E, which occurs only in the CS, enters the SRS through the same procedure, with the horizontal projections of taxon E's intersection points with the LOC becoming new range data in the SRS.

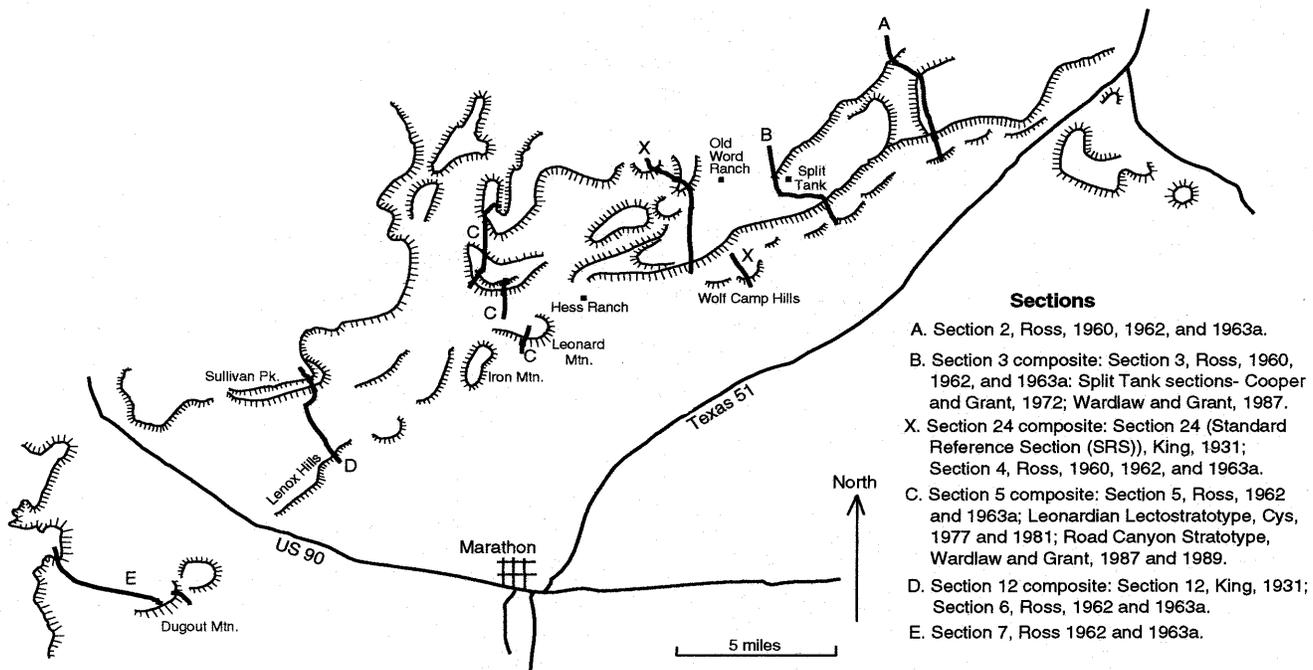


Figure 5. Location of Glass Mountains stratigraphic sections used in the present study (Modified after Ross, 1962, 1963a).

presented by Wardlaw, 1996).

The ranges of CS taxa are summarized in Figure 8. In this range chart, only those taxa ranges that are important in the delineation and subdivision of the Leonardian Series (Artinskian-Kungurian stages) are illustrated (Discussion of the criteria used to produce the zonation presented herein can be found in Benoist, 1997). Also, resulting from factors discussed in the previous paragraph, the uncertainty attaining to taxon ranges is illustrated by: 1) placing relatively wide gray lines between biostratigraphic subdivisions, 2) noting after each taxon's name its total number of appearances, and 3) indicating those CS taxon ranges that conflict significantly with published zonal schemes within the southwestern United States.

Conclusion

In the Glass Mountains, graphic correlation was facilitated for the reasons that all study sections 1) extend through the study interval and are in objective stratigraphic position relative to the overlying Guadalupian Series, 2) are dominated throughout their extent by rocks representative of marine paleoenvironments, and 3) have a comparable fauna that contains abundant representatives of rapidly evolving and wide ranging marine groups such as conodonts, fusulinaceans, and ammonoids. Furthermore, species descriptions and range data for key conodont and fusulinacean taxa were obtained primarily from Wardlaw and Grant (1987, 1989) and Ross (1960, 1962, 1963a) respectively; therefore, these taxa were consistently described among the study sections.

The CS produced in this study combines the biostratigraphic data of the study sections into a single section and incorporates any taxon range extensions produced during the graphic correlation process. Therefore, the CS serves as a better standard of reference for Glass Mountains Leonardian strata than any one of the study sections. Negative factors are that: 1) the Glass Mountains SRS and other study sections contain major breaks in rock accumulation (Ross, 1987; Ross and Ross, 1994), 2) only biostratigraphic data from measured stratigraphic sections could be

correlated, 3) taxa distributions are strongly facies controlled, and 4) many of the Glass Mountains sections are not accessible to scientific researchers, although the type area for the Leonardian Series (Lectostratotype of Cys (1977, 1981)) remains open to qualified researchers.

References

- Benoist, S. L., 1997, Application of graphic correlation to upper Lower Permian (Artinskian-Kungurian) stratigraphic sections of the Glass Mountains, West Texas and the western slope of the Ural Mountains, Russia (Ph.D. thesis): Iowa City, Iowa, The University of Iowa, ~241p.
- Cooper, G. A., and Grant, R. E., 1972, Permian Brachiopods of West Texas, Part I: *Smithsonian Contributions to Paleobiology*, no. 14, p. 1-230.
- Cys, J. M., 1977, Lectostratotype of North America Leonardian Series, Glass Mountains, West Texas (abs.): *Geological Society of America Abstracts with Programs*, v. 9, p. 14.
- Cys, J. M., 1981, Preliminary report on proposed Leonardian lectostratotype section, Glass Mountains, West Texas: Symposium and Guidebook, 1981 Field Trip, *Permian Basin Section, Society of Economic Paleontologists and Mineralogists*, p. 183-205.
- Edwards, L. E., 1982, Quantitative biostratigraphy: the method should suit the data: in Cubitt, J. M., and Reymont, R. A., eds., *Quantitative Stratigraphic Correlation*, John Wiley and Sons, p. 45-60.
- King, P. B., 1931, Geology of the Glass Mountains, Texas; part I, Descriptive geology: *University of Texas Bulletin*, 3038, 167p.
- Kozur, H., and Mostler, H., 1995, Guadalupian (Middle Permian) conodonts of the sponge-bearing limestones from the margins of the Delaware Basin, West Texas: *Geologia Croatica*, v. 48/2, p. 107-128.
- Mann, K. O., and Lane, R. H., 1995, Graphic correlation: a powerful stratigraphic technique comes of age: in, Mann, K.

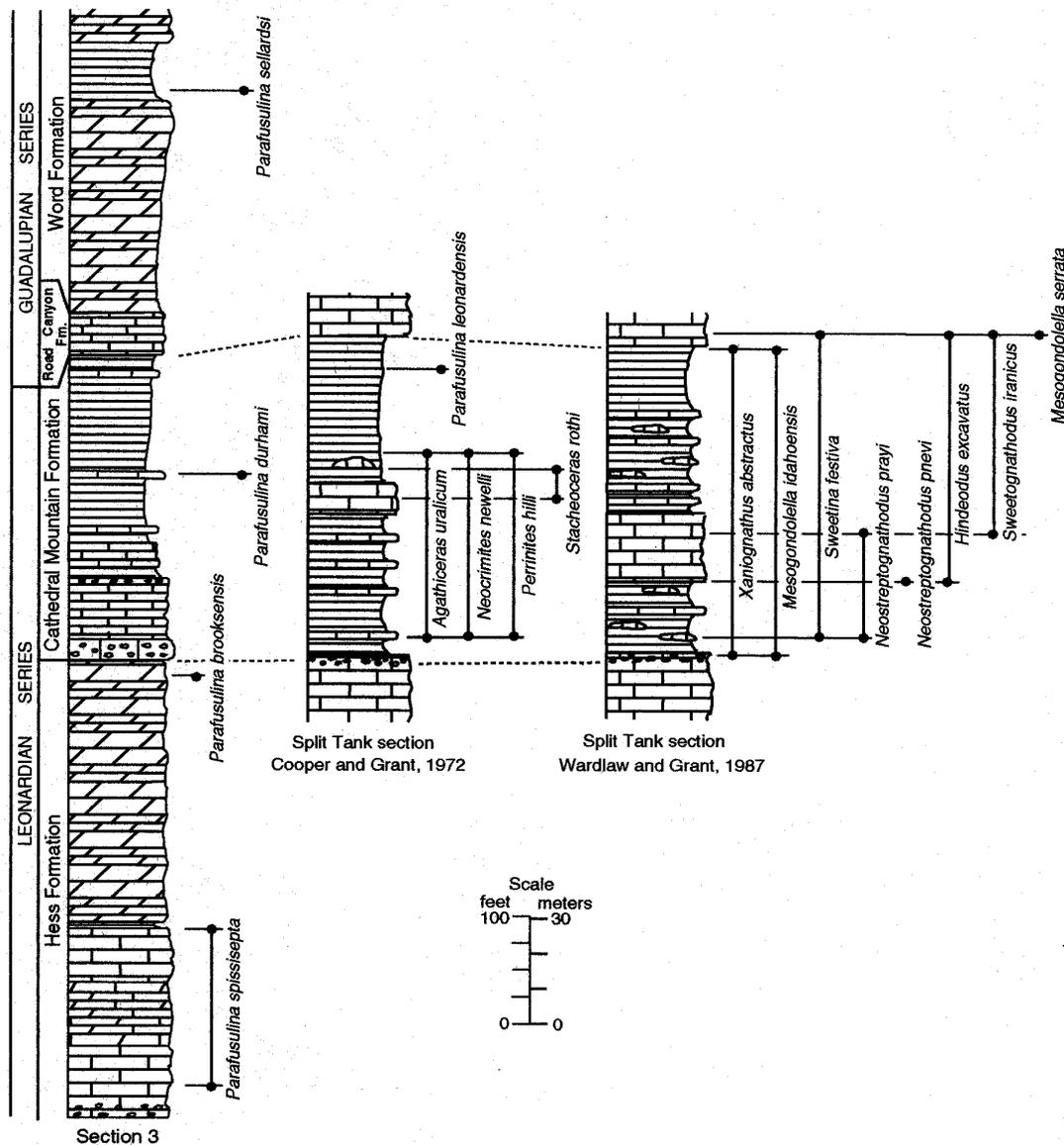


Figure 7. Lithologic correlation of the upper portion of Section 3 (Ross, 1960, 1962, 1963a) and the Split Tank sections of Cooper and Grant (1972), and Wardlaw and Grant (1987).

- O., Lane, R. H., and Scholle, P. A., eds., Graphic Correlation, SEPM Society for Sedimentary Geology Special Publication No. 53, p. 3-13.
- Ross, C. A., 1960, Fusulinids from the Hess Member of the Leonard Formation, Leonard Series (Permian), Glass Mountains, Texas: *Contributions from the Cushman Foundation for Foraminiferal Research*, v. 11, Pt. 4, p. 117-133.
- Ross, C. A., 1962, Fusulinids from the Leonard Formation (Permian), western Glass Mountains, Texas: *Contributions from the Cushman Foundation for Foraminiferal Research*: v. 13, Pt. 1, p. 1-21.
- Ross, C. A., 1963a, Fusulinids from the Word Formation (Permian), Glass Mountains, Texas: *Contributions from the Cushman Foundation for Foraminiferal Research*, v. 14, Pt. 1, p. 17-31.
- Ross, C. A., 1963b, Standard Wolfcampian Series (Permian), Glass Mountains, Texas: *Geological Society of America Memoir* 88, 205 p.
- Ross, C. A., 1964, Two significant fusulinid genera from the Word Formation (Permian), Texas: *Journal of Paleontology*, v. 38, p. 311-315.
- Ross, C. A., 1987, Leonardian Series (Permian), Glass Mountains, West Texas, in, Cromwell, C., and Mazzullo, L., eds., *The Leonardian facies in W. Texas and S.E. New Mexico and guidebook to the Glass Mountains, West Texas: 1987 Permian Basin Section Society of Economic Paleontologists and Mineralogists Publication* 87-27, p.
- Ross, C. A., and Ross, J. R. P., 1994, Permian sequence stratigraphy: in, Scholle, P. A., Peryt, T. M., and Ulmer-Scholle, D. S., eds., *The Permian of Northern Pangea*, Vol. 1, Springer-Verlag, Berlin, Heidelberg, New York, p. 98-123.
- Shaw, A. B., 1964, *Time in Stratigraphy*: McGraw Hill, New York, 365p.
- Wardlaw, B. R., 1996, Range charts for the Permian of West Texas: in, Guadalupean II, Abstracts and Proceedings of the Second International Guadalupean Symposium, Sul Ross University, Alpine, Texas, p. 40-60.
- Wardlaw, B. R., and Grant, R. E., 1987, Conodont biostratigraphy

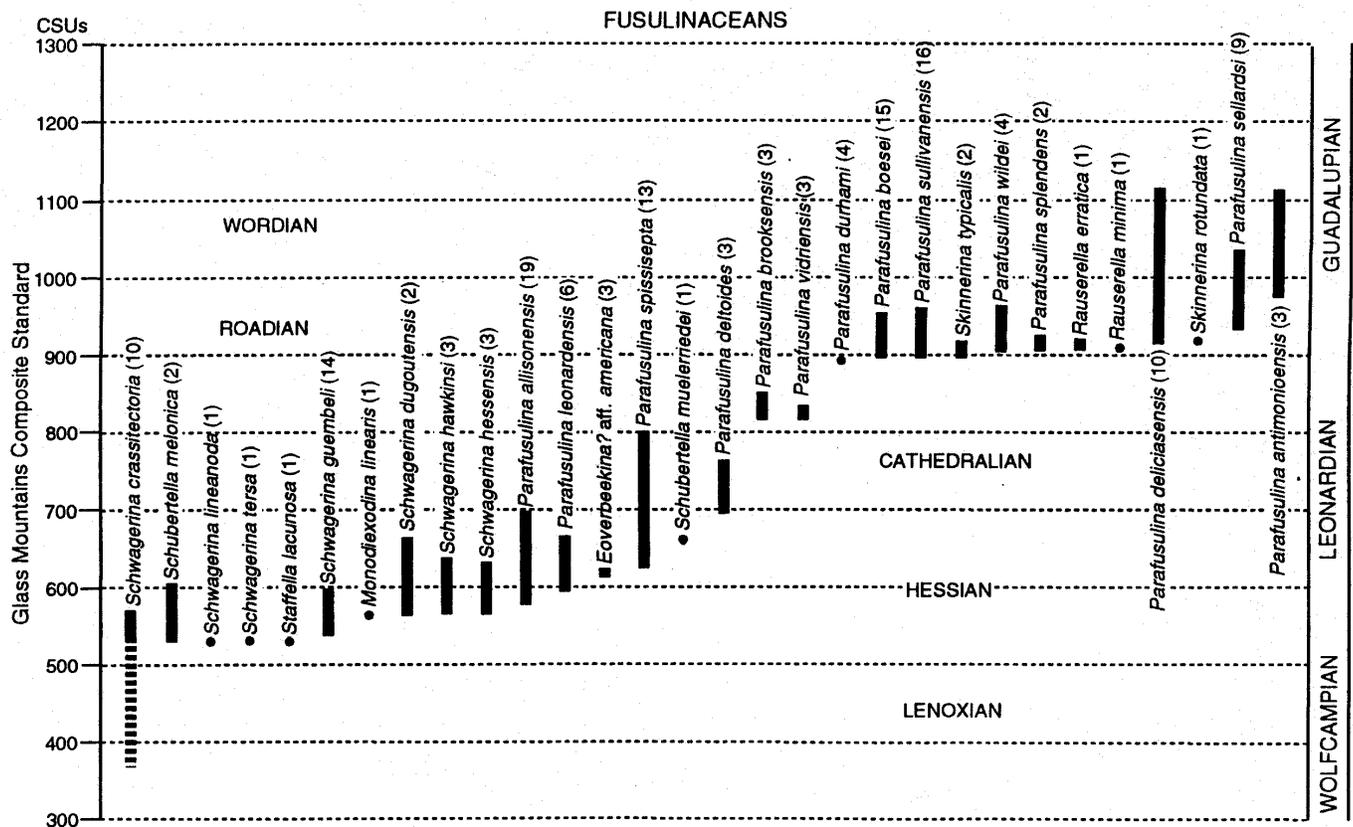
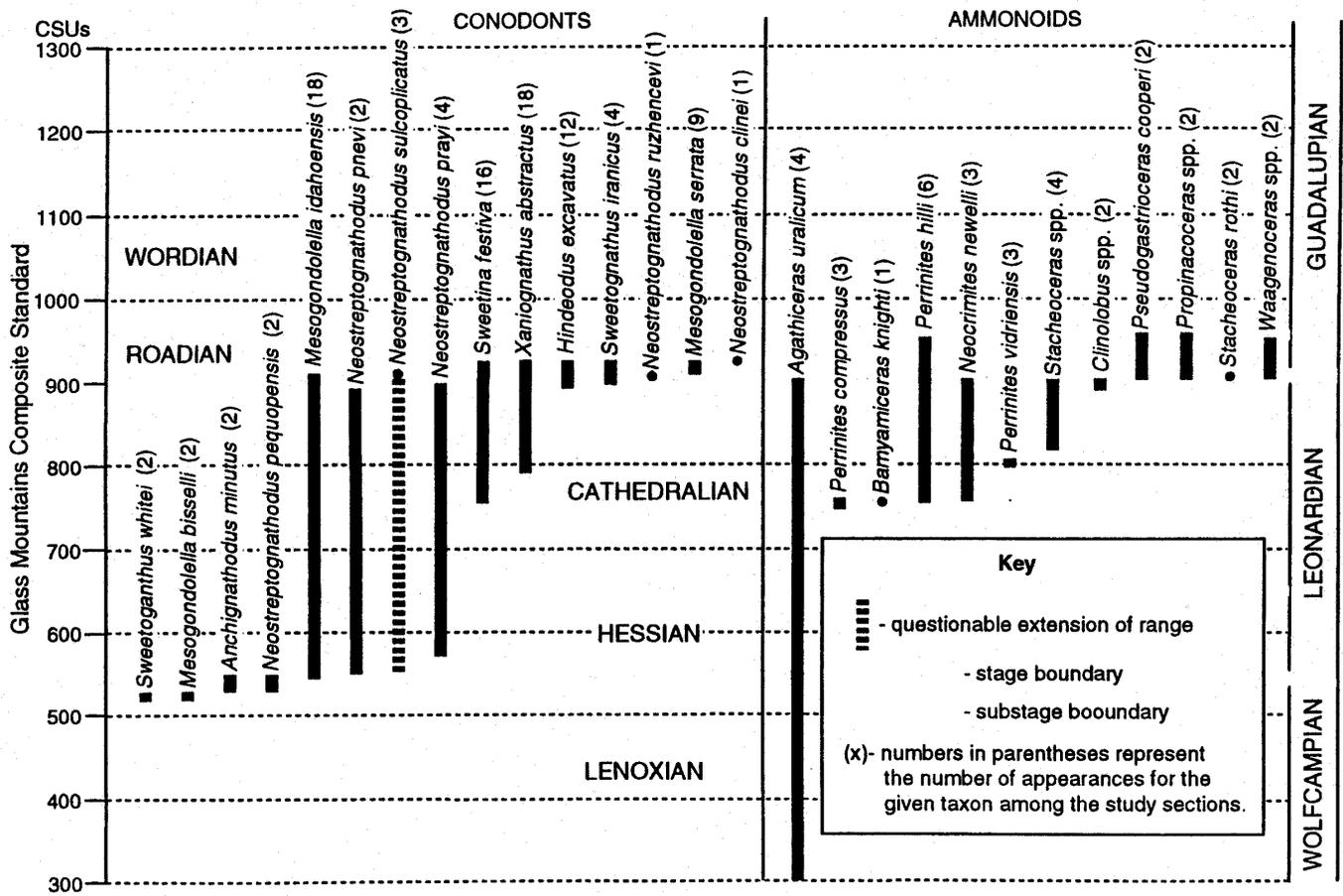


Figure 8: Range chart for selected taxa in the Glass Mountains CS with proposed stages and substages.

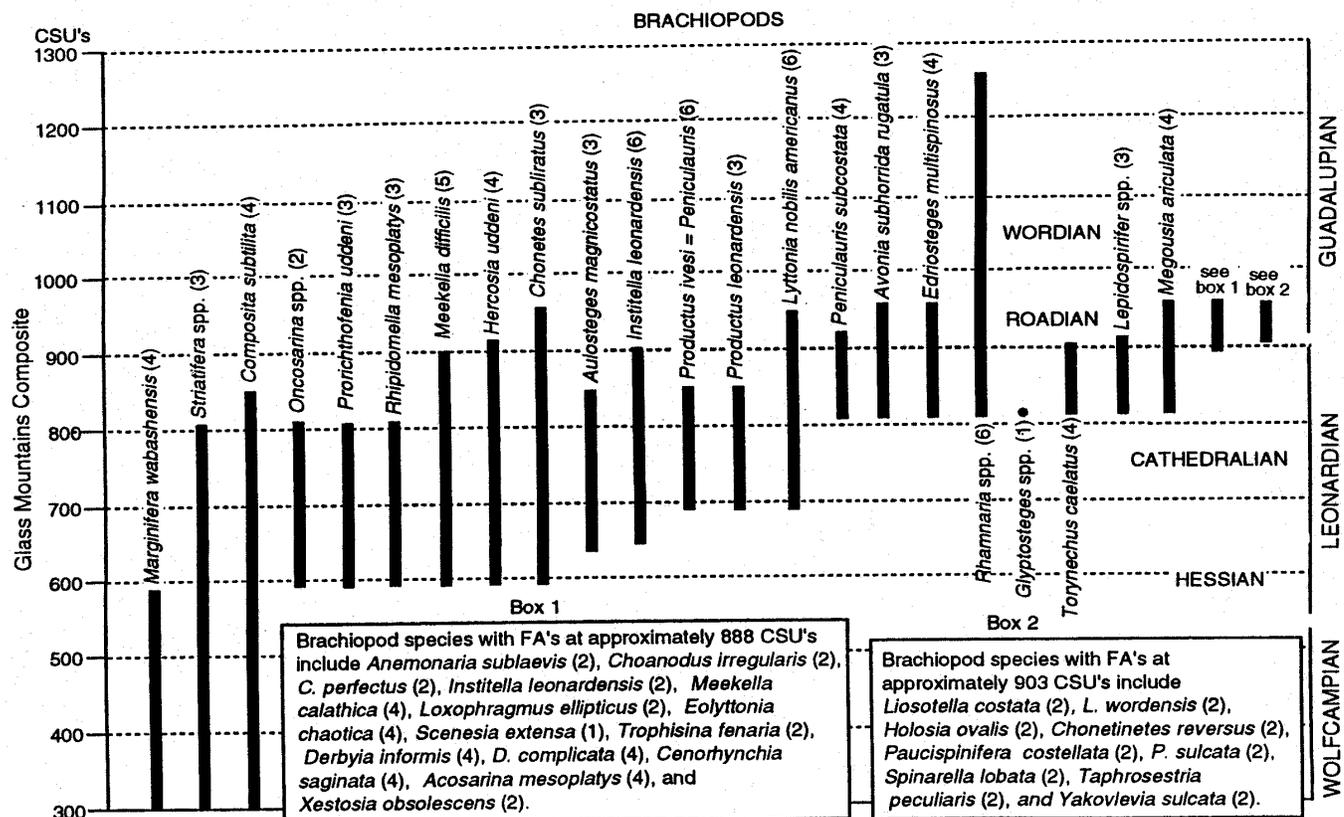


Figure 8: continued

phy of the Cathedral Mountain and Road Canyon formations, Glass Mountains, West Texas: in, Cromwell, D., and Mazzullo, L. J., eds., The Leonardian facies in West Texas and Southeast New Mexico and guidebook to the Glass Mountains, West Texas: 1987 *Permian Basin Section, Society of Economic Paleontologists and Mineralogists Publication 87-27*, p. 63-66.

Wardlaw, B. R., and Grant, R. E., 1989, Conodont biostratigraphy of the Permian Road Canyon Formation, Glass Mountains, Texas: *United States Geological Survey Bulletin 1895*, Shorter Contributions to Paleontology and Stratigraphy, p. A1-A18.

Stephen L. Benoist
 10461 Remington Lane
 Dallas, TX 75229
 (972) 406-8343

Graphic Correlation of Upper Carboniferous-Lower Permian Strata of Spitsbergen and the Loppa High, Barents Sea Shelf

R. M. Anisimov, V. I. Davydov, I. Nilsson

Introduction

Graphic correlation (GC) is a semiquantitative biostratigraphic correlation technique that uses total fossil content of sections to provide refined correlation. Whereas other biostratigraphic methods provide correlation at the zonal scale, graphic correlation enables correlation within zones. Values for the relative sedimentation rates can be estimated even for short intervals and the position of unconformities can be estimated with a fair degree of accuracy. Consequently, graphic correlation is a valuable tool for correlating unconformities and estimating the duration of hiatuses. Moreover, graphic correlation can be used to predict the presence of a hiatus or a series of diastems in unsampled or poorly sampled intervals. In addition, with zonal boundaries represented on the graph, graphic correlation can be used to adjust the position of zone boundaries in a local section.

The present study is based on Upper Carboniferous-Lower Permian (upper Moscovian - Sakmarian) successions from Spitsbergen (fig. 1) and from a well drilled in upper Paleozoic strata of the Loppa High on the Barents Sea. Fusulinid biostratigraphy of the Spitsbergen localities was established by Nilsson (1988, 1993) and Nilsson & Davydov (1992); these authors recognized a series of breaks in the sedimentary succession but the precise duration was not established.

Sampling density is important in graphic correlation because

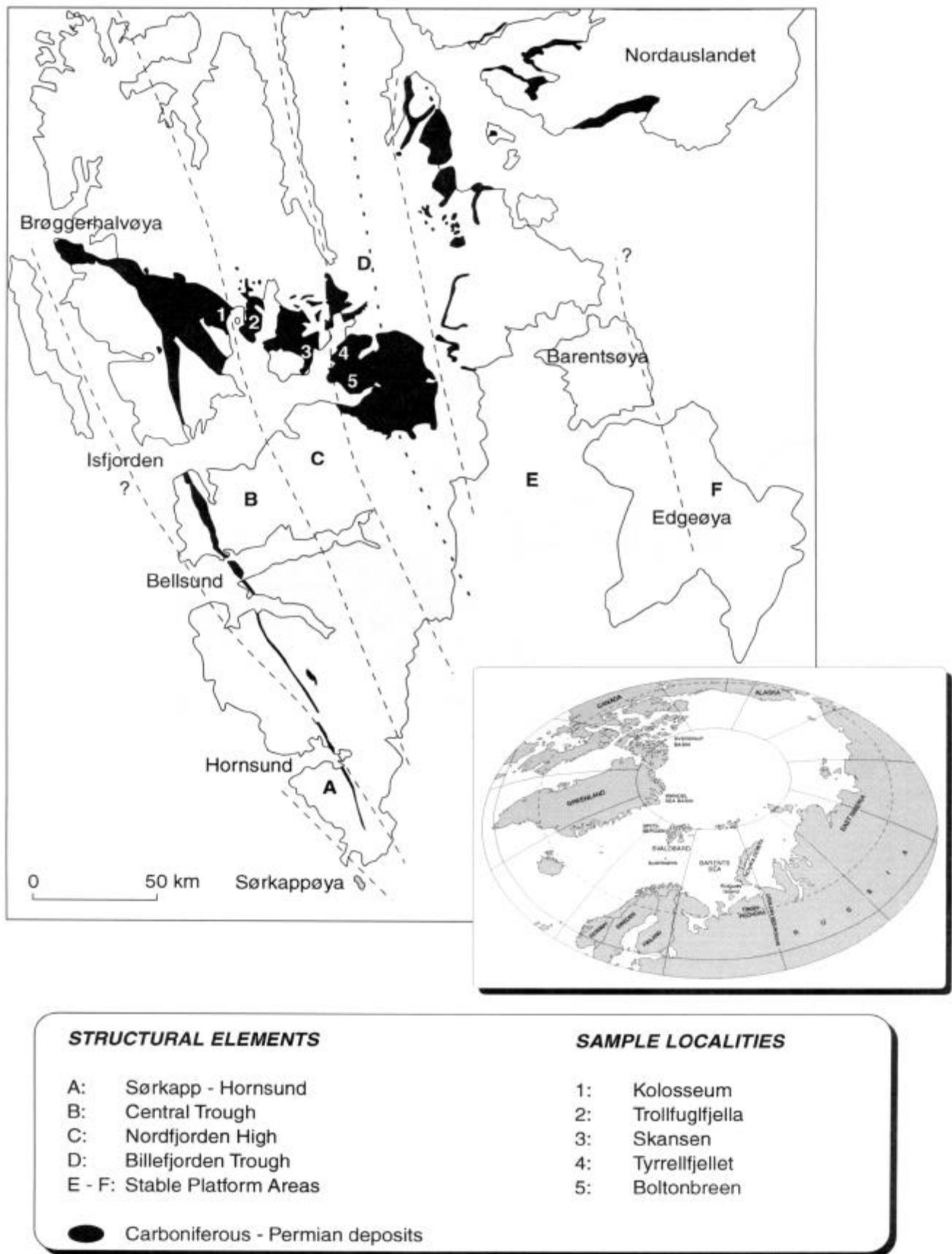


Figure 1. Location of studied sections showing structural elements

the last and first occurrence of taxa define the line of correlation (LOC). Due to sampling gaps in our data, certain important stratigraphic intervals, where graphic correlation indicates the occurrence of substantial sedimentation changes, remain uncharacterized. These are referred to as "intervals of reduced thickness." This term indicates that a non-sampled interval, although corresponding to a relatively long period of time on the biostratigraphic scale, is represented by a short interval on the graph. Such features either may be linked to relative sea level rise, deepening of the basin, and the formation of condensed sections (not the case in Spitsbergen), or, they could indicate hiatuses or diastems associated with sea level fluctuations.

Methodology

The methodology used in this project is based on the technique introduced by Shaw (1964) and summarized by later authors (e.g., Miller, 1977; Edwards, 1984, 1989). A recent and comprehensive discussion on the principles and applications of graphic correlation was presented by Mann and Lane (1995).

In addition to species ranges, we utilized generic ranges, especially where specific data were not available. The stratigraphic ranges of genera, although longer than those of their component species and less useful in determining the LOC, do provide additional data points on the graph and are useful in correlation of sections with inadequate sampling.

Bases of fusulinid zones were used for correlation and provided relative time indicators on the graph. The biostratigraphic scale with fusulinid zones and their respective numbers are presented in Figure 2.

Generally the LOC (line of correlation) is positioned so that range tops plot to the left and range bases plot to the right of the LOC, and the number of adjustments of taxonomic ranges is minimal; that is the data points form as tight a cluster around the LOC as possible.

The alignment of data points at a particular stratigraphic level suggests the presence of hiatus or a condensed section.

Abbreviations

LOC: Line of correlation. The LOC is defined by an infinite number of time-equivalent points common to the sections being compared. The position of the LOC is controlled by the data points on the graph. The LOC is drawn as straight line, ignoring the frequent, minute changes in sedimentation pattern that produce so-called depositional noise because it shows general pattern of sedimentation.

RRS: Relative rate of sedimentation. The RRS is reflected by the slope of the LOC and indicates how much rock had accumulated in the two sections during the same time intervals. The sedimentation rate in the composite section equals 1.0. If the rate of sedimentation is greater in the comparison section than in the composite section, the RRS will be greater than 1.0; if the rate is lower it will be less than 1.0.

RSL: Relative sea level. RSL changes may indicate eustatic (global) or local (tectonic) transgression-regression events, with RSL lows and highs corresponding to hiatuses and condensed sections, respectively.

Geologic History Of The Spitsbergen Region As Inferred From Graphic Correlation

The Spitsbergen localities and, to a lesser degree, the Loppa

High share a common geologic history (fig. 2) as could be expected from their proximity. Sedimentation in the region appears to have been controlled by local tectonic events superimposed on eustatic sea level changes.

The relative span of hiatuses in the sections and their correspondence to one another were employed to develop the relative sea-level curve (fig. 2). The following succession of major transgression-regression events were recognized:

Late Moscovian time (zones 21 and 22) in the Loppa High corresponds to an intermediate, to highstand of relative sea level and a high RRS roughly equal to 4 or 5. (fig. 8). The lower Kasimovian hiatus (zone 23 and possibly part of 24) in well BG-1, Kolguev Island (Barents Sea shelf) (Davydov, 1997) suggests a lowering of RSL. However, the corresponding hiatus in Spitsbergen occurs only in Skansen (fig. 4). Therefore, the RSL change does not appear to be eustatic in origin. Data from Skansen, which is interpreted to be a maximum flooding surface (probably due to its high paleotopographic position), indicates a short-term transgression during lower Kasimovian, corresponding to the boundary succession of zones 23/24.

Upper Kasimovian-lower Gzhelian time (zones 25 through 27) corresponds to a RSL highstand with maximum flooding in earliest Gzhelian. The corresponding strata is not present (except for the basal part of zone 27) only in Skansen section, probably due to erosion.

The hiatus spanning the upper part of lower Gzhelian and middle Gzhelian (upper part of zone 27 and zone 28) in the Trollfuglfjella (Fig. 3) and Skansen sections, and possibly in Kolosseum (fig. 7) and Boltonbreen (fig. 6), corresponds to an intermediate to low RSL.

The upper Gzhelian (zone 29) corresponds to intermediate to high RSL; only the Skansen locality is missing this stratigraphic interval.

The lower Orenburgian (zone 30) is missing in all Spitsbergen sections, although data from Kolosseum locality is inconclusive.

Remnant middle Orenburgian strata (zone 31) are present in the Trollfuglfjella and Boltonbreen sections, and they are assumed to be preserved in Kolosseum locality. Therefore, this stratigraphic interval is interpreted to represent a short-term transgression with intermediate to high RSL.

The stratigraphic interval encompassing the upper part of the middle to the uppermost Orenburgian (upper part of zone 31 to the uppermost part of zone 32) corresponds to an extensive hiatus that occurs in all of Spitsbergen localities that is interpreted as a major regression event.

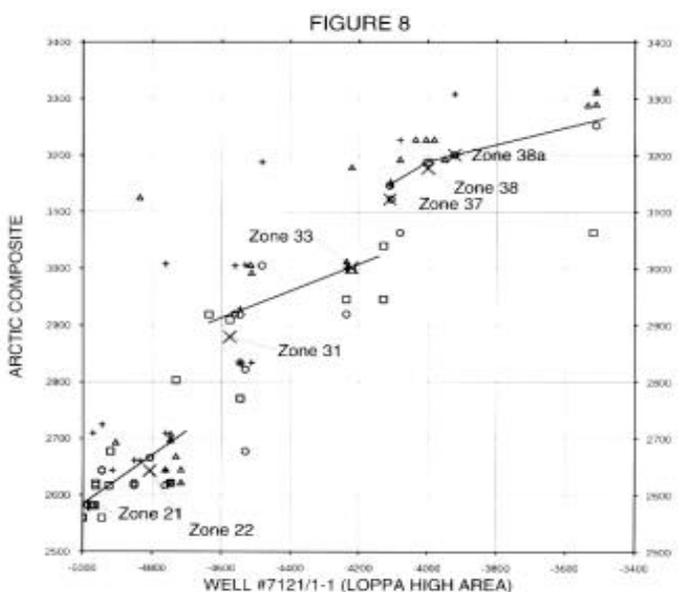
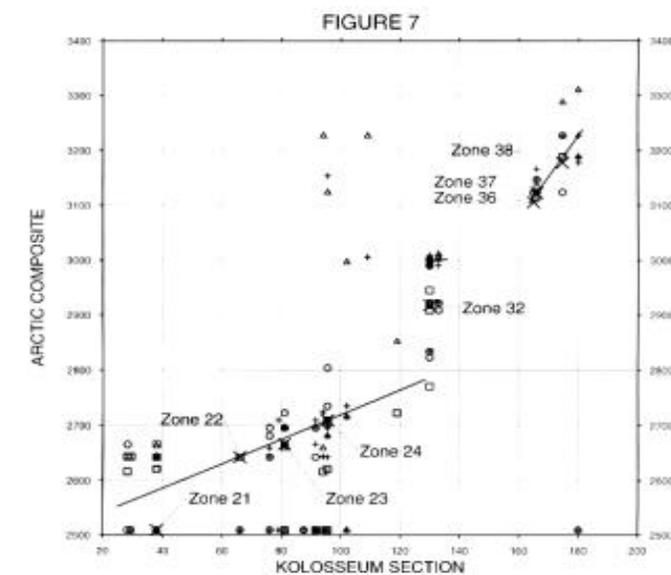
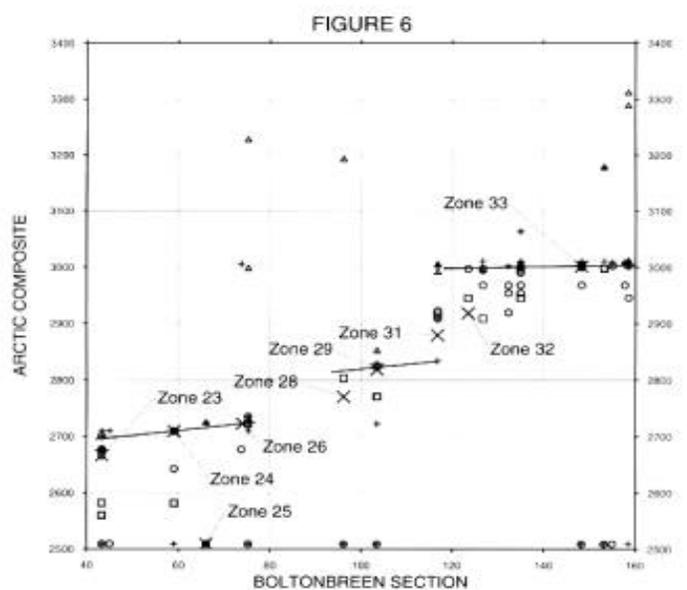
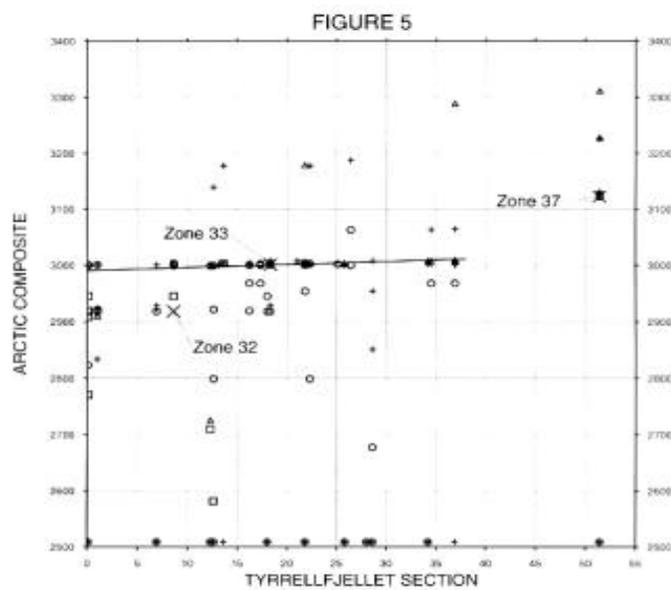
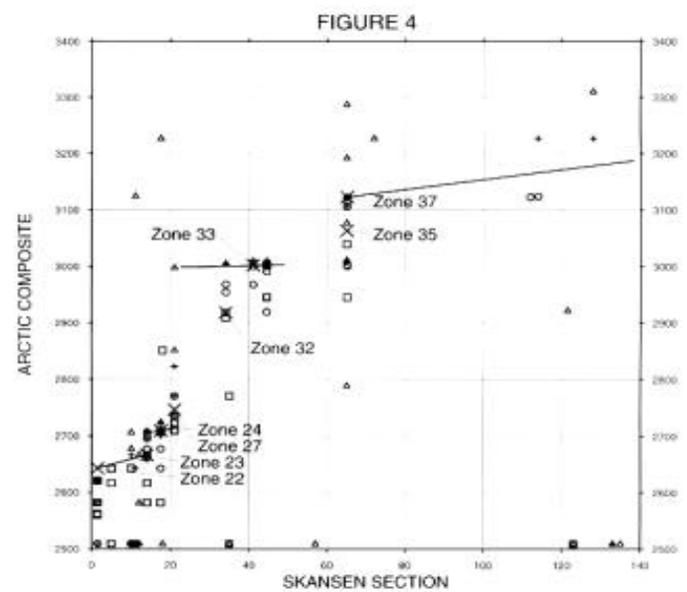
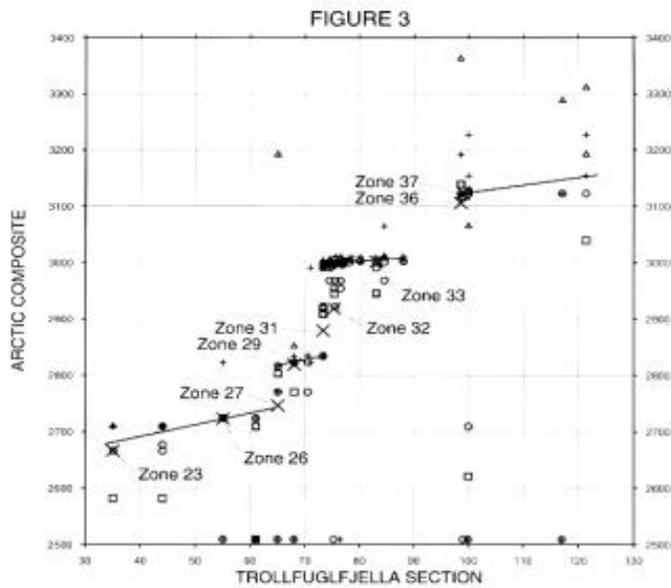
Sedimentation resumed in latest Orenburgian and appears to be continuous across the C/P boundary, extending to the middle of lower Asselian (up to the middle part of zone 33). Unusually high and uniform RRS during this stratigraphic interval is interpreted in all Spitsbergen sections including Tyrrellfjellet where this stratigraphic interval is densely sampled (Fig. 5). RRS range from 3 to 13 and suggest a major transgression during latest Orenburgian-early Asselian time. These interpretations are consistent with preliminary graphic correlation of well # X (Loppa High) where RRS within this stratigraphic interval equals approximately 8.0.

The middle Asselian stage (zones 34 through 36) corresponds to an intermediate to low position of RSL. This stratigraphic interval apparently is absent in Skansen with only the basal or some other part of zone 35 preserved. The corresponding strata in the rest of the Spitsbergen sections are not sampled. Nonetheless, the

GLOBAL SCALE Boreal province LOPPA HIGH SPITSBERGEN

System	Series	Stage	Zone #	Fusulinid zonation	Duration Ma	RELATIVE SEA-LEVEL HIGH/LOW	WELL X		TYRRELLFJELLET		BOLTONBREEN		KOLOSSEUM		TROLLFUGLFJELLA		SKANSEN			
							BASE OF THE ZONE, M	STRATIGRAPHIC ZONE, M	SEMI-STRATIGRAPHIC ZONE, M	BASE OF THE ZONE, M	STRATIGRAPHIC ZONE, M	SEMI-STRATIGRAPHIC ZONE, M	BASE OF THE ZONE, M	STRATIGRAPHIC ZONE, M	SEMI-STRATIGRAPHIC ZONE, M	BASE OF THE ZONE, M	STRATIGRAPHIC ZONE, M	SEMI-STRATIGRAPHIC ZONE, M	BASE OF THE ZONE, M	STRATIGRAPHIC ZONE, M
PERMIAN	Cisuralian	Artinskian	40	<i>Parafusulina jenkinsi</i> <i>Parafusulina solidissima</i>	6.0															
			39	<i>Parafusulina ludugini</i> <i>Pseudofusulina solida</i>	2.4															
				<i>Pseudofusulina concavatus</i> <i>Zigarella urdalenensis</i> <i>Zigarella plicatissima</i>	2.4	?														
			38	<i>Schwagerina verneuili</i> <i>Schwagerina moelleri</i>	1.8															
		<i>Eoparafusulina paratinnearis</i> <i>Schwagerina firma</i> <i>Sphaeroschwagerina sphaerica</i>		1.8	-4000.0															
		Asselian	37	<i>Schwagerina fecunda</i> <i>Pseudoschwagerina robusta</i>	2.4	-4130.0														
			36	<i>Schwagerina nua</i> <i>Sphaeroschwagerina fusiformis</i>	0.7															
			35	<i>S. vulgaris aktjubenensis</i>	0.7															
		CARBONIFEROUS	Pennsylvanian	Orenburgian	34	<i>Ultradatina bobydaquensis</i> <i>Schwagerina robusta</i>	0.7	-4225.0?												
					33	<i>Datrina sokensis</i> <i>Schellwienia modesta</i>	2.2	-4555.0?												
Gzhelian	31			<i>Schellwienia arctica</i> <i>Datrina enormis</i>	0.7	-4576.0														
	30			<i>Jugulites jugulensis</i> <i>Datrina ruzhensei</i>	0.7															
Gzelian	29			<i>Rauserites stuckenbergti</i> <i>Datrina crista</i>	0.7															
	28			<i>Datrina fragilis</i> <i>Rauserites rossicus</i>	0.7															
Kasimovian	27			<i>Rauserites variabilis</i> <i>Montiparus suberassulus</i>	1.2	-4696.0?														
	26			<i>Montiparus paramontiparus</i> <i>Wedekindellina ellipsoides</i>	0.6															
Moscovian	25			<i>Obsoletes obsoletus</i> <i>Protitictes pseudomontiparus</i>	0.6															
	24			<i>Protitictes ovaatus</i> <i>Præobsoletes burkemensis</i> <i>Quasifusulinoides fusiformis</i> <i>Fusulinella bocki</i> <i>Pulchrella eopudchra</i>	0.6	-4921.0														
Moscovian	Moscovian	18	<i>Beedyina kamenensis</i> <i>Fusulinella colarizae</i> <i>Aljutovella priscoidea</i> <i>Schubertella pauciseptata</i>	1.2	-4999.0															
			19		1.2															
			20		1.2															
			21		1.2															

Figure 2. Correlation chart of studied sections in Spitsbergen and the Loppa High with the interpreted relative sea level curve. Horizontally striped areas represent intervals of reduced thickness due to diastems; diagonally-striped areas represent hiatus.



Figures 3 - 8. Graphic correlation of sections from Spitsbergen and the Loppa High, Barents Sea. Crosses indicate tops, and circles bases of species. Triangles indicate tops, and squares bases of genera. 3: Trollfuglfjella section. 4: Skansen section. 5: Tyrrellfjellet section. 6: Boltonbreen section. 7: Kollseum section. 8: well - X : Loppa High.

positions of data points, constraining the LOCs immediately below and above the interval, indicate major changes in sedimentation pattern and are tentatively called "intervals of reduced thickness." This term suggests either a pronounced hiatus somewhere within the middle Asselian or a number of short hiatuses (diastems). The same interpretation appears to be valid for the well #X (Loppa High). However, the presence of part of zone 35 in the Skansen section suggests a major, though short-term, transgression within zone 35.

A major transgression during Late Asselian (from zone 37 or the uppermost part of zone 36) is suggested by the relatively high RRS in the Trollfuglfjella and Skansen sections (1.5 and 2 respectively) and, probably well # X where the RRS, interpreted from poorly constrained LOC, equals 5. However, biostratigraphic data from these sections are poor and the Sakmarian stage is either poorly defined paleontologically or not defined at all in the Spitsbergen localities. In addition, data from the Kolosseum section, where the LOC suggests uniform sedimentation from zone 37 to the Asselian-Sakmarian boundary, contradict the notion of a major latest Asselian transgression because of a low RRS (0.27).

Therefore, there are two possible scenarios for the sedimentation pattern during latest Asselian-early Sakmarian time. If the interpretations for Trollfuglfjella and Skansen sections, and well # X are correct, the low RRS in Kolosseum could best be explained by a local tectonic event involving a short-scale uplift of the tectonic block. Alternatively, there is evidence for a hiatus spanning the lower part of zone 37 in Trollfuglfjella and Kolosseum sections. If this turns out to be correct, the LOC position in Kolosseum section should have a different slope indicating higher RRS with the alignment of data points at 166 m-level corresponding to the hiatus spanning the lower part of zone 37.

Conclusions

I. Sea-level changes: relative versus eustatic

It is difficult to distinguish between eustatically driven and tectonically driven sedimentation changes. The Spitsbergen sections are located 60 km apart and it is difficult to correlate the RSL curve drawn for these locations to the global sea-level curve. Most significantly, major RSL changes do not coincide with the boundaries of the relative time scale. There is no "basal" Asselian transgression in Spitsbergen, rather there is continuous sedimentation across the C/P boundary interval. A major transgression begins in latest Orenburgian time. Similarly, there is no apparent hiatus at the Asselian-Sakmarian boundary and transgression begins in the late Asselian; however, these data, derived only from graphic correlation of the Kolosseum section, are regarded as tentative.

Naturally, the hiatuses are related to RSL lowstands and correlation of sedimentation breaks over great distances could help distinguish local from eustatic sea-level changes. At this point, at least some hiatuses identified in Spitsbergen can be traced interregionally. The preliminary correlation of Spitsbergen localities and sections in Darvas region of Pamirs (Middle Asia), separated by 5000 km, indicates the presence of the prominent middle Gzhelian (zone 28) and middle-upper Orenburgian (the upper part of zone 31 to the uppermost part of zone 32) hiatuses.

References

Anisimov, R. M., and Davydov, V. I., 1998, Graphic Correlation of Upper Carboniferous-Lower Permian strata in Spitsbergen, Norwegian Arctic: Abstracts of the Fortieth

Annual Meeting of Idaho Academy of Science, J. of I. A. of Science, v. 34, p. 31

Davydov, V. I., 1997b, Fusulinid biostratigraphy of the Upper Paleozoic of Kolguev Island and Franz Josef Land: International Symposium "Biostratigraphy of Oil-Gas bearing Basins", St. Petersburg: 40-59 (In Russian and English).

Edwards, L. E., 1984, Insights on why Graphic Correlation (Shaw's method) works: *Journal of Geology*, v. 93, p.583-597

Edwards, L. E., 1989, Supplemental Graphic Correlation: a powerful tool for paleontologists and non-paleontologists: *Palaios*, v. 4, p.127-143

Mann, K. and Lane, R., eds, 1995, Graphic Correlation, SEPM special publication # 53, 263 p.

Miller, F. X., 1977, The Graphic Correlation method in biostratigraphy, in Kauffman, E. and Hazel, J., eds., *Concepts and Methods of Biostratigraphy*: Stroudsburg, Dowden Hutchinson and Ross, p. 165-186

Nilsson, I., 1988, Carboniferous and Permian fusulinids on the Nordfjorden Block, Spitsbergen (Svalbard): Unpublished Ms. Thesis, University of Oslo, 143 p.

Nilsson, I., 1993, Upper Paleozoic fusulinid stratigraphy of the Barents Sea and surrounding areas: Dr. Sci. Thesis, University of Tromsø, 538 p.

Nilsson, I. and Davydov, V., 1992, Middle Carboniferous-Lower Permian fusulinid stratigraphy in central Spitsbergen, Arctic Norway. *IKU Report 23.1356.00/07/92*, 175p.

Shaw, A. B., 1964, *Time in Stratigraphy*: New York, McGraw-Hill Book Co., 365 p.

Stemmerik, L. and Worsley, D., 1995, Permian history of the Barents shelf area, in Scholle, P., Peryt, T. and Ulmer-Scholle, D., eds., *The Permian of Northern Pangea*, v. 2, p. 81-97

Worsley D. et al., 1986, Evolution of an arctic archipelago; the geological history of Svalbard: *Den Norske Stats Oljeselskap*, Stavanger, 120 p.

R. M. Anisimov
Permian Research Institute
Department of Geosciences
Boise State University
1910 University Drive, Boise, ID, 83725
ranisimo@trex.idbsu.edu
V. I. Davydov
Permian Research Institute
Department of Geosciences
Boise State University
1910 University Drive, Boise, ID, 83725

I. Nilsson
Saga Petroleum ASA
N-1301 Sandvika, Norway
Inger.Nilsson@saga.comostbox 49

Carboniferous and Permian Stratigraphy of the Baoshan Block, West Yunnan, Southwest China

Wang Xiang-dong, Tetsuo Sugiyama and Katsumi Ueno

The Baoshan Block is one of the key areas for understanding Gondwana dispersion and Asian accretion. The present contribution is intended to provide an improved framework for the Carboniferous and Permian stratigraphy of the Baoshan Block based on recent cooperative studies between Chinese and Japanese researchers.

The Lower Carboniferous sequence in the Baoshan Block includes two distinct sedimentary facies: a shallow-marine carbonate platform facies and a basinal facies. The former is subdivided into the Yudong, Shihuadong, and Yunruijie formations, in ascending order, which are widely distributed in the block.

The Yudong Formation consists of shale and mudstone. It was dated as late Tournaisian by conodonts such as *Gnathodus punctatus* and *Doliognathus latus* (Li and Duan, 1993), by corals such as *Zaphrentes parallelus* and *Communia szulczewskii* (Wang et al., 1993), and by brachiopods such as *Lamellosathyris lamellosa*, *Spinocyrtia laminosa*, *Sprifer tomacensis*, *Schuchertella magna*, and *Dictyoclostus triznae* (Jin and Fang, 1983). The Dazhaimen Formation, which disconformably underlies the Yudong Formation, yields abundant late Devonian conodonts, including *Palmatolepis wolskjae*, *Bispathodus costatus*, and *Palmatolepis triangularis*. Therefore, the disconformity between these two formations indicates a distinct hiatus representing latest Devonian and earliest Carboniferous time.

The Shihuadong Formation, which conformably overlies the Yudong Formation, consists mainly of mudstone, and dolomitic and argillaceous limestone with chert nodules. The boundary between the Tournaisian and Viséan is defined by the first occurrence of *Gnathodus texanus* in the lower part of the formation. Very abundant dissepimental corals, such as *Siphonophyllia*, *Keyserlingophyllum*, *Cyathoclisia*, *Palaeosmilia*, *Kueichouphyllum*, and *Siphonodendron* occur in the middle and upper parts of this formation.

The Yunruijie Formation is characterized by oolitic grainstone and bioclastic grainstone. It yields the dissepimental corals *Diphyphyllum carinatum*, *Dibunophyllum* sp. and *Palaeosmilia* sp. and smaller foraminifers, which indicate a late Viséan age.

The Lower Carboniferous basinal facies in the Baoshan Block is composed of the Qingshuigou Formation and overlying Jiangjiawan Formation in ascending order. The Qingshuigou Formation consists of dark lime-mudstone and wackstone containing the conodonts *Polygnathus bischoffi*, *Gnathodus pseudosemiglaber*, and *Mestognathus beckmanni* (Wang et al., 1993), the ammonoids *Merocanites* (*Michiganites*) *bicarinatus*, *Bollandites bashatchensis*, and *Dzhaprakoceras deflexum* (Liang and Zhu, 1988), and the non-dissepimented corals *Pentaphyllum hibernicum* and *Rotiphyllum* sp. (Wang et al., 1993). This faunal association indicates a late Tournaisian to early Viséan age. The Jiangjiawan Formation conformably overlies the Qingshuigou Formation, and is composed of mudstone with iron nodules and shales in the lower part. It yields abundant small, non-dissepimented rugosan species of *Pentaphyllum*, *Ufimia*, *Communia*, *Sychnoelasma*, and *Zaphrentes*, and some conodonts,

such as *Gnathodus semiglaber* and *G. pseudosemiglaber*. The upper part of the formation is characterized by the alternation of mudstone containing small solitary corals, and sandstone.

The Lower Carboniferous strata of the block are unconformably overlain by the Lower Permian Dingjiazhai Formation. A depositional break encompassing Serpukhovian to probable Asselian is widely recognized in the Baoshan Block. The Dingjiazhai Formation is mainly composed of clastics with diamictites in the lower part. These diamictites are considered by some authors to be glaciomarine in origin (e.g., Jin, 1994). In the upper part of the formation, there are a few limestone intercalations containing abundant brachiopods, bryozoans, and crinoids (BBC communities). Chen (1984) first reported fusulinaceans, including *Triticites ohioensis*, *T. pusillus*, *T. parvulus*, and *Hemifusulina maoshanensis*, from these limestones and considered the age of the Dingjiazhai Formation to be Late Carboniferous. Until recently, a Late Carboniferous age has been accepted for the formation (Fang and Fan, 1994; Jin, 1994). However, according to our preliminary examination of foraminifers from limestone intercalations in the type section, the fauna includes *Pseudofusulina* sp., *Eoparafusulina* spp., *Boultoniidae* n. gen.?, and *Pachyphloia* sp. We prefer to consider the age of the fauna as Early Permian (probably Sakmarian). This conclusion is coincident with the assessment of the brachiopod fauna by Shi et al. (1995). In addition, several small solitary non-dissepimented corals, including *Cyathaxonia* sp., *Plerophyllum* sp., and *Hapsiphyllidae* n. gen.? were found in these limestone intercalations. These corals have often been referred to as the *Cyathaxonia* fauna, which inhabited stressed environments.

The Woniusi Formation comprises thick basaltic lava sheets and some tuffaceous intercalations. It lies on the Dingjiazhai Formation without a distinct hiatus in the Dongshanpo and Dingjiazhai areas. Formerly, it was also dated as late Carboniferous, based on the occurrence of *Triticites* from the limestone intercalations in its lower part. However, as a result of our field investigation at the type section of the formation, we consider these limestone intercalations, together with associated clastics, to be faulted repetitions of the underlying Dingjiazhai Formation.

The Bingma Formation rests on the Woniusi Formation in Daaozi Village. It is characterized by volcanoclastic conglomerate with several thin lava intercalations in the lower part, and red and purple siltstone and mudstone in the upper part. No fossils have been found in the type area.

The Shazipo Formation is the uppermost stratigraphic unit of the upper Paleozoic in the Baoshan Block. It consists of wackstone and bioclastic grainstone in the lower part, dolomitic limestone in the middle part and dolostone in the upper part. Foraminifers (*Eopolydiexodina afghanensis*, *Neoschwagerina* sp., *Verbeekina* sp., *Shanita amosi*) and massive corals (*Ipciphyllum* sp.) have been reported from this formation (Sheng and He, 1983; Fang and Fan, 1994; Zhang, 1996). In addition, we have found *Wentzelophyllum persicum*, *Wentzelella shidianensis* and a probable new genus of the family *Staffellidae*. The fauna is slightly different from the typical Tethyan faunas observed in South China and Indochina. The Shazipo fossils indicate that the age of the formation is possibly late Chihhsian to early Lopingian.

To sum up, the Carboniferous and Permian stratigraphy (Figure 1) of the Baoshan Block can be closely compared with that of the Sibumasu Block, which is considered to be one of the Gondwana-derived terranes in present-day Southeast Asia.

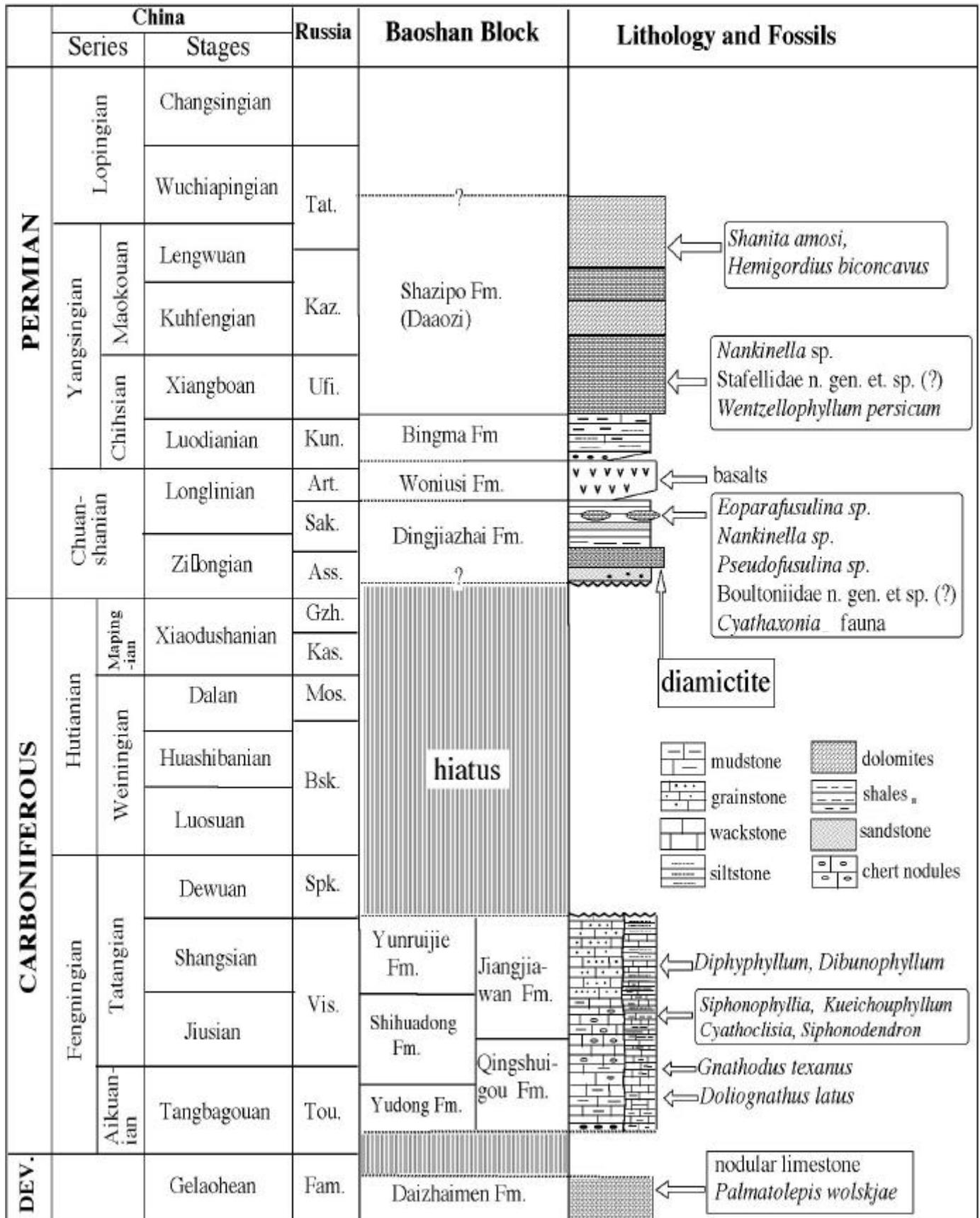


Figure 1. Carboniferous - Permian stratigraphic framework of the Baoshan block.

References

- Chen G. B., 1984, The Carboniferous of the Baoshan area, West Yunnan. *Jour. Stratigr. (China)*, 8(2): 129-135. (in Chinese)
- Fang R. S. and Fan J. C., 1994, Middle to Upper Carboniferous-Early Permian Gondwana facies and palaeontology in western Yunnan. Yunnan Science and Technology Press, Kunming, 121p. (in Chinese with English abstract)
- Jin X. C., 1994, Sedimentary and paleogeographic significance of Permo-Carboniferous sequences in Western Yunnan, China. *Geologisches Institut der Universitaet zu Koeln Sonderveroeffentlichungen*, 99: 1-136.
- Jin Y. G. and Fang R. S., 1983, Early Carboniferous brachiopods from Shidian, Yunnan. *Acta Palaeontologica Sinica*, 22(2): 139-151. (in Chinese with English abstract)
- Li R. J. and Duan L. L., 1993, Early Carboniferous conodont sequence in the Baoshan-Shidian area, Yunnan and its stratigraphic significance. *Acta Micropalaeontologica Sinica*, 10(1): 37-52. (in Chinese with English abstract)
- Liang X. L. and Zhu K. Y., 1988, Early Carboniferous cephalopods of Baoshan, Yunnan. *Acta Palaeontologica Sinica*, 27(3): 288-301. (in Chinese with English abstract)
- Sheng J. Z. and He Y., 1983, Permian Shanita ? Hemigordius (Hemigordiopsis) (Foraminifera) fauna in western Yunnan, China. *Acta Palaeontologica Sinica*, 22(1): 55-61. (in Chinese with English abstract)
- Shi G. R., Archbold, N. W. and Fang Z. J., 1995, The biostratigraphical and palaeogeographical significance of an Early Permian brachiopod fauna from the Dingjiazhai Formation, Baoshan Block, Western Yunnan, China. *Proceedings of the IGCP Symposium on Geology of SE Asia, Hanoi, XI/1995. Jour. Geology, Ser. B, 5/6, 63-74.*
- Wang X. D., Zhu K. Y. and Chen Z. T., 1993, The Lower Carboniferous of Baoshan, Yunnan. *Jour. Stratigr. (China)*, 17(4): 241-255. (in Chinese with English abstract)
- Zhang, Y. Z. (ed.), 1996, *The lithostratigraphy of Yunnan*. China University of Geoscience press, Wuhan, 370p. (in Chinese)

Wang Xiang-dong
Nanjing Institute of Geology and Palaeontology,
Academia Sinica, Nanjing 210008, China
Present address
Department of Earth System Science,
Fukuoka University, Fukuoka 814-0180, Japan

Tetsuo Sugiyama
Department of Earth System Science,
Fukuoka University, Fukuoka 814-0180, Japan

Katsumi Ueno
Institute of Geoscience, University of Tsukuba,
Ibaraki 305-8571, Japan

ANNOUNCEMENTS

International Conference on Pangea And The Paleozoic-Mesozoic Transition

Organizer

Professor Yin Hongfu, Member of Academia Sinica, President of China University of Geosciences (Wuhan)

Objective

The conference is designed to provide a forum to all kinds of scientists who are interested in the special interval of Pangea for discussing Pangea formation and dispersion; global changes related to Pangea integration and break-up; biotic crisis, extinction, recovery and evolution at the Paleozoic-Mesozoic transition; and Tethys evolution during Pangea interval.

Date

Pre-Conference Field Excursion: 7-8 March, 1999

Conference: 9-11 March, 1999

Post-Conference Field Excursion: 12-16 March, 1999

Place

China University of Geoscience (Wuhan)

Language

English will be the official language for all presentations.

Important Dates

1 April 1998: Deadline for submission of response to first circular

1 October 1998: Deadline for submission of abstracts

1 February 1999: Deadline for submission of pre-registration

Themes

1. Tectonics and dynamics of Gondwana break-up, Pangea integration and Tethys evolution;
2. Paleogeography, paleoclimatology and paleoecology during Pangea interval;
3. Stratigraphy, sea level changes, high-resolution events and boundary;
4. Biotic crisis, mass extinction, recovery and evolution at the Paleozoic-Mesozoic transition.

Field Excursion

Pre-conference Field Excursion-Huangsi, Southeast Hubei Province (7-8 March, 1999). This two day field excursion will visit some typical marine Carboniferous-Lower Triassic and terrestrial Middle Triassic sections in Huangsi, southeastern Hubei Province. Some key boundaries will be examined there as well.

Post-conference Field Excursion-the Yangtze Gorges (12-16 March, 1999). The Yangtze Gorges areas are not only famous for the attractive scenery and the Dam construction, but also for the well-exposed Pre-Cambrian-Triassic stratigraphic sequences and their special geological significance. The excursion is planned mainly to examine the stratigraphic sequence and its related geological aspects. As the Yangtze Gorges Dam cut off the river at the end of 1997, a search for new exposures may be necessary.

Publications

We anticipate that refereed and accepted papers will be published either as a book or as a special issue of an international journal series. Papers must be presented (either orally or in poster) before being considered for publication.

Registration and excursion

Registration should be made on the registration form attached to the second circular, which will be sent to all who respond to the first circular. Registration fee for the Conference (including the proceedings, morning and afternoon teas and three lunches) will be \$150 US Dollars. Pre-conference field excursion fee (including transportation, accommodation, field guidebook and meals) will be \$120 US Dollars. As the Yangtze Gorges Dam is under construction and began damming the river late in 1997, the post-conference field excursion fee is presently uncertain but is estimated at about \$500 US Dollars (refer to second circular for details).

Transportation

Wuhan is the capital of Hubei Province, situated in the center of China. The international airport has daily flights from Hong Kong, Beijing, Shanghai, Guangzhou and other major cities in China. Wuhan is on the mid-way of Beijing-Guangzhou Railway with more than 20 express and rapid trains daily from Beijing and Guangzhou. Meanwhile, Wuhan is situated in the middle part of Yangtze River with more than 10 scheduled boats from Shanghai and Chongqing every day.

Send all Correspondence to:

Dr. Tong Jinnan (Secretariat)

Faculty of Earth Science

China University of Geosciences

Wuhan, Hubei 430074, P. R. CHINA

Tel: +86-27-7482031 Fax: +86-27-7801763

Email: jntong@dns.cug.edu.cn

XIV ICCP, First Circular XIV International Congress On The Carboniferous And Permian

Hosted by

The Department of Geology and Geophysics
University of Calgary
and University of Calgary Conference Services
Calgary, Alberta

Date

August 17-21, 1999

Associated Meetings:

The Pander Society

The Canadian Paleontology Conference

Sponsorship

The Canadian Society of Petroleum Geologists has agreed to lend their name

as a supporting agency of this conference.

Organizing Committee

Honourary Chairman, Bernard Mamet

Chairman, Charles Henderson

Fieldtrips Chairman: Barry Richards

Technical Program Committee:

Charles Henderson, Bernard Mamet, Barry Richards, Wayne Bamber, Jim Barclay, Benoit Beauchamp, Richard Brandley, Pauline Chung, John Utting.

Core Workshop Committee: Jim Barclay, Pauline Chung, Tony

Hamblin.

Invitation

Geologists from around the world interested in Carboniferous and Permian rocks are invited to meet at Calgary Alberta Canada between August 17-21, 1999.

Theme

A World in Transition: Understanding Resources And Environment For Tomorrow

The theme is intended to reflect a temporal duality. The world today is in a state of transition from the industrial revolution to the communication-information revolution. Technological changes are occurring at an amazing pace, affecting the way we do our science. The world of the Carboniferous and Permian was also in transition as continental fragments amalgamated into Pangea and changes occurred at a pace too great for many organisms. The deposition, burial, and alteration of communities of these organisms provided the resources for today. The integrative and multidisciplinary efforts of current geoscientists to better understand the evolution of the earth during the Carboniferous and Permian will help us find more resources for tomorrow and provide insight into important environmental questions about how we affect our world.

Technical Program

The congress will focus on the many global aspects of Carboniferous and Permian environments and resources as well as the various system boundaries (Devonian/Carboniferous, mid-Carboniferous, Carboniferous/Permian, Permian/Triassic). The following are the major theme sessions planned:

1. Carboniferous-Permian conodonts; Pander
2. Other conodonts; Pander
3. Upper Paleozoic Palynology
4. Other Paleontology (Forams, Corals, Brachs, Ammonoids)
5. Mississippian Tectonics and Stratigraphy
6. Pennsylvanian Tectonics and Stratigraphy
7. Permian Tectonics and Stratigraphy
8. Reefs
9. Evaporites
10. Phosphates
11. Coal
12. World Petroleum
13. Boundaries/Chronostratigraphy
14. Extinctions/Recovery
15. Western Canada Carboniferous and Permian Geology; Petroleum for Local crowd
16. Canadian Paleontology; CPC
17. General Sedimentology
18. Global Synthesis; Climate, Cycles, Geochemistry, Pangea

Core Conference

The Carboniferous of the Western Canada Sedimentary Basin contains substantial accumulations of conventional oil and gas (14% of basin's conventional oil reserves and 16% of conventional gas reserves). The Permian contains about 2% of both conventional oil and gas reserves of the eastern Canada Sedimentary Basin. As a result there are many wells that have penetrated and cored the Carboniferous and Permian. The Core Research Centre of the Alberta Energy and Utilities Board is an outstanding facility in Calgary where most cores from wells in Western Canada are stored. A one day workshop during the Congress is planned.

Fieldtrips

Pre-convention trips (August 12-16, 1999)

Trip 1. Upper Carboniferous to Lower Permian paleoenvironments of the Maritimes Basin, Atlantic Canada. Principal leader J. Calder; start and end in Halifax Nova Scotia; 4 days duration.

Trip 2. Mississippian tectonics and sedimentary facies; Idaho and Montana, USA. Principal leaders: P. Link and B. Skipp; trip will start in Salt Lake City, USA and end in Calgary; 4 days duration.

Trip 3. Structural geology of Canadian Rocky Mountain Foothills and Front

Ranges west of Calgary. Principal leader M.E. McMechan; day trip from Calgary.

Trips 4 to 7. Carboniferous sequence stratigraphy, biostratigraphy and basin development, Banff region of southwestern Alberta. This series of four day trips will provide an overview of the upper Devonian (Famennian) to upper Carboniferous (Moscovian) succession along an east to west (shelf to deep basin) transect through the Rocky Mountain Foothills and Front Ranges near the towns of Banff and Canmore. Excursions will leave from Calgary each morning and return in the evening. Participants can register for one or more of the trips, which will be run consecutively. Principal Leaders: B.C. Richards, B.L. Mamet and E.W. Bamber.

Trip 4. Lower Carboniferous (Tournaisian and Viséan) carbonates and clastics of the Moose Mountain oil and gas field, Rocky Mountain Foothills.

Trip 5. Uppermost Devonian (Famennian) and Lower Carboniferous (Tournaisian) carbonates and black shale at Exshaw and Mount Rundle, Rocky Mountain Front Ranges.

Trip 6. Lower Carboniferous platform and ramp carbonates and Upper Carboniferous sandstones at Canmore and Banff, Rocky Mountain Front Ranges.

Trip 7. Basin to supratidal carbonates, bedded chert and sandstones in the thick Famennian to Permian section at Chester Lake in Kananaskis Country, western Rocky Mountain Front Ranges.

Trip 8. Carboniferous cyclothem in the mid-continent region of the United States of America. Principal leader P. Heckle; trip will start in Chicago, Illinois and end at Kansas City, Missouri; 5 days duration.

Post-convention trips (August 22-25)

Trip 9. Sequence stratigraphy and biostratigraphy of Viséan to Moscovian carbonates and clastics in Rocky Mountain Foothills and Front Ranges of Highwood Pass region, Alberta. Principal leaders B.L. Mamet, B.C. Richards and E.W. Bamber; day trip from Calgary.

Trip 10. Pennsylvanian-Permian Oquirrh-Wood River Basin and Phosphoria Formation, eastern Idaho, USA. Principal leaders P. Link, B. Skipp; trip will start in Calgary and end at Salt Lake City, Utah, USA; 4 days duration.

Trip 11. Late Paleozoic Island arc and oceanic terranes, south-central British Columbia. Principal leaders J. Nelson, M. Orchard, T.W. Danner, and J.T. Fyles; trip will start in Calgary and end at Kamloops, British Columbia; 4 days duration.

Trip 12. Lower Carboniferous stratigraphy and basin development, Maritimes Basin, Atlantic Canada. Principal leaders P. Giles and J Utting; trip will start and end in Halifax; 4 days duration.

Trip 13. Structure and Lower Carboniferous stratigraphy of the Rocky Mountain Front ranges southeast of Jasper, Alberta. Principal leader D. Lebel; trip will start and end in Calgary; 2 days duration.

Trip 14. Sequence stratigraphy and conodont biostratigraphy of the Upper Carboniferous and Permian in Rocky Mountain Front Ranges at Banff and Kananaskis Country, southwestern Alberta.

Principal leaders C. Henderson and D. Moore; trip will start and end in Calgary; 2 days duration.

Trip 15. Lower and Upper Carboniferous sequence stratigraphy, biostratigraphy and basin development on western margin of ancestral North America in Cordillera of southwestern Alberta and southeastern British Columbia. Principal leaders B.L. Marnett, E.W. Bamber and B.C. Richards; trip will start and end at Calgary; 3 days duration.

Trip 16. Coal rich cyclothem in Kentucky. Don Chestnut
More details and accommodation forms will be sent to all who respond to this notice or the first circular.

Send All Correspondence to:

XIV ICCP

Department of Geology and Geophysics

University of Calgary,

Calgary, Alberta, Canada T2N 1N4 or

FAX: 403-284-0074 or email: henderson@geo.ucalgary.ca

International Field Conference on: The continental Permian of the Southern Alps and Sardinia (Italy). Regional reports and general correlations.

Date: 16-25 September, 1999

Venue

Brescia Museum of Natural Sciences, Italy, and excursions in Sardinia and in the Southern Alps.

Organizer

A team of Italian geologists already involved in the IGCP projects n. 203, 272, 343, 359, jointly sponsored by the Italian Geological Society (SGI), the National Research Council (CNR), and other scientific organizations. Foreign geologists have also collaborated for this meeting.

Subjects

The proposed aim of the Conference is not only to present the results of research carried out over recent years in the aforementioned Italian areas, but above all, to establish possible correlations between these regions and other Permian continental domains of the world. Two field trips are planned. The first pre-Conference excursion will be held, from 16 to 18 September, in Sardinia, specifically both in the central-eastern continental basins of Escalaplano, Perdasdefogu, Seui, and in the northwestern Nurra. Afterwards, the participants can reach Brescia by ferry-boat and bus. The Conference, which will take place in Brescia from 20 to 22 September, is designed to improve our current understanding of the continental Permian; as well as the presentation of papers and posters, there will be restricted meetings on specific research topics. The focus will be on stratigraphic, palaeontologic, magmatic and tectonic separate sections. An additional section on the Permian-Triassic boundary in the continental, or on the continental-marine transition domains, is being planned. A further three-day excursion, from 23 to 25 September, will be dedicated to the Permian of the central-eastern Southern Alps. The Collio and Tregiovo continental basins, the Bolzano volcanics, and the Val Gardena Sandstone-Bellerophon Formation of the well-known Butterloch-Bletterbach section in the western Dolomites, will all be visited. The trip will also take in the famous P/T type-section of Tesero, near Cavalese (Fiemme Valley).

Correspondent

Prof. G. Cassinis, Dipartimento di Scienze della Terra, Università di Pavia, Via Ferrata 1, I-27100 Pavia, Italy- Phone. 39-382-505834, telefax: 39-382-505890, Email: cassinis@ipv36.unipv.it

31st International Geological Congress

The International Commission on Stratigraphy and Subcommission on Permian Stratigraphy will sponsor a international symposium on:

International Standard References for the Permian System: Cisuralian of Southern Ural Mountains, Guadalupian of Southwestern North America, Lopingian of South China

Date: August 6th through 17th, 2000

Venue: Riocentro Convention Center

Rio de Janeiro - Brazil

Subject: The symposium is to showcase progress on final recommendations for Permian series and stage definitions. This symposium creates the forum for the working groups of the SPS to present their findings and conduct an open discussion on the Permian System. The symposium will consist of both an oral and a poster session held during the scientific program of the 31st International Geological Congress. This is a general announcement, details will be given in subsequent issues.

Conveners: Brian F. Glenister (University of Iowa), Bruce R. Wardlaw (USGS), Tamra A. Schiappa (BSU)

Correspondent: Tamra A. Schiappa, Permian Research Institute, Boise State University, Boise, Idaho, 83725, USA. Email: tschiapp@bsu.idbsu.edu.