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ALBERTIANA

Waagen's (1895) lithographic plate of the Ceratite limestone from Khoora section, Salt Range

THE GLOBAL MARINE PERMIAN-TRIASSIC BOUNDARY: OVER A CENTURY OF ADVENTURES AND CONTROVERSIES (1880–2001)

by Aymon Baud

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DECEMBER 2014

ISSN 0619-4324

Feature Historical Review

THE GLOBAL MARINE PERMIAN-TRIASSIC BOUNDARY: OVER A CENTURY OF ADVENTURES AND CONTROVERSIES (1880–2001)

Aymon Baud

BGC, Parc de la Rouvraie 28, CH-1018 Lausanne, Switzerland. Email: aymon.baud@unil.ch

FOREWORD

Different views have been recounted on the Permian-Triassic boundary story. Here are considered only some aspects of a long story and for a more full account, especially of the early development of the Permian-Triassic boundary, I refer to some parts the Tozer's (1984) book. As researcher in IGCP projects from 1974, vice-chairman, chairman and past-chairman of the Subcommission on Triassic Stratigraphy (1984–2000), I provide here an insider point of view.

INTRODUCTION
FROM GRIESBACH TO DIENER: THE DISCOVERY OF THE OTOCERAS AMMONOID IN THE HIMALAYA

Carl Ludloph Griesbach

The story starts in 1880, when Carl Ludloph Griesbach (Fig. 1) was publishing a note on the Paleontology of the Lower Triassic of the Himalaya: during his Survey of the Central Himalaya, he discovered the *Otoceras* ammonoid (Fig. 1) and he was the first who understood the importance of this fossil to mark the base of the Triassic Series and the Permian-Triassic boundary. His Central Himalaya's studies were published in 1891.

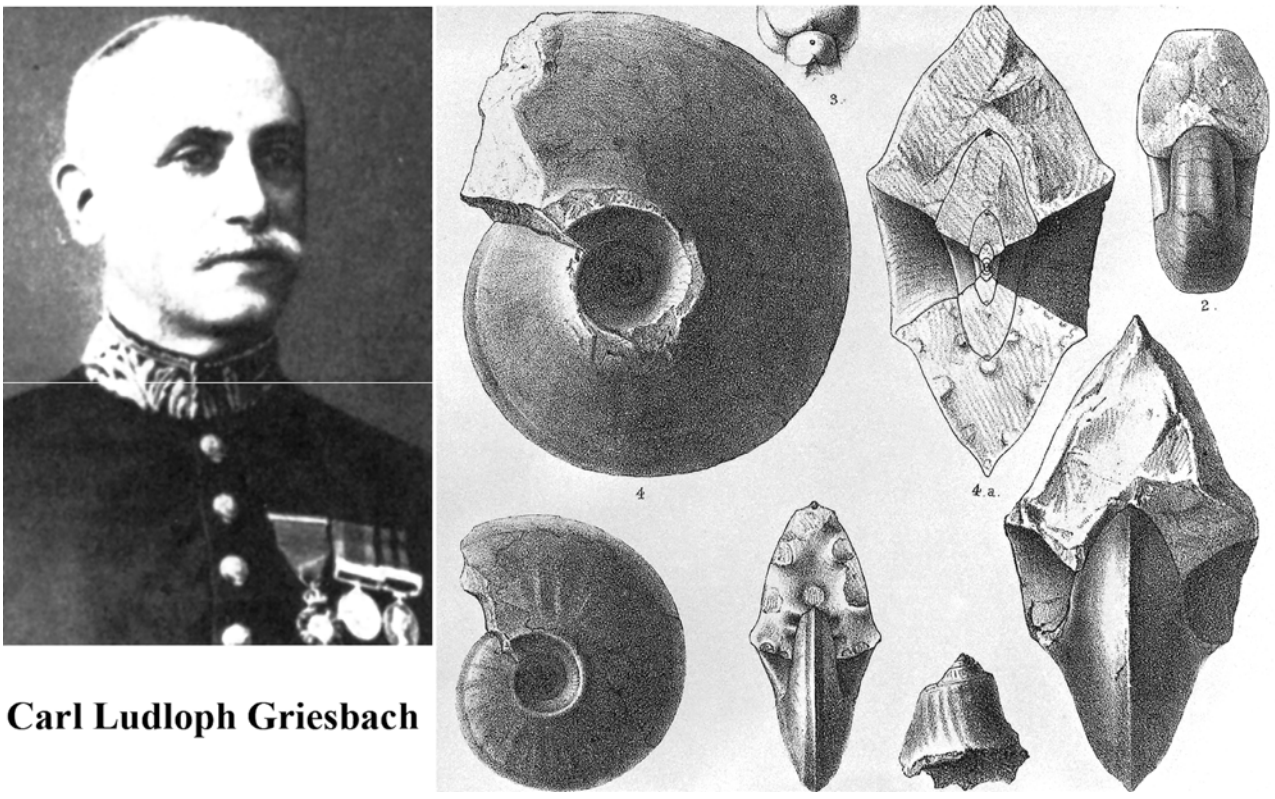


Figure 1 – Carl Ludloph Griesbach with its *Otoceras* original plate (Griesbach, 1880).

Edmond von Mojsisovics, Wilhelm Waagen and Carl Diener

Shortly after Griesbach's publication came out the Mojsisovics, Waagen and Diener 1895 paper with the Lower Triassic subdivision proposal made by Waagen and Diener (Fig. 2) in which they strongly advised the use of the *Otoceras* Beds described in the Central Himalaya to define the base of the Triassic. In the same year, Wilhelm Waagen published an impressive paleontological work on the Salt Range fossils (Fig. 3). This was soon followed by the contributions of Carl Diener who explored the Central Himalaya and published his survey in 1895 (Fig. 4). Like Waagen before him, Diener visited the Salt Range, then the Permian-Triassic sections in Kashmir. He discovers also *Otoceras* specimens in Spiti Valley sections and made correlations with the Shalshal Cliff section in the Central Himalaya (Diener, 1912). All these extensive paleontological collections have been carefully stored at the Geological Survey of India in Calcutta.

The first controversy starts with von Krafft (1901), Frech (1902) and Noetling (1905) who assumed the Permian age of *Otoceras* with references to the Transcaucasia sections.

Untere Trias nach W. Waagen und C. Diener.

Serien	Stufen	Unterstufen	Mediterrane Triasprovinz: Zone (der pelagischen Facies)	Mediterrane Triasprovinz: Schichtbezeichnung (verschiedenartiger örtl. Entwicklung)	Indische Triasprovinz: Zone (der pelagischen Facies)	Indische Triasprovinz: Schichtbezeichnung (verschiedenartiger örtlicher Entwicklung)	
Dinarisch	Anisisch	Bosnisch	10. Z. des *Ceratites trinodosus*	Oberer Muschelkalk	Z. des *Ptychites rugifer*	Muschelkalk des Himalaya	
		Balatonisch	9. Z. des *Ceratites binodosus*	Unterer Muschelkalk	Z. des *Sibirites Prahlada*	Brachiopoden-Schichten mit *Rhynchonella Griesbachi* (Himalaya)	
	Hydaspisch				8. Z. des *Stephanites superbus*	Obere Ceratiten-Kalke der Salt Range	
Skythisch	Jakutisch		Z. des *Tirolites Cassianus*	Werfener Schichten	7. Z. des *Flemingites Flemingianus*	Ceratiten-Sandstein der Salt Range	Subrobustus Beds des Himalaya
					6. Z. des *Flemingites radiatus*		
					5. Z. des *Ceratites normalis*		
	Brahmanisch	Gandarisch		der Ostalpen	4. Z. des *Proptychites trilobatus*	Ceratite Marls der Salt Range	
					3. Z. des *Proptychites Lawrencianus*		
		Gangetisch			2. Z. des *Gyronites frequens*	Untere Ceratiten-Kalke der Salt Range	
					1. Z. des *Otoceras Woodwardi*	Otoceras Beds des Himalaya	

Figure 2 – The Lower Triassic scale according to Waagen and Diener *in* Mojsisovics et al. (1895).

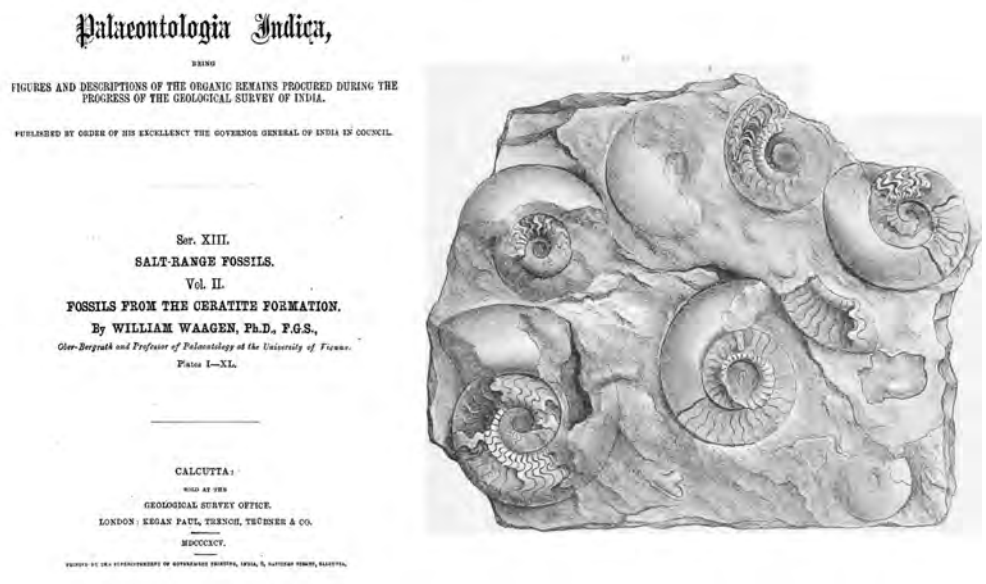


Figure 3 – Left, cover of the Salt Range fossils by Waagen (1895); right: plate XL of Waagen (1895) showing a limestone slab of the Lower *Ceratite* limestone, Khoora section.

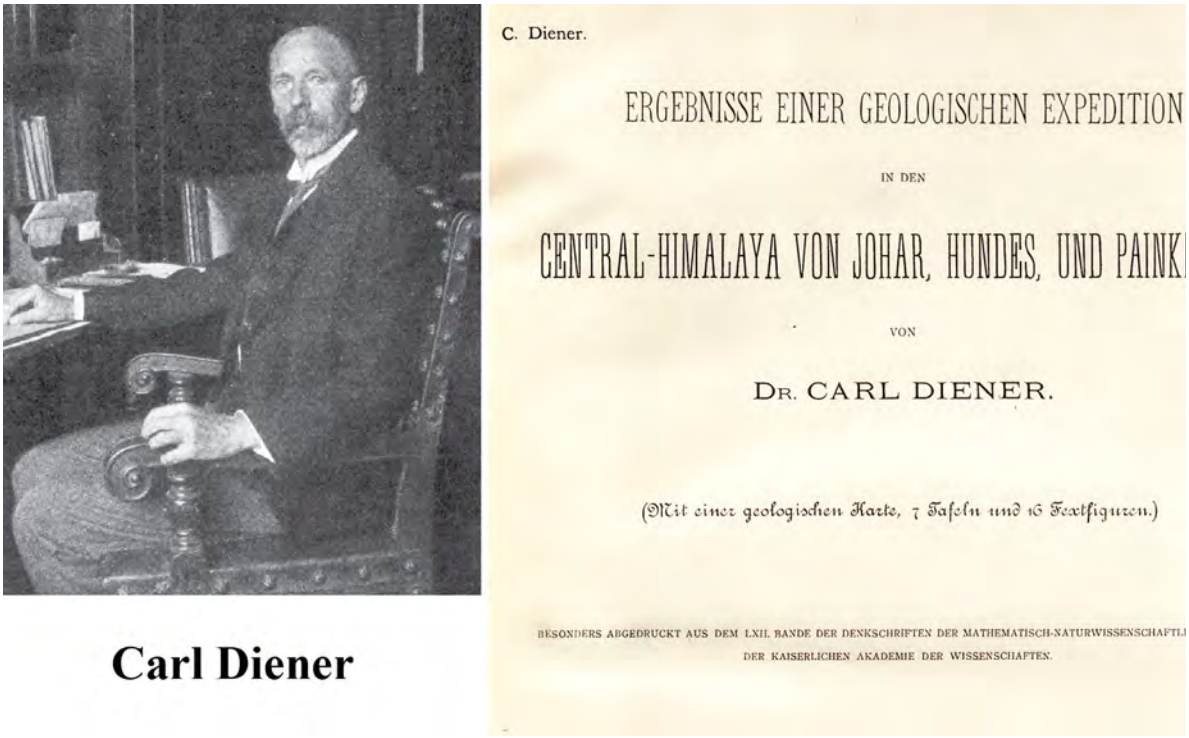


Figure 4 – The cover of the Central Himalaya paper of C. Diener (1895).

THE ARCTIC ADVENTURES, AMMONOIDS AND MIXED FAUNA

The Permian-Triassic succession and boundary of three main areas of the Western Arctic have been intensely studied (Fig. 5, left): Jameson Land on East Greenland with the expeditions of Lauge Koch in the 1930's (Fig. 5, right), of R. Trümpy in the 1950's, and of C. Teichert and B. Kummel at the end of the 1960's; Axel Heiberg and Ellesmere Islands surveyed by E.T. Tozer; and Spitsbergen (Svalbard) Islands studied during three expedition of a Japanese team leaded by Nakamura (1984) and by K. Nakazawa in 1986.

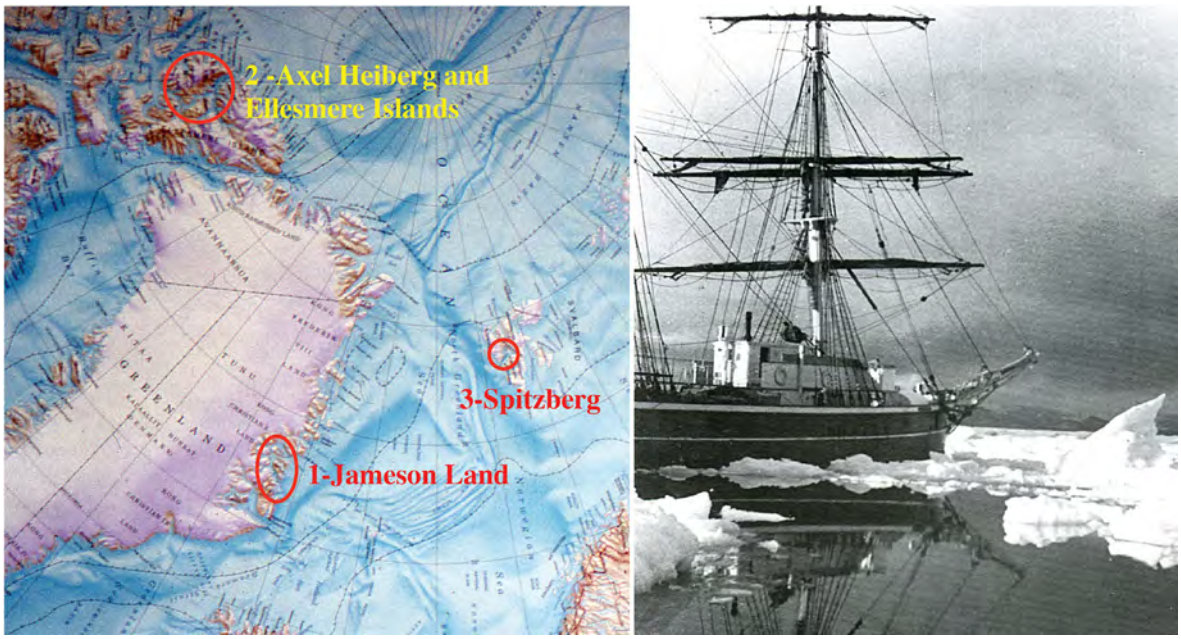


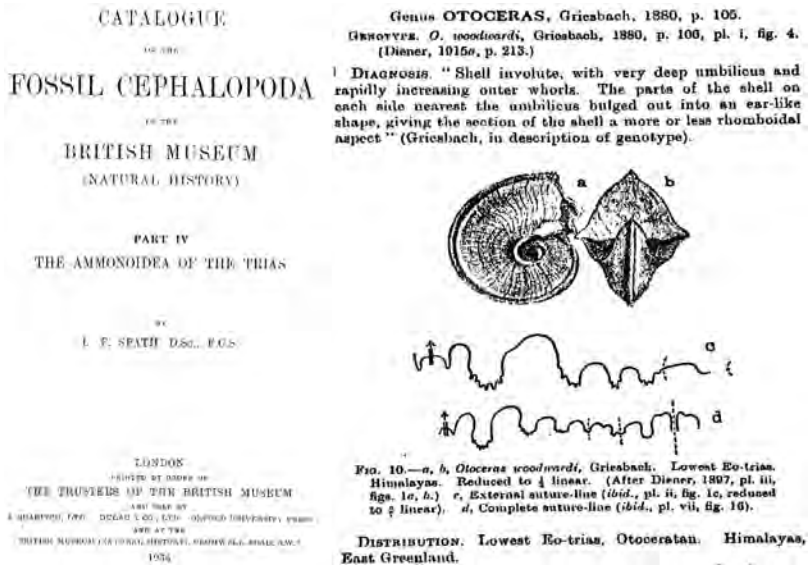
Figure 5 – Left, Western Arctic map: 1– Jameson Land, 2- Axel Heiberg and Ellesmere Islands, 3- Spitsbergen (Svalbard) Islands; right: the "Gustave Holmes" boat of the Lauge Koch Expedition close to Jameson Land (photo from Augusto Gansser, a young geologist of the expedition).

Lauge Koch collections and Leonard Frank Spath

Between 1930 and 1950, large Cephalopod collections from Eastern Greenland made by Lauge Koch (1931) were carefully studied by Leonard Frank Spath (Fig. 6), allowing him to publish a new and very fine subdivision of the Lower Triassic from the Arctic region. Working on ammonoid biochrones, his basal Triassic was called Otoceratan (Spath, 1934, Spath et al., 1951).

Rudolf Trümpy

At the end of the 1950s, Rudolf Trümpy, Professor in Lausanne and Zürich, Switzerland went to East Greenland (Jameson Land, Kap Stosch), studied the late Permian to basal Triassic macrofossils and, in 1960, he wrote an interesting study about the problematic of the mixed fauna at the Permian-Triassic transition. Later, in 1969, Trümpy published his work on the Lower Triassic Ammonites from Jameson Land (Fig. 7) with refined subdivisions of the local basal Triassic.


CATALOGUE

FOSSIL CEPHALOPODA

BRITISH MUSEUM

(NATURAL HISTORY)

PART IV

THE AMMONOIDEA OF THE TRIAS

L. F. SPATH D.Sc., F.G.S.

LONDON

THE TRUSTEES OF THE BRITISH MUSEUM

1934

Genus **OTOCERAS**, Griesbach, 1880, p. 105.

Genotype. *O. woodwardi*, Griesbach, 1880, p. 106, pl. i, fig. 4. (Diener, 1915*a*, p. 213.)

Diagnosis. "Shell involute, with very deep umbilicus and rapidly increasing outer whorls. The parts of the shell on each side nearest the umbilicus bulged out into an ear-like shape, giving the section of the shell a more or less rhomboidal aspect" (Griesbach, in description of genotype).

a b

c

d

Fig. 10.—*a*, *b*, *Otoceras woodwardi*, Griesbach. Lowest Eo-trias. Himalayas. Reduced to ¼ linear. (After Diener, 1897, pl. iii, figs. 1*c*, *b*.) *c*, External suture-line (*ibid.*, pl. ii, fig. 1*c*, reduced to ⅔ linear). *d*, Complete suture-line (*ibid.*, pl. vii, fig. 16).

Distribution. Lowest Eo-trias. Otoceratan. Himalayas, East Greenland.

Figure 6 – Left, cover of the Spath's catalogue; right, his *Otoceras* description (Spath, 1934).


Rudolf Trümpy

MEDDELELSER OM GRØNLAND

UDGIVNE AF

KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND

Bd. 168 · Nr. 2

DE DANSKE EKSPEDITIONER TIL ØSTGRØNLAND 1947–58

Under Ledelse af Lauge Koch

NOTES ON TRIASSIC STRATIGRAPHY AND PALEONTOLOGY OF NORTH-EASTERN JAMESON LAND (EAST GREENLAND)

BY

S. DEFRETIN-LEFRANC, K. GRASMÜCK AND R. TRÜMPY

I

TRIASSIC STRATIGRAPHY AND GENERAL GEOLOGY OF THE COUNTRY AROUND FLEMING FJORD (EAST GREENLAND)

By K. Grasmück and R. Trümpy

II

LOWER TRIASSIC AMMONITES FROM JAMESON LAND (EAST GREENLAND)

By R. Trümpy

III

LES CONCHOSTRACÉS TRIASSIQUES DU GROENLAND ORIENTAL

Par Simone Defretin-Lefranc

KØBENHAVN

C. A. REITZELS FORLAG

BIANCO LUNOS BOGTRYKKERI A/S

1969

Figure 7 – Cover of the 1969 Jameson Land Triassic paper with the Trümpy's ammonites study.

Edward Timothy Tozer

In the sixties, a Canadian paleontologist ammonoid specialist, Edward Timothy Tozer (Fig. 8, left), started his famous Triassic studies in the High Arctic, for the Geological Survey of Canada (Fig. 8, right). As only geographic names are allowed for stage name, Tozer gave the name of the pioneers of the Triassic studies to small gullies or creeks, both on Axel Heiberg and on Ellesmere Island (Fig. 9). That is why, in 1965, he took the opportunity to subdivide the Lower Triassic Series in four stages, named from these creeks: Griesbachian, Dienerian, Smithian and Spathian.

With Norman Silberling, the ammonoid specialist from Denver (USA), Tozer extended the Arctic lower Triassic subdivisions to the whole of North America and published (Tozer and Silberling, 1968), as point of reference, the biochronological scale and the subdivisions of the Western North America Triassic (Fig. 10).

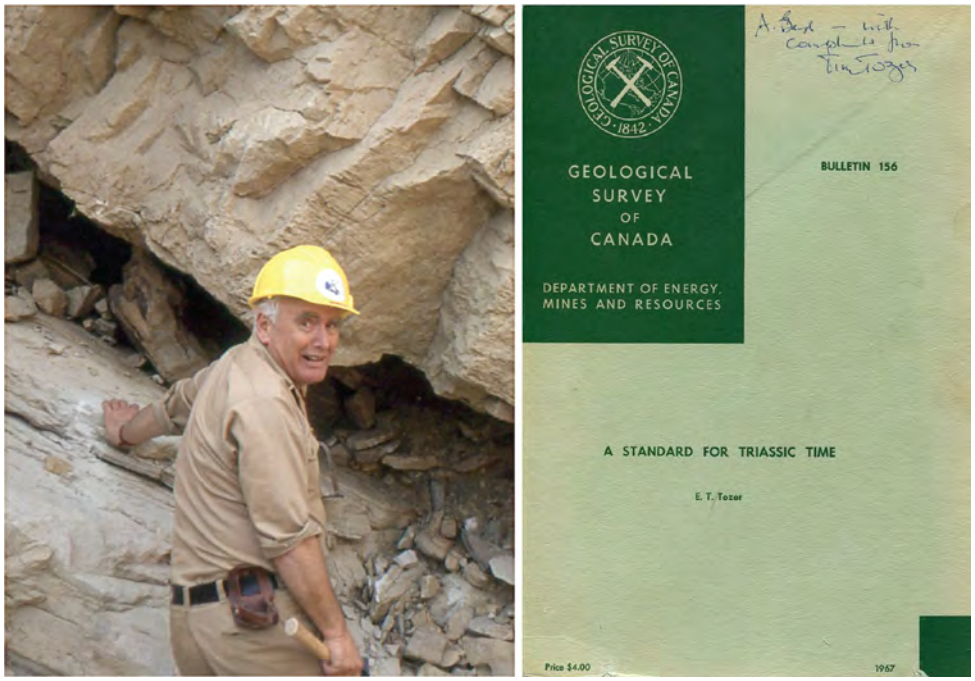


Figure 8 – Left, Tim Tozer surprised at the PTB in Nammal Gorge (Salt Range, Pakistan, December 1987); right, cover of the Tozer's (1967) Triassic book.

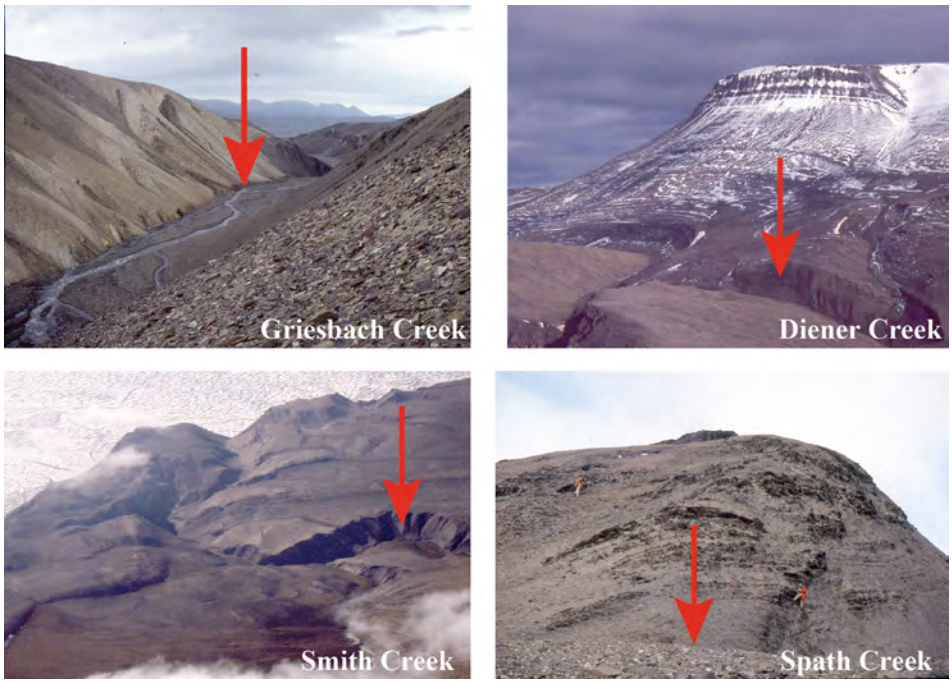


Figure 9 – The four remote gullies (Creeks) used by E.T. Tozer as lower Triassic stages stratotypes.

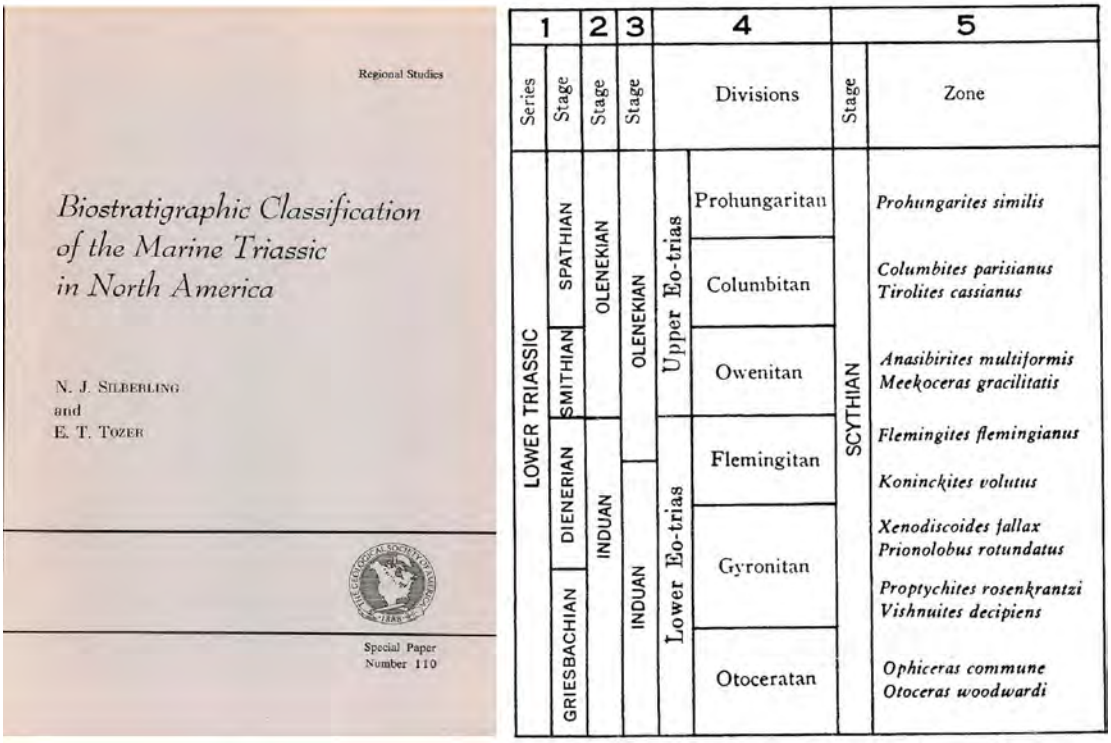
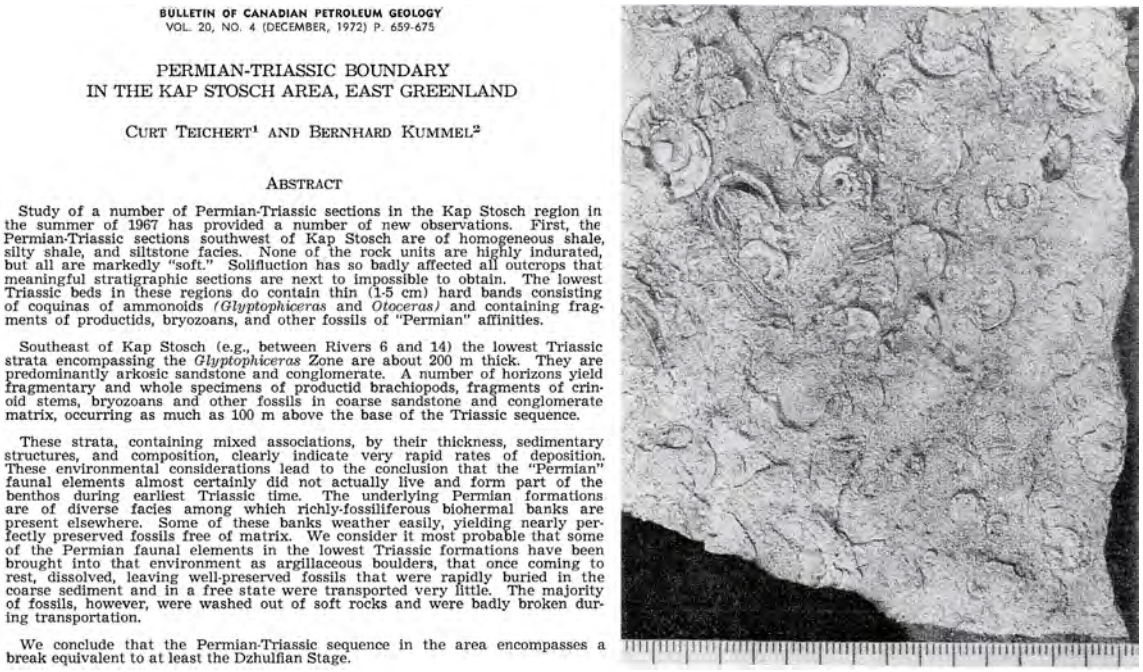


Figure 10 – Left, cover of the Silberling and Tozer (1968) basic Triassic paper; right, Tozer's (1965, table 2) Lower Triassic comparative classification with: 1 = Silberling and Tozer (1968), 2= Kiparisova & Popov (1956, 1961), 3 = Kiparisova & Popov (1964), 4 = Spath (1934), 5 = Kummel (1957).

Curt Teichert and Bernhard Kummel

During the 1967 Summer, Curt Teichert specialist of Permian Cephalopods and Bernhard Kummel specialist of Triassic ammonoids get the opportunity to go and work on the Permian Triassic transition in the famous Kap Stosch area. They finally went to the conclusion that the Permian fossils with brachiopods and bryozoans are reworked within the basal Triassic *Ophiceras* beds (so called mixed fauna). The first paper was published in 1972 (Fig. 11), and the detailed description of the sections appear in their 1976 paper with the conodont description in an appendix written by Walter C. Sweet.



BULLETIN OF CANADIAN PETROLEUM GEOLOGY
VOL. 20, NO. 4 (DECEMBER, 1972) P. 659-675

PERMIAN-TRIASSIC BOUNDARY
IN THE KAP STOSCH AREA, EAST GREENLAND

CURT TEICHERT[1] AND BERNHARD KUMMEL[2]

ABSTRACT

Study of a number of Permian-Triassic sections in the Kap Stosch region in the summer of 1967 has provided a number of new observations. First, the Permian-Triassic sections southwest of Kap Stosch are of homogeneous shale, silty shale, and siltstone facies. None of the rock units are highly indurated, but all are markedly "soft." Solifluction has so badly affected all outcrops that meaningful stratigraphic sections are next to impossible to obtain. The lowest Triassic beds in these regions do contain thin (1-5 cm) hard bands consisting of coquinas of ammonoids *(Glyptophiceras* and *Otoceras)* and containing fragments of productids, bryozoans, and other fossils of "Permian" affinities.

Southeast of Kap Stosch (e.g., between Rivers 6 and 14) the lowest Triassic strata encompassing the *Glyptophiceras* Zone are about 200 m thick. They are predominantly arkosic sandstone and conglomerate. A number of horizons yield fragmentary and whole specimens of productid brachiopods, fragments of crinoid stems, bryozoans and other fossils in coarse sandstone and conglomerate matrix, occurring as much as 100 m above the base of the Triassic sequence.

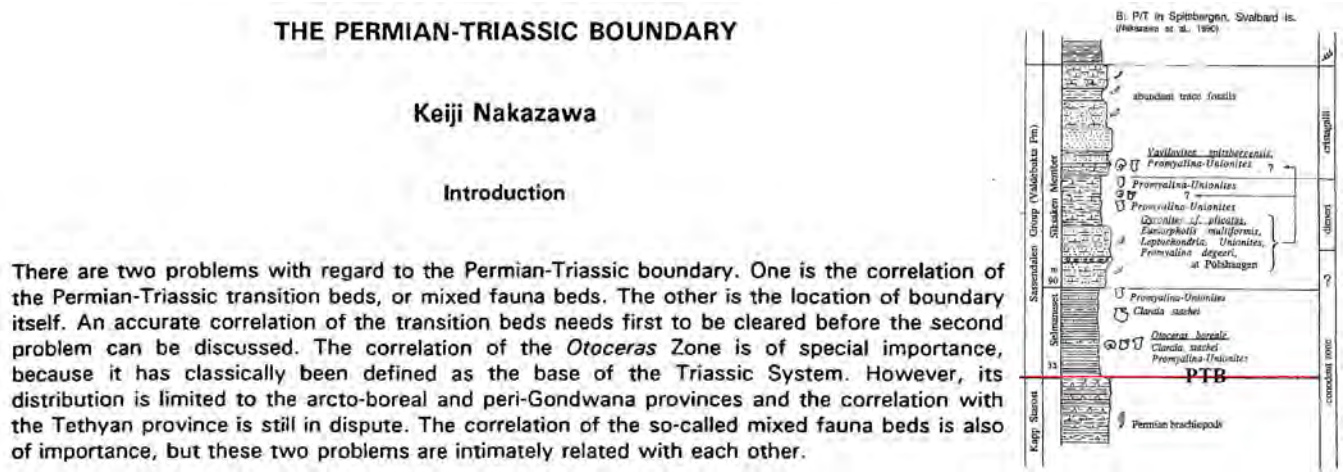
These strata, containing mixed associations, by their thickness, sedimentary structures, and composition, clearly indicate very rapid rates of deposition. These environmental considerations lead to the conclusion that the "Permian" faunal elements almost certainly did not actually live and form part of the benthos during earliest Triassic time. The underlying Permian formations are of diverse facies among which richly-fossiliferous biohermal banks are present elsewhere. Some of these banks weather easily, yielding nearly perfectly preserved fossils free of matrix. We consider it most probable that some of the Permian faunal elements in the lowest Triassic formations have been brought into that environment as argillaceous boulders, that once coming to rest, dissolved, leaving well-preserved fossils that were rapidly buried in the coarse sediment and in a free state were transported very little. The majority of fossils, however, were washed out of soft rocks and were badly broken during transportation.

We conclude that the Permian-Triassic sequence in the area encompasses a break equivalent to at least the Dzhulfian Stage.

Figure 11 – Left, first page of the Teicher and Kummel's (1973) Kap Stosch paper; right, their plate with Ophiceratids accumulation.

Koji Nakamura, Keiji Nakazawa and the Japanese Group

As reported by Nakamura et al. (1987), a cooperative study between Norsk Polarinstitutt and Hokkaido University, Japan was undertaken during the year 1984 in West Central Spitsbergen. The main objective of which was to obtain detailed stratigraphical and palaeontological informations on the Permian and the Permian-Triassic boundary (Fig. 12). During the Summer 1986, Keiji Nakazawa leaded a Japanese geological expedition to Svalbard with a report of *Otoceras boreale* finding in 1987. Further studies were made in 1990, and the final Report published by Tatsumi (ed.) in 1990 with the Nakamura et al. paper on Permian-Triassic boundary.



THE PERMIAN-TRIASSIC BOUNDARY

Keiji Nakazawa

Introduction

There are two problems with regard to the Permian-Triassic boundary. One is the correlation of the Permian-Triassic transition beds, or mixed fauna beds. The other is the location of boundary itself. An accurate correlation of the transition beds needs first to be cleared before the second problem can be discussed. The correlation of the *Otoceras* Zone is of special importance, because it has classically been defined as the base of the Triassic System. However, its distribution is limited to the arcto-boreal and peri-Gondwana provinces and the correlation with the Tethyan province is still in dispute. The correlation of the so-called mixed fauna beds is also of importance, but these two problems are intimately related with each other.

Figure 12 – Left, Introduction of the PTB paper of Nakazawa (1992); right, a Permian-Triassic transition section in Spitsbergen

THE CENTRAL TETHYS

Research on Permian-Triassic transition along the central Tethys margins concerned Transcaucasia (Armenia and Azerbaidjan), Iran, Pakistan, Northern India and Tibet.

In the Salt Range, they started again in the 1950s, with Schindewolf short survey published in 1954 and were followed in the sixties by Curt Teichert, Bernhard Kummel and Walter Sweet, and later by Keij Nakazawa and his Japanese team.

Transcaucasia; from Hermann Abich (1878) to Tim Tozer (1969)

Due to the highly fossiliferous late Paleozoic, the Transcaucasia attracted paleontologists as Abich (1878) and Mojsisovics (1879). For Frech and Arthaber (1900) the Himalayan *Otoceras* were Permian in age as the Armenian one's. Bonnet (1919, Fig.13) found large similarities between the *Otoceras joulfense* Abich and the Himalayan *Otoceras woodwardi*, and fighting against Diener, he strongly claimed a same Eo-Triassic age of the Armenian red "*Otoceras*" beds. Due to the abundance of Xenodiscidae and early Otoceratidae, the area became source of biochronological problems and misplaced correlation. The story continued and later Ruzhentsev and Sarycheva (1965), Russian paleontologists incorrectly determined a basal Triassic *Tompophiceras* zone below the *Dzhulfites* and *Paratirolites* beds. Influenced by this, D.L. Stepanov, F. Golshani and J. Stöklin (1969) published, on the Iranian Julfa sections, a wrong correlation with a Permian-Triassic boundary in the middle of the red ammonoid limestone with *Productus*. Fortunately, after carefully studying Armenian specimens, Tozer, the same year (1969), reinterpreted the data and went to the right conclusion that the Permian-Triassic boundary is to be placed above the red ammonoid limestone, at the top of the *Paratirolites* beds. A long controversy was resolved.

Curt Teichert and Bernhard Kummel in association with Walter C. Sweet

In the 1960s, Curt Teichert specialist of Permian Cephalopods, Bernhard Kummel specialist of Triassic ammonoids and Walter C. Sweet conodont specialist started to work together on Permian-Triassic boundary sections of the Tethys: first in the Salt-Range, then in Kashmir and finally in the Julfa section of NW Iran. Both, separately or together, published very detailed reports on examined sections and their macrofossil contents.

Curt Teichert and Bernhard Kummel undertook field work in the Salt Range sections, Pakistan, in 1961 up to1964, and Kummel published a first report in 1966, followed by an edited book (Teichert and Kummel, 1970) that contains the description of 12 main sections with the Permian-Triassic transition (Fig. 14). Walter C. Sweet (1970) wrote a section on the lower Triassic conodont succession.

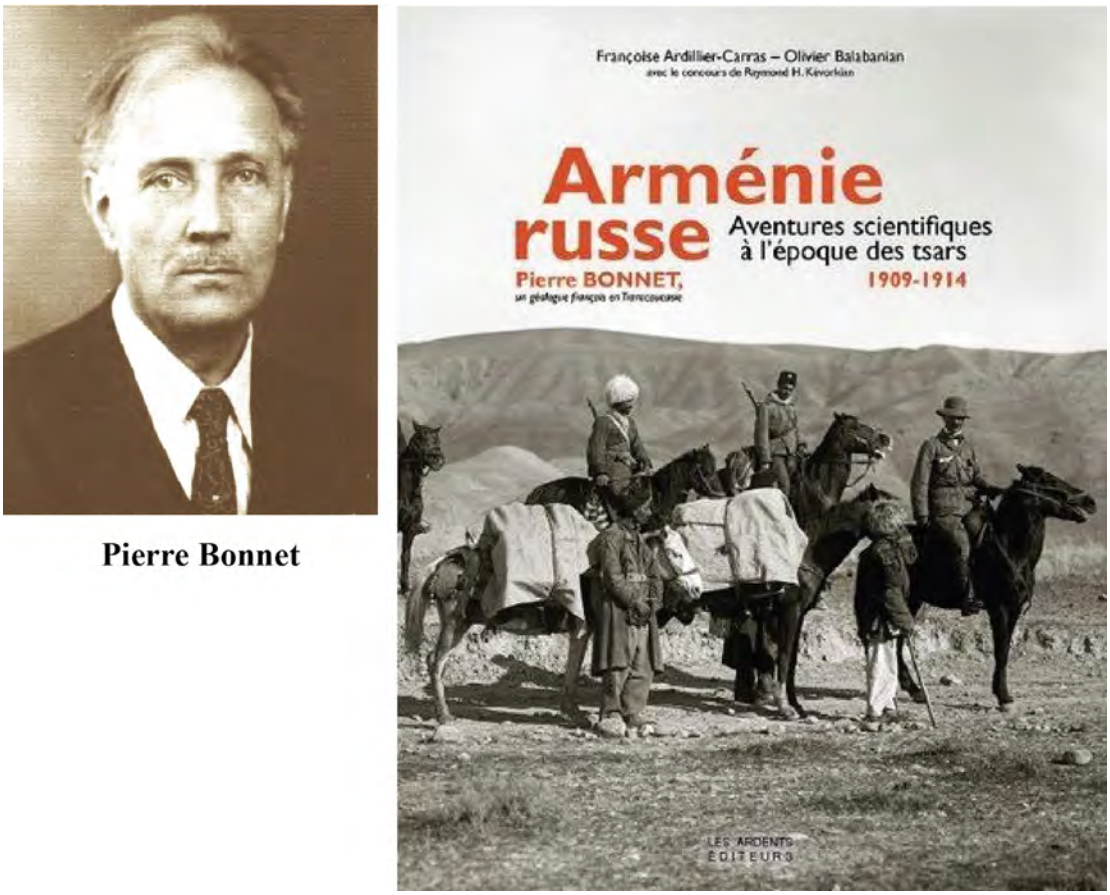


Figure 13 – Cover of the book on the story of the Pierre Bonnet geological explorations in Transcaucasia, from 1909 to 1914.

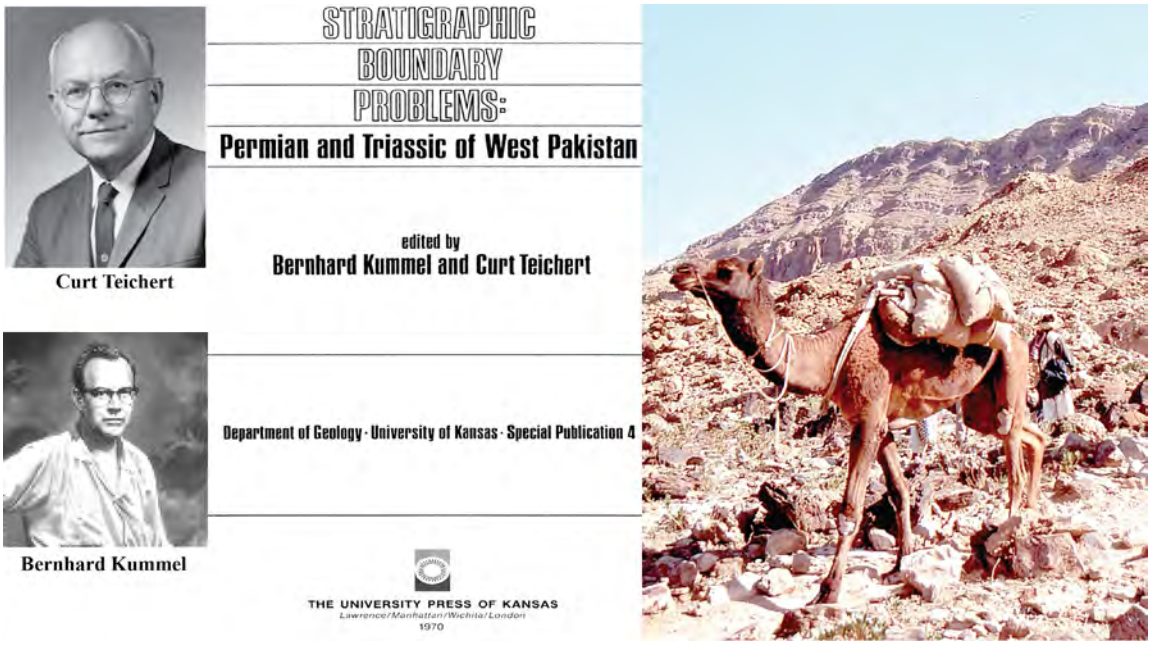


Figure 14 – Left, C. Teichert photo and B. Kummel portrait; middle, cover of the Kummel and Teichert book (1970) on the Salt Ranges; right: slide of the Central part of the Salt Range with, in the foreground, the Lower Triassic strata worked by Teichert and Kummel.

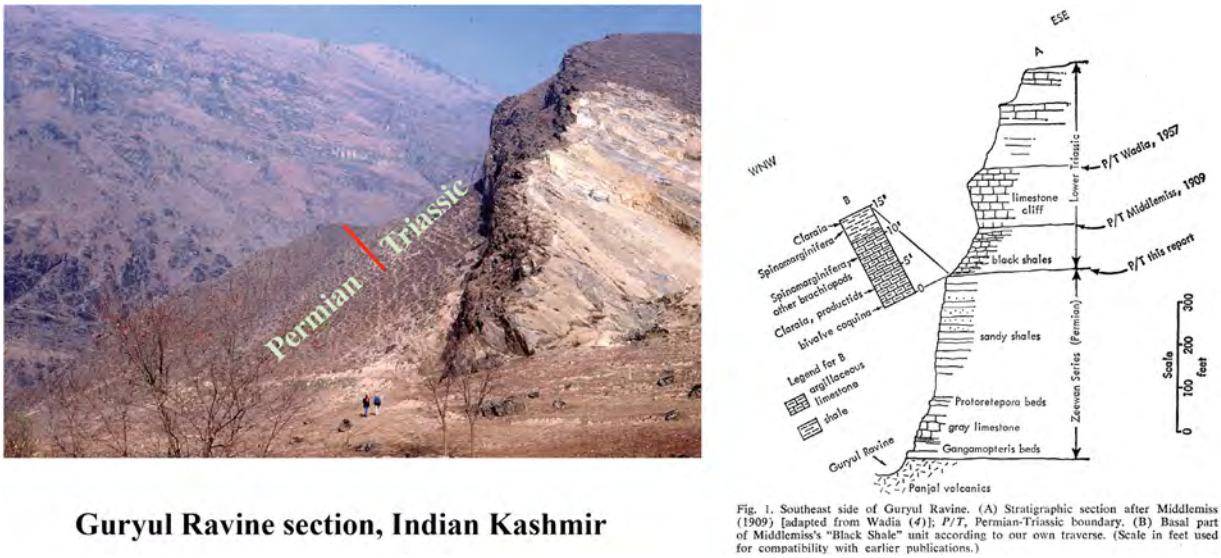


Figure 15 – Left, view on the Guryul Ravine section; right: the Guryul Ravine section drawn by Teichert & Kummel (1970).

In 1968, Curt Teichert and Bernhard Kummel spend 2 days at the Guryul Ravine section, Kashmir, India (Fig. 15), collected samples and wrote a paper (Teichert & Kummel, 1970). The same year, Sweet gave an account on the conodont zonation from late Permian to early Triassic at Guryul Ravine (Sweet, 1970).

After short reconnaissance on Iranian side of the Transcaucasia in 1966, Teichert went back with Bernhard Kummel in Julfa area in 1968 and studied four sections along the slope. The Teichert et al. paper was printed in 1973 (Fig. 16, left) and took account of the Tozer's views for interpreting the PTB position. The "upper Julfa beds" was sampled in their locality 4 (Fig. 16, right), packed, sent and stored at the Museum of Comparative Zoology, but probably wrongly labeled with the name of the overlying unit "Ali Bashi Formation". This mistake has been the starting point of controversies on the late Permian conodont succession and determination, explained by Henderson et al., 2008 (this story is related by Baud, 2008 and recently by Ghaderi et al., 2013).

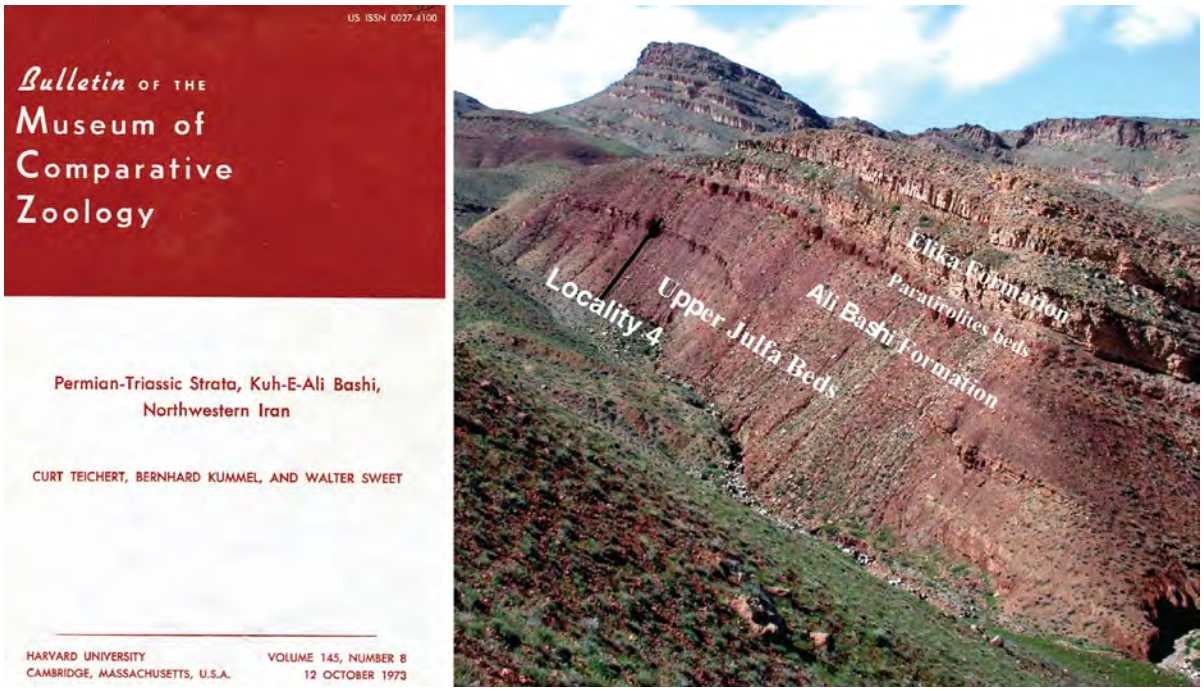


Figure 16 – Left, cover of the Kummel and Teichert (1973) booklet on Julfa sections; right, view on the locality 4 of Kummel and Teichert.

Keiji Nakazawa and the Japanese Group

In 1969 and during the seventies, a Japanese Group leaded by Keiji Nakazawa, in cooperation with local Survey, started extensive studies of three main Permian–Triassic marine and fossiliferous area of the central Tethys and published bed by bed description and fossil contents.

In l972, detailed paleontological and sedimentological studies have been carried out in Abadeh, Central Iran (Fig. 17, right) and in Elburz Mountain by geologists of the Geological and Mineral Survey of Iran and by a research staffs of Japanese universities leaded by Keiji Nakazawa. Supplementary fieldwork was done in l975 and the extensive results (Fig. 17, left) were published in the Kyoto University Memoirs (Iranian-Japanese Research Group, IJRG, 1981)

With Hari Mohan Kapoor from Indian Survey, the Japanese Group leaded by Keiji Nakazawa studied the Guryul Ravine section, (Fig. 18, right) and surrounding sections of the Indian Kashmir, during 1971 and 1972. The extensive results were published in the Kyoto University Memoirs (Nakazawa et al., 1975), the fauna in Nakazawa and Kapoor, 1981 (Fig. 18, left), with the ammonoids systematic description by Bando, and during the 80's, Tetsuo Matsuda (1981, 1982, 1983 and 1984) wrote detailed conodont papers on the Kashmir Permian-Triassic succession.

With colleagues from the Pakistani Geological Survey, the Japanese Group leaded by Keiji Nakazawa studied in 1975, 1976 and 1979 the Nammal Gorge and seven surrounding sections in the Salt and the Surghar Ranges, Pakistan (Fig. 19, right). The first results were published by Pakistanese-Japanese Research Group (PJRG), first in 1981 (Fig. 19, left) and later in a 90 pages detailed report (PJRG, 1985).

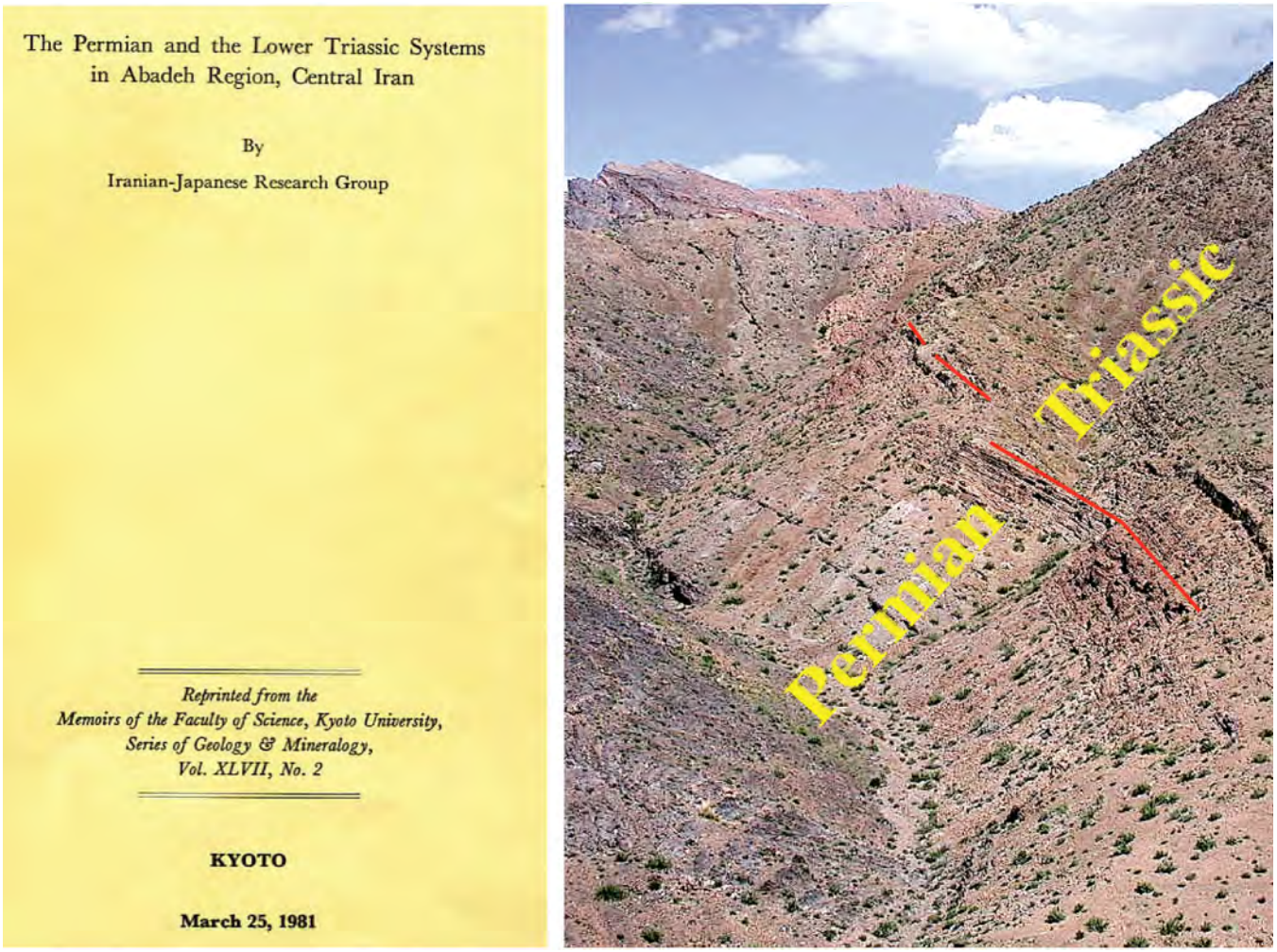


Figure 17 – Left, cover of the Kyoto University Memoirs on Abadeh (IJRG, 1981); right: view of the Abadeh section.

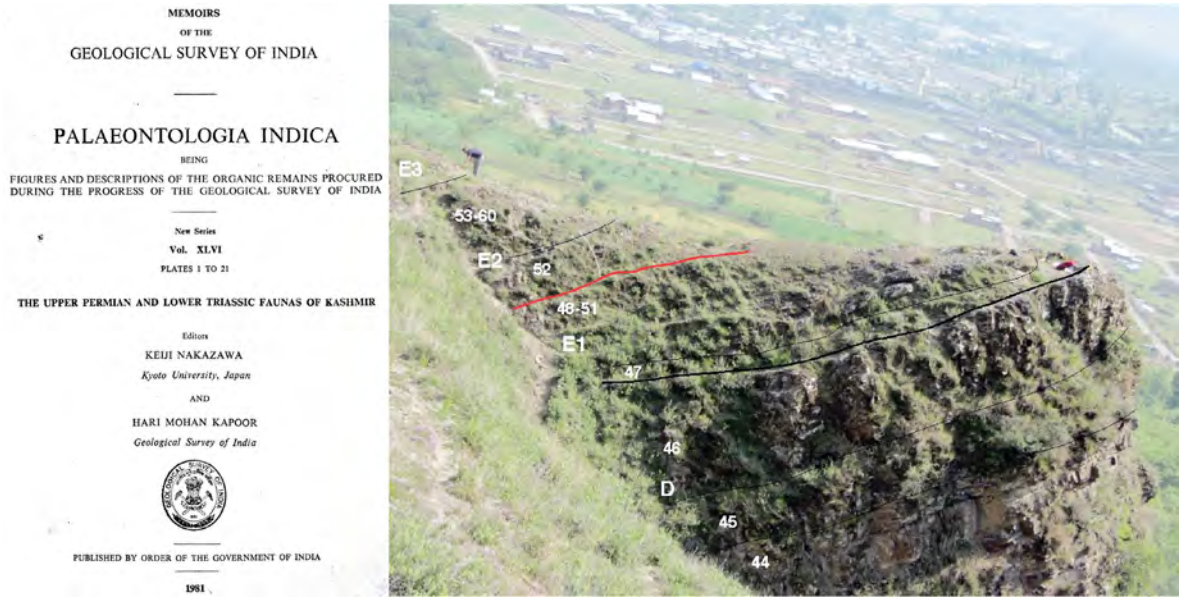


Figure 18 – Left, Cover of the Kashmir book (1981); right: slide of the Guryul Ravine Permian-Triassic section with the Nakazawa beds numbering and PTB (red line).

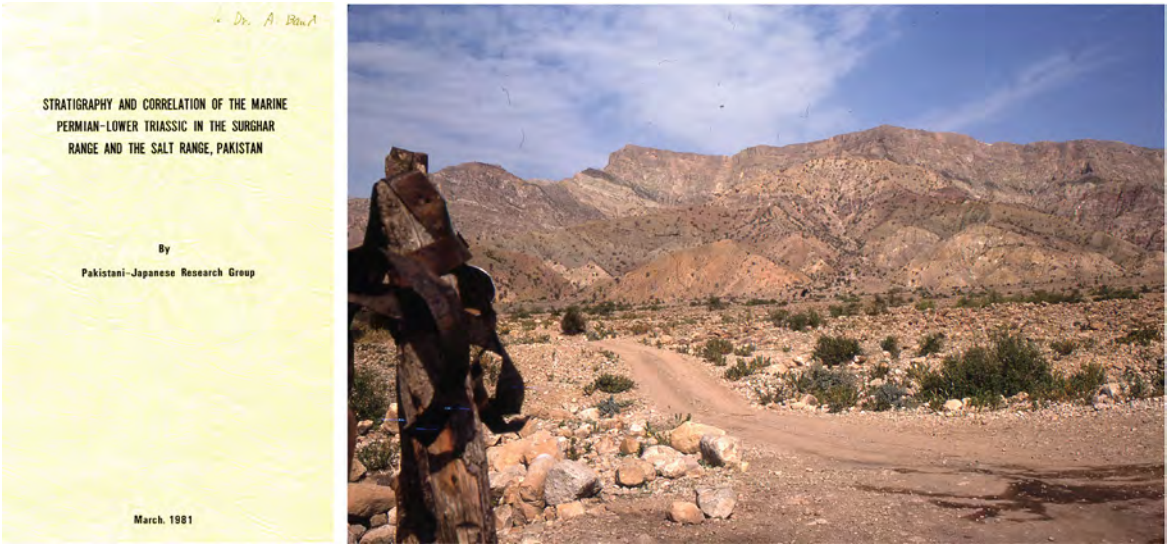


Figure 19 – Left, cover of the first Salt Range paper (PJRG, 1981); right: view on the Surgar Range with upper Permian and lower Triassic in the ground.

THE INTERNATIONAL GEOLOGICAL CORRELATION PROGRAM (IGCP), CONFERENCES AND FIELD WORKSHOPS (1974–2001)

Three years prior to the beginning of the International Geological Correlation Program, a turning point event in the Permian-Triassic boundary studies was the first International Permian-Triassic Conference held August 23-26, 1971 in Calgary (Canada) with over fifty contributions on the paleontology, stratigraphy, sedimentology, radiometric chronology, paleoclimatology and paleomagnetism of this time interval and of the boundary. A. Logan and L. V. Hills edited the Proceeding entitled "The Permian and Triassic Systems and their Mutual Boundary" in 1972.

For nearly a century, the research of this boundary mainly dealt with macrofossils and associated biochronology as tool for correlation. Microfossils as conodont systematic and geochemical analyses were only at the opening as magnetostratigraphy.

Heller at al. (1988) gave a first study on marine PTB magnetic time scale on Shangsi section (Sichuan, China), a candidate for the Permian-Triassic boundary section. Later on, Ogg and Steiner (1991) published their data on the Lower Triassic stratotype of Ellesmere and Axel Heiberg Islands, showing a normal polarity within the *Otoceras* zones.

IGCP Projects 4 and 106 (1974-1984), Figs. 20 and 21 left.

Sponsored by UNESCO, in 1974 started the International Geological Correlation Program with the Project 4 on "Triassic of the Tethys Realm", leaded by Prof. H. Zapfe from Vienna University and Austrian Academy. The Project 106 "Permo-Triassic stage of geological evolution" followed it up to 1984, leaded by a Russian team with Dr. A.N. Oleynikov.

Two successful fieldtrips on Permian-Triassic boundary of new areas, the Setorym Creek in Verkoyansk mountains (East Siberia) and the Vedi and Sovetachen sections in Transcaucasia (Armenia) were organized during the 1984 IGC in Moscow. It was a unique opportunity for participants to collect samples of these remote sections (Fig. 20).

Figure 20 – Left, E.T. Tozer between Y. Arkhipov and A. Dagis, field trip leaders, at the lower *Otoceras* beds, Setorym Creek (E Siberia); right: Field trip participants in front of the snowy Ararat summit (Armenia), Zun-Yi Yang is on the right and G. Kotlyar in the middle.

Progress of IGCP Projects*

No. 4/106 TRIASSIC OF THE TETHYS REALM

H. Zapfe, Erdwissenschaftliche Kommissionen der Österreichischen Akademie d. Wissenschaften, A-1010 Wien, Postgasse 7, Austria.

Description. Revision of the biostratigraphy in the Tethyan Triassic. Redefinition of classical stages and substages, their emendation for a worldwide application. Comparison of the scheme with other major faunal realms (North America, Eurasia, Indo-Pacific) aiming at a global Triassic time scale. Once this stage has been achieved, other important topics are to be studied, such as palaeogeography, faunal provinces and palaeomagnetism during Triassic time. An original study was made of the Upper Triassic and during recent years the work has expanded more and more to cover the entire Triassic, and the Project has been expanded to Asia in order to include the Triassic of the Himalayas, China and the Far East.

NO. 203 - PERMO-TRIASSIC EVENTS OF EASTERN TETHYS AND THEIR INTERCONTINENTAL CORRELATION

Yang Zunyi, Beijing Graduate School, Wuhan College of Geology, Beijing 100083, China.

J.M. Dickins, BMR, P.O.B. 378, Canberra City, ACT 2601, Australia.

W.C. Sweet, Department of Geology, Ohio State University, Ohio 43210, USA.

Description : The main objectives of Project 203 include : (1) a detailed study of the Permo-Triassic strata in the Eastern Tethys region and their correlation with equivalent stratigraphic units in Gondwana and Circum-Pacific realms,

Figure 21 – left, IGC Project. 4. 106 and 203 short description; right: Zun-Yi Yang and Norman Newell at the PT boundary, Shangsi section, March 1984.

IGCP Project 203: "Permo-Triassic events in the Eastern Tethys", 1984-1989

In 1984 began the first Chinese IGCP project 203 (Fig. 21, left) proposed and leaded by Prof. Zun-Yi Yang from Beijing Graduate School, on "Permo-Triassic events in the Eastern Tethys".

With this project, the large opening of China to Western scientists became operative and a successful conference took place in Beijing, March 1984, followed by the fieldtrip to Shangsi section in northern Sichuan province (Fig. 21, right). This is the start of an active collaboration on Permian-Triassic boundary studies with Chinese colleagues.

In July 1986 at Brescia (northern Italy), our Italian colleagues organized a field conference on Permian and Permian-Triassic boundary of Western Tethys sponsored by the IGCP Project 203. The Proceedings of the Field Conference were published at the "Memorie della Societa Geologica Italiana" (Cassinis, ed., 1988, Fig. 22, left) with new views and aspects on the Permian-Triassic boundary. An invitation was addressed to the members of the International Sub-commission on Triassic stratigraphy (SST) and to the members of the Permian-Triassic Boundary working group to participate to a post conference field trip (Fig. 22, right) on Permian and Triassic of Western and Southwestern Turkey (Visscher, 1986) with the Kemer Gorge and the Curuk Dagh PTB sections and a guidebook was published (Marcoux, ed., 1986).

IGCP Project 199: "Rare events in Geology", 1984

The IGCP project 199 on "Rare events in Geology" started in 1984 under the leadership of Prof. Ken Hsu (ETH Zurich, Switzerland).

Among "Rare events", the Permian-Triassic largest extinction was the subject of a Conference in Beijing in 1987, followed by a visit to the Nanjing Geological Institute (Fig. 23) and by an international field workshop to the Meishan section, with the first opportunity to sample the PT Boundary in the Meishan quarries.

Boosted during the 1980's by the IGCP Project 199, Bill Holser (Fig 24), from Oregon University in Eugene (USA), directed geochemical studies towards Permian and Triassic successions. With him and Mordekai Magaritz from Rehovot University (Israel), we started in 1985, the first database on stable carbon isotopes of more than twenty Permian-Triassic boundary sites from Southern Alps to South China, from studied sample collections stored in Lausanne Geological Museum. We published (Baud et al., 1989) twelve well dated sections with C isotope curve from bulk rock marine carbonate samples showing, for the first time, the global shift (Fig. 24 right) at the boundary: a new tool for marine Permian-Triassic boundary correlation was open and two main PTB candidate sections, Meishan and Shangsi were concerned and illustrated.

With Viorel Atudorei and Halil Sharp (Lausanne University), we provided a detailed C isotope data on a third PTB candidate, the Guryul Ravine section, Indian Kashmir (Baud et al., 1996). Some years later in Lausanne, Viorel Atudorei was the first to publish a complete C isotope curve of the marine lower Triassic, showing large positive anomalies within the well dated marine succession of the Spiti Valley (Atudorei, 1999) and, Sylvain Richoz (2004) first reported very detailed C isotope curves from PTB sections in Turkey, Iran and Oman.

IGCP Project 272: Late Paleozoic and Early Mesozoic Circum-Pacific Bio-Geological Events, 1988-1992

Succeeding to the IGCP Project 203, the Project 272: Late Paleozoic and Early Mesozoic Circum-Pacific Bio-Geological Events was leaded by J.M. Dickins from Australian Geological Survey.

Just after the Kyoto IGC (end of August 1992), Profs. Yuri Zakharov and Galina Kotlyar organized with my help the first Permian-Triassic conference (Fig. 25, right) and field workshop in Vladivostok (Russia). It was sponsored by the IGCP Project 272 and supported by the STS. The participants get the opportunity to visit four main Permian-Triassic sections of this Far-East Russian area, just open to foreigners' scientists. A first report was published by Dickins (1993). The proceedings of the field workshop went out in Lausanne (Baud et al., ed., 1997, Fig. 25, left) and the main Project 272 results were published by Dickins et al. (1997).

LATE PERMIAN AND TRIASSIC WORKSHOP MEETING IN WESTERN TURKEY (July 12-23, 1986) - REPORT

Four institutions joined their efforts to organize a workshop and field meeting on the Late Permian and Triassic of western Turkey: (1) the Technical University of Istanbul (with Prof.Dr. K. Kafali, rector of the University), (2) the Faculty of Mines, Istanbul (with Prof.Dr. E. Yüzer, Dean of the Faculty, Dr. A.M.C. Sengör, Dr. N. Ozgül, Dr. R. Akkök), (3) the "Laboratoire de Tectonique" of Paris VII University (with Dr. J. Marcoux) and (4) the Subcommission on Triassic Stratigraphy (with Dr. A. Baud, Vice Chairman).

The meeting was attended by 22 specialists from 11 countries and 4 continents; it was small enough to enable warm and durable contact between the participants.

Figure 22 – Left, cover of the Brescia Conference Proceedings; right: report on the PT West Turkey field workshop, 1986.

NO. 199 – RARE EVENTS IN GEOLOGY

K.J. Hsü, Geological Institute, ETH-Zentrum, Sonneggstrasse 5, 8006 Zürich, Switzerland.

The Second International Meeting of the project was held in Beijing, China, 3–5 March 1987, with participants coming from ten countries: Austria, Canada, People's Republic of China, France, Italy, Spain, Switzerland, the United Kingdom, U.S.A. and USSR. Some 30 papers were presented followed by two sessions of general discussion on various aspects of rare events and mass extinctions. Chinese geologists reported that biological mass extinctions, stable isotope perturbations, geochemical anomalies and microspherules have been found not only across the Cretaceous/Tertiary boundary, but also the Permian/Triassic, Devonian/Carboniferous, Frasnian/Famennian, Ordovician/Silurian, and Precambrian/Cambrian boundaries in China. However, much work is needed to confirm the preliminary results. Professor K.J. Hsü gave a paper on the use of carbon isotope as a monitor for biomass. D. McLaren emphasized that the mass extinctions in geological history are not only distinguished by the disappearance of many taxa, but more impressive is the nearly total destruction of the biomass by the boundary event. Many participants took part in a five-day post-conference field trip to Changxing in Zheijang province.

Figure 23 – Left, IGC Project 199 Beijing meeting report; right: the participants of the "rare events" meeting on the steps of the Nanjing Geological Institute, March 1987; in black and in middle front, Ken Hsü, leader of IGC Project 199.Institute, March 1987.

William T. Holser

Sonderdruck

aus

Geologische Rundschau

Band 78, 1989 · Heft 2, August 1989

A. Baud, M. Magaritz and W. T. Holser

Permian-Triassic of the Tethys: Carbon isotope studies

Ferdinand Enke Verlag · Stuttgart

Geologische Rundschau 78/2 | 649–677 | Stuttgart 1989 | © Geologische Vereinigung, Mendig

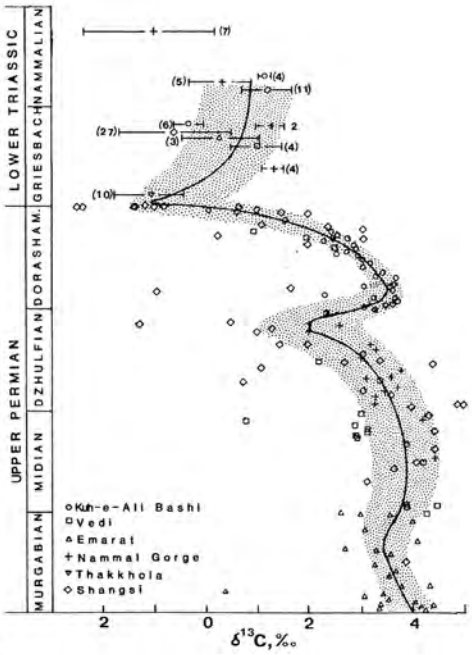


Figure 24 – Left, W.T. Holser photo; middle: cover of the 1989 Baud, Holser and Magaritz Carbon isotope studies paper; right: the Carbon isotope global shift as shown in the last figure.

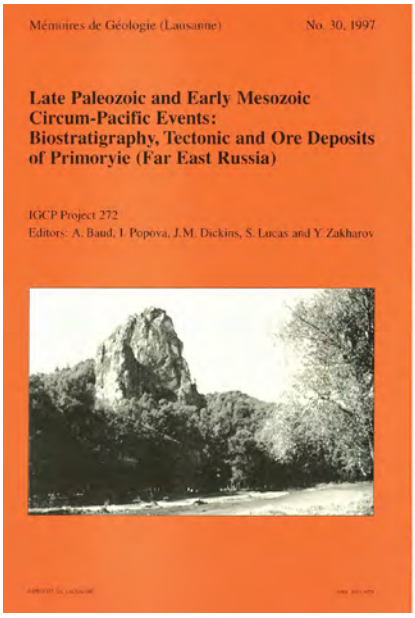


Figure 25 – Left, cover of the Vladivostok Permian-Triassic conference Proceedings; right: round table on IGCP Project 272 during the Vladivostok Permian-Triassic conference with Y. Zakharov, G. Kotlyar, J. M. Dickins, chairman, and the author.

IGCP project 359: Correlation of Tethyan, Circum-Pacific and marginal Gondwanan Permo-Triassic (1993-1998)

Led by Prof. Hongfu Yin (Fig. 26), this project, starting in 1993 and continued through 1997, gave to the participants the opportunity to participate to specific international meetings with group discussion on the PTB and to visit Permian-Triassic sections in South China, in North Vietnam and in North Caucasus. For the PTB, one of the major achievements was the publication of the Yin's edited book (1996) on the four PTB candidates (Fig. 26, right).

Hongfu Yin

International Geological Correlation Programme, Project no. 359: Correlation of Tethyan, Circum-Pacific and marginal Gondwanan Permo-Triassic

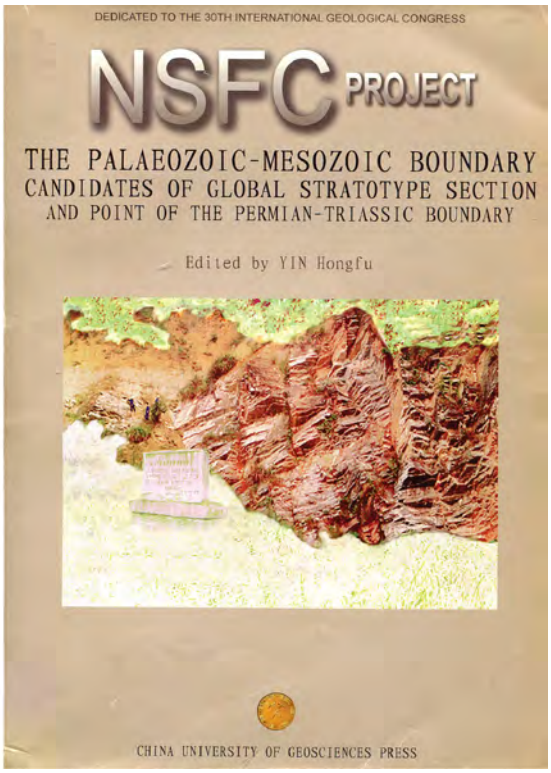


Figure 26 – Cover of Yin's edited book on the four PTB candidates (1985)

THE INTERNATIONAL SUBCOMMISSION ON TRIASSIC STRATIGRAPHY (SST) AND THE PERMIAN-TRIASSIC BOUNDARY WORKING GROUP (PTBWG)

The history of the Subcommission on Triassic stratigraphy up to 1984 has been well described by Tozer (1985). Albertiana, the STS newsletter and platform of discussion publishing preliminary notes, played a very important role in promoting agreement among scientists about criteria fixing the Permian-Triassic boundary, as did Permophiles, the Subcommission on Permian Stratigraphy newsletter (Fig. 27).

Divergent opinions to define the boundary: ammonoid versus conodonte

During the 1980's two main camps rose out, the ammonoid workers with Tim Tozer and the new conodont worker group supported by Prof. H. Yin, former student of Prof. Z.-Y. Yang.

In 1984, Tim Tozer asked the PTBWG members about how to define the base of the Triassic. The great majority answered the *Otoceras* beds. But Normam Newell expressed his choice with the base of the Dienerian as published in his 1988 paper. Galina Kotlyar (1990) was in favor of the *Ophiceras* zone and correlative *Isarcica* conodont zone as Walter Sweet (1988, 1992). The Tozer's proposal was supported by the papers of A. Dagis (1988) and of Nakazawa (1992, 1993).

The conodont specialists get their defender with the H. Yin proposals (Yin, 1988): the first occurrence of the *Hineodus parvus* conodont to define the base of the Triassic, -and the top of boundary clay of Chinese sections as boundary stratotype.

The Lausanne Conference (1991)

Elected STS Chairman during the Washington ICS in 1989, I prepared with my colleagues Jean Guex (Lausanne), Maurizio Gaetani (Milano), Jean Marcoux (Paris) and Hans Rieber (Zurich) a Triassic Conference in Lausanne, Switzerland, for October 1991 with the participation of most of the Subcommission voting members. This conference was followed by a one day fieldtrip in the Triassic succession of the nearby Prealps (Fig. 28, right). The Triassic Conference proceedings were published 3 years later (Guex and Baud, eds., 1994, Fig. 28 left). Urged by the International Commission on Stratigraphy (ICS) we had, during this conference, to decide how to subdivide the Early Triassic period among four proposals (subdivision in 1, 2, 3 or 4 stages). After a long discussion, the majority of the

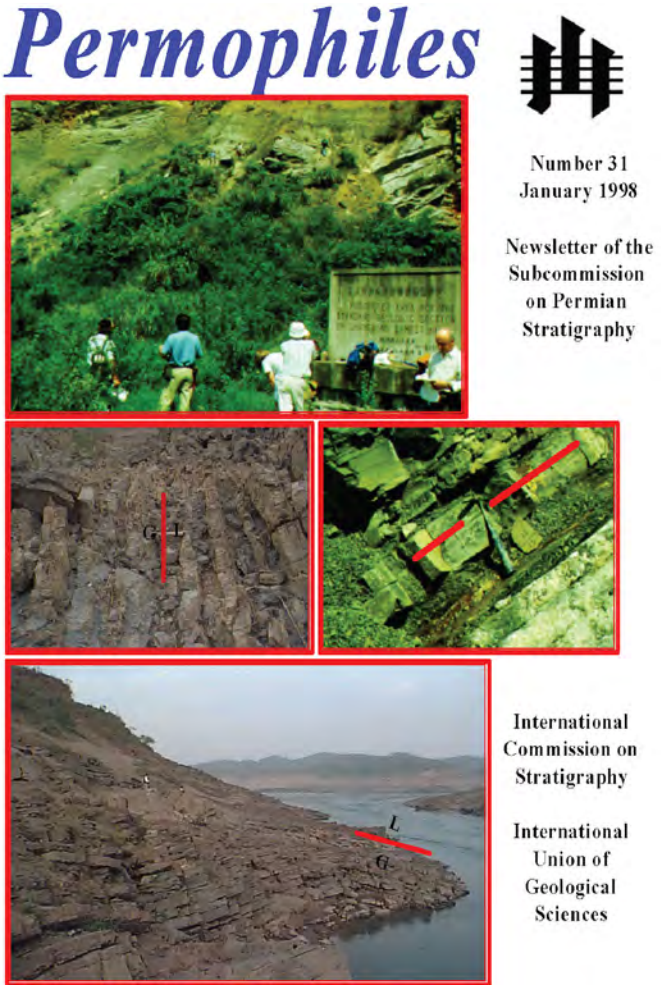


Figure 27 – Left, cover of Albertiana 17 with *Ophiceras tibeticum*; left: cover of Permophiles 31 with PTB view in Meishan quarry (up and right).

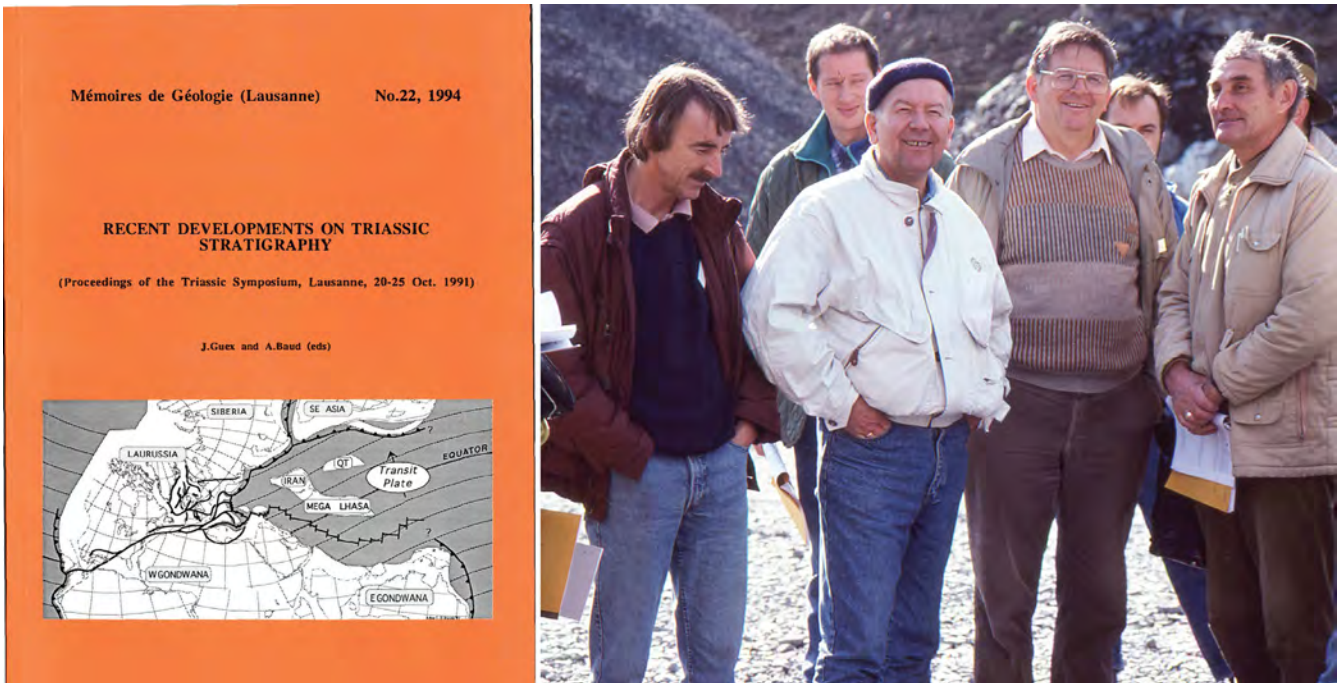


Figure 28 – Left, cover of the 1991 Triassic conference Proceedings (Guex and Baud, Eds., 1994); right: the Triassic ammonite specialists W. Weitschat, A. Dagis, H. Rieber and Y. Zakharov in the Saint-Triphon quarry (post-Triassic conference fieldtrip in Western Switzerland).

voting members proposed the two stage subdivision, named Induan and Olenekian. A detailed report was made by Gaetani (1992). I forwarded the choice to the International Commission on Stratigraphy (ICS) and the new stage names were officially adopted in 1992 during the International Geological Congress (IGC) in Kyoto.

The Permian-Triassic Boundary Working Group (PTBWG) reactivated

The next step of the STS was the setting up of stage boundary working groups on Global Stratigraphic Section and Point (GSSP). As the discussion at the PTBWG was, from 1984, deadlocked, I proposed to H. Yin to reactivate it. Early in 1993, a majority of the voting members elected Yin Hongfu as new chairman. Efficiently, he submitted four GSSP candidates for the boundary: the Meishan section (South China), the Shangsi section (West China), the Selong section (South Tibet) and the Guryul Ravine section (Kashmir, Northern India).

Very active, with the support of the Chinese geological community, he answered point by point to the 1988 Tozer's views, showing the main difficulties when using the ammonoid *Otoceras* to fix the boundary, and the great advantage to move to conodont study for the correlations (Yin, 1994). This was debated during the 1994 PTBWG meeting in Calgary. Yin Hongfu received also a strong support in a 30 pages paper leaded by H. Kozur, with A. Ramovs, C.Y. Wang and Y. Zakharov, to use *Hindeodus parvus* (Kozur & Pjatakova, 1976) for the PTB definition and to set up the Meishan quarry for the stratotype (Kozur et al., 1994).

In 1995, a majority of the working group approved the Meishan section proposal for Permian-Triassic GSSP. This was forwarded to the STS members with the new Yin's edited book (Fig. 26) on the four candidates (1996).

Return to High Arctic lower Triassic stratotype

Invited by Benoit Beauchamp I started collaborative work on the Permian-Triassic transition on Ellesmere Island during the summer 1992. Two years later, with Charles Henderson, we sampled High Arctic localities with *Otoceras* for conodont studies, to solve the controversy about the lower *Otoceas* zone correlation. The results were published in the Proceedings of the Beijing IGC 1996 (Henderson and Baud, 1997, Fig. 29, left) showing for the first time that overlying Changxingian conodonts, the *Hindeodus parvus* species appears in the middle of the upper *Otoceras* zone (*Otoceras boreale*).

ACHIEVEMENTS: THE NEW GSSP IN THE MEISHAN QUARRY

At the International Geological Congress (IGC) in Beijing (1996), Yin Hingfu proposed the base of bed 27C at Meishan section D with the first occurrence of the conodont *Hindeodus parvus* for the base of the Triassic GSSP (Yin et al., 1996). But I made the following warning of the very condensed succession of the Permian-Triassic transition at the Meishan locality with a frequent facies changes just below the boundary (not recommended for a stratotype, Baud, 1996)). And the long range, with numerous morphotypes of the selected *H. parvus* conodont genus erected by Heinz Kozur on the finding of Pjatakova in Transcaucasia (Kozur and Pjatakova, 1976) can

Proc. 30th Int'l. Geol. Congr., Vol. 11, pp. 143-152
Wang Naiwen and J. Remane (Eds)
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CORRELATION OF THE PERMIAN-TRIASSIC BOUNDARY IN ARCTIC CANADA AND COMPARISON WITH MEISHAN, CHINA

CHARLES M. HENDERSON
Department of Geology and Geophysics, University of Calgary, Calgary, Alberta, CANADA
and
AYMON BAUD
Geological Museum, UNIL-BFSH 2, CH-1015, Lausanne, SWITZERLAND.

ABSTRACT

Correlation of the Permian-Triassic boundary (P-T) is impeded, in part, by the lack of biostratigraphic correlations between tethyan and boreal settings and the presumed unconformity at many P-T sections in the world. Sequence stratigraphic and biostratigraphic data were collected from six sections of the basal part of the Blind Fiord Formation (Confederation Point Member) on northwestern Ellesmere and Axel Heiberg islands; sequence biostratigraphic data are presented in this paper for only the Griesbach Creek and South Otto Fiord sections. These data address some of these impediments, and allow comparisons to be made with the possible Global Stratotype Section and Point (GSSP) at Meishan, China.

Figure 29 – Left, first page of Henderson and Baud (1997); right: the Permian-Triassic team with the author between Charles Henderson (left) and Benoit Beauchamp at Otto fiord, Ellesmere Island, 1994.

likely brought problems in the determination and consequently in the correlation. Also a detailed discussion on the diachronic *H. parvus* conodont first occurrence was published in Orchard and Krystyn (1998).

Following a positive vote in 1999 by the STS voting members on the Meishan GSSP, the proposal was sent by Maurizio Gaetani, new STS Chairman to the ICS and ratified by the ICS general Assembly, during the Rio de Janeiro IGC in 2000. And the new GSSP final report appears in Episode (Yin et al, 2001). Officially, the Meishan section became the new Erathem boundary with the base of the Triassic Period fixed in the Meishan quarry (Fig. 30, left) .

This was unveiled in this quarry by an opening Ceremony of the GSSP Monument, August 11, 2001 (Fig. 30, right), during the International Symposium on "The Global Stratotype of the Permian-Triassic Boundary and the Paleozoic- Mesozoic Events" held in Changsing City and leaded by H. Yin.

Thus, after a long time, a successful achievement were done and now the Meishan quarry houses a huge Geopark including an Earth History Museum with giant sculptures and educational exhibitions.

Figure 30 – Left, cover Albertiana 26; right the red ribbon cut ceremony of the Erathem boundary monument, in the Meishan quarry, August 11, 2001 with Charles Henderson (left) and the author.

SOME CONCLUSIONS

During more than a Century were a rash of stage names for the underlying late Permian as Saxonian, Araxian, Chhidruan, Amarassian, Tatarian, Djoulfian / Dorashamian, Changhsingian. Same of plenty stage names happen to the following lower Triassic with successively Buntsandstein, Scythian, Brahamian, Gangetian, Werfenian, Induan or Griesbachian. Finally, the ICS adopted the Changhsingian for the latest Permian stage and the Induan for the Earliest Triassic stage.

With the adoption of the Permian-Triassic GSSP in the Meishan quarry by the ICS and the IUGS, started a boom in Permian-Triassic transition studies, special volumes and publications. Large opening of South China to foreign scientists, new IGCP projects on extinction and recovery were encouraging teams of young researchers in paleontology, biostratigraphy, magnetostratigraphy, geochemistry and absolute dating, with the coming out of hundreds of new papers each year.

But now, with the discover of extended latest Permian sections in South China and extended earliest Triassic sections in Artic areas, the actual Meishan highly condensed GSSP section shows his borderline. As an extremely short duration of the Induan have been established recently (see Burgess et al., 2014, Ovtcharova et al., 2007), sure a new subdivision of the lower Triassic will be proposed and a new locality for the GSSP will come in the next future.

ACKNOWLEDGEMENTS

Thanks to Prof. Christopher A. McRoberts for his advice and help to improve a first version of this illustrated historical study.

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