Preliminary paleomagnetic results from the Permian-Triassic boundary interval, Central and NW Iran

Michael Szurlies[1] & Heinz W. Kozur[2]

[1]*GeoForschungsZentrum Potsdam, Section 3.3 Climate dynamics and Sediments, Telegrafenberg, D-14473 Potsdam, Germany*

[2]*Rézsü u. 83, H-1029 Budapest, Hungary*

Introduction

The global character of geomagnetic polarity reversals has made magnetostratigraphy an essential tool for precise facies-independent correlation between different depositional environments. Because of the absence of pre-Jurassic seafloor in present oceans and thus marine magnetic anomalies, magnetostratigraphy in Permian and Triassic sections requires good biostratigraphic control. By decision of the IUGS the Global Stratotype Section and Point (GSSP) of the Permian-Triassic boundary (PTB) is now the Meishan section D (China), base of bed 27c, at the first appearance of the conodont *H. parvus* (e.g., Yin et al. 2001), providing a point of reference for both magnetostratigraphic and biostratigraphic investigations. In the last two decades, significant progress has been made in constructing a geomagnetic polarity scale for the PTB interval (e.g., Heller et al. 1988, Steiner et al. 1989, Li & Wang 1989, Ogg & Steiner 1991, Zakharov & Sokarev 1991, Heller et al. 1995, Hounslow et al. 1996, Nawrocki 1997, Scholger et al. 2000, Gallet et al. 2000, Szurlies et al. 2003).

With respect to magneto- and biostratigraphy, two main correlation problems are present at the PTB. First, there are published different geomagnetic polarity patterns for the *C. meishanensis-H. praeparvus* and *H. parvus* zones at Meishan (Li & Wang 1989, Zhu & Liu 1999). Secondly, in several studies the base of the thick normal magnetozone around the PTB is regarded as the PTB (e.g., Steiner et al. 1989, Ogg & Steiner 1991, Scholger et al. 2000, Gallet et al. 2000, Jin et al. 2000), whereas in others it is located within the uppermost Permian (e.g., Li & Wang 1989, Zakharov & Sokarev 1991, Szurlies et al. 2003, Bachmann et al. 2003).

The aim of this and a following more detailed study of the PTB interval from the Jolfa section of NW Iran is to examine the base and size of the thick normal magnetozone around the PTB using both magnetostratigraphy and high-resolution conodont zonation (Kozur, in press).

Remarks to magnetostratigraphies around the Permian-Triassic boundary

Li & Wang (1989) presented a magnetostratigraphy for the Meishan section, in which the relatively thick normal magnetozone (V) begins at least 1.2 m (or 2.7 m, with the first 1.5 m being of unclear polarity) below the Boundary Clay. According to Mei et al. (1998), the base of this normal interval is situated within the *C. yini-C. zhangi* Zone (Upper Permian). However, recently Zhu & Liu (1999) have shown that the normal magnetozone begins much earlier, just about 5.07 m below the PTB within the upper third of the *C. changxingensis-C. deflecta* Zone well below the *C. yini-C. zhangi* Zone. Consistently, in both polarity patterns the normal magnetozone ranges up to the *I. isarcica* Zone, but in the recent study just around the PTB, there is a 0.06 m thick reversed polarity zone within Bed 27, which is straddling the PTB (two samples below the PTB, one sample above it).

Peng et al. (2001) used these new paleomagnetic data from the GSSP at Meishan for a high-resolution correlation with the Shangsi section (China). They compare Bed 26 from Shangsi, being of reversed polarity with the thin reversed magnetozone of Bed 27 from Meishan. As clearly seen by the fauna and also by carbon isotope data, this correlation cannot be confirmed. Whereas Bed 26 from Shangsi is characterized by a rich conodont fauna, before the event boundary, belonging to the *C. changxingensis-C. deflecta* Zone, Bed 27 from Meishan has a poor conodont fauna, after the event boundary, spanning the upper *H. praeparvus* Zone and the entire *H. parvus* Zone. In terms of magnetostratigraphy, Beds 22-26 from Shangsi show reversed polarity, Bed 27 is of unknown polarity and Beds 28-31 belong to a normal magnetozone (e.g., Heller et al. 1988, Steiner et al. 1989). According to Nicoll et al. (2002), the *H. parvus*-calibrated PTB is located within Bed 30. In addition, around the PTB there is a minimum in the carbon isotope curve (Baud et al. 1989). Correspondingly, the base of the Triassic is located within the relatively thick normal interval, which is extending into the uppermost Permian.

According to results from Abadeh, Central Iran (Gallet et al. 2000), the thick normal magnetozone begins latest somewhat above the Boundary Clay (0.77m above the base of the Boundary Clay). Since the FAD of *H. parvus* is 1.38 m above the base of the Boundary Clay (Kozur 2003), the thick normal interval starts in the uppermost Permian. Between 0.45 m below the Boundary Clay (uppermost sample with reversed polarity) and 0.77m above the Boundary Clay (lowermost sample with normal polarity) is an interval which did not yield palaeomagnetic data by Gallet et al. (2000). Thus, the thick normal interval starts probably already in the uppermost Hambast Formation. Close to the FAD of *H. parvus,* there begin negative values in the carbon isotope curve (Korte et al. in press).

In the Dorasham II-3 section of Azerbaijan the thick normal magnetozone starts at 0.5 m below the top of the *Paratirolites* Beds (Zakharov & Sokarev 1991). The *H. parvus*-calibrated PTB is located more than 1 m above the top of the *Paratirolites* Beds, thus the base of the normal interval is situated in the uppermost Permian. In the only a few kilometer distant Jolfa section (Iran), the corresponding level 0.5 m below the top of the *Paratirolites* beds belongs to the upper *C. yini-C. zhangi* Zone. Therefore, paleomagnetic results from the GSSP at Meishan (Li & Wang 1989) and the composite Dorasham (Zakharov & Sokarev 1991) and Jolfa sections from the Azerbaijan-NW Iran region, and from the Abadeh section are in good accordance.

In the Bulla (Pufels) section of the Southern Alps (Italy) the thick normal magnetozone (Scholger et al. 2000) begins close to the boundary between the Bellerophon Limestone Formation and the Tesero Horizon (youngest reversed sample 5 cm below the top of the Bellerophon Limestone Fm, oldest normal sample 5 cm above the base of the Tesero Horizon), distinctly below the FAD of *H. parvus*. The carbon isotope values of the lowermost Tesero Horizon correspond to those of the *C. yini-C. zhangi* Zone of Meishan and Jolfa (Korte & Kozur in press). In the WSW-ward situated Siusi (Seis) section the base of the normal magnetozone is located in the interval between 42 cm (uppermost reversed magnetised sample) and 72 cm above the base of the Tesero Horizon (lowermost normal magnetised sample) either within the uppermost Tesero Horizon or within the lowermost Mazzin Member (Scholger et al. 2000). Since the PTB in this section is located some 7 m above the base of the Tesero Horizon, being also indicated by negative values in the carbon isotope curve (Newton et al. 2004), the normal magnetozone is extending into the uppermost Permian. The comparison of the beginning of the normal magnetozone which straddles the PTB in the Bulla and Siusi section indicates a clearly diachronous boundary between the Bellerophon Limestone Formation and the Tesero Horizon which was already postulated by Kozur (1994) and can be also confirmed by stable isotope data (Korte & Kozur, in press).

In the Arctic the FAD of *H. parvus* is within the *T. pascoei* Zone, which is located between the *O. boreale* s.s. and the *Ophiceras commune* zones (Kozur 1998b). In terms of magnetostratigraphy, both ammonite zones belong to an interval of normal polarity, to which belongs also the *O. concavum* Zone (Griesbach Creek, Arctic Canada, Ogg & Steiner 1991). Therefore, also in the Boreal realm the base of the relatively thick normal magnetozone is situ-

Figure 1: Position of the studied Iranian sections
1: Kuh-e-Ali Bashi section, 9 km W of Jolfa village.
2: Shahreza section, 14 km NW of Shahreza village, 3.5 km SE of Shahzadeh Ali Akbar village.
3: Abadeh section, Kuh-e-Hambast, 60 km SE of the town of Abadeh

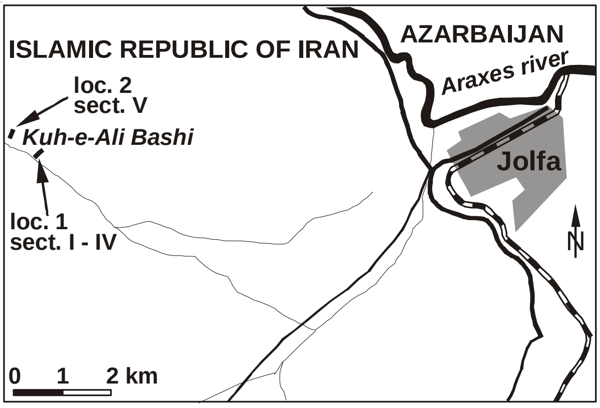

Figure 2: Investigated sections from Kuh-e-Ali Bashi, 9 km SW of Jolfa village (after Korte & Kozur, in press). Palaeomagnetic samples are from section V.

ated within the uppermost Permian.

Summarily, in virtually all well dated marine sections straddling the PTB, there is no reversed horizon around the FAD of *H. parvus*, except the recent study from the GSSP at Meishan (Zhu & Liu 1999).

Preliminary rock and paleomagnetic results from Central and NW Iran

The Iranian sections Abadeh (Conodont Alteration Index, CAI = 3), Shahreza (CAI = 2.5) and Jolfa (CAI = 1) (**Fig. 1**) were sampled for rock and paleomagnetic investigations in order to check the beginning and size of the thick normal interval around the PTB. All these sections were around the PTB on the southern hemisphere between tropic of Capricorn (Abadeh) to about 1000 km north of it (Jolfa), and Shahreza in between. 12 limestone beds were collected, yielding a total of 42 oriented standard (~11 cm^3) paleomagnetic samples. Whereas 26 specimens were subjected to thermal demagnetization, 16 samples were demagnetized by alternating fields. The thermal treatment was performed using an ASC Scientific TD48 oven. Measurements of natural remanent magnetization (NRM) were made using an AGICO JR5A spinner magnetometer. The alternating field demagnetization was performed using the in-line triaxial alternating field demagnetizer of an automatic DC-SQUID 755SRM cryogenic magnetometer (2G Enterprises).

Furthermore, from each horizon one specimen was exposed stepwise, to peak fields of 10 to 2700 mT in order to record complete acquisition curves of isothermal remanent magnetization (IRM). It was applied with a 2G Enterprises 660 pulse magnetizer and measured with a Molyneux MiniSpin fluxgate magnetometer.

The magnetic properties obtained from this preliminary study are similar to results recently presented by Gallet et al. (2000). The NRM intensities of the limestones range between 0.2 and 5.5 mA/m.

In the Abadeh section two horizons were sampled, the first limestone bed above the Boundary Clay (*C. meishanensis-H. praeparvus* Zone) and another one (upper stromatolithe layer) located ~1.8 m above the base of the Boundary Clay (*H. parvus* Zone). All 5 specimens reveal a rather strong present-day overprint. It is removed below 300°C, with the majority of NRM unblocked below 150°C and linked to a high coercivity component not reaching saturation of IRM by 2.7 T, indicating the presence of goethite. Demagnetization to higher temperatures yielded scattered directions. Thus, no identifiable characteristic component of ancient origin is apparently present in these samples. Only one specimen from the *H. parvus* Zone reveals an isolable high temperature component with a maximum unblocking temperature of 570°C. It is linked with a low coercivity component saturated between 100 and 200 mT, which can be ascribed to magnetite. It has a shallow negative inclination and a southeastward declination, similar to recently obtained data (Besse et al. 1998, Gallet et al. 2000). It is regarded as a primary component, aquired during a geomagnetic field of normal polarity.

In the Shahreza section three horizons around the PTB were sampled, yielding a total of 10 specimens. In most cases, the samples are characterized by a strong recent overprint, with the majority of NRM, being unblocked below 200°C, which is attributed to goethite. Above 200°C most samples are indicated by scattered directions, being similar to results obtained from the Abadeh section. Only two samples from a horizon 7-11 cm below the base of the Boundary Clay (around the boundary between the *C. iranica* Zone and *C. hauschkei* Zone of upper Dorashamian) reveal a characteristic component aquired during a normal geomagnetic field. It is carried by a low coercivity component, aquiring majority of IRM below 100 mT and being unblocked at maximum blocking temperatures of 580°C, ascribed to the presence of magnetite.

In the Jolfa section (**Figs. 2, 3**) seven horizons were investigated, yielding a total of 27 specimens. The IRM acquisition curves are all similar in shape acquiring the majority of IRM in fields smaller than 100 mT, but not reaching saturation by 2700 mT. At first, a weak local present-day overprint with maximum unblocking temperatures of 250°C is removed. Usually, above 250°C with maximum unblocking temperatures of 560-580°C a further component is isolated and interpreted as characteristic remanence, carried by magnetite. Only in specimens from site P1 the high-temperature component is characterized by maximum unblocking temperature of 670°C and linked with a high-coercivity component, being saturated between 500 and 1000 mT, indicating the presence of hematite.

Whereas specimens of site P0 from the upper *C. changxingensis-C. deflecta* Zone were magnetized during a reversed geomagnetic field, all other samples (P0A-P5) from the *C. hauschkei, H. parvus* and *I. isarcica* zones aquired their magnetization during a normal geomagnetic field. These preliminary data are consistent with results

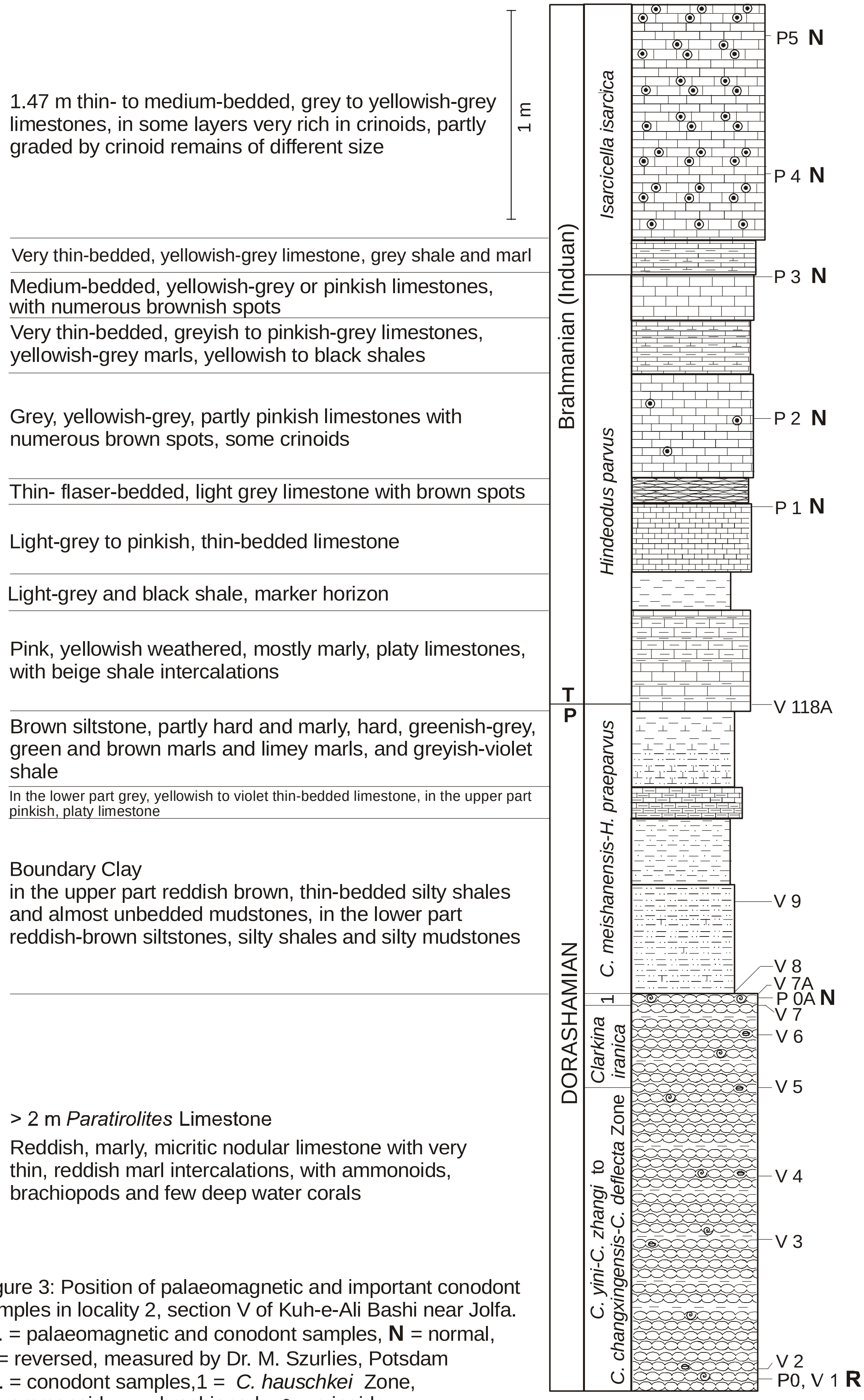

Figure 3: Position of palaeomagnetic and important conodont samples in locality 2, section V of Kuh-e-Ali Bashi near Jolfa. P... = palaeomagnetic and conodont samples, **N** = normal, **R** = reversed, measured by Dr. M. Szurlies, Potsdam V... = conodont samples,1 = *C. hauschkei* Zone, = ammonoids, = brachiopods, = crinoids

from Azerbaijan (Zakharov & Sokarev 1991).

Conclusions

As to expect from the Conodont Alteration Index (CAI), the Jolfa section (Kuh-e-Ali Bashi, locality 2, section V) has brought the best paleomagnetic results. In future, this section will be studied in detail. Preliminary results suggest, that the PTB does not coincide with the base of the thick normal magnetozone, but that interval straddles the boundary extending into the uppermost Permian.

Including the beginning of the normal interval 0.5 m below the top of the *Paratirolites* beds in the nearby Dorasham II-3 section in Azerbaijan (Zakharov & Sokarev, 1991) some kilometers toward the north of the Jolfa section, the upper *C. yini*-*C. zhangi* Zone (proven in Dorasham II-3, Zakharov & Sokarev, 1991), the *C. hauschkei* Zone (proven in Jolfa), the *C. iranica* Zone (proven in Shahreza), the *C. meishanensis*-*H. praeparvus* Zone (proven in Abadeh, Gallet et al., 2000), the *H. parvus* Zone (proven in Abadeh, Gallet et al., 2000, and confirmed by our rather weak data from this locality and our good data from Jolfa), and the lower and middle *I. isarcica* Zone (proven in Jolfa) belong to the normal interval which straddles the PTB. Beneath, the upper third of the *C. changxingensis*-*C. deflecta* Zone (proven in Jolfa), and perhaps the lower part of the *C. yini*-*C. zhangi* Zone (no data) belongs to a short reversed Zone.

Presented preliminary results and previous studies around the *H. parvus*-calibrated PTB (e.g., Heller et al. 1988, Zakharov & Sokarev 1991, Scholger et al. 2000) confirm the paleomagnetic data published by Li & Wang (1989) from the GSSP at Meishan. Furthermore, the results confirm the position of the PTB within the lower Calvörde Formation of the Lower Buntsandstein (e.g., Kozur, 1989, 1998a, 1999, Szurlies, 2001), situated within the lower part of the thick normal interval (sn1) (Szurlies, 2001, Bachmann et al., 2003, Kozur, 2003, Szurlies et al. 2003). The underlying thin reversed Zone (zrz) (Szurlies at al., 2003) corresponds to the upper third of the *C. changxingensis*-*C. deflecta* Zone, and to the lower part of the *C. yini*-*C. zhangi* Zone. In the Germanic Basin it comprises the lower Fulda Formation and the basal part of the overlying upper Fulda Fm (Szurlies et al. 2003).

References

Bachmann, G.H., Kozur, H.W. & Szurlies, M. (2003):Cyclostratigraphy, magnetostratigraphy and microspherules of the continental Permian-Triassic Boundary interval, Germany.- XVth Intern. Congr. on Carboniferous and Permian Stratigraphy, Abstracts Volume, 36-38, August 2003, Utrecht.

Baud, A., Magaritz, M. & Holser, W.T. (1989): Permian-Triassic of the Tethys: Carbon isotope studies.- Geol. Rdsch., **78**(2): 649-677.

Besse et al. (1998): Late Permian to Late Triassic palaeomagnetic data from Iran: constraints on the migration of the Iranian block through the Tethyan Ocean and initial destruction of Pangaea.- Geophys. J. Int., **135**: 77-92.

Gallet, Y., Krystyn, L., Besse, J. & Saidi, A. (2000): New constraints on the Upper Permian and Lower Triassic geomagnetic polarity timescale from the Abadeh section (central Iran).- J. Geophys. Res., **105** (B2): 2805-2815.

Heller, F., Lowrie, W., Li, H.M. & Wang, J.D. (1988): Magnetostratigraphy of the Permian-Triassic boundary section at Shangsi.- Earth. Planet. Sci. Lett., **88**: 348-356.

Heller, F., Chen H., Dobson, J. & Haag, M. (1995): Permian-Triassic magnetostratigraphy - new results from South China.- Physics Earth Planet. Inter., **89**: 281-295.

Hounslow, M.W., Mørk, A. Peters, C. & Weitschat, W. (1996): Boreal Lower Triassic magnetostratigraphy from Deltadalen, Central Svalbard.- Albertiana, **17**: 3-10.

Jin, Y., Shang, Q. & Cao C. (2000): Late Permian magnetostratigraphy and its global correlation.- Chinese Sci. Bull., **45**(8): 698-704.

Korte, C. & Kozur, H.W. (in press): Carbon isotope stratigraphy across the Permian/Triassic boundary at Jolfa (NW-Iran), Sass de Putia, Pufels/Bulla, Tesero (Southern Alps).- GeoAustria.

Korte, C., Kozur, H.W., Joachimski, M.M., Strauss, H. Veizer, J. & Schwark, L. (in press): Carbon, sulfur, oxygen and strontium isotope records, organic geochemistry and biostratigraphy across the Permian/Triassic boundary in Abadeh, Iran.- Int. Earth Sci.

Kozur, H. (1989): The Permian-Triassic boundary in marine and continental sediments.- Zbl. Geol. Paläont., **1988** (11/12): 1245-1277.

Kozur, H. (1994): The correlation of the Zechstein with the marine Standard.- Jb. Geol. B.-A., **137**(1): 85-103.

Kozur, H.W. (1998a): Some aspects of the Permian-Triassic boundary (PTB) and of the possible causes for the biotic crisis around this boundary.- Palaeogeogr., Palaeoclimatol., Palaeoecol., **143**: 227-272.

Kozur, H.W. (1998b): Problems for evaluation of the scenario of the Permian-Triassic boundary biotic crisis and its causes.- Geol. Croat., **51**(2): 135-162.

Kozur, H.W. (1999): The correlation of the Germanic Buntsandstein and Muschelkalk with the Tethyan scale.- Zbl. Geol. Paläont. Teil I, **1998** (7-8): 701-725, Stuttgart.

Kozur, H.W. (2003): Integrated ammonoid, conodont and radiolarian zonation of the Triassic and some remarks to Stage/Substage subdivision and the numeric age of the Triassic stages.- Albertiana, **28**: 57-74.

Kozur, H.W. (in press): Pelagic uppermost Permian and the Permian-Triassic boundary conodonts of Iran. Part I: Taxonomy.- Halle. Jb. Geowiss.

Li H. & Wang J. (1989): Magnetostratigraphy of Permo-Triassic boundary section of Meishan of Changxing, Zhejang.- Science in China, **8**(6): 652-658.

Mei S., Zhang K. & Wardlaw, B.R. (1998): A refined succession of Changhsingian and Griesbachian neogondolellid conodonts from the Meishan section, candidate of the global stratotype section and point of the Permian-Triassic boundary.- Palaeogeogr., Palaeoclimatol., Palaeoecol., **143**: 213-226.

Nawrocki, J. (1997): Permian to Early Triassic magnetostratigraphy from the Central European Basin in Poland: Implications on regional and worldwide correlations, Earth Planet. Sci. Lett., **152**: 37-58.

Newton, R.J., Pevitt, E.L., Wignall, P.B. & Bottrell, S.H. (2004): Large shifts in the isotopic composition of seawater sulphate across the Permo-Triassic boundary in northern Italy.- Earth Planet. Sci. Lett., **218**: 331-345.

Nicoll, R.S., Metcalfe, I. & Wang C. (2002): New species of the conodont genus *Hindeodus* and the conodont biostratigraphy of the Permian-Triassic boundary interval.- J. Asian Earth Sci., **20**: 609-631.

Ogg, J.G. & & Steiner, M.B. (1991): Early Triassic magnetic polarity time scale - integration of magnetostratigraphy, ammonite zonation and sequence stratigraphy from stratotype sections (Canadian Arctic Archipelago).- Earth Planet. Sci. Lett., **107**: 69-89.

Peng Y., Tong J., Shi G.R & Hansen, H.J. (2001): The Permian-Triassic boundary stratigraphic set: Characteristics and correlation.- Newsl. Stratigr., **39**:55-71.

Scholger, R., Mauritsch, H.J. & Brandner, R. (2000): Permian-Triassic boundary magnetostratigraphy from the Southern Alps (Italy).- Earth Planet. Sci. Lett., **176**: 495-508.

Steiner, M., Ogg, J., Zhang, Z. & Sun, S. (1989): The Late Permian-Early Triassic magnetic polarity time scale and plate motions of South China.- J. Geophys. Res., **94**(86): 7343-7363.

Szurlies, M. (2001): Zyklische Stratigraphie und Magnetostratigraphy des Unteren Buntsandsteins in Mitteldeutschland.- Diss. Uni. Halle, 116 pp.

Szurlies, M., Bachmann, G.H., Menning, M., Novaczyk, N.R. & Käding, K.-C. (2003): Magnetostratigraphy and high-resolution lithostratigraphy of the Permian-Triassic boundary interval in Central Germany.- Earth Planet. Sci. Lett., **212**: 263-278.

Yin H., Zhang K., Tong J., Yang Z. & Wu S. (2001): The Global Stratotype Section and Point (GSSP) of the Permian-Triassic boundary.- Episodes, **24**(2): 102-114.

Zakharov, Y. D. & Sokarev, A. N. (1991): Biostratigrafija i paleomagnetism permi i triasa Evrazii.- AN SSSR, Dalnevostochnoe otdelenie, Dalnevostochnyj Geologicheskij Institut, 135 pp., Nauka (Moskva).

Zhu Y. & Liu Y. (1999): Magnetostratigraphy of the Permian-Triassic boundary section at Meishan, Changxing, Zhejiang Province.- In: Yin H. & Tong J. (eds.) - Proceedings of the International Conference on Pangaea and the Paleozoic-Mesozoic transition. 79-84, Wuhan.