IGCP 572: RECOVERY OF ECOSYSTEMS AFTER THE PERMIAN-TRIASSIC MASS EXTINCTION

CR2P
Centre de Recherches sur la
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Field Guide Book

THE PERMIAN-TRIASSIC TRANSITION IN THE SOUTHWESTERN TAURUS MOUNTAINS (SOUTH TURKEY)

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In Memory of Jean Marcoux

PART 1 - HISTORICAL REVIEW, GEOLOGY AND STRUCTURE OF THE VISITED AREA

A- Historical review *(summary of Baud, 2009)*

Jean Marcoux in the Kemer Mountains at the start of his PhD (1970)

Jean Marcoux, in Memory of whom this Guidebook is dedicated, has studied and mapped the geology of the visited area.
Jean Marcoux studied in Paris XI University at Orsay in the geological laboratory of the Professor Jan Houghton Brunn. Getting an assistant position in 1969, he started out in Brunn’s laboratory a PhD thesis (French "Thèse d'Etat") on "The anatomy of the Antalya nappes in SW Turkey" after being introduced in the field by R. Lefèvre. He began his thesis in western Taurus together with four other Brunn’s students, Jean-François Dumont, Olivier Monod, André Poisson, and Marcel Gutnic.

From 1969 to 1976, he spent each year from 1 to 3 month in the field, mapping the geology of up to the equivalent of 20 sheets in 1:25'000 scale with the assistance and sponsoring of the Mineral Research and Exploration Institute (MTA) in Ankara

During this time he not only discovered and mapped 9 superposed nappes of different ages west of Antalya, but also learnt Turkish of the countryside. Working on shallow to deep water thrusted units of the Taurus Mountains, Jean reconstructed a model of the Neotethys Southern margin and, with his colleagues and friends J.P. Brun, J.P. Burg and E. Ricou, he was able to prove, by shear zone and microtectonic studies the Southward emplacement of the Ophiolite and Nappe system and consequently the northern position of the Neotethys Ocean in regard of the Taurus (Marcoux et al., 1987).

In 1985, we were invited by C. Şengör from Istanbul to organize, with L. Krystyn, O. Monod a field workshop of the Subcommission on Triassic Stratigraphy (STS) in Istanbul and in Kemer. Jean and I went to Kemer Gorge and Çürük dağ in October to verify sections for the Field guidebook. This workshop was very successful and about twenty STS Members participated with great interest (Marcoux et al., 1986). With W.T. Holser we sampled the boundary transition for C isotope studies. With Jean Marcoux we published a first paper on "The Permo-Triassic boundary in the Antalya Nappes (western Taurides, Turkey" (Marcoux and Baud, 1986) and with W.T. Holser and M. Magaritz we included the Çürük dağ section in our paper on "Permian-Triassic of the Tethys: Carbon isotope studies" (Baud et al. 1989).

In summer 1988, Jean started with his colleagues J. Besse, Y. Gallet and L. Krystyn a very successful research program in Southern Turkey on Triassic magnetostratigraphy. His broad knowledge of well-calibrated Triassic profiles had significant impact for their success. For a magnetostratigraphic study we starded fieldwork with J. Besse, drilling samples on the PT transition at the Çürük dağ crest. But according to J. Besse, after the laboratory processing, the magnetic records were too weak for reliable results. Following a detailed study of the

Çürük dağ thin sections and a comparisons with Iranian PT sections, we discovered a PT global change in carbonate sediments with the shift from Permian skeletal factories to basal Triassic microbial factories and we published with S. Cirilli a paper on "Biotic response to mass extinction: the Lowermost Triassic microbialites" (Baud et al., 1997) and this discover has been presented at numerous congresses.

Studying accessory elements (Sr, Mg, Mn, Fe) from samples of the Çürük dağ crest section, S. Zerari-Leduc published the results in her PhD Memoir (S. Zerari-Leduc, 1999) and her datas are presented in Fig. 6.

S. Richoz, started in 1999 his thesis on C isotope evolution during the PT transition. Jean Marcoux brought him his large knowledge of the geology of Taurus and N. Özgül from Istanbul introduced us to new PT sections in the Alanya and Taskent areas. A paper on Taurus basal Triassic microbialites was published in 2005 (Baud et al., 2005) and S. Richoz published his thesis one year later (Richoz, 2006).

S. Crasquin started ostracodes studies on samples of the Çürük dağ crest section and a first paper was published in 2002 (Crasquin et al., 2002).

For paleontologists (L. Angiolini, S. Crasquin and A. Nicora), Jean organised in 2002 successful fieldwork on the Çürük dağ section and participated as co-author in the three papers, results of these researches (Crasquin et al., 2004 a,b, Angiolini et al., 2007). We were given at that time, and up to 2007, a great help for logistics from the Demirel University of Isparta, and particularly from the Prof. F. Yagmurlu and we invited in the field geologists from Isparta.

Jean was always ready to help colleagues to have access to data or to get field permits to work as he did for D. Bottjer and S. Pruss, and in 2003 we sampled again the Çürük dağ crest section. P. Marenco started studies on S isotope from carbonate (Marenco et al., 2004, 2005) and we published two papers on microbialites (Pruss et al., 2006, Baud et al., 2007).

During these last years, we worked with Jean and S. Richoz on the Permian-Triassic paleotectonics of the upper Antalya nappes and we were able to measure the real thickness of the Çürük dağ Permian succession outcropping in dangerous cliffs and we get the surprise of a near 1km of thickness (Fig.14), twice as expected and reported in our previous papers and correlative to the new Permian section of the Kemer Gorge unit. Prospecting in the area of Gazipaça, we founded in 2007 the new Permian-Triassic section of Oznurtepe.

In 2008 we benefit from the support of the Akdeniz University Antalya, Faculty of Engineering (Geological Engineering) and Dr Erdal Kosun helped us greatly for logistics and in the field. S. Crasquin and M.B. Forel sampled the Çürük dağ crest section for ostracodes and C. Randon for conodonts. A. Nicora and a PhD student collected middle Permian brachiopods and sampled for conodontes on Çürük dağ basal south section. With S. Kershaw we looked at the microbialites and made a detailed study of the Permian-Triassic transition of the Oznur Tepe section. M.B. Forel sampled for ostracodes and C. Randon for conodonts. During our fieldworks on Jean's well-known sections, we all had his illness in the mind and when coming back we told him our deep gratitude and the success of the new paleontological field studies. He died few days later on June 17, 2008 and we can write here that Jean is still living in our memory and that he is at the root of many results presented in this guidebook.

B- **Geology and structure of the visited area** *(A.Baud and S. Richoz based on J. Marcoux studies)*

The three visited localities (Fig. 1) occur in the western and central Taurus, crop out southwest and southeast respectively of Antalya and belong to the Antalya Nappe complex. The western Taurus is built from a carbonate platform (autochtonous and parautochthonous units, Fig. 1), surmounted by a nappes complex of ophiolite, slope and basinal sediments. The platform units, appearing in windows below the nappes complex, are Cambrian to Miocene in age (Ricou et al., 1975). They record an Upper Senonian pre-obduction subsidence. The sedimentological and faunistic records show affinities with Gondwana (Ricou et al. 1975, Gutnic et al., 1979: "Axe calcaire du Taurus").

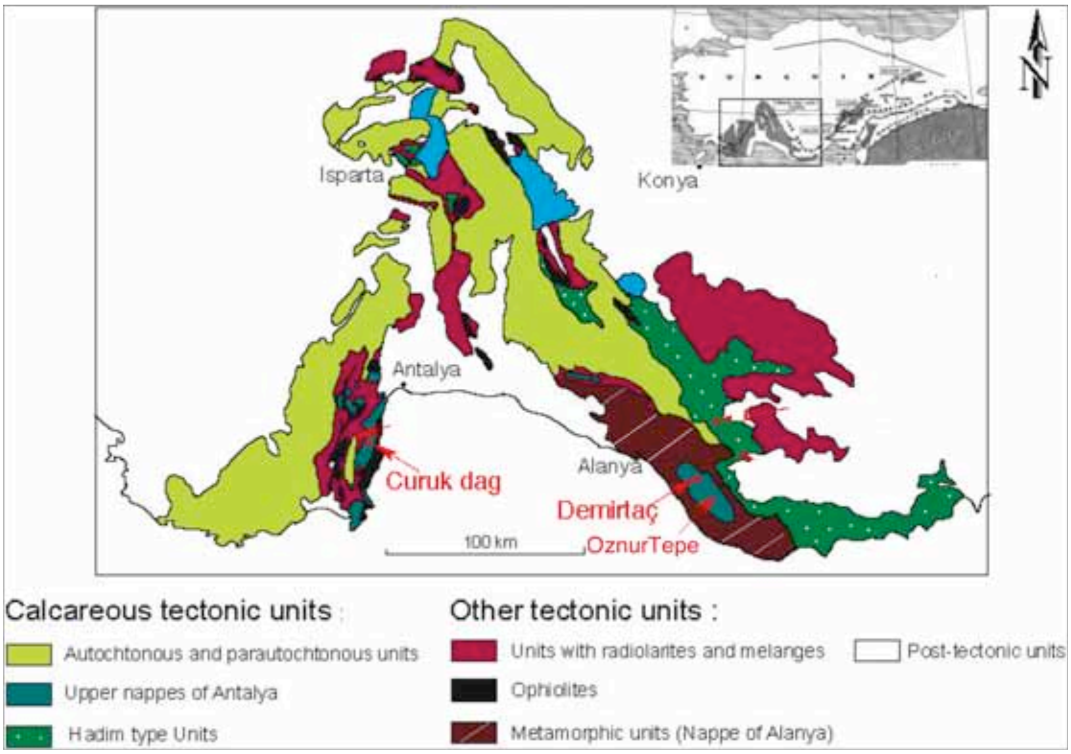


Figure 1: geological outline map of the Western Taurus with location of the fieldtrip sections and place of the Taurus in a sketch map of Turkey. Çürük dağ, N36'41'32-E30'27'40, alt. 1425m. Demirtaç 2: N36°27'35", E32°14'86", alt. 140m. Oznurtepe: N36°19'58", E32°21'3". alt. 101m. All the three sections are located in the Upper nappes of Antalya. Blue color is lakes! The Permian-Triassic succession of the Hadim type units has been described by Ünal et al., 2003, by Groves et al., 2005 and by Payne et al., 2007.

The allochtonous nappes include Lower Cretaceous ophiolitic Nappes with metamorphic sole, slope units (allodapic breccia, turbiditic sandstone), basinal units (radiolarite, pelagic limestone and alkali-basalts). These nappes lie on some place on olistostromes formed at the nappes front (Marcoux, 1970, 1987; Şenel et al., 1996). Three major tangential tectonic phases occur in the Late Cretaceous (obduction), in Eocene and Miocene with leapfrog events and are responsible of the structural complexity of the western and central Taurus.

This Antalya Nappe complex has been subdivided into the Lower, Middle and Upper Nappe, and each of them is further subdivided into tectonic units (Lefèvre, 1967; Marcoux, 1970, 1977, 1979, and Brunn et al., 1971). They are overlying the Beydağları para-autochthonous platform sequences. The Lower Antalya Nappes comprise upper to lower slope deposits (Çatal Tepe and Dereköy units of Marcoux and Poisson, 1972).

The Median Antalya Nappes comprise three superposed thrust units. From bottom to top these are: the Alakîr çay nappe (Brunn et a1. 1971; Marcoux, 1970; Delaune Mayere et a1., 1977) which is composed of Mesozoic basinal sediments; the Kara Dere-Sayrun Nappe (Marcoux, 1970; Juteau, 1975) characterized by thick Upper Triassic pillow-basalts; the ophiolitic nappe (Juteau, 1975, 1979) made up of peridotites and minor gabbros capped by Upper Cretaceous ophiolitic clasts (Lagabrielle et a1., 1986). This primary succession has been deformed by duplex thrusting and folding.

The Upper Antalya Nappes (Bakırlı, Kemer gorge and Tahtalı nappes of Marcoux, 1979) are made up of Paleozoic to Upper Cretaceous sediments (mainly limestones). Both the Bakırlı and Kemer gorge occupy the lower position; their distinction is mainly based on their differing stratigraphic sequences although both are truncated by southward ascending ramps. The Tahtalı Nappe rests upon an Upper Cretaceous olistostrome, which contains radiolarites and ophiolite debris on top of the Kemer gorge Nappe. The basal thrust plane truncates folds within this unit.

Following new mapping work, these tectonic units have been renamed by Şenel et al. (1996) and Şenel (1997). But here we will use the original nomenclature of J. Marcoux. Also in nappe position, the Antalya Units occurs to the southeast in the Alanya Tectonic Window below the metamorphic (blue schist) Alanya Nappes as shown by Ozgül (1976, 1984).

Concerning the origin of the Antalya and Alanya nappes with respect to the Taurus Autochthon (Beydaglan and Geyikdag Unit) a detailed historical review is given in Robertson et al. (2003) on the different hypotheses (sub-autochtonous, southern or northern origin).

As Marcoux, in Stampfli et al. (1991), we support the ideas that the Antalya nappes consist of an obducted Cretaceous oceanic crust and slivers belonging to the former Neotethyan continental margin and there is an agreement on the internal origin north of the Taurus Autochthon as proposed by Ricou et al. (1975, 1979, 1985) and by Marcoux et al. (1989). This has been also followed by recent Stampfli team's work (Moix et al., 2008).

PART 2: GENERAL OVERVIEW OF THE PERMIAN-TRIASSIC TRANSITION IN THE TAURUS MOUNTAINS

A- Introduction *(A. Baud).*

Part of the Permian-Triassic giant carbonate platform crops out in the Western Taurus Range (S Turkey) within different thrusted units of the Upper Antalya Nappes (Fig. 1). The Permian shallow carbonate limestones belong to the Pamuçak Formation and the Early Triassic calcimicrobial rocks (Fig. 2) to the Lower Kokarkuyu Formation. In Central Taurus (Aladag, Bolkardag and Antalya Nappes), similar lithological units have been named by Ozgül (1976, 1984) respectively Yüglüktepe Formation and Sapadere Formation and have been described by Ünal et al., 2003, Groves et al., 2005 and Richoz, 2006.

The Pamuçak Formation is formed by up to 950 m limestone thickness (wackestones to packstones) representing open-marine conditions with some more restricted level. These limestones are deposited in subtidal environment reached by storm events. They are capped by a 30-50cm thick oolitic level with well-rounded, parallel-encrusted oolites. The oolites still include an impoverished Permian fauna, mainly foraminifers, bivalve and ostracods and are dated as latest Changhsingian (Angiolini et al., 2007).

The Lower Kokarkuyu Formation start with a calcimicrobial caprock (Baud et al. 1997, Richoz 2006; Baud et al., 2005, Fig. 2 and detail, below), followed by alternation of yellow shales multicoloured limestones and marls rich in bivalves.

B- Calcimicrobial caprock *(S Kershaw, A. Baud).*

There is a very interesting controversy of definitions of microbialites, and this involves the formation of oolites. It is well-recognised that ooids contain a component of microbial action in their formation, but whether or not that means oolite deposits should be classified as microbialites is something to discuss in the field. It could be argued that the term microbialite should be kept for stromatolite, thrombolite, dendrolite and leiolite, in order to distinguish these from oolites. On the other hand, it needs to be recognised that oolites are indeed found in the aftermath of some extinctions; is this just an environmental setting control, or is there a real relationship between

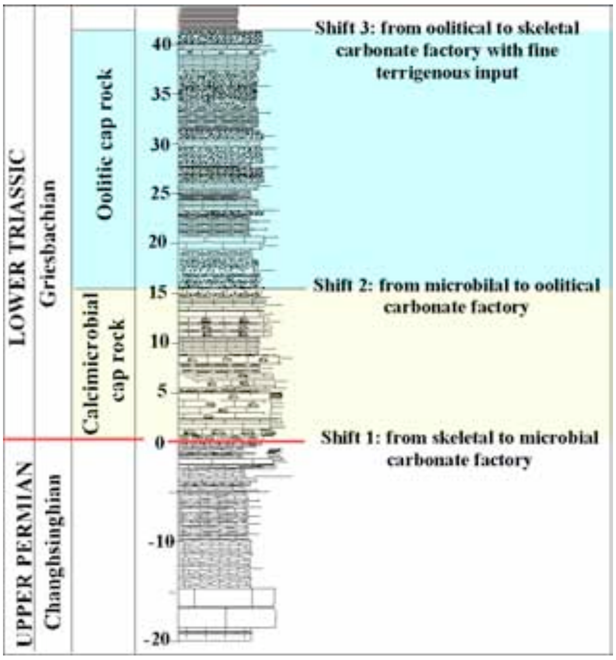


Figure 2: changes or shift of the carbonate factories at the Permian-Triassic transition and during the basal Triassic succession of the Çürük dağ section (see also Fig. 22).

oolites and mass extinctions, and therefore is it justifiable to maintain oolite as part of the calcimicrobialite? Such considerations are important in the debate about the meaning of microbialites in mass extinctions, because in Çürük dağ, the stromatolite and thrombolite components form only 15 m of the total 42 m reported by Baud et al. (2005) and named "calcimicrobial caprock" (Fig. 2, 3). We will have an excellent opportunity to consider this classification dilemma, directly on the outcrops.

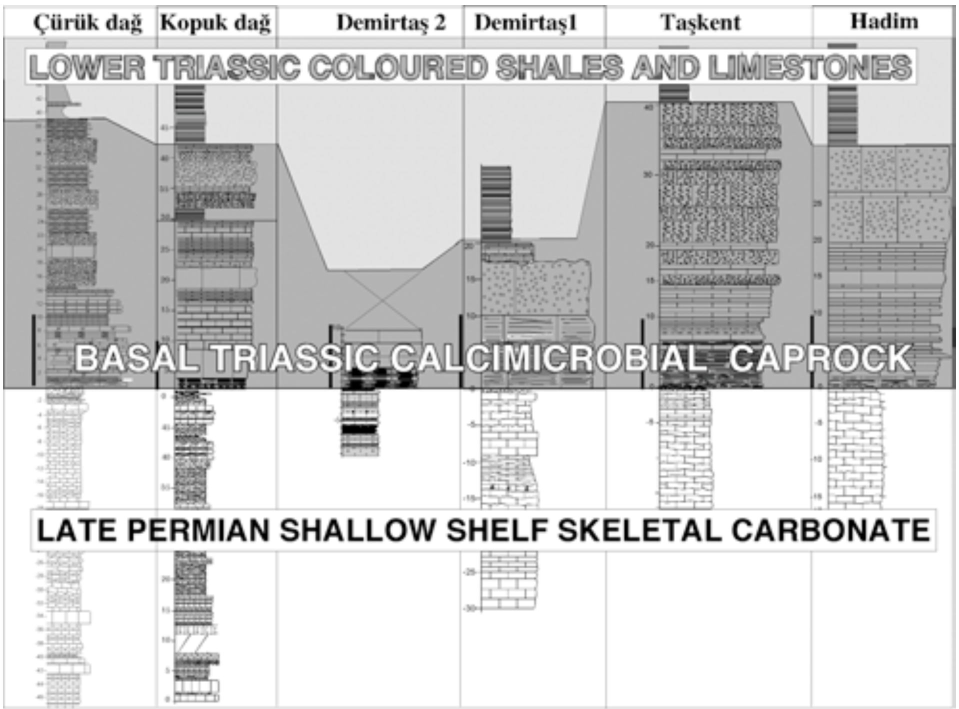


Fig. 3: stratigraphical sketch of six Taurus sections with their calcimicrobial cap rock development above the Late Permian skeletal carbonate. Thickness in meter, scale vertical bar=10m (modified from Baud et al., 2005)

C- Biochronology of the studied outcrops *(A.Baud).*

The main fossils for the Permian are brachiopods and foraminifera. The brachiopods have been studied by L. Angiolini in the Çürük dağ section and she described a brachiopod succession from middle to late Permian (Angiolini et al., 2007). In the same paper A. Nicora reported a *H. preparvus* conodont of latest Changhsingian age from the topmost oolitical beds of the Permian. The Permian foraminifera have been studied first by Lys in Lys and Marcoux, 1978, and later by Altiner, 1984 in some localities of the Taurus belt. Looking recently at the Çürük dağ thin sections, we noted that the biseriamminid foraminiferan *Paradagmarita monodi* indicating a Changhsingian age (Gaillot & Vachard, 2007) appears first 150m below the Permian-Triassic boundary. Comparing to the South China sections, the Changhsingian succession at the Çürük dağ is much more thick.

At the base of the Kokarkuyu Formation, S. Richoz reported the Griesbachian conodont *Isarcicella staeschei* and 55 cm above it, Hindeodus *parvus* and illustrated this finding (Richoz, 2006). The Çürük dağ section is the only place of the Taurus were *H. parvus* has been found. Thirty-one meters above the base of the Kokarkuyu Formation, within the oolitic beds (Fig. 2), A. Nicora founded *Isarcicella lobata*, a conodont indicating the second zone of the Griesbachian (Nicora in Angiolini et al., 2007). The bivalve *Claraia wangi* (Griesbachian) has been reported 15 m above the PTB in the near Kemer Gorge unit (Marcoux et al., 1986). The *Claraia* and other bivalves from the above coloured shales and limestones have not yet been determined (Dienerian?).

D- Depositional model of the upper Pamuçak Formation and the Lower Kokarkuyu Formation of the Çürük dağ section. *(S. Crasquin, M.B. Forel).*

The last 12 meters of the Pamuçak formation and the first 38 meters of the Kokarkuyu formation were sampled for ostracodes study (Crasquin *et al.*, 2002, 2004a, b) and new data are in progress.

The top of Pamuçak formation yielded 28 species belonging to 19 genera (Plate 1), whereas the base of Kokarkuyu formation yielded 12 species from 5 genera (Plate 2). No species has been found to cross the boundary (Table 1). Noteworthy is the presence in Early Triassic beds of Palaeocopida (Crasquin-Soleau *et al.*, 2004a, b) that were considered not to range across the Permian-Triassic boundary, such as *Reviya*.

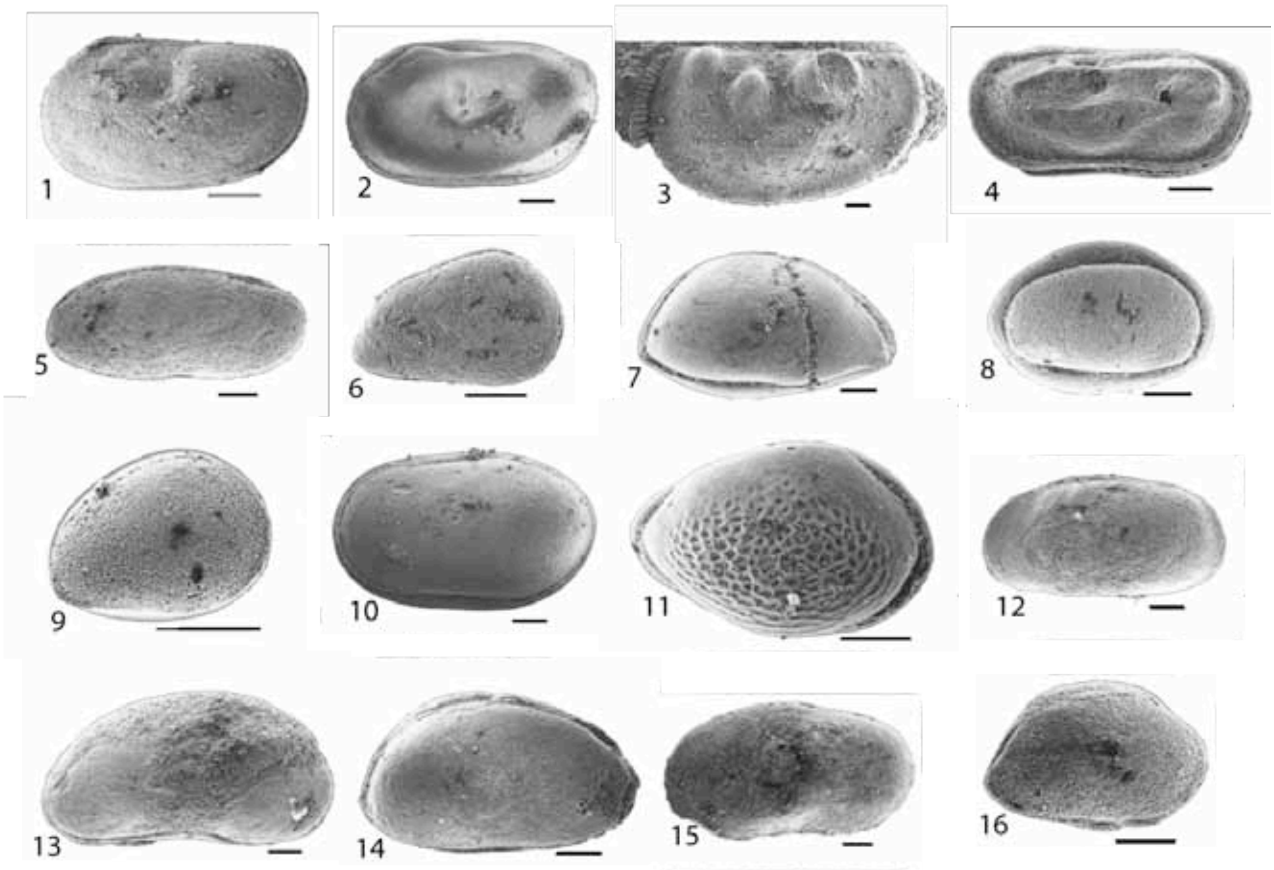
All the ostracodes reported from the upper Pamuçak and lower Kokarkuyu formations are typical of intertropical warm waters.

The main palaeoecological requirements features of genera and/or superfamilies encountered are:

- *Kirkbyoidea, Kloedenelloidea, Hollinoidea* and *Youngielloidea* are present in the intertidal zone with variations of palaeoenvironmental conditions (salinity, bathymetry…).
- *Cavellinoidea* and *Paraparchitidae* are found in the internal zone with euryhaline environments in shallow to very shallow waters.
- *Bairdioidea* develop on the outer shelf zone in open carbonate environments with normal salinity and oxygenation.

The upper Pamuçak formation is mostly dominated by *Bairdioidea*, indicating an open marine setting. The faunas of the very base present however intertidal environments forms such as *Kloedenelloidea* and *Youngielloidea*, indicating shallower conditions. The setting became shallower again in the very upper part of the formation, as shown by internal forms.

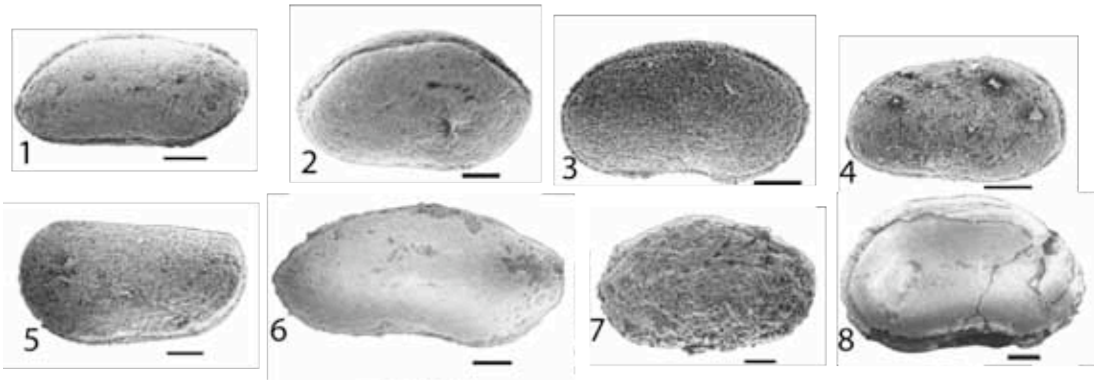
Plate 1: PERMIAN



Scale bar is 100μm.

1: *Knoxiella infirma* Shi 1982. Left lateral view.
2: *Sargentina pamucakensis* Crasquin-Soleau 2004. Left lateral view.
3: *Hollinella (H.) herrickana* Girty 1909. Left lateral view.
4: *Permoyoungiella bogschi* Kozur 1985. Right lateral view.
5: *Fabalicypris parva* Wang 1978. Right lateral view.
6: *Baschkirina n.sp.1*. Right lateral view.
7: *Acratia changxingensis* Shi 1987. Right lateral view.
8: *Microcheilinella sp.*. Right lateral view.
9: *Basslerella tota* Chen and Bao 1986. Right lateral view.
10: *Sulcella sulcata* Coryell and Sample 1932. Right lateral view.
11: *Arqoviella tahtaliensis* Crasquin-Soleau 2004. Right lateral view.
12: *Callicythere lysi* Crasquin-Soleau 2004. Left lateral view.
13: *Liuzhinia* cf. *L. parva* Wei 1981. Right lateral view.
14: *Macrocypris* cf. *M. deducta* Zalanyi 1974. Right lateral view.
15: *Sulcella* cf. *S. suprapermiana* Kozur 1985. Right lateral view.
16: *Bairdia sp.A*. Right lateral view.

Plate 2: TRIASSIC



Scale bar is 100μm.

1: *Bairdia kemerensis* Crasquin-Soleau 2004. Right lateral view.
2: *Bairdia subsymmetrica* Shi 1987. Right lateral view.
3: *Bairdiacypris ottomanensis* Crasquin-Soleau 2004. Right lateral view.
4: *Liuzhinia antalyaensis* Crasquin-Soleau 2004. Right laterl view.
5: *Reviya curukensis* Crasquin-Soleau 2004. Left lateral view.
6: *Bairdia* cf. *B.piscariformis* Chen 1958. Right lateral view.
7: *Sulcella* cf. *S. mesopermiana* Kozur 1985. Left lateral view.
8: *Bairdiacypris sp.2*. Right lateral view.

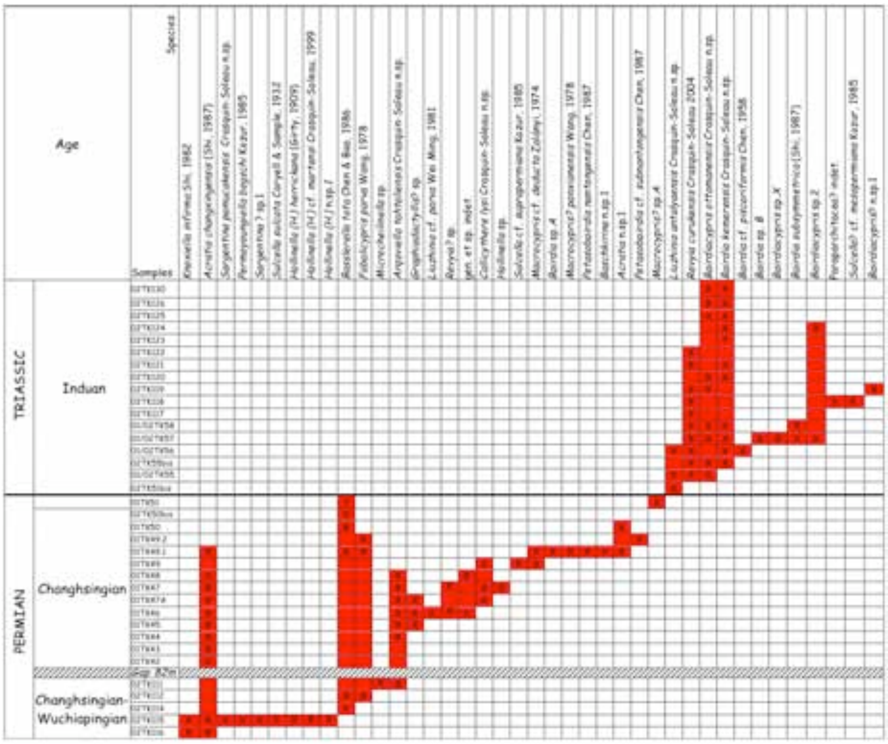


Table 1: Distribution of ostracodes species in Çürük dağ section at the Permian-Triassic boundary.

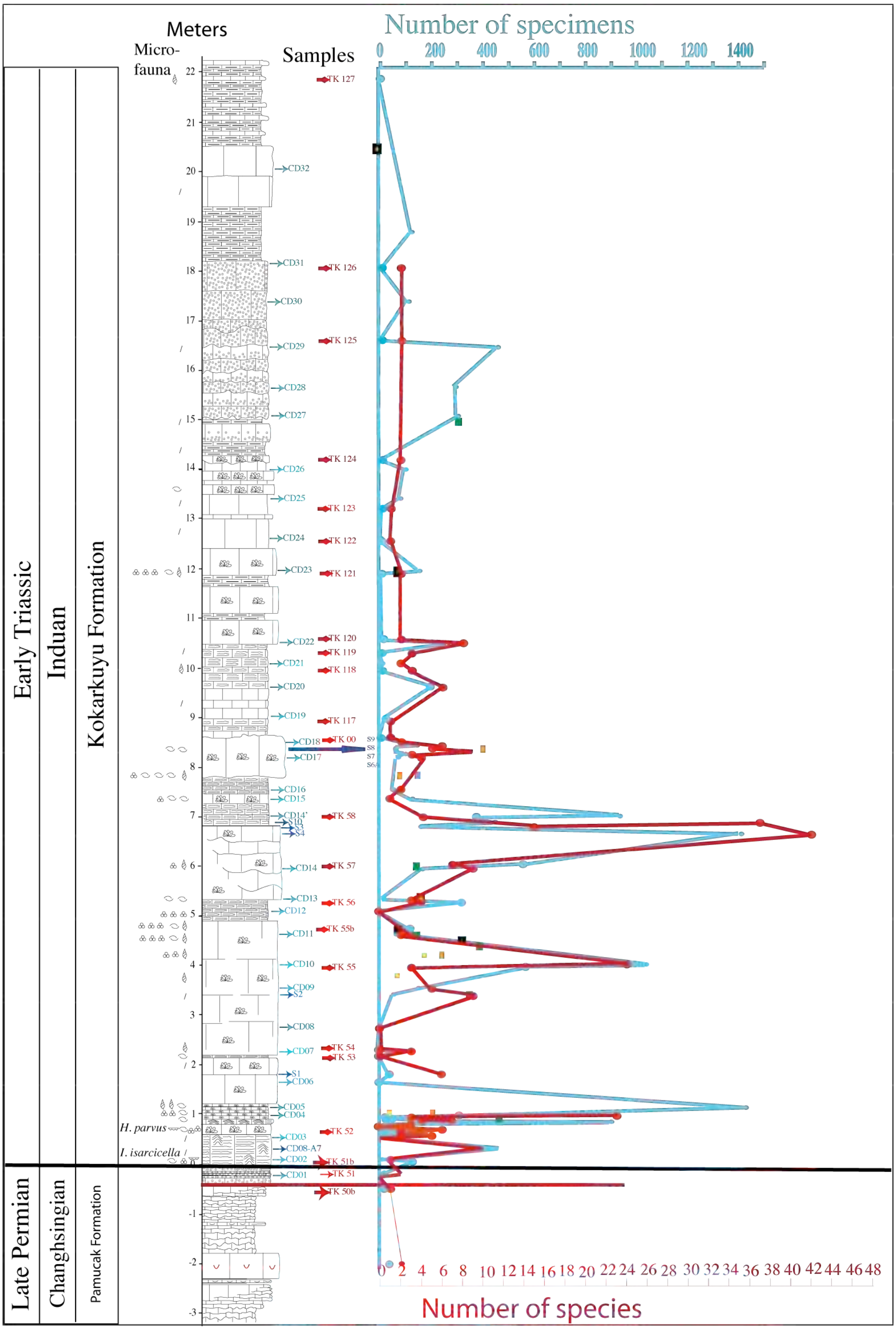


Figure 4: Ostracode diversity within the basal Triassic microbial limestones (Çürük dağ section) Adapted from Crasquin in Richoz, 2006.

The lower Kokarkuyu formation is dominated (never less than 50%) by *Bairdioidea*, open marine forms. The very base of this formation is also characterized by shallower forms, with *Kirkbyidae*, *Paraparchitacea* and *Cavellinidae*. The faunas here represent open marine environments and tend to indicate a shallower setting at the very base.

E- Geochemical studies *(A. Baud).*

For the first C isotope study, a detailed boundary section of the Çürük dağ was sampled on the crest by Baud & Holser in 1986 and the isotope results were published by Baud et al. in 1989. With this spaced sampling studied more than twenty years ago (Fig. 5) we had shown that the late Permian limestones are enriched in heavy Carbon ($\delta^{13}C > +4\%$,,), and the Lower Triassic rocks were comparatively depleted with $\delta^{13}C$ values of about + 1%. In detail $\delta^{13}C$ declines gradually from +4.5% at the base of the sampled section to about +3.5%. near the boundary. The transition across the P/Tr boundary is rather abrupt, dropping in two steps (shift 2 and 3) through about 3% across the boundary.

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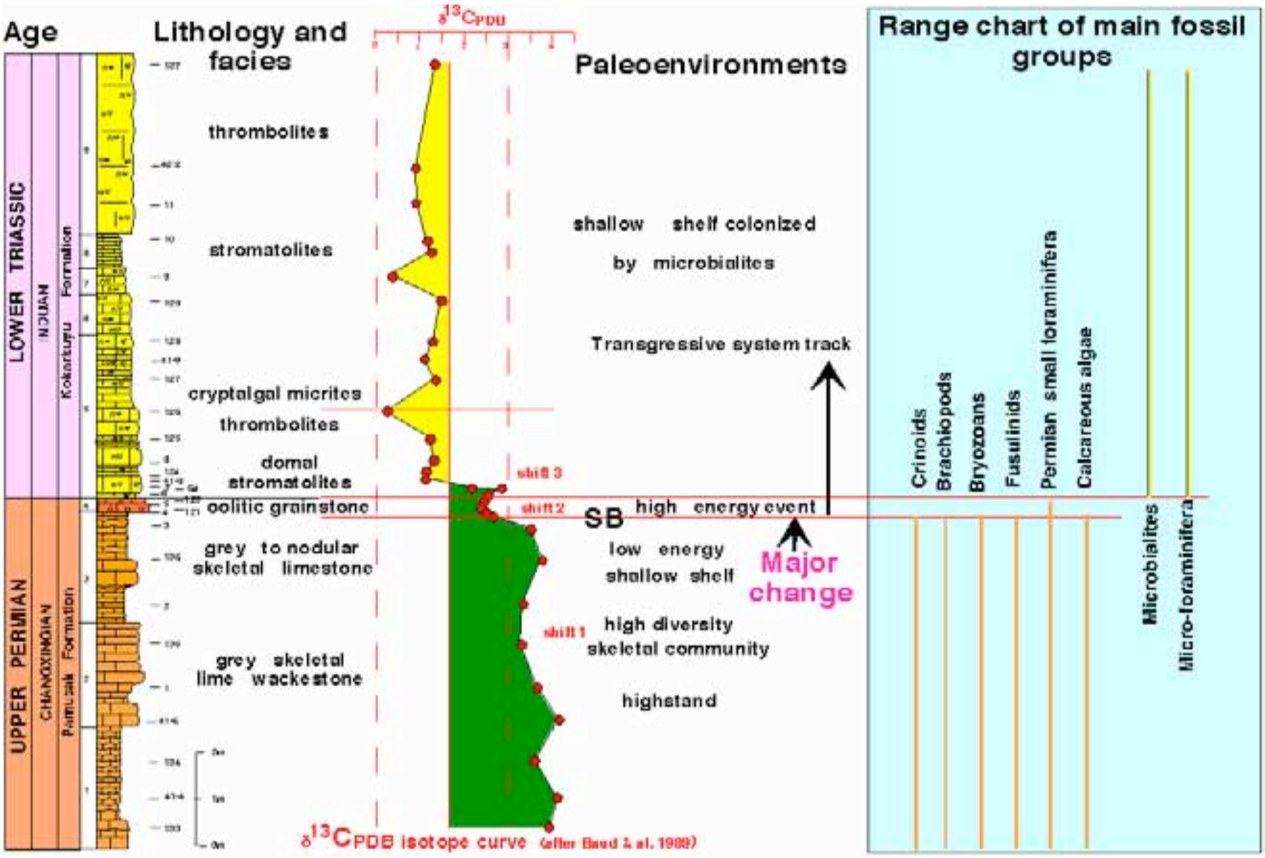


Figure 5: Çürük dağ crest section with main facies, paleoenvironments, Carbon isotope profile and range chart sketch (modified from Baud et al., 1997).

The same samples were studied for Sr, Mg, Mn and Fe geochemistry by S. Zerari for her PhD Memoir (Zerari-Leduc, 1999) and her results are give below in the Fig. 6.

In comparison with the upper Permian black nodular bioclastic limestones (1), the lower Triassic microbial limestones (3) are depleted in Mg and Mn and enriched in Sr and Fe. Interesting are the oolitic limestones (2) at the top of the Permian succession showing a sudden increase of Fe and Mn and a shift to lower values of Sr and Mg. The unconformity/short gap at the base of the oolites is well marked by a step/shift for each element (Fig. 6).

P. Marenco (work in progress) showed in published abstracts (Marenco et al., 2004, 2005) that high-resolution $\delta^{34}S$ data from carbonate associated sulfate from the Çürük dağ section reveal extreme and rapid sulfur isotopic fluctuations (up to 10‰) just before the end Permian mass extinction, followed by smaller but significant rhythmic fluctuations in the Early Triassic.

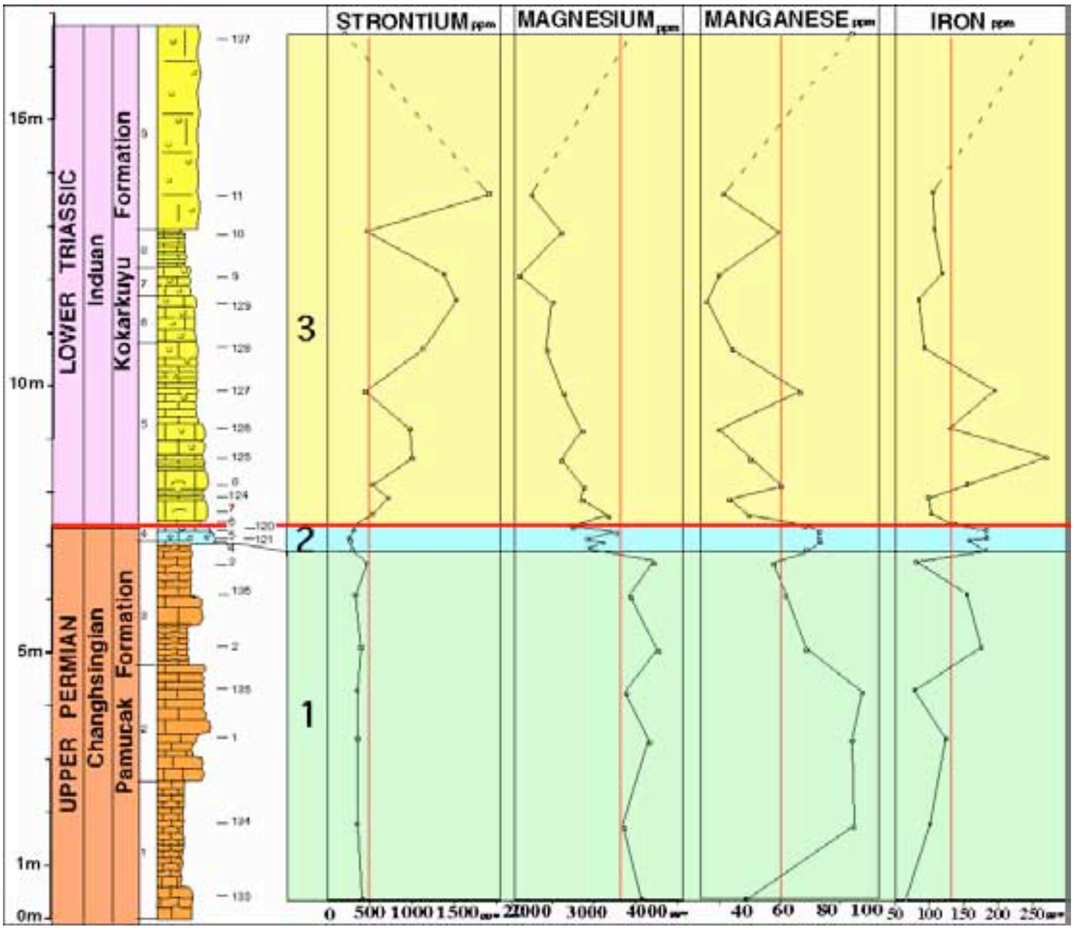


Figure 6: Accessory elements (Sr, Mg, Mn, Fe) from PTBI of Çürük dağ crest section (S. Zerari-Leduc, 1999).

F- Detailed Carbon isotope stratigraphy *(S. Richoz)*.

More recently, S. Richoz studied two of the visited sections for carbon isotopic stratigraphy (Çürük dağ, Fig. 7 and 8 and Demirtaş-Kusdavut, Fig. 31) and the results given here have been published in Richoz (2006). For isotopic analyses, powders were produced from selected micrite samples. The detailed methods description and numerical data are found in Richoz (2006).

Both sections show the well-know decrease at the Permo-Triassic Boundary Interval (PTBI). The total decrease is of 5.1‰ at Çürük dağ and 4.9‰ at Demirtaş-Kusdavut. In detail both sections are also well correlatable with the synthetic carbon isotope curve for the central Neotethys (see Fig. 9, Richoz 2006), based on well dated biochronologically Iranian sections. Around the Permo-Triassic Boundary Interval (PTBI), the synthetic curve (Fig. 7) shows four distinctive features, which we can also be followed in the Antalya Nappes:

1) An Upper Wuchiapingian (Top *Ng. leveni* Zone) small negative excursion of around 1.2‰. This could be found in the Çürük dağ section, in the unit B of the Pamucak Formation, around 100m below the PT Boundary Interval, there we have a small negative trend (see Fig. 7) but it is here not well documented and we miss more biostratigraphic control to confirm it. The sampling of the Demirtaş-Kusdavut section begins clearly above this level.

2) A pre-extinction decrease with rare and small second order variations starting in *C. subcarinata* zone?, Lower Changhsingian, and finishing at the base of the *meishanensis-praeparvus* Zone, having a total amplitude of 1.5‰ to 2.8‰ with an average of 2.2‰ for the whole Neotethys. At Çürük dağ the pre-event decrease has an amplitude of 3.1‰ and begin

around 10m below the event-boundary and end at sample T20/119, top of bed the third oolitic beds 02b (see Fig. 8). Angiolini et al. 2007 describe a *H. cf. praeparvus* in the middle of the oolitic beds, which correspond very well with our isotope data. A rapid 0.6‰ decrease between the last sample in the nodular limestone and the first one in the oolite, suggests a small amplitude gap. At Demirtaş-Kusdavut, the pre-event decrease has an amplitude of 3.5‰, begin around 15m below the boundary and end also on the upper part of the oolite limestone. The less detailed sampling did not allow to demonstrate here the presence or absence of a gap at the base of the oolite. Both section show a feature that has not been measured in other tethyan sections: a small rebound of 0.8‰ between 1,10m and 1,50m below the event boundary at Çürük dağ and 0,8m and 1,20m at Demirtaş.

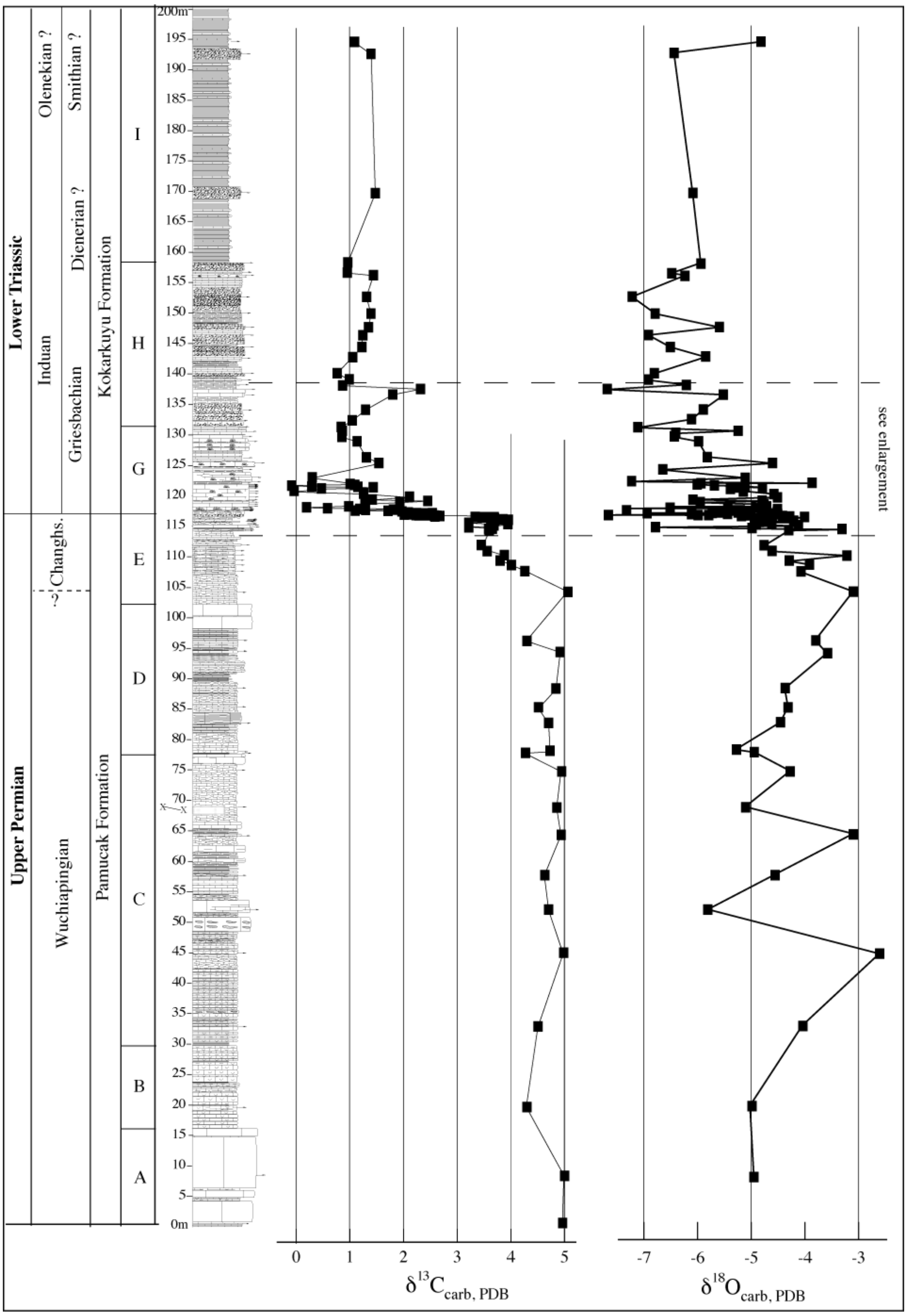


Figure 7: Carbon and Oxygen isotopes profile of the Çürük dağ crest section (from Richoz, 2006)

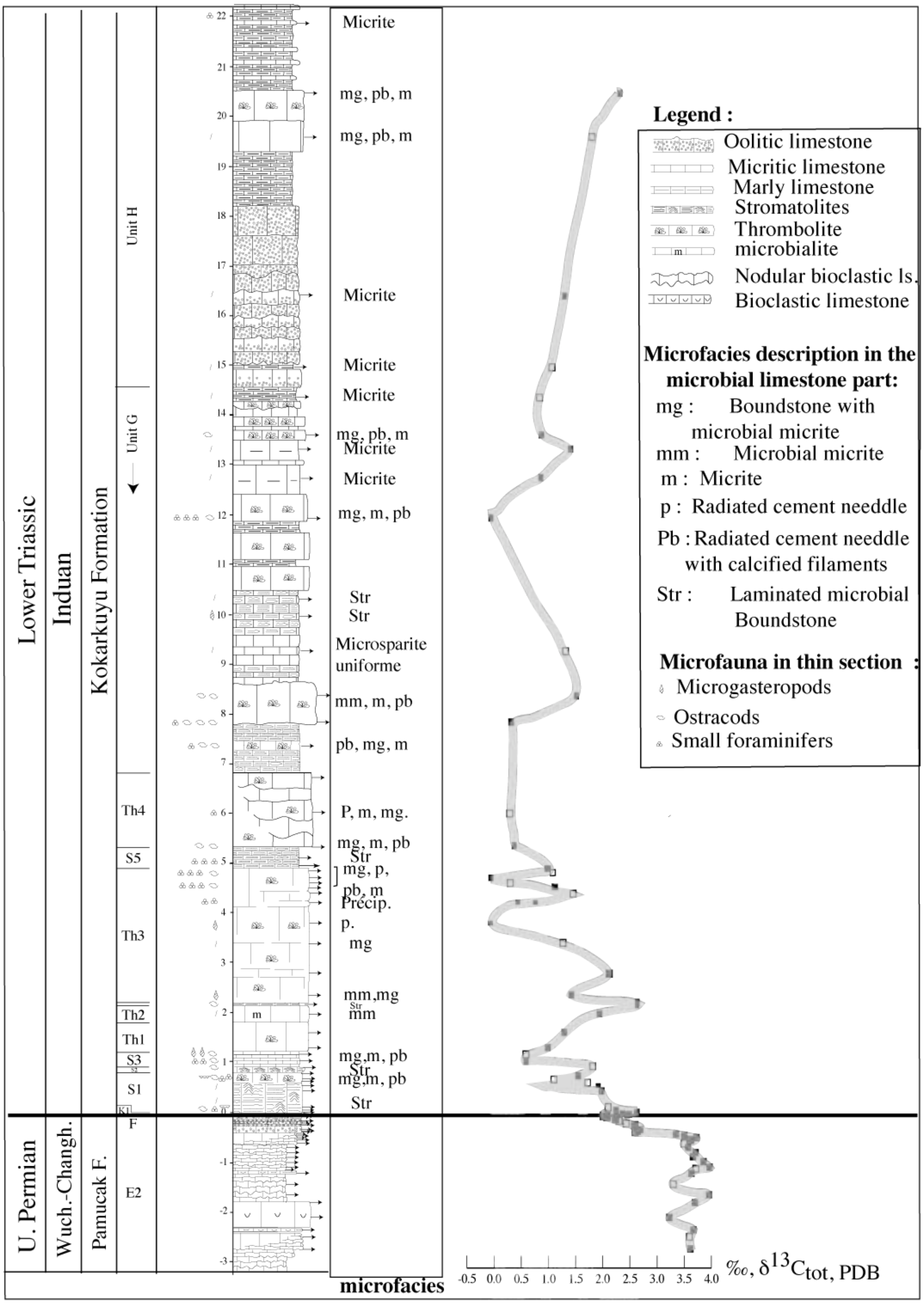


Figure 8: Enlargment of Carbon isotope profile of the Çürük dağ crest section (from Richoz, 2006).

3) Small positive excursion in the *meishanensis-praeparvus* Zone. In the well-dated Iranian sections (Richoz, 2006; in review and Korte et al., 2004), *Hindeodus parvus* appear for the first time when the isotopic values reaches again the smallest values before this positive excursion. Both in Çürük dağ and Demirtaş-Kusdavut the more positive values of this excursion is the first sample of the stromatolite (T99/14, see Fig. 8). In correlation with Iran, the first appearance of *H. parvus* should be in Çürük dağ 15cm above the first stromatolite and 30cm in Demirtaş Kusdavut. This could imply that the first stromatolite are still uppermost Permian. We can say that stromatolites appear in Antalya Nappes slightly before the microbial structure in Iran and Oman.

4) A post-extinction event decrease with an amplitude of 1.2 ‰ to 2.7‰ and an average of 1.8‰. This part shows several second order variations with amplitude varying between 0.5 and 1.0‰. It starts in the very top of the *meishanensis-praeparvus* Zone and reaches it's minimum in the *isarcica* Zone. This post-event decrease has an amplitude of 2,7‰ at Çürük dağ and 1,7‰ at Demirtaş-Kusdavut. But this 'Triassic part is more difficult to correlate with the synthetic curve. We have not so many biostratigraphic tie-point and we noticed that the different microfacies of the thrombolite in Çürük dağ have different isotopic values. It is possible that the isotope variations have been influenced by microbial activity as explained in Richoz (2006).

Both sections show thus very similar results and are as well correlatable with other PTBI curve.

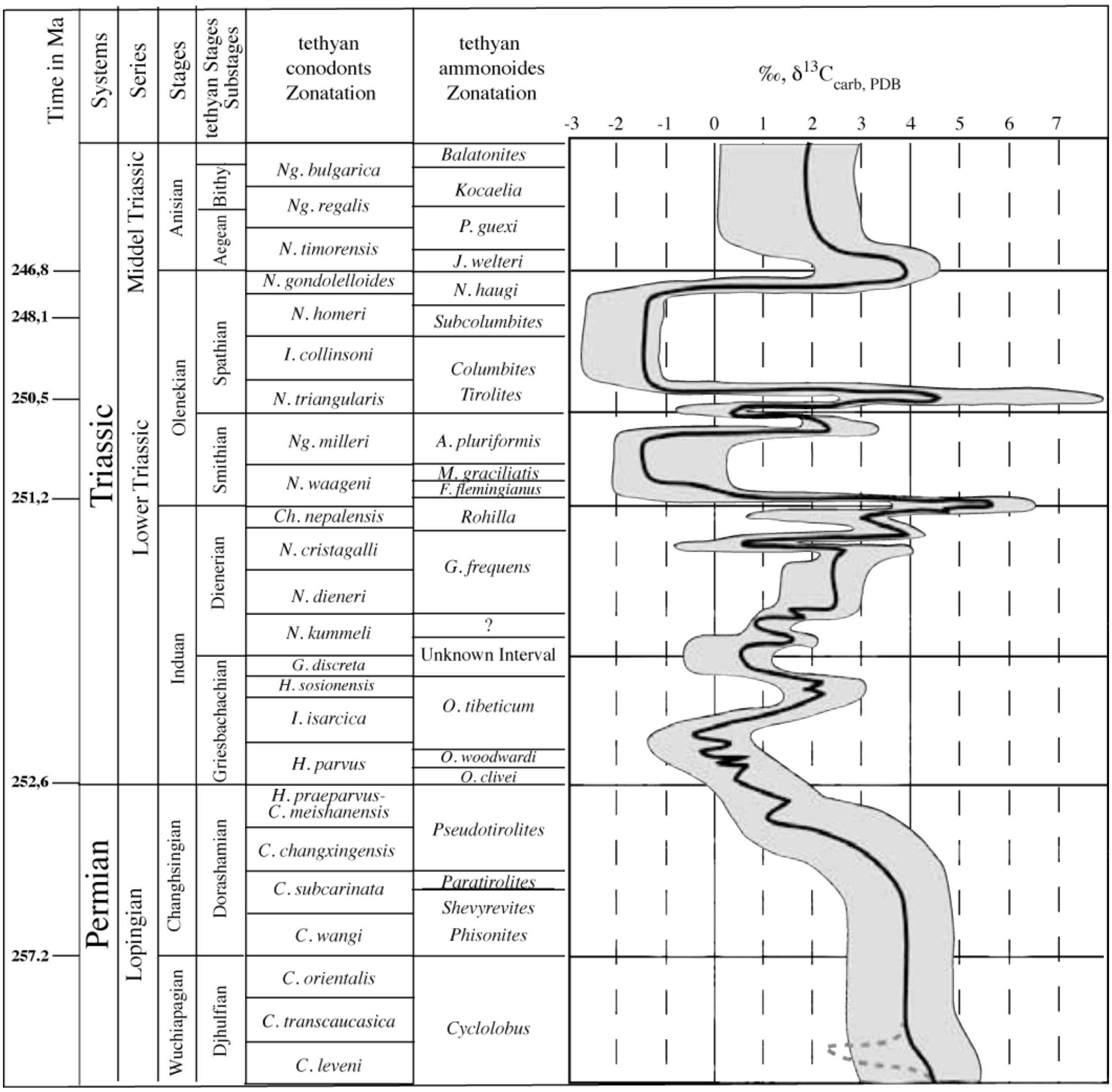


Figure 9: Synthesis of Carbon isotope data in the Tethys for late Permian and early Triassic (Richoz, 2006)

G- Extinction and recovery *(S. Crasquin, S. Kershaw).*

The end-Permian extinction led to drastic change in marine diversity (Figure 10). The protracted upper Permian biodiversity decline lasted about 10 Ma. The Triassic recovery can be divided into 3 phases (Erwin, 1993). The Early Triassic is characterized by biotic poverty. Middle Triassic sees a return to normal marine faunas. The true expansion of Mesozoic marine faunas took place during the Late Triassic.

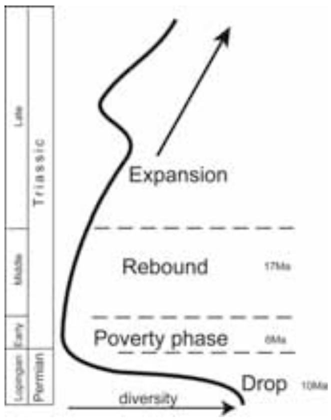


Figure 10**:** Divisions of the post-extinction recovery (modified from Erwin, 1993)

Despite their great adaptative potential, ostracodes were deeply affected by the end-Permian mass extinction (Figure 2). This period marked an important change in their evolution, Palaeozoic faunas being replaced by Meso-Cenozoic assemblages during the Late Triassic. Data are currently too poor to date the end of the extinction stage of ostracodes, questionably placed about in the middle Changhsingian. Palaeozoic forms are still found in the Spathian, indicating a longer survival stage for ostracodes than for brachiopods. Additionally, Mesozoic representatives are found in the Late Permian, indicating that the recovery phase may have begun earlier for ostracodes. The final turnover from Palaeozoic to Meso-Cenozoic faunas took place later during the Anisian.

According to Mundil *et al.* (2004) and Ovtcharova *et al*. (2006), a minimum duration of about 4,5±0,6 My can be attributed to the Early Triassic: the recovery is significantly shorter than previously estimated.

An important point to note is that Lilliput effect has never been observed for ostracodes in the aftermath of the extinction whereas it has been recognized for brachiopods (e.g. He *et al.*, 2007).

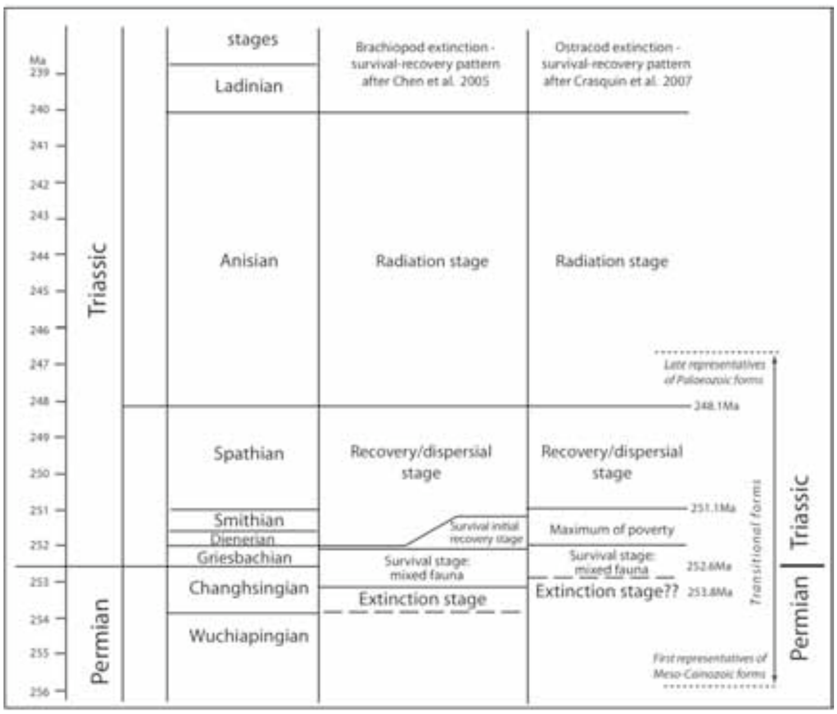


Figure 11: Comparison between extinction and recovery patterns of brachiopods and ostracodes through the Permian-Triassic boundary events. Brachiopod data after Chen *et al*., 2005. Datations from Ovtcharova *et al*., 2006. From Crasquin *et al*., 2007.

H- Unconformity, subaerial erosion versus submarine dissolution *(A. Baud, S. Kershaw and S. Richoz).*

During the latest Permian deposits, two unconformities–paraconformities have been recorded in the three analysed sections as in the Central Taurus sections (Ünal et al., 2003) and the correspondance with the Southern Alps unconformities as reported by Farabegoli et al. (2007) will be discussed in the field.

The first one occurs at the top of the nodular limestone just below the oolites and is corresponding to a sequence boundary and important sea-level fall with a short gap in sedimentation. This is illustrated at the Çürük dağ section by line 1 in Fig. 12 and 16. It is reported in the Demirtaş (Fig. 30) and Oznurtepe sections (Fig. 40) and has been described in the Taşkent area by Ünal et al., 2003, Groves et al., 2005 and Richoz, 2006. As shown in Fig. 8, this unconformity is well recorded by the sudden shift of the C isotope.

In detail, this surface is largely smooth-polished in field and in thin section views from the Oznur Tepe and Çürük dağ profiles, but in thin section some micro-irregularity is observed. Clasts of the nodular limestones occur rarely in the oolites, demonstrating that erosion certainly occurred.

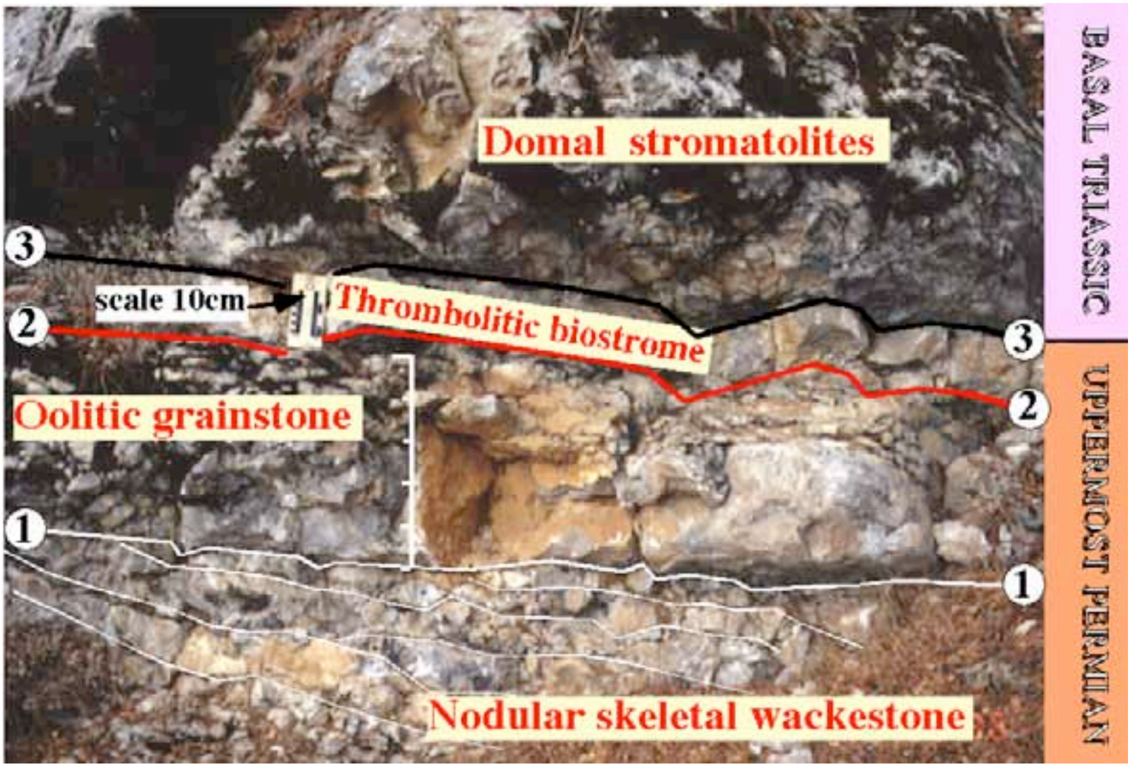


Figure 12: the Permian-Triassic transition with unconformity surfaces (1,2,3) at the Çürük dağ crest section (description in the text).

The second one (lines 2 and 3 in Fig.12 and 16) is at the top of the oolitic grainstone and the interpretations are still the object of a large discussion: subaerial karstic erosion, acid rain leaching versus submarine dissolution. On the Çürük dağ crest section, the basal surface of the domal stromatolites is very irregular with palaeotopographic highs and lows up to 20cm cuting the thrombolitic biostrome bed up to diagenetic alteration at the top of the oolitic grainstone. We interpreted this surface to represent a subaerial exposure surface (Marcoux and Baud, 1986; Baud et al., 1989, 1997, 2005) with apparent vadose textures. Are they similar to those described in south China by Collin et al. (2009) is still a question? For the Taşkent section the subaerial exposure interpretation have been also published by Ünal et al., 2003, and bv Groves et al., 2005, but, based on petrographic analysis of the truncated contact between the microbialites and the graintones, Payne et al. (2007) proposed a subaqueous sea-floor dissolution. It is interesting to note that in the Demirtaş section, 10 cm of shales occur between the oolitic grainstones and the stromatolites and in the Oznur Tepe section the stromatolites are growing directly within the same bed on the irregular grainstone surface.

Thus whether the erosion surface was subaerial or subaqueous cannot be determined on present evidence and will be discussed on the outcrop.

The microbialites contain several minor breaks, most of which do not show clear evidence of erosion, indicative of episodic development of the microbialite unit, and emphasise its shallow water nature

A fourth event is characterized by the sudden terrigenous influx and the onset of the yellow shales and marly limestones in all the analyzed sections. In some sections (Demirtaş) it overlains a paleokarstic surface and a ferruginous hardground (Figs. 30, 35A and B). Within the upper Antalya nappes, this transgressive unit seals important paleotectonic extended movements and in an area 2 km north of the Çürük dağ the yellow shales and the marly limestones are directly in contact with the middle Permian limestones of an uplifted block (Marcoux et al., in prep.).

PART 3: DESCRIPTION OF THE VISITED OUTCROPS

<u>September 4, 2009</u> -The Permian-Triassic transition at the Çürük dağ section.

(A. Baud, S. Crasquin, B. Forel, S. Richoz).

Routing (Fig. 13): Starting in the late afternoon September 3 from Antalya, we will move to the West and take the road climbing the Hisar valley up to the crest at the head of the Göynük valley where is the Gül Mountain hotel, 4 km South of the Çürük dağ. September 4 morning, we will move by car close to the Çürük dağ crest (Fig. 13).

Figure 13: Antalya Mountains map with road itinerary in orange.

Introduction: one of the best exposure of the Permian-Triassic transition is at the Çürük dağ (Figure 14), a section more than 1000m thick of shallow water carbonate (middle-upper Permian to lower Triassic) situated at about 15km NW of Kemer (Fig. 15). In this section, the Pamuçak Formation is represented by a thick cyclic succession of inner to outer platform facies (Guadalupian to Lopingian).

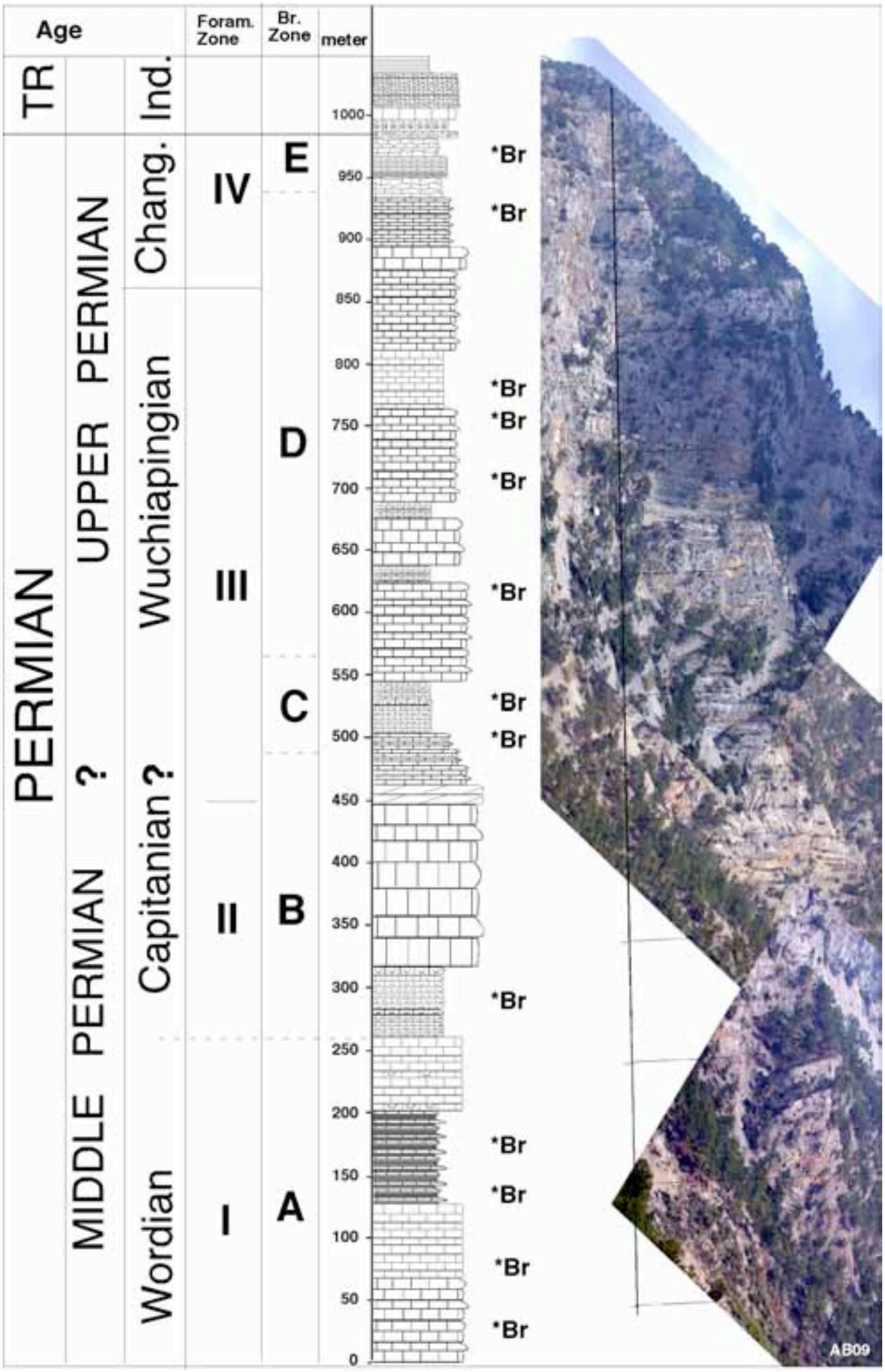


Figure 14: the 1100m thick Çürük dağ section (Br= Brachiopod rich levels) with the south flank scaled and the photo orientated to fit the log (Baud and Marcoux, unpublished log).

The 4 stops of the day will be on the crest of the Çürük dağ (Fig. 15), the first one at the Permian-Triassic transition, the second one a little higher at the thrombolite facies, the third one at the oolite facies and the fourth at the overlying marly limestones and yellow shales.

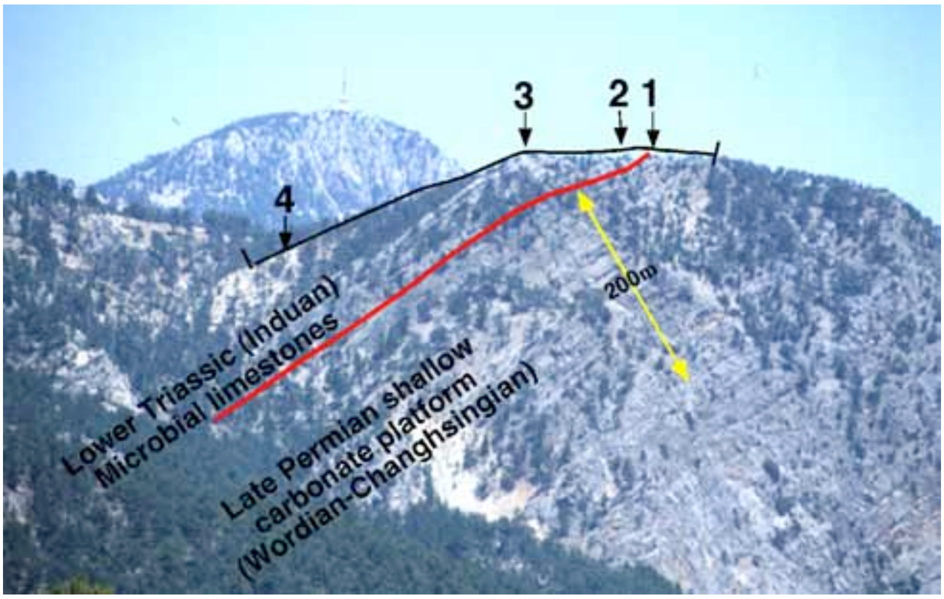


Figure 15: the Çürük dağ from the south, the crest section with 1, 2, 3 and 4 = visited outcrops.

Stop 1: The Permian-Triassic transition is illustrated in the next 7 pictures (Fig. 16 to 22) and details of the stratigraphy and recovery will be discussed in the field

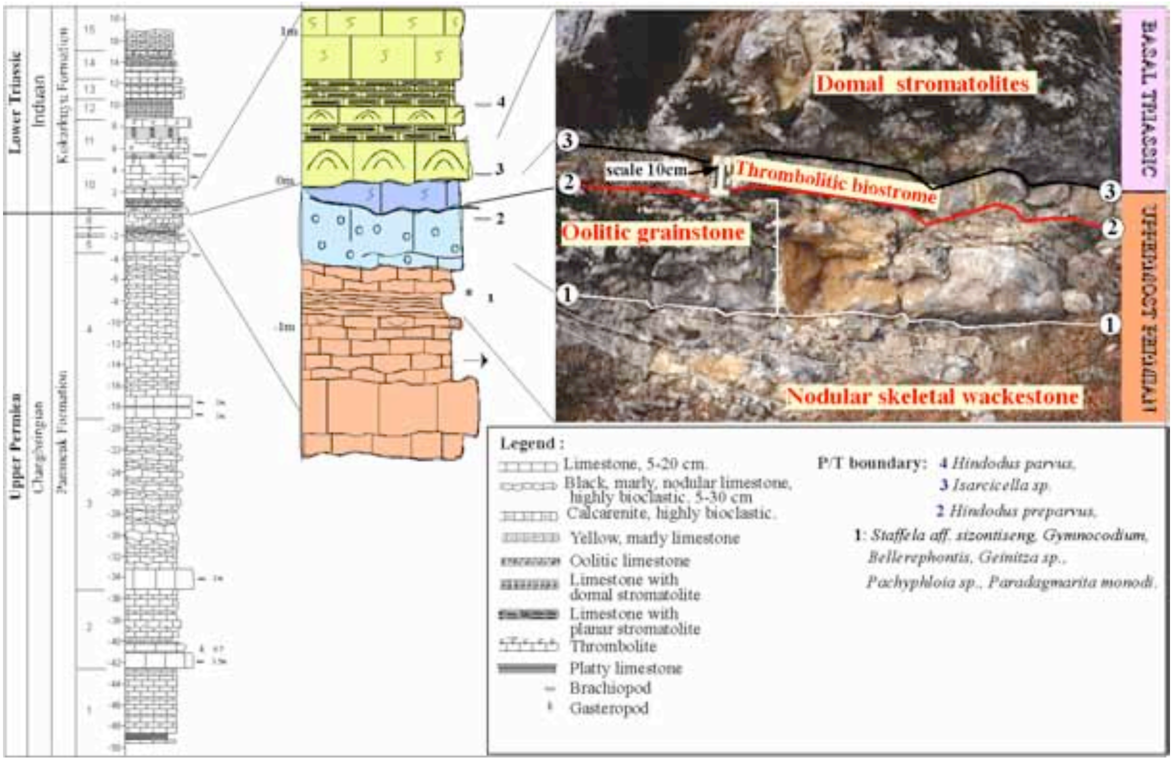


Figure 16: general + detailed logs with legend and outcrop picture of the Permian-Triassic transition at the Çürük dağ crest section (1, 2, and 3 -circles = unconformities described in the text).

The upper part of the Pamuçak Formation is composed of dark-grey highly bioclastic nodular limestones rich in calcareous algae (Dasycladacea and Gymnocodiacea), cyanobacteria and small foraminifera (mainly Millliolidae), with bioclastic beds rich in brachiopods, bivalves and echinoderms (Fig. 17). The microfacies consist of bioclastic wackestones/packstones of low energy (algal biomicrites of Ünal et al., 2004) and O.7m below the Permian - Triassic boundary the facies changes with prominent bed-parallel unconformity (event 1) into oolitic grainstones with rare echinoderms and bivalves (Crasquin et al. 2004a, Baud et al., 2005, Richoz, 2006).

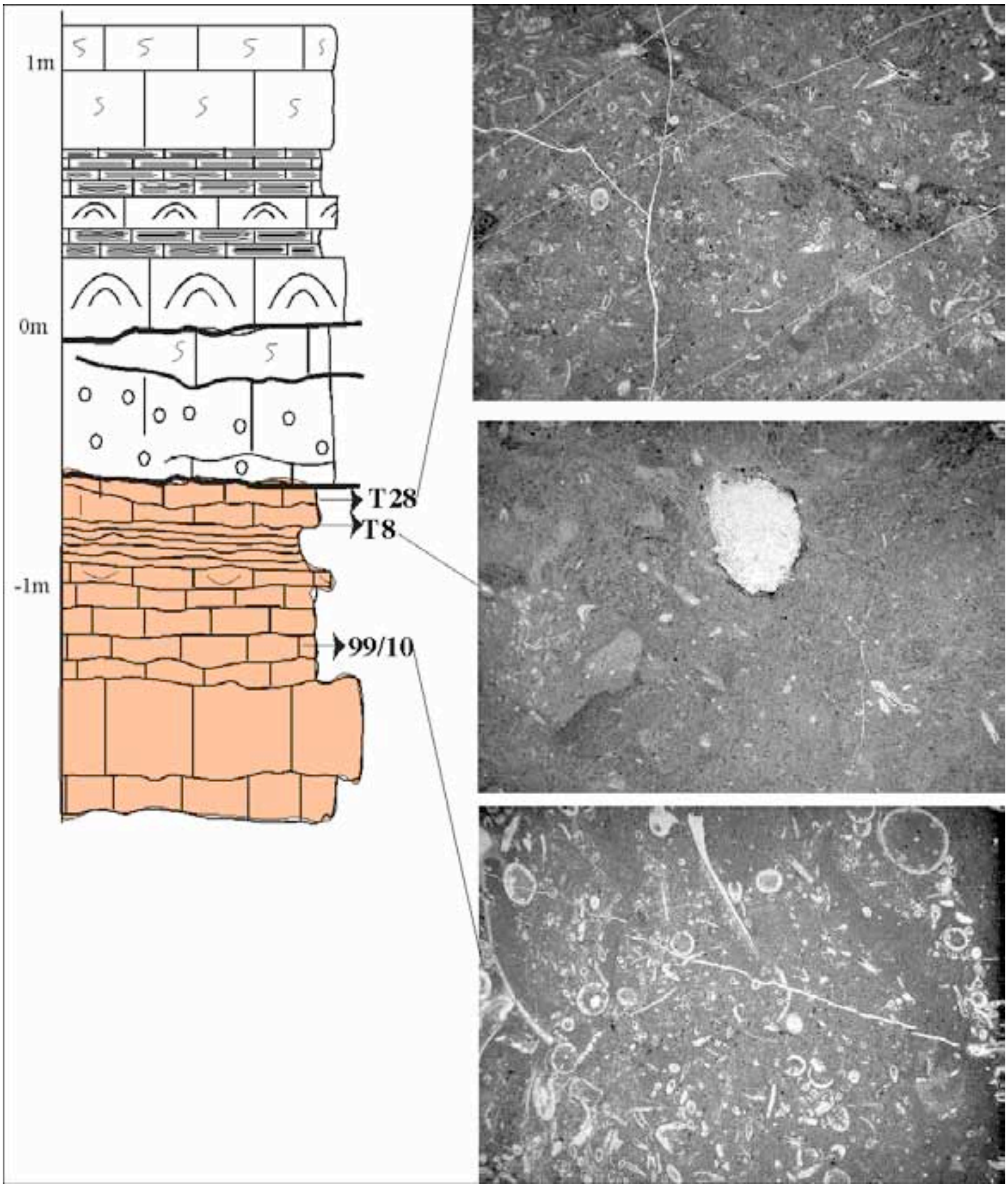


Figure 17: detailed log and microfacies of the uppermost (Changhsingian) nodular limestones (thin sections wide, 2cm).

Above the nodular limestones, the facies and the microfacies changes abruptly (paraconformity 1, fig. 16) into high-energy grainstones, then into oolitic grainstones (Fig. 18, microfacies), with echinoderms, bivalves and foraminifera of latest Changhsingian age.

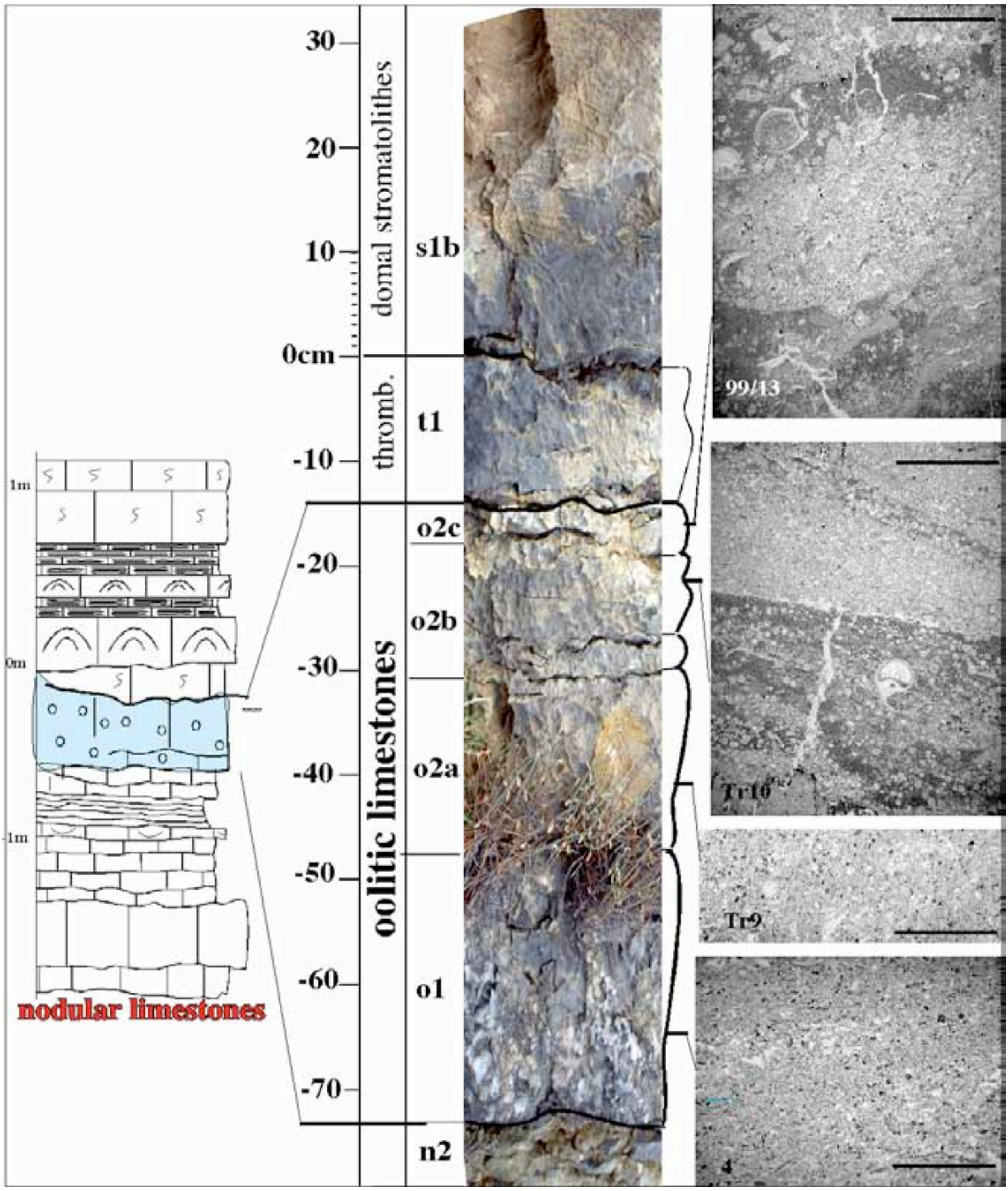


Figure 18: detailed log, outcrop picture and microfacies of the latest Changhsingian oolitic limestones (*preparvus* zone). Scale bar=1 cm.

The base of the calcimicrobial cap rock at the Çürük dağ section consists of a 0.2 m thick bed of thrombolitic texture (Fig. 19) overlain by domal stromatolites 0.6 m thick (Fig. 20).

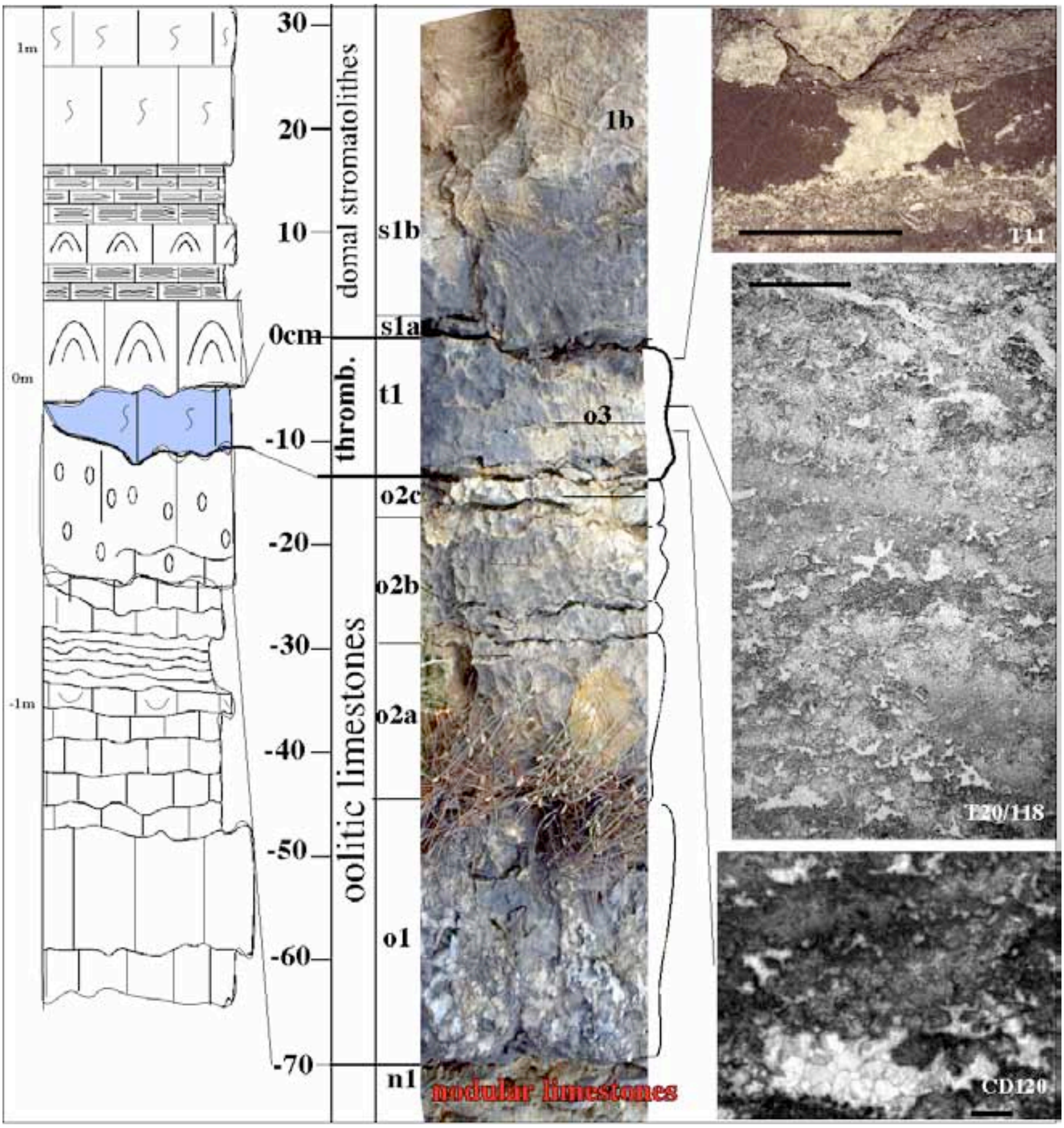


Figure 19: detailed log, outcrop picture and microfacies of the latest Changhsingian discontinuous thrombolite bed. Scale bar=5 mm, CD120=1 mm.

The following domal stromatolites form an extensive layer up to 1m thick with a 5cm relief of sromatolite heads; in some places stromatolites form isolated columns, which have a diameter of 10-15cm.

This facies is common in the Antalya nappes. The most frequent microfacies shows a laminated microbial films with remains of twisted filaments and with cocoidal peloids and pseudo-peloids resulting from dismantling of microbial filamentous mats alternating with layers of fringe isopachous crystals. Drusy cements infill the fenestral porosity due to the degradation of the microbial mucilage.

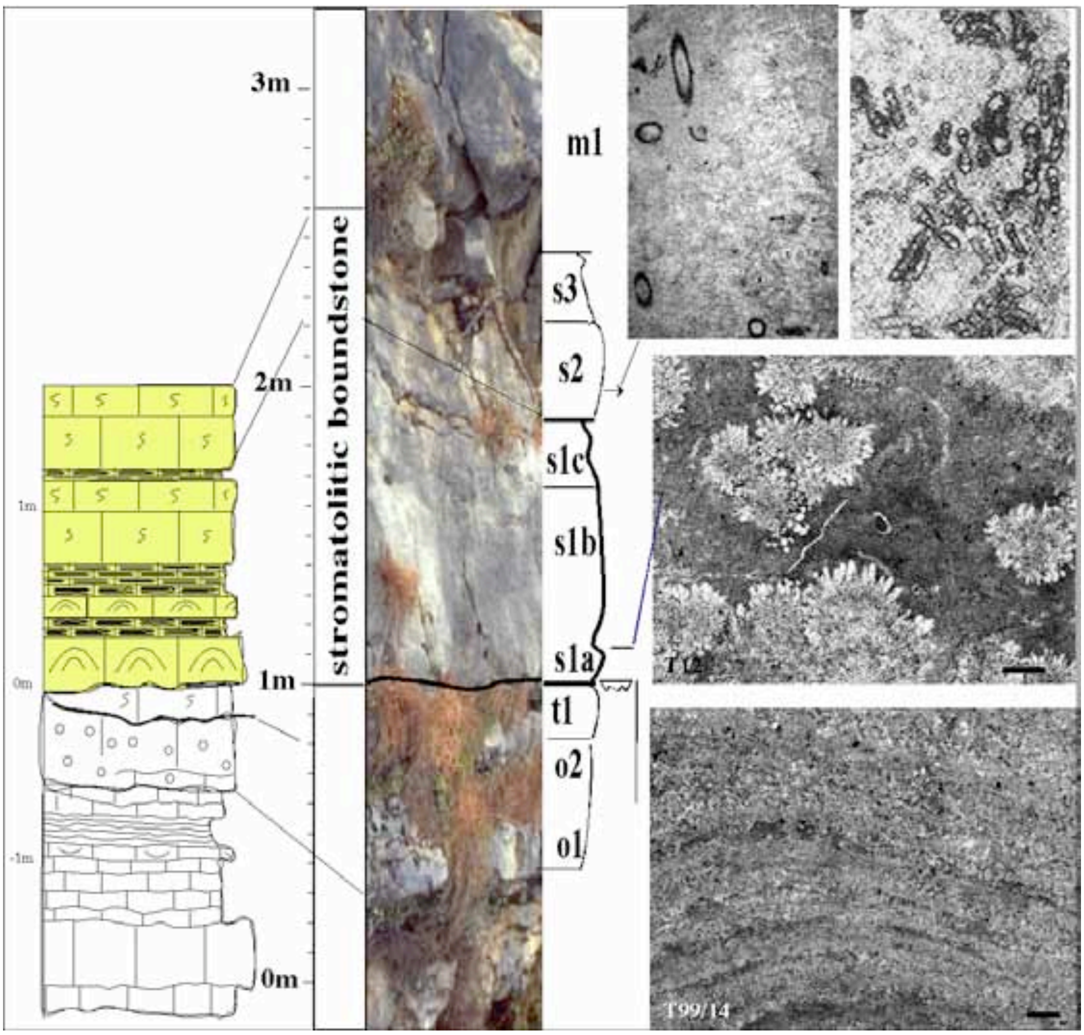


Figure 20: detailed log, outcrop picture and microfacies of the earliest Triassic stromatolitic limestones. The upper 2 slides shows the lilliput foraminifera (*Cornuspira mahajeri-Rectocornuspira kalhori* assemblage) and *Earlandia* spp. that are abundant and sometimes trapped within crystal or accumulated parallel to the lamination. Scale bar= 0.1mm. In the middle (T12), the microfacies consists of microspherulitic aragonite crystal pseudomorphs (*Rivularia* like microbial colony) and completely surrounded by micrite. Scale bar=0.5mm. The lower microfacies (T99/14) shows the fine lamination of the domal stromatolite. Scale bar=1mm.

Figure 21: facies of flat laminated stromatolitic limestones. This stromatolites form typical tabular body here 30 cm thick.

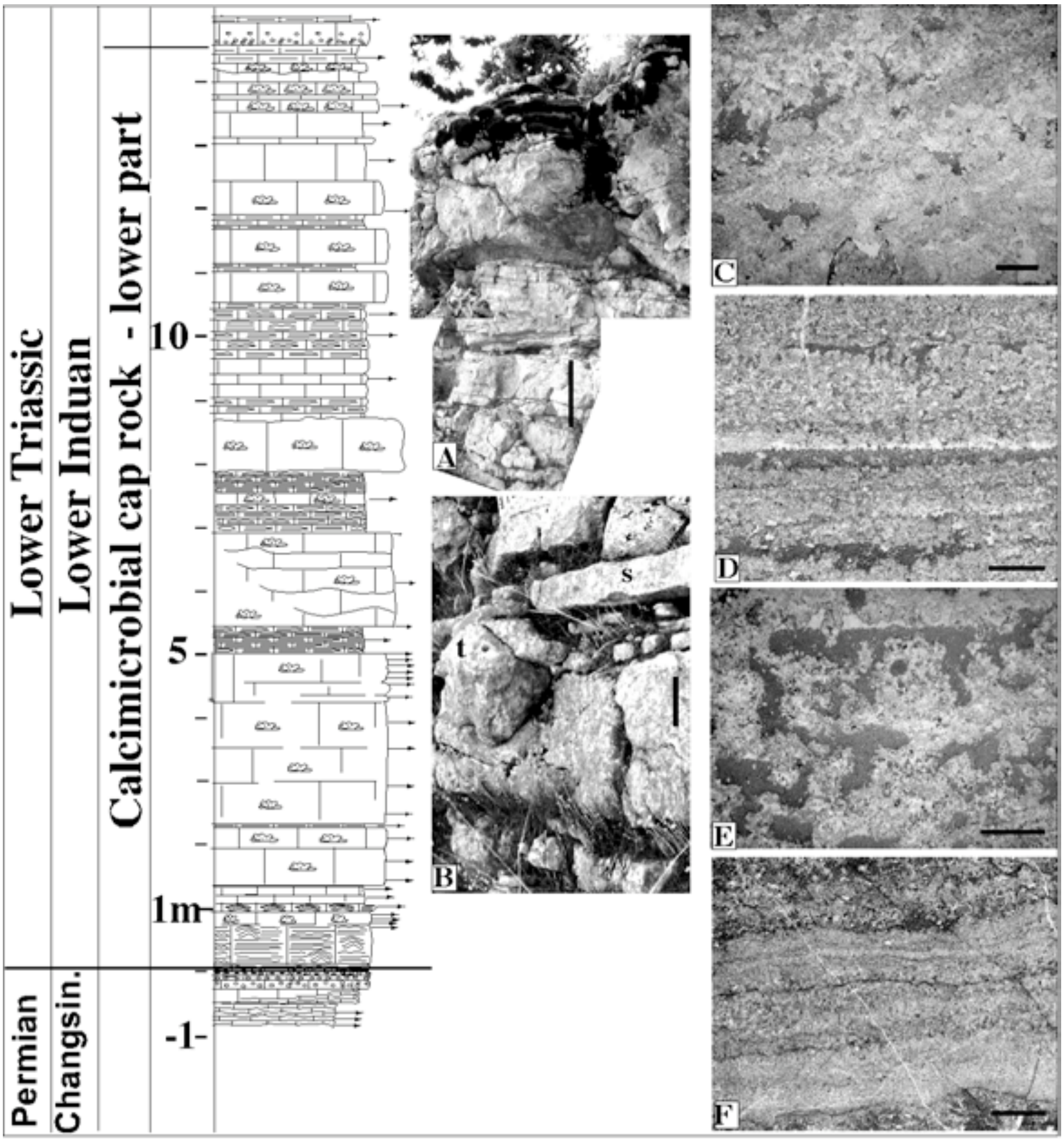


Figure 22: stratigraphic section, outcrop picture and microfacies of the basal Triassic calcimicrobial cap rock. This 14 m thick limestones, consists of an interdigitation of massive beds or domes with a thrombolitic texture and of thin bedded laminar stromatolites. Some levels are very rich in ostracodes as shown by the Fig. 4, in lilliput-foraminifera (Fig. 20) and in micro-gastropods.

Stop 2: the thrombolite bioherms (Baud et al,. 1997, 2005, 2007, Pruss et al., 2006).

The thrombolite bioherms are well developed, particularly in the Çürük dağ section (Figs .22, 23 and 24). They consist of bedded limestone or of mounds from 0.2 up to 2m thick and extend laterally up to 10-20m. They are intercalated in the thinly laminated stromatolitic limestones (Fig. 21). No mesostructures are visible in the field. The microfacies are illustrated in the Fig. 22. A microsparitic matrix with patches or drums of micrite is showing abundant millimetric to centimetric cavities with geopetal textures filled by dark peloids or micrite and cemented by blocky calcite. In some case a first generation of acicular fringe cement precedes the final blocky calcite. Micro-ostracods are found within the dark peloids infilling and within the clotted recrystallized microsparitic matrix, accompanied by micro-foraminifera.

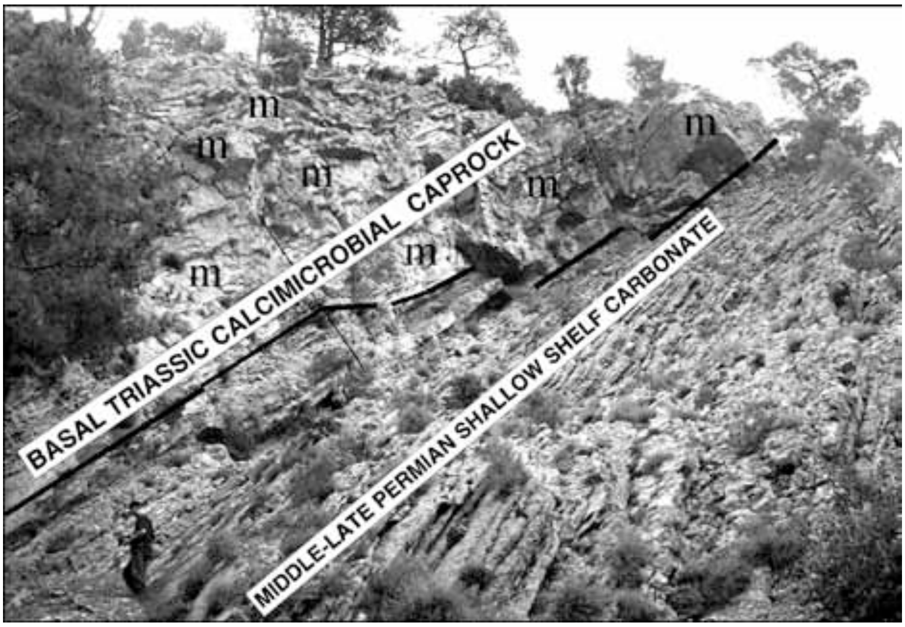
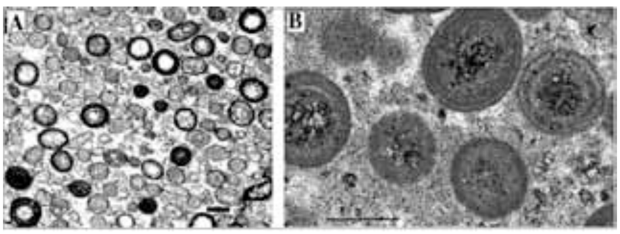


Figure 23: view on thrombolitic mounds (=m) of the basal Triassic calcimicrobial caprock, Çürük dağ south section. The scale is given by S. Richoz at the lower left corner

Figure 24: thrombolitic mound (stop 2).

Stop 3: the ooids facies.



The upper part of the calcimicrobial cap rock consists mainly of oolitic beds with minor intercalation of microbial calcilutite and thrombolitic beds. In most of the cases the oolites are recrystallized (Fig. 25A), but in Fig. 25B the fine concentric laminations are still preserved.

Figure 25 :Main meso- and microstructures of the oolitic facies **,** A- diagenetically altered oolitic grainstone; B- detail of the oolite with a preserved concentric texture, Scale bar of the microfacies (MF) is 1mm.

Stop 4: the multicoloured limestones, yellow shales and marls with Claraia**.**
A sudden fine terrigenous input marks the end of the calcimicrobial cap rock. In some sections a ferrigenous hardground is well developped.

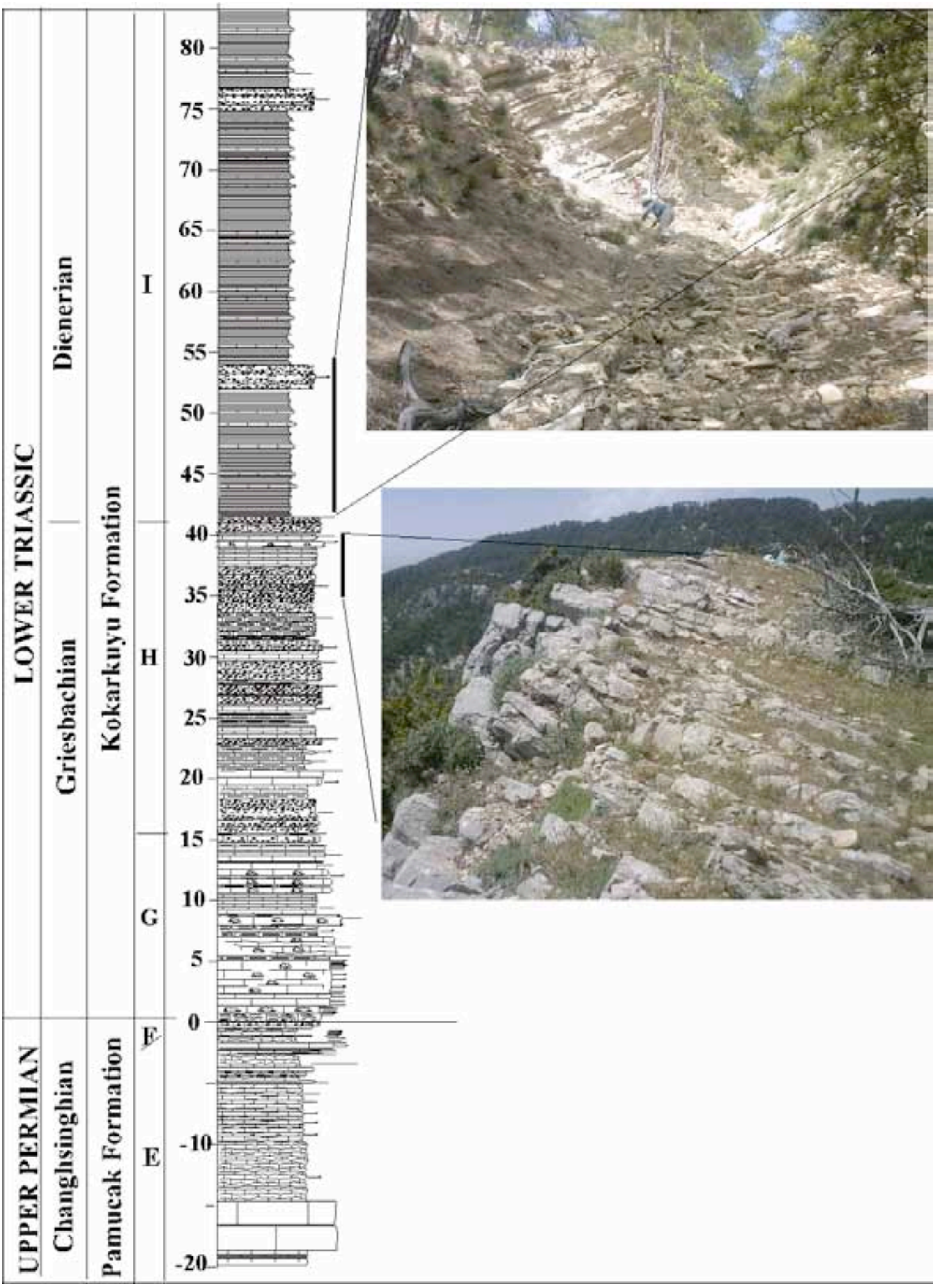


Figure 26: log of the upper part of the Çürük dağ section.The lower picture shows the top part of the oolitic limestones (stop 3) and the picture above illustrates the base of the yellow shales and multicoloured limestones (stop 4).

<u>September 5</u>, The Permian-Triassic transition at the Demirtaş section *(A. Baud, S. Richoz)*.

Introduction: the Antalya Nappes of the southern allochthons of the central Taurides (upper diagenesis grade), appears as a tectonic window below the Alanya Nappes of blue schist metamorphic grade. Both of northern origin, they were thrust southward during the Alpine Orogeny as shown by Ricou et al. (1990). The lithostratigraphic nomenclature in the Antalya tectonic unit was introduced by Özgul (1976, 1984), who proposed the Yüglük Tepe Formation for Permian bioclastic limestones and Sapadere Formation for the lower Triassic. The Demirtaş-Kuçdavut section has been investigated previously by Özgul (1976, 1984) and recently by Richoz (2006) with lithological and Carbon isotope studies and by Groves et al. (2005) with foraminifera extinction and recovery data.

Routing: The Demirtaş-Kuçdavut section is located about 10 km northeast of the town of Demirtaş¸ (Fig. 27).

Figure 27: Itinerary from Alanya to Demirtaş section (topographic ground from Google map).

Short description: this section is situated just above the paved road leading to the village of Kasiaglu (coord.: N 36°28'96'', E 32°14'99'', alt. 150m).

At the Demirtaş-Kuçdavut locality, the Lower Triassic Sapadere Formation overlies the Upper Permian Yüglüktepe Formation. The basal domal stromatolites (8 in fig. 30) are also present at this locality. Small carbonate precipitated fans (< 0.5 m) that resemble abiotically precipitated stromatolites were found in one limestone bed. No large carbonate mounds were preserved at this locality. The capping unit at this locality is an 8 m thick cross-bedded oolite (10 in fig. 30).

The upper 30m of the Yüglüktepe Formation has been investigated previously and a detailed description is given in Richoz (2006). As shown in Fig. 28, the decimetric thick dark limestone beds are very regular with some beds rich in gastopods and calcareous algae and belong to the uppermost part of the *Paradagmarita* Zone (Late Changhsingian, Groves at al., 2005, Gaillot & Vachard, 2007). The lithofacies of the upper part consists of an algal lime wackestone-packstone with both broken fragments and large unbroken thalli of gymnocodiacean and some dasycladacean algae. The presence of foraminifera, and fragments of crinoids, bivalves, brachiopods, gastropods and rare trilobites. The paleoenvironmental interpretations is a shallow subtidal inner carbonate platform (Groves et al., 2005, Richoz, 2006)

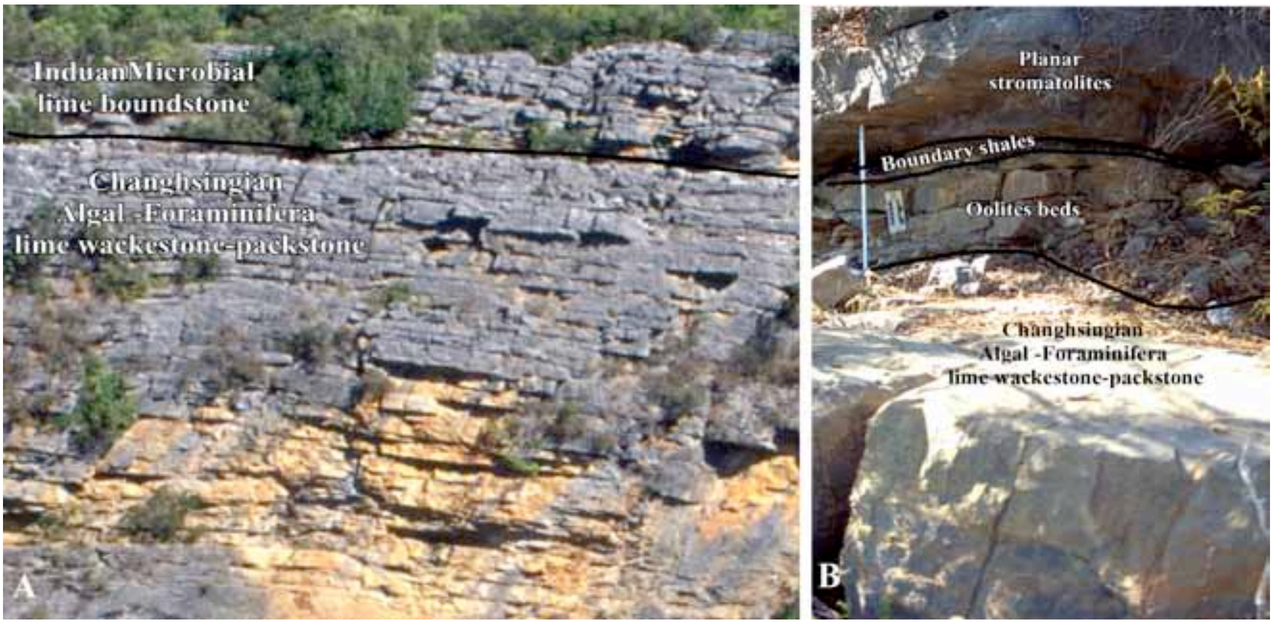


Figure 28: view of the Upper Permian (A, units 1-10, Fig. 30) and Permian-Triassic transition in the Demirtaş-Kuçdavut area (B, units 6 to 8, Fig. 30).

According Groves et al. (2005), the thin oolitic grainstones at the top of the skeletal wackestones and packstones reflect shoaling conditions in latest Permian time prior to emergence and subaerial weathering at the Permian–Triassic transition. This interpretation was not shared by Payne et al., 2007, who claimed submarine erosion. However, Collin et al. (2008) described evidence of subaerial vadose fabrics in grainstones directly below the late Permian erosion surface below the PT boundary section of the Great Bank of Guizhou in south China. This demonstrates that sea-floor dissolution is not proved, but erosion certainly occurred, as interpreted for the Demirtaş site.

Figure 29: the basal Triassic planar stromatolites (unit 8 in fig. 30)

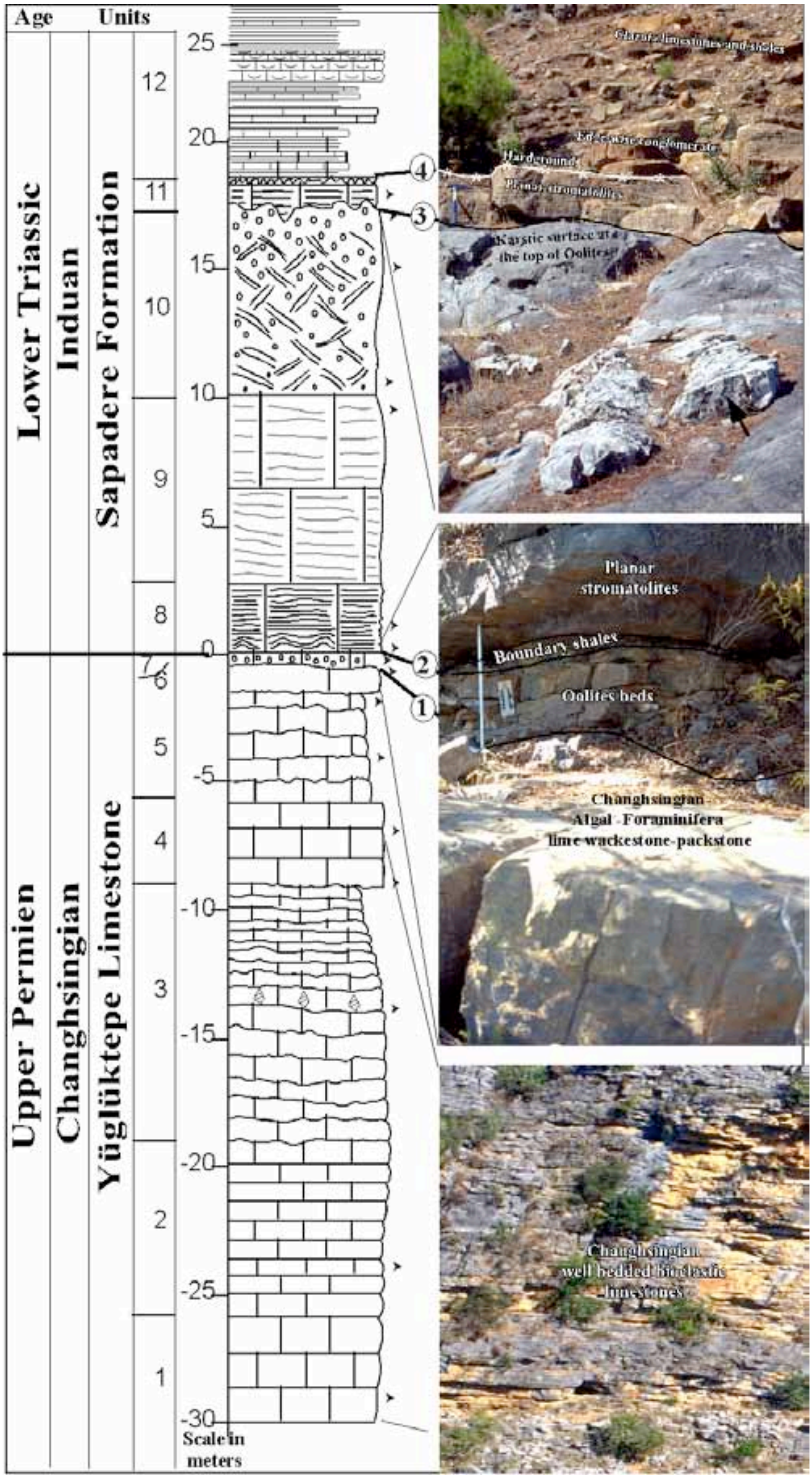


Figure 30**:** Demirtaş-Kuçdavut log section, Demirtaş window, outcrops views with the successive events 1 to 4 (circles); explanations in the text.

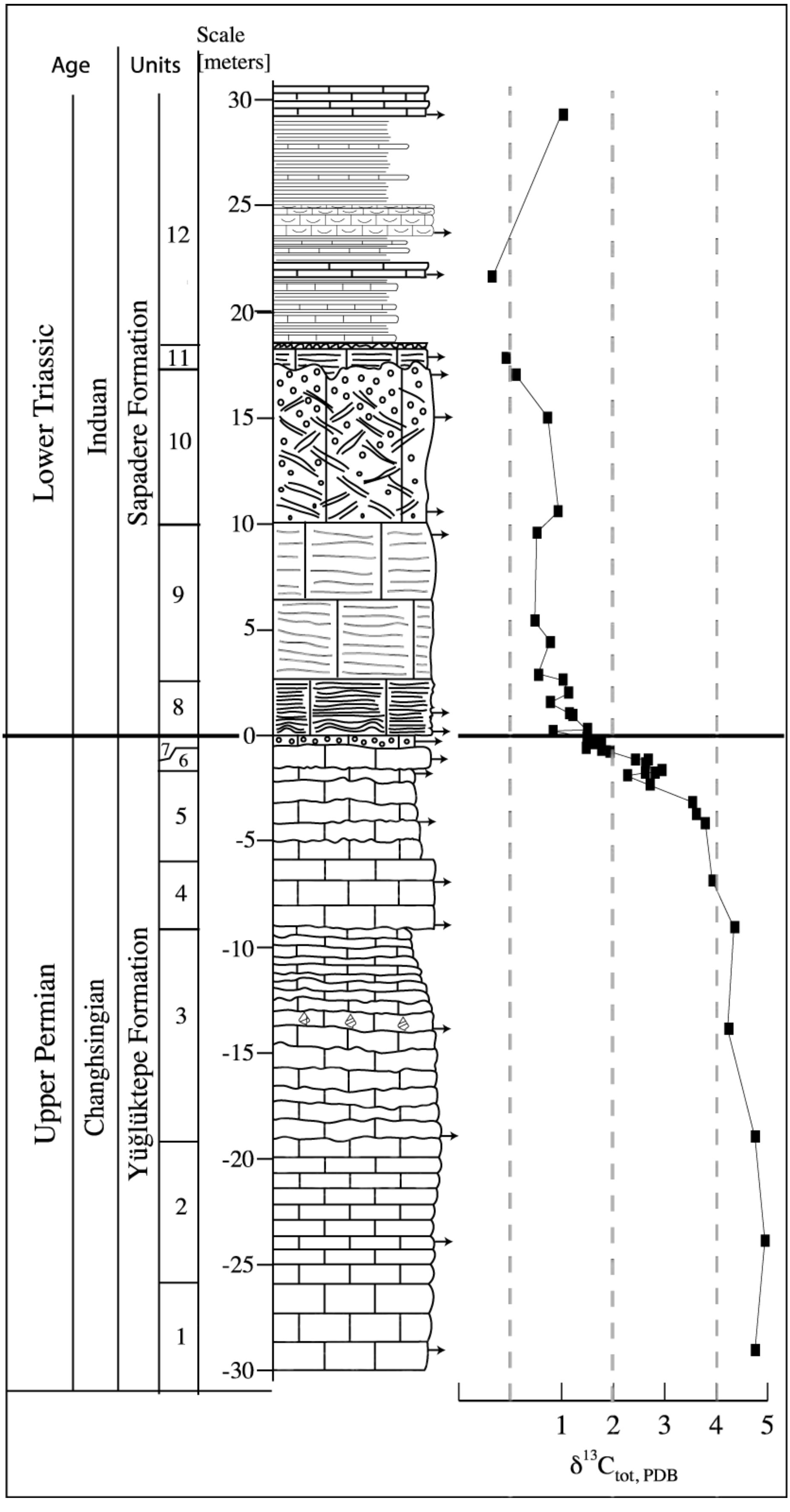


Figure 31: Carbon isotope profile of the Demirtaş-Kuçdavut section (from Richoz, 2006). Explanation on p. 10 to 13.

Stop 1: look at the Changhsingian bioclastic limestones and the Permian-Triassic transition illustrated in the next 3 pictures (Figs. 32-33) and details will be discussed in the field

Figure 32: right, general overview of the the Permian-Triassic transition, Demirtaş-Kuçdavut section: left, close view of the transition.

Stop 2: planar stromatolites at the base of the Sapadere Formation (Figs. 30, 32 and 33)

As in Çürük dağ section, the basal domal stromatolites are also present at this locality. But no large carbonate mounds were preserved here and the planar stromatolite beds of about 10 m thick form small cliffs and contain large numbers of the lilliput foraminiferal as *Rectornuspira kalhori* and *Earlandia* sp. In the upper part, the laminations became indistinct because of recrystallization

Figure 33: cliff built up by planar stromatolites, Demirtaş-Kuçdavut section. Scale given by Marie-Béatrice Forel.

Stop 3: the stromatolite - oolite transition (Figs. 30, 34).

The stromatolites are conformably overlain by a 8 m thick sequences of cross-bedded oolitic grainstones with bi-directionally oriented cross-laminae (Fig. 34). The oolites are badly recrystallized and partly dolomitized. Concentric cortices are barely discernible because of micritization, and nuclei are replaced by blocky calcite spar (Groves et al., 2005).

Figure 34: left, the contact between planar stromatolites and oolitic grainstones; right, erosional channel in the oolitic grainstones. Scale bar=1 m.

Stop 4: the contact between the calcimicrobial cap rock and the *Claraia* limestones and yellow shales (events 3 and 4, fig. 30, fig. 35).

An abrupt change separates the Griesbachian oolites from overlying strata. The oolites are truncated by a karstic surface at which a meter or more of erosional relief is developed (event 4). This irregular surface is filled by light colored micrite (Fig.35A) and by 0.85 m of yellowish-brown, planar stromatolites, on which surface a reddish to brown ferruginous hardground is developed (Fig. 35B). This surface (event 4) is in turn overlain by at least 19 m of alternating calcareous shales and thin-bedded, yellowish *Claraia* - *Aviculopecten* packstones.

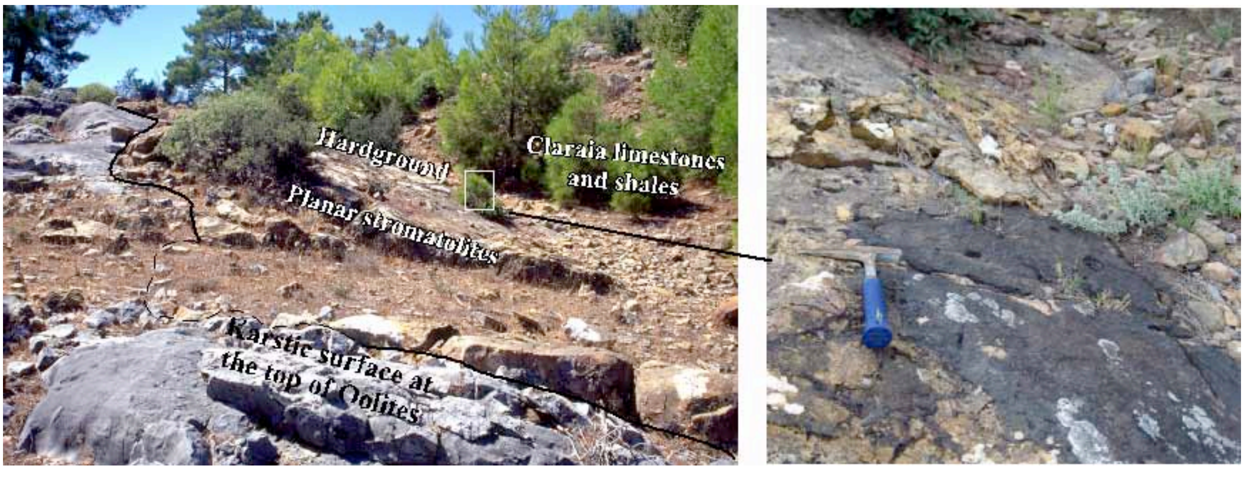


Figure 35: left (A), the transition on paleokarstic surface between the Oolites and the Claraia limestones and yellow shales (events 3 and 4); right (B), the ferruginous hardground.

At Demirtaş¸ according to Groves et al., 2005, the last occurrences of most Lagenide taxa fall within a 4 m interval of the skeletal wackestone/packstone facies of the upper Yüglüktepe Formation. They founded very few identifiable specimens from the overlying uppermost Permian oolite facies, and only indeterminate syzraniids were recovered from the stromatolitic and molluscan limestone facies of the Triassic Sapadere Formation

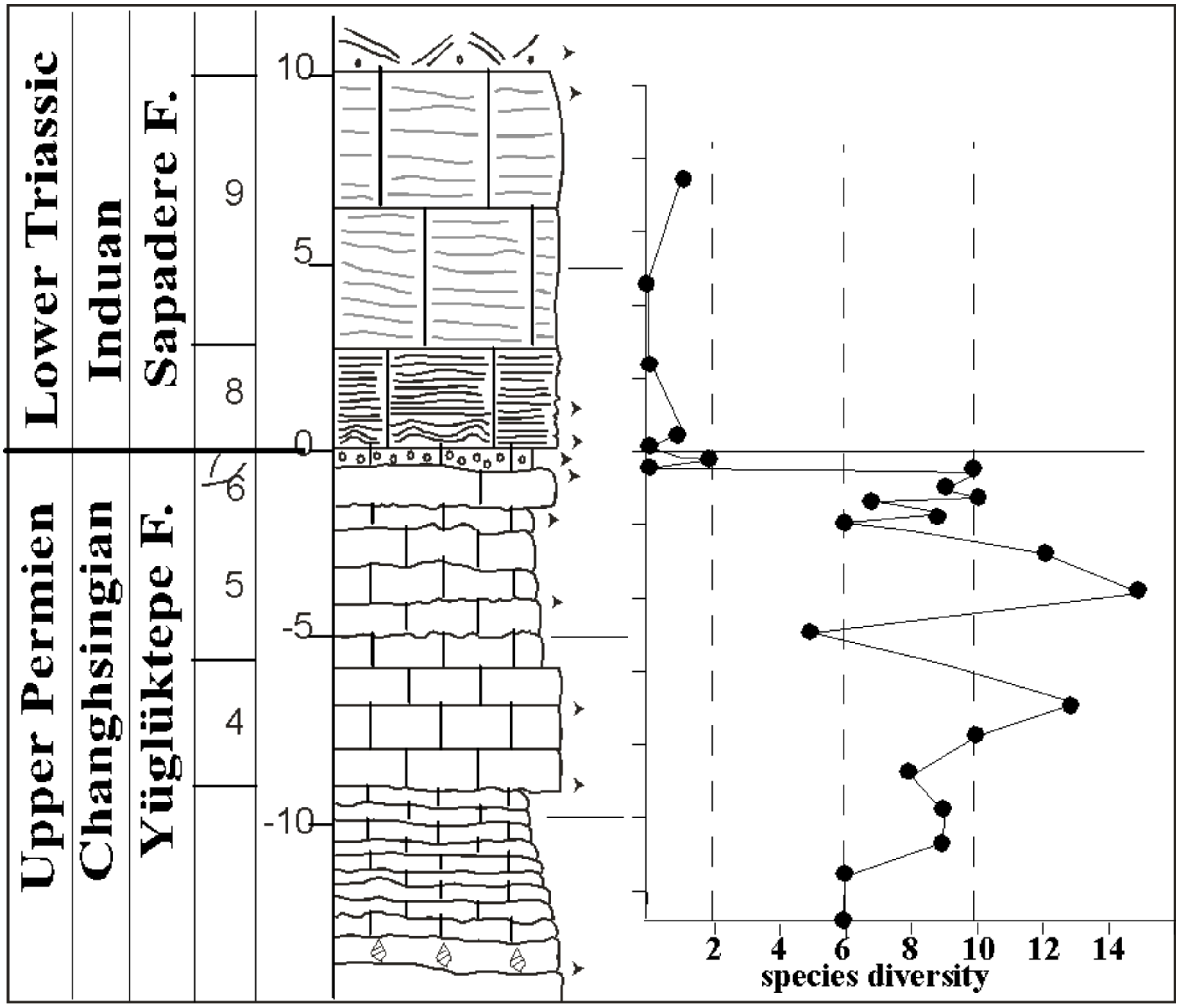


Figure 36: Lagenide species diversity across Permian–Triassic boundary at Demirtaş (from Groves et al., 2005, fig. 15).

These results (Fig. 36) from Groves et al., 2005, strongly suggested to the authors that the extinctions were abrupt, a conclusion that is equally evident from inspection of species diversity curves. They wrote that it is unclear, however, whether the main pulse of extinction occurred at the Permian–Triassic boundary or at the transition from skeletal wackestones and packstones to oolitic grainstones within the upper half-meter of the Permian. These authors even suspected that the paucity of lagenides in uppermost Permian oolites at Demirtaş was a consequence of paleoenvironmental exclusion and/or sediment dilution (rare bioclasts among large numbers of ooids).

September 6: the Permian-Triassic transition at the Oznur Tepe section.

(S. Kershaw, A. Baud, M.B. Forel).

Routing: The Permian-Triassic Boundary section at Oznur Tepe is located at N36°19'58", E32°21'32", east of Gazipaça on the eastern side of Antalya bay (Fig. 37).

Figure 37: itinerary from Demirtaş to Oznur Tepe section, crossing Gazipaşa and going for overnight to Selenius Hotel

Brief description of Oznur Tepe site and sections: rocks are exposed in a river cut, and dip steeply, so a vertical section of outcrop is easily accessed along the river path. Access to the site is in the area of heavily wooded hillsides where a lefthand turn immediately goes steeply downhill as the start of a long (c.3km) narrow unmade road through the woods down to the river level and then park at the end of the road 200 m from a small dam in the river (Figs. 38, 39). Cross the river and walk north 200 m to access the section which is located just beyond the dam, behind the trees on the west bank (Fig. 39 left). The overlying section along the road (Fig. 39 right) is faulted and only the lower Triassic limestones transition to the yellow shales and marly limestones is outcropping and clearly displayed (Fig. 47).

The section (sketch log in fig.40), which is composed almost completely of dark grey limestone, dips south, so walk past the section to begin at the lower part with the Permian-Triassic boundary and work your way back, up the section. The microbialite sequence is harder rock and forms a notable rock spur; north of this the cliff is recessed away from the river. A few m upslope from the path at the base of the section is a nice outcrop of a Late Permian erosion surface (Fig. 41). Below the erosion surface the rock is fine-grained, and is presumed here to be Permian in age. Above the erosion surface a skeletal grainstone marks the beginning of transgression leading to the earliest

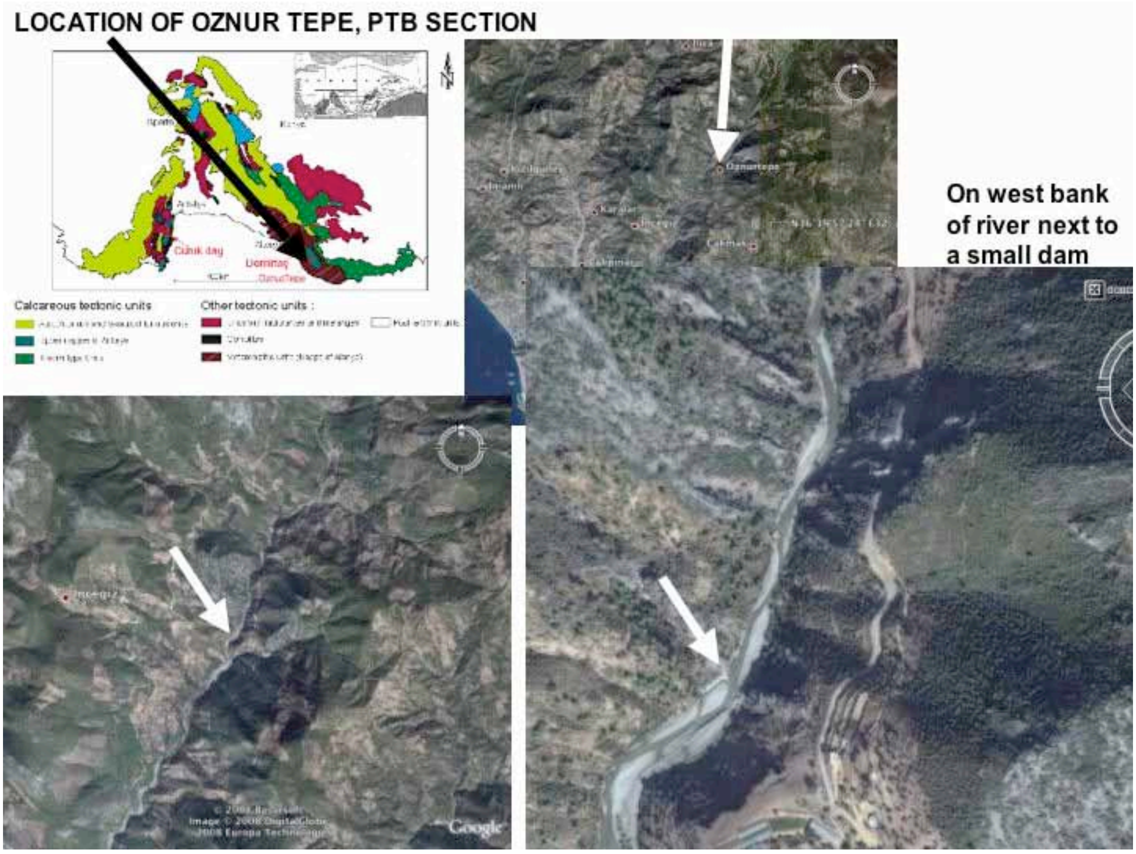


Figure 38: location of the Oznur Tepe PTB section.

Figure 39: overview of the Oznur Tepe PTB site, stop 1 at the river section and stop 2, if time, at the road section

Triassic microbialites and other shallow water sediments. The first microbialites are small domal stromatolites (Figs. 42, 43) that initiated in skeletal debris, and therefore were presumably mobile substrates. Above, the main development of thick tabular and domal stromatolites (Fig. 44) dominate the facies throughout the microbialite unit, with only small amounts of thrombolitic microbialite (Fig. 45), in contrast to the interlayered thrombolites and stromatolites of Çürük Dağ. Thus Oznur Tepe has similiarities to the Demirtaş section. At Oznur Tepe, there is little evidence of erosion surfaces within the microbialite (e.g. possibly in fig. 46).

The differences between Çürük Dağ and Oznur Tepe / Demirtaş suggests the conditions of formation were a little different from Çürük Dağ. The reasons for these differences can be discussed on the outcrop.

Stop 1: look at the Permian-Triassic transition (illustrated in the next 7 pictures, Fig. 40 to 46) and details will be discussed in the field.

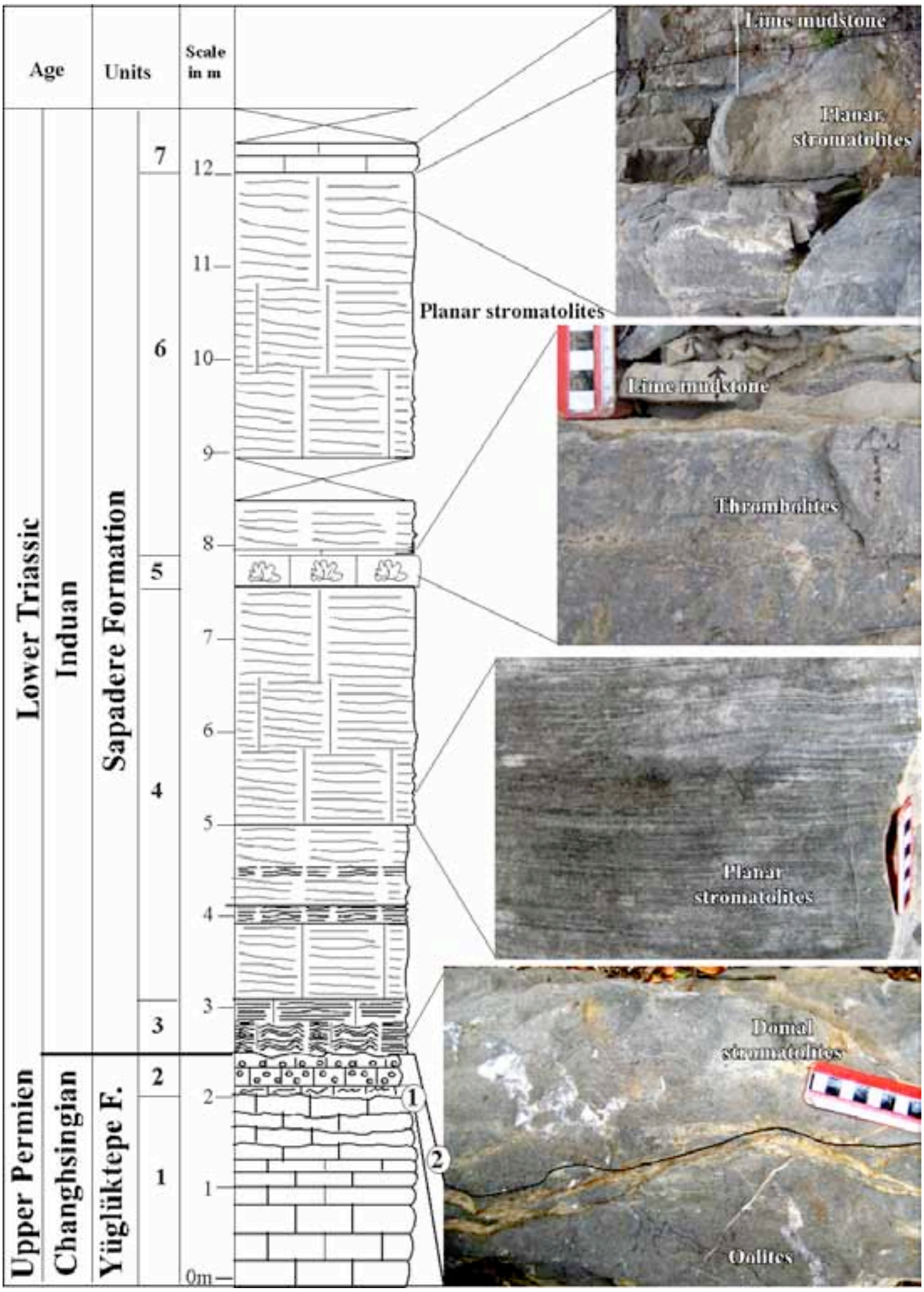


Figure 40: sketch log of Oznur Tepe PTB section with outcrop photos of the main facies. Events 1 and 2 (circles).

Figure 41: close-up of Late Permian erosion surface (line 1, in log fig. 40).

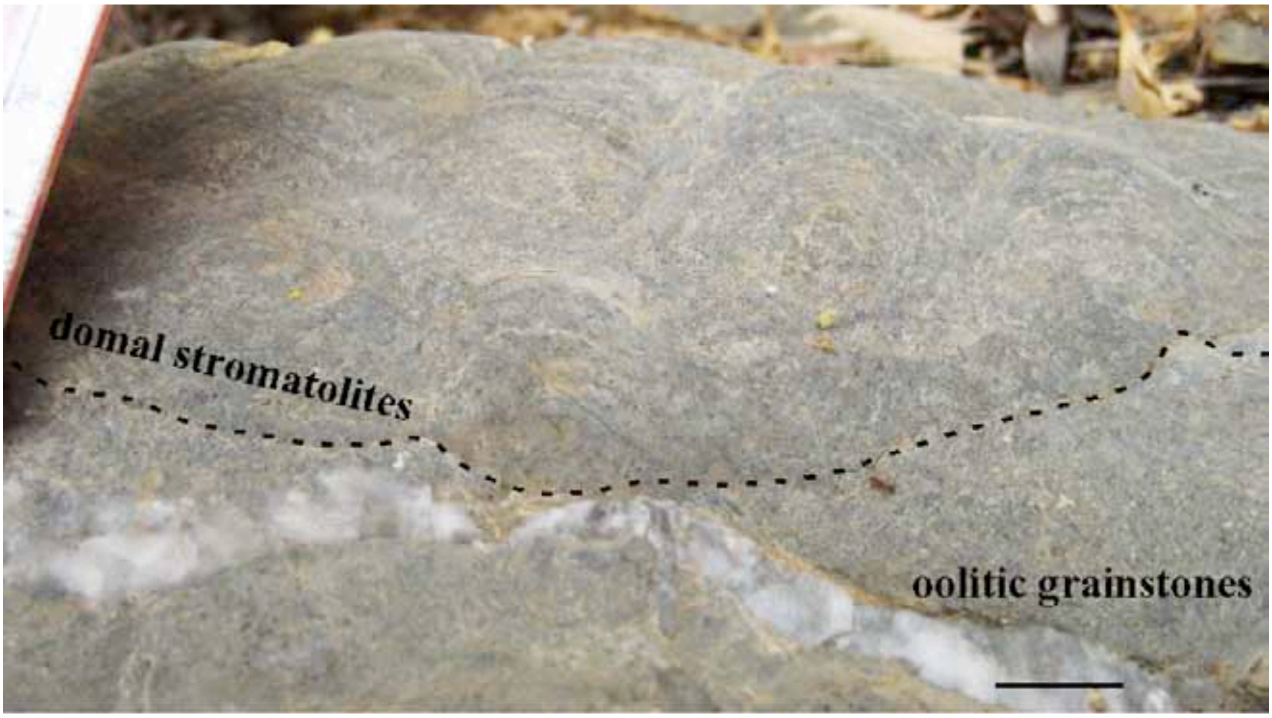


Figure 42; close-up of the contact between the oolitic grainstones and the lowermost domal stromatolites (line 2, in log fig. 40).

Figure 43: close-up of the lowermost domal stromatolites (above line 2, in log fig. 40).

Figure 44: domal and tabular stromatolites close to the base of the section, showing the massive stromatolitic development.

Figure 45: thrombolite in the middle of the section; this is the only significant thrombolite in the whole sequence. It is shown on the log Fig. 40 between 7.5 and 8 m.

Figure 46: thin micrite beds directly above the thrombolite in Fig. This rapid facies changes in the middle of the microbialite sequence suggest environmental changes, that we can discuss.

Stop 2 (if time): from oolites to yellow shales and marly limestones, the upper part of the section along the road (situation on Fig. 38 and illustrations on Fig. 47 to 49).

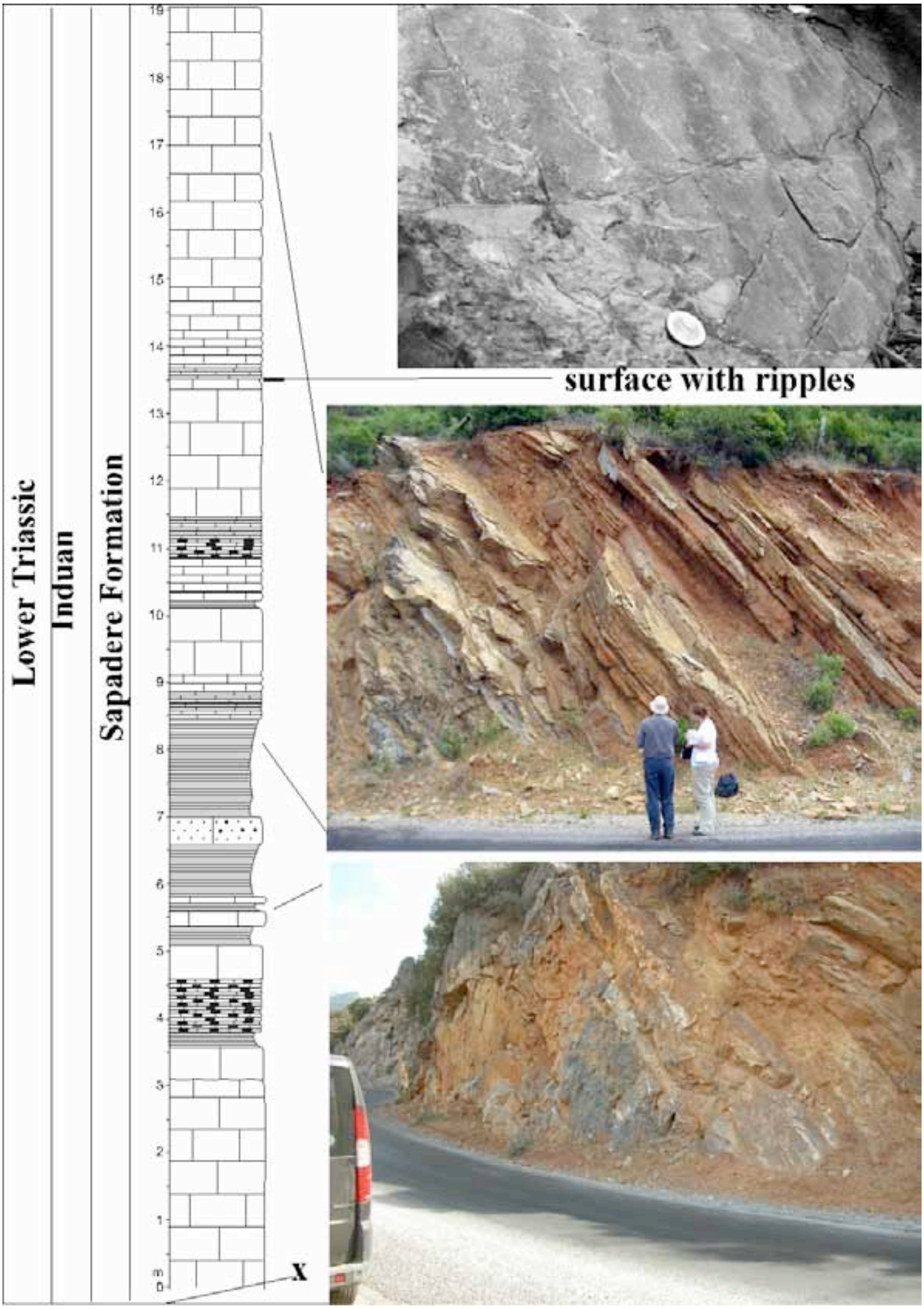


Figure 47: stop 2, log and outcrops view of the Oznur Tepe road section.

Figure 48: stop 2, (A) outcrops view of yellow -gray marly limestones.(B) upper surface of the bivalves limestones.

We always tried to choose the good road - Enjoy south Turkey!

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Notes