NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF ARMENIA

INSTITUTE OF GEOLOGICAL SCIENCES

IGCP 630:

Permian-Triassic climatic & environmental extremes and biotic response

IGCP630 5th INTERNATIONAL CONFERENCE

THE PERMIAN-TRIASSIC TRANSITION IN SOUTHERN ARMENIA

OCTOBER 8th-14th, 2017

Yerevan-2017

INTERNATIONAL GEOLOGICAL FIELD TRIP

IGCP 630: Permian and Triassic integrated Stratigraphy and Climatic, Environmental and Biotic Extremes

THE PERMIAN-TRIASSIC TRANSITION IN SOUTHERN ARMENIA

October 8th - 14th, 2017

Field photograph of the Vedi area (southern Armenia). In the foreground, carbonates at the Permian-Triassic boundary (PTB) are tectonically overlain by Cenomanian limestones

IGCP 630 Field Workshop in Armenia

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IGCP 630 Field Workshop 2017 in South Armenia

October 8 to 14, 2017, Yerevan, Armenia

Conveners: L. Sahakyan[1], A. Baud[2], A. Grigoryan[1] & Zhong-Qiang Chen[3]

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Workshop schedule:

October 8: Arrival in Yerevan, transfer to a hotel.

October 9: Conference Day 1, at the Round Hall of Presidium of the Armenian National Academy of Sciences, Yerevan.

October 10: Conference Day 2, at the Round Hall of Presidium of the Armenian National Academy of Sciences, Yerevan., and Visit of the Khor Virap monastery and the Matenadaran Scientific Research Institute of Ancient Manuscripts.

October 11: Field Trip, Day 1,Yerevan to Ogbin (166 km by bus). Visit to the Ogbin outcrop section. Accommodation in the Hotel Amrots in the city of Vayk.

October 12: Field Trip, Day 2,Vayk to Zangakatun, 50 km. Visit to the Chanakhchi outcrop section. Return to Hotel Amrots.

October 13: Field Trip, Day 3,Vayk to Vedi (86 km). Visit to the Vedi outcrop sections and visit of the Noravank monastery.
Return to Yerevan (67 km), Conference dinner in evening.

October 14: Samples packing for expedition, departure of the participants in the afternoon or in the night.

Monastery visit: according to time, two old Monasteries visit are planned.

1- Khor Virap monastery on October 10, afternoon

2- Noravank Armenian monastery (13th-century) on October 13, morning.

Sponsors
National Academy of Sciences of Armenia
National Natural Science Foundation of Armenia
IGCP 630 Committee

Field trip organizing committee:

Dr. Kh. Meliksetian[1], Dr. L. Sahakyan[1], Dr. A. Grigoryan[1], A. Baud[2], Dr. A. Avagyan[1]
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Scientific collaboration between Armenia, Austria and Switzerland

At the invitation of the Institute of Geological Sciences, National Academy of Sciences of Armenia, a collaborative team of four scientists comprising Dr. Sylvain Richoz, and Evelyn Friesenbichler from Graz University, Austria, Prof. Leopold Krystyn from Wien University, Austria, and Dr. Aymon Baud, from Lausanne, Switzerland, undertake field work on South Armenia Permian - Triassic sections. Dr. Lilit Sahakyan of the Academy of Sciences of Armenia leaded this Research program, from September 28 to October 6, 2014.

A Master Dissertation has been presented (Friesenbichler, 2016), a result paper is submitted (Friesenbichler et al., sub.) and only abstracts have been published (Friesenbichler et al., 2015, Baud et al., 2015, Friesenbichler et al., 2016a, Friesenbichler et al., 2016b).
Part of the work are still in progress and this guide book take account of the unpublished Friesenbichler Master dissertation, of old and new thin section pictures and of unpublished field notes and field pictures from all of us.

Part A – Introduction to the Permian–Triassic of South Armenia

1. Geological setting

Three main tectono-stratigraphic domains can be distinguished in the Southern Caucasus including Armenia, from NE to SW: (a) the southern margin of Eurasia; (b) the NW-SE oriented Sevan–Akera NeoTethyan suture zone (Fig. A1), extending for about 400 km to the north of Lake Sevan; and (c) a Gondwana-derived terrane known as the South Armenia micro-continent or block (SAM; Fig. A2, Sosson et al., 2010). The SAM is bounded by the Iranian terranes in the east, the Bitlis-Zagros suture zone in the south and the Turkish Anatolide-Tauride Block in the west. The SAM is considered as the tectonic eastern continuation of the Anatolide-Tauride Block (Meijers 2015). However the Permian and Triassic facies are very similar to the one developed in the Iranian Terrane and not to the one developed on the Anatolian microplate, suggesting rather a Cimmerian position of the SAM during the Permian and the Triassic.
After the subduction of the Neotethyan oceanic lithosphere beneath the Eurasian margin, a collision occurred between the South Armenia block and Eurasia beginning in the Paleocene. This resulted in: (1) folding of ophiolitic, arc-related and Upper Cretaceous volcanic and sedimentary rocks (Transcaucasus massif to Karabakh - Artsakh); (2) thrusting toward the SW; (3) development of a foreland basin in front [to the south] of the orogenic belt (Sosson et al., 2010).
Middle Eocene sedimentary unconformably overlies all three tectono-stratigraphic domains. As a result of the collision of the Arabian plate and the South Armenia block, a southward propagation of shortening with folding and thrusting occurred throughout the belt from the Eocene to the Miocene,. This deformed Tertiary succession is unconformably overlain by Miocene to Quaternary siliciclastic and volcanic rocks of uncertain origin (Sosson et al., 2010, Figs A1 and A2).

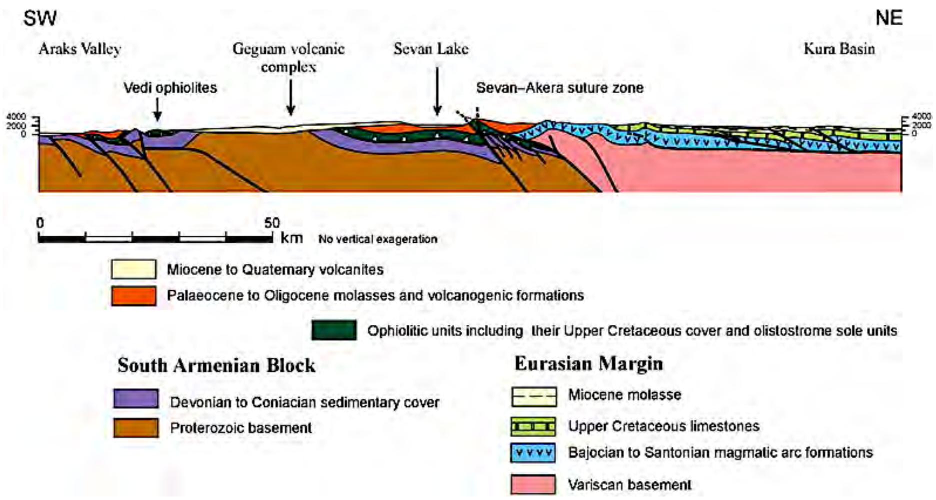

Figure A1: Cross-section of the Lesser Caucasus (Sosson et al. 2010, Fig. 4).

Paleozoic rocks of the South Armenian block crop out in SW Armenia (Fig. A2). The 500–1500 m thick Permian succession is composed of black limestones and marls sometime bituminous. Lower Triassic deposits conformably rest on Upper Permian limestones and are composed of conodont-rich, thin-bedded limestones (Grigoryan, 1990, Grigoryan et al., 2015, Zakharov et al., 2005), which pass upward into Upper Triassic sandstones, black siltstones and mudstones.

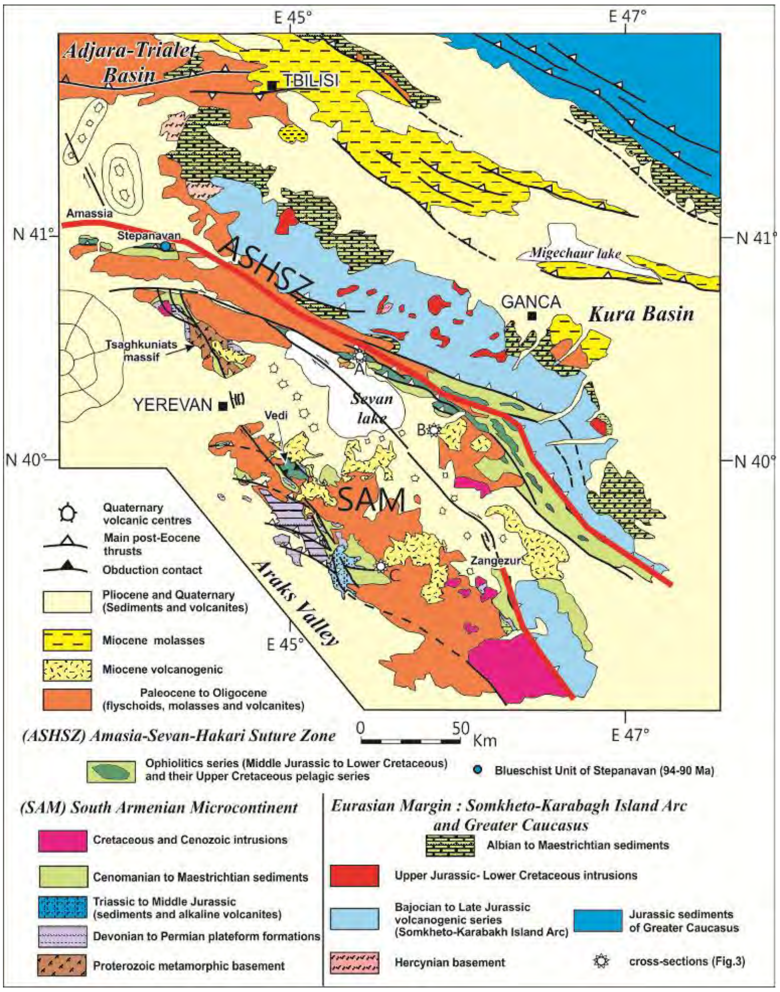

Figure A2: Structural map of the southern Armenian portion of the Lesser Caucasus (Sosson et al. 2010). The location of the Vedi thrust is according to Karakhanyan et al. (2013).

The Permian-Triassic boundary is exposed at the **Ogbin, Chanakhchi and Vedi** sections in South Armenia which are located about 170, 60 and 45 km from Yerevan, respectively (Fig. A3).

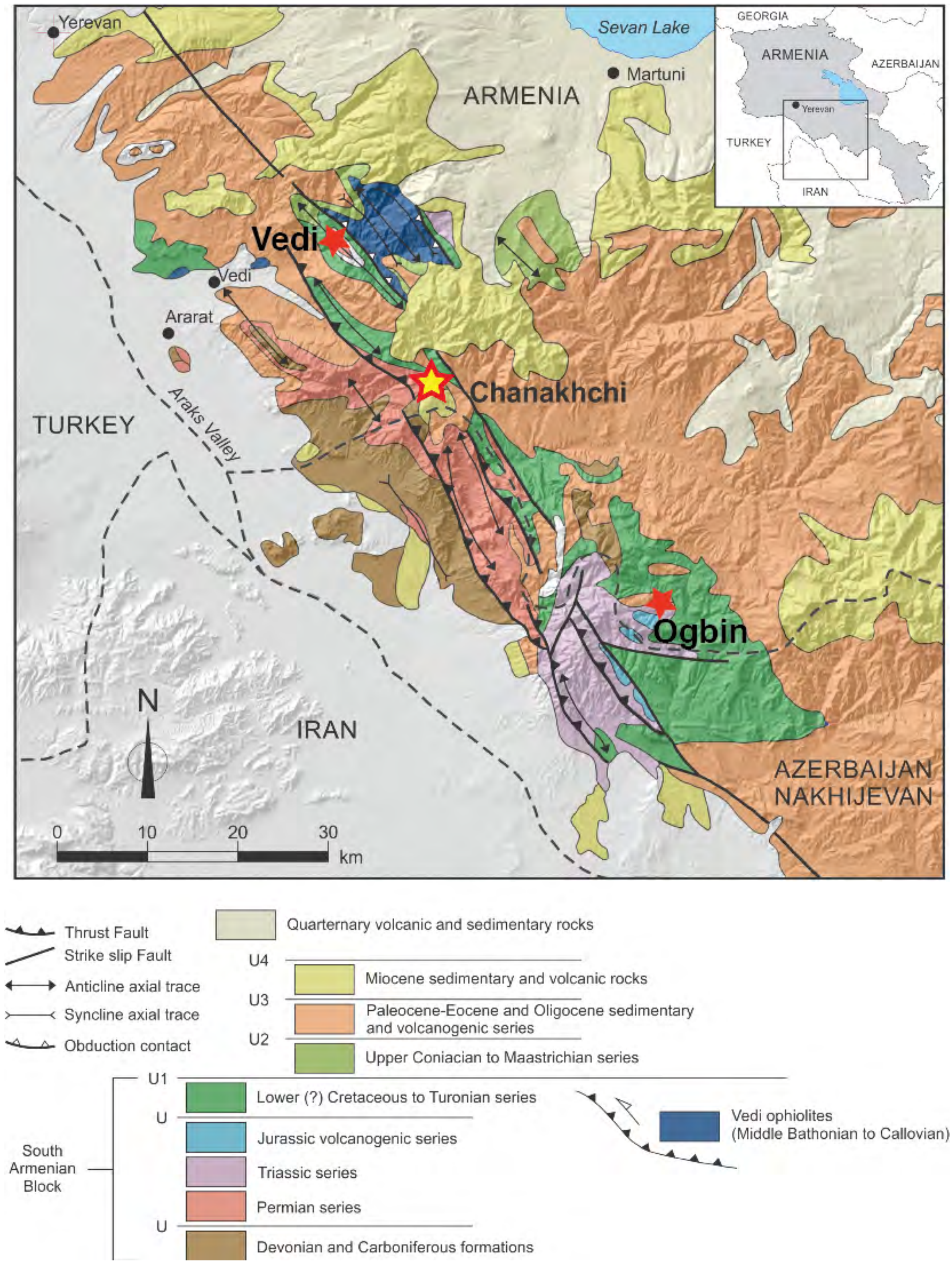

Figure A3: Geological map of S Armenia with the locations of the Vedi , Chanakhchi and Ogbin outcrop sections, where the Permian-Triassic boundary is exposed (Friesenbichler et al., submitted, modified after Sosson et al., 2010).

2. Overview on Permian-Triassic stratigraphy

The Southern Caucasus region is one of the few places in the World where continuous successions of Upper Permian and Lower Triassic strata with marine fauna can be observed at outcrop.

2.1 Historical Perspective

Due to its highly fossiliferous beds, the Upper Paleozoic of the Transcaucasia attracted very early paleontologists as Abich (1878), Möller, 1879 and Mojsisovics (1879). Very early as well came the long-lasting debate if the *Otoceras* ammonoids fauna can define the basal Triassic as proposed by Griesbach (1891) followed by Mojsisovics, Waagen and Diener (1895) based on Himalayan discovers, or if they represent the latest Permian. For Frech and Arthaber (1900) the Himalayan Otoceras were Permian in age as the Armenian one's.
A new genus *Paratirolites* is described by Stoyanov (1910), based on the "Triassic" so called *Tirolites* gr. discovered in the red "*Otoceras*" limestone near Julfa. This reinforces Bonnet (1919), because he was strongly fighting against Diener, and claimed an Eo-Triassic age of the Armenian red "*Otoceras*" beds based on large similarities between the Caucasian *Otoceras joulfense* and the Himalayan *Otoceras woodwardi*. One year later, Bonnet (1920a) published a paper on the Permian-Triassic Boundary (PTB) lying below the red limestone in Armenia and formulate comparisons with the Himalayan one. The PTB sea level change in the two areas was the subject of his next short paper (Bonnet,1920b), but still with this miscorrelation. The same point of view is well explained later, within the book on Transcaucasia geology published by Bonnet and Bonnet (1947).
Following studies are written by Paffenholtz (1948, 1964), Rostovtsev (1958), Azizbekov (1961), Arakelyan (1964), Rostovtsev et al. (1966), Tumanskaya (1966) and Shevyrev (1968a,b).
Due to the abundance of *Xenodiscidae* and early *Otoceratidae*, the biochronological problems and misplaced correlations continued until 1969. Ruzhentsev and Sarycheva (1965), incorrectly determined a basal Triassic *Tompophiceras* zone below the *Dzhulfites* and *Paratirolites* beds. Influenced by this, Stepanov et al., (1969), published, on the Iranian Julfa sections, a wrong correlation with a Permian-Triassic boundary in the middle of the red ammonoid limestone containing Permian *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 (Baud, 2014).

Afterwards, the Late Permian-Early Triassic succession is described by Rostovtsev and Azaryan (1973), by Kotlyar et al. (1983) and Aslanian (1984). Studies on stable Carbon isotopes started with Baud et al. (1989) and Zakharov et al. (2005) published some additional datas as Grygorian et al., 2015. Recently, works on C and O isotopes of the latest Permian - basal Triassic Chanakhchi section is published by Friesenbichler (2016). Conodonts was first studied by Kozur et al., (1978), then by Grigoryan (1990) with a stratigraphical list published by Zakharov et al. (2005). Transcaucasia Permian foraminifera are studied first by Ruzhentsev and Sarycheva, 1965, then by Kotlyar et al., 1983, 1989, by Pronina, 1990, by Leven, 1998 and by Jenny et al., 2009.
Zakharov et al. (2005) described the section Chanakhchi at village Zangakatun (former Sovetachen). Recent studies on basal Triassic sponge-microbial build-ups (SMB) are in progress (Friesenbichler et al., sub.) and some abstracts or poster have been published (Friesenbichler et al., 2015, Baud et al., 2015, Friesenbichler et al., 2016a, Friesenbichler et al., 2016b).

It is only recently that the new standard Stage names have been adopted and replace the Midian, Dzhulfian and Dorashamian regional Stages as still used in the papers of Zakharov et al., 2005 and Jenny et al., 2009.

2.2 The Middle to Upper Permian units.

The Middle and Upper Permian units in Armenia are represented by the Khachik Formation and the Akhura Formation, which have been described in detail by Leven (1998). For a better stratigraphic understanding we are giving part of his text in quotes below

2.2.1 The Khachik Formation (Capitanian-Wuchiapingian).

"It was established by Arakelyan (Geology of Armenian SSR, 1964) in the Avush Gorge, to the south of the Khachik Village. The unit shows a transitional boundary with the underlying Arpa Formation (Guadalupian), from which it may be distinguished by its darker color. It is mainly composed of thin-bedded clayey, bituminous limestone passing into calcareous mudstone and alternating with more compact, thick-bedded algal-foraminifera and biodetrital limestone commonly dark gray and black in color. Cherty interbeds and lenticular inclusions are characteristic. The lighter-colored compact limestones called "Chanahchi Beds" 10-15 m thick (Lopingian base) may be observed at the very top of the unit (Kotlyar et al., 1989). The total thickness of the formation is about 150-200 m.

The paleontological content of the Khachik Formation is described thoroughly by Ruzhentsev and Sarycheva (1965) and Kotlyar et al. (1983, 1989). As in the underlying formations, Fusulinids, small foraminifers and algae are the main components. Miliolids are especially abundant among small foraminifers. They form white disseminations in the dark deposits, which can be noticed by naked eye. Rare corals, brachiopods, and bryozoans, as well as ostracods, more abundant than those of the older deposits, are recorded." If large foraminifera are present in the lower and middle part (Upper Guadalupian) as *Pseudofusulina*. ex gr. *chihsiaensis*, *Eoverbeekina* ex gr. *intermedia*, etc., and higher *Neoschwagerina pinguis*, *Chusenella schwagerinaeformis*, *Ch. minuta,* they totally disappear in the upper part (*Reichelina* -*Araxilevis* beds, Lopingian). This Upper part was Capitanian in age for Leven but became Wuchiapingian for Kotlyar et al., 1989 (discussion in Leven, 1998, p. 310). These *Reichelina* -*Araxilevis* beds are now well correlated with Lower Wuchiapingian sections.

2.2.2 The Akhura Formation (Wuchiapingian-Changhsingian).

It was established by Leven (1975) in its type section at the Dorasham 2 railway station, near the town of Dzhulfa (Nakhitchevan). "Another good section crops out near the Armenian Akhura Village. The Formation differs sharply in every aspect from other formations. It consists commonly of limestones, which alternate with mudstones in the type section. The limestones, opposite to the underlying ones, are represented mainly by well-bedded, thin, detrital micritic varieties with frequent clayey content. The bituminous content of the underlying limestones is not recorded. Detritus includes fragmentary shells of brachiopods, cephalopods, gastropods, and ostracods. Interbeds composed entirely of crinoid or brachiopod and cephalopod shells are present. Some interbeds are crowded with conodonts.

The limestones and mudstones of the lower part of the formation are commonly white, yellowish and greenish colored while those of the upper part are predominantly pink and brick red. The sharp contact between the Akhura and Khachik Formations suggests a short gap in sedimentation. The sharp boundary between the Akhura Formation and the Triassic deposits was wrongly interpreted as a major gap with three missing cephalopod zones (Zhao et al., 1978, 1981)."

However, the records of Zakharov (1988), as well as data on conodonts (Kozur et al., 1978, Grigoryan, 1990 and Zakharov et al. 2005) indicate the continuity of the section. Unlike the other Permian units, the Akhura Formation is very thin, varying between a maximum of 51 m recorded in the Dorasham 2 section and a minimum of 3 m in the Ardych section. Although heavily condensed, the section is continuous, as demonstrated by the occurrence of all the conodont zones recognized in thicker sections. Since the paleontological description of the Formation was presented extensively in a number of papers and monographs (see Chap. 2.1), no further discussion is here necessary.

"It should only be emphasized that the composition of the biotic associations underwent as sharp and considerable changes between the Khachik and Akhura Formations, as it was first in the Upper Khachik Formation at the base of the *Reichelina* -*Araxilevis* beds. Almost all Fusulinids and part of smaller foraminifers and algae, which were sediment-producers, became extinct. Tabulate corals and Waagenophyllids rugose corals only reappeared temporarily within the *Paratirolites* beds. The brachiopod assemblage was completely renewed. Conodonts and cephalopods acquired a leading role. This, in combination with different lithofacies, suggests significant changes in sedimentation, environments and habitats, whose characteristics are still unknown" (Leven, 1998).

2.3 The Triassic units.
Three stratigraphic subdivisions are distinguished: the Karabaglyar Formation (Early Triassic), the Tananam Formation (Middle Triassic) and the Djermanis Formation (Late Triassic).

The Karabaglyar Formation (Early Triassic) consists of platy limestones up to 400 m thick. The base, with the thin bedded *Claraia* beds, 20-30 m thick, surrounding SMB will be described in detail for each examined sections. According to Ruzhentsev and Sarycheva (1965), Kotlyar et al. (1983), Zakharov et al., (2005) these lower beds are yielding numerous *Ophiceras* and rare *Gyronites*, *Koninckltes* and *Kymatites* sp. ammonoids.
The middle part consists of massive oolitic beds and haven't been studied in detail.

The Tananam Formation (Middle Triassic?) is built of massive dolomite, 400 to 600 m thick with rare fossils as *Undularia* cf.*scalata*, *Omphaloptycha* sp. gastropods and *Pleuromya* sp. bivalves.

The Djermanis Formation (Late Triassic) consists of dark colored mudstones bedded in laminated mudstones and sandstones with rare coal and bituminous horizons containing plant fossils. The thickness is nearly 550m.

3. Carbon isotope stratigraphy and paleotemperature measurement.

First studies on stable carbon isotopes from the Vedi and Chanakhchi (former Sovetachen) section have been published by Baud et al. (1989), who revealed three negative carbon isotope shifts recorded in Middle Permian and Early Triassic limestones at the Vedi section (Fig. A4).

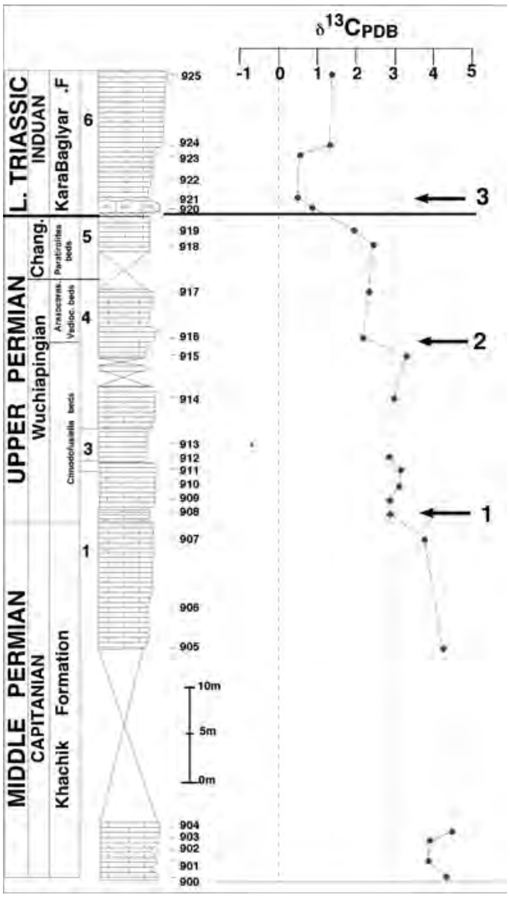

Figure A4: Carbon isotope curve at the Vedi section (from Baud et al., 1989, corrected).

The first shift (1) occurs near Guadalupian-Lopingian boundary (about 1 ‰). The second (2) is in the Upper Wuchiapingian at the facies change between dark and light limestone (about 1 ‰). The third (3) is the well-known PTB shift, here about 2 ‰.
Supplementary carbone isotope analyses were presented by Zakharov et al. (2005) and Grygorian et al. (2015). New Carbon isotope analyses of the Chanakhchi section are given by Friesenbichler (2016) and Friesenbichler et al. (2015, 2016a, 2016b). Additionally to carbon isotope analyses, Zakharov et al. (2005) also performed stable oxygen isotope analyses on well-preserved brachiopod shells for paleotemperature calculations.

New paleotemperature data on PTB section in Armenia calculated from from $\delta^{18}O$ measured on conodont apatite were announced in abstracts by Joachimski et al., 2013 and by Grygorian et al., 2015.

Notes

Part B - Description of the visited outcrops

4. The Ogbin section

11th October: Yerevan to Ogbin (170 km, 2 h. 45 min by bus); accommodation in the Amrots Hotel in the city of Vayk (Fig. B1).

Figure B1: Field Workshop Itinerary (Road in white, Border in red).

4.1 Geological setting

The Ogbin section is located about 5 km west of the village of Khndzorut. Here, Permian limestones are exposed to both north and south of the ruins of the ancient village of Ogbin, in the gorge of the Tchahuk river (Figs B2 and B3).

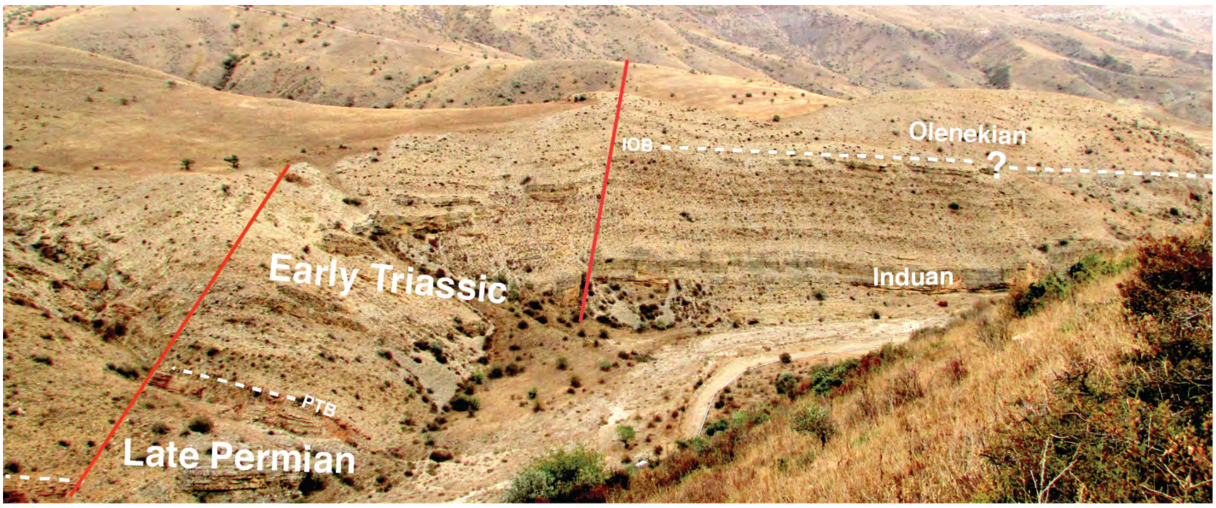

Figure B2: The Ogbin section area looking to the NE, along the Tchahuk river. The visited outcrops will be on the left down with the condensed Upper Permian Units and the Permian-Triassic Boundary (dashed white line, PTB). On the right we can see the well developed Lower Triassic Karabaglyar Formation with an obvious cyclic sedimentation and we draw a tentative Induan-Olenekian Boundary (dashed white line, IOB) that still need to be studied.

Around the ruins of Ogbin village, the Permian-Triassic succession is overlain by thick brown and brownish-gray conglomerates of Coniacian age (Hakobyan, 1978), which contain large pebbles and boulders of limestones derived from the Permian and Triassic successions together with volcanic rocks and sandstones. Jurassic sediments have limited distribution in the area and are represented by volcanogenic-sedimentary deposits (cross section in Fig. B4).

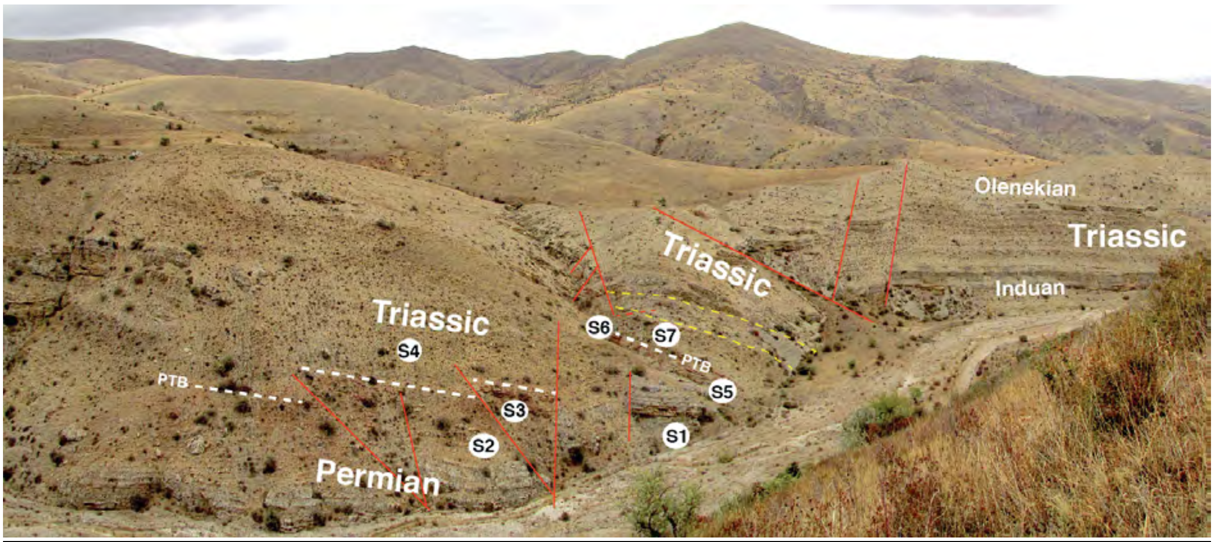

Figure B3: Field picture of the Ogbin section looking North and showing the contact between Permian limestones and Lower Triassic lime mudstones. The planned stops are S1 to S7. Red lines: faults; dashed yellow line: internal thrust planes; dashed white lines: PTB=boundary between Permian red nodular limestones and Triassic yellow thin bedded limestones with some light-gray Sponge-microbial build-ups (SMB).

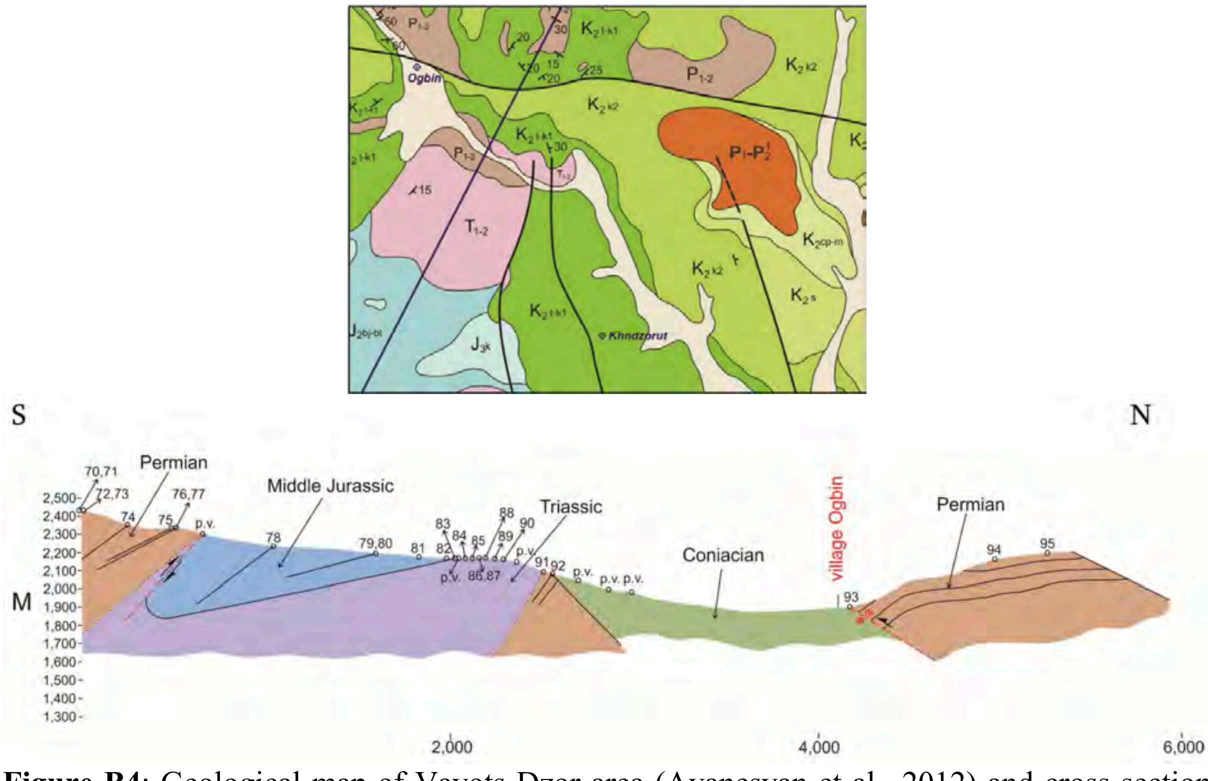

Figure B4: Geological map of Vayots Dzor area (Avanesyan et al., 2012) and cross section through the Ogbin Valley (Galoyan et al., 2009).

4.2 The seven stops of the day (Fig. B3).

Stop 1: Our first stop will be the Upper Permian Khachik unit cropping out along the Ogbin Valley (Fig. B5). The Permian units of Ogbin have been worked out in detail by Kotlyar et al., 1983. Their Ogbin section with levels K1 to K10 is shown at Fig. B6 B.

The upper part of the Khachik Formation that consists of the *Reichelina* - *Araxilevis* beds (14.7 m thick, Wuchiapingian) is cropping out along the left side of the river with thick bedded dark gray limestones (2 in Fig. B5).

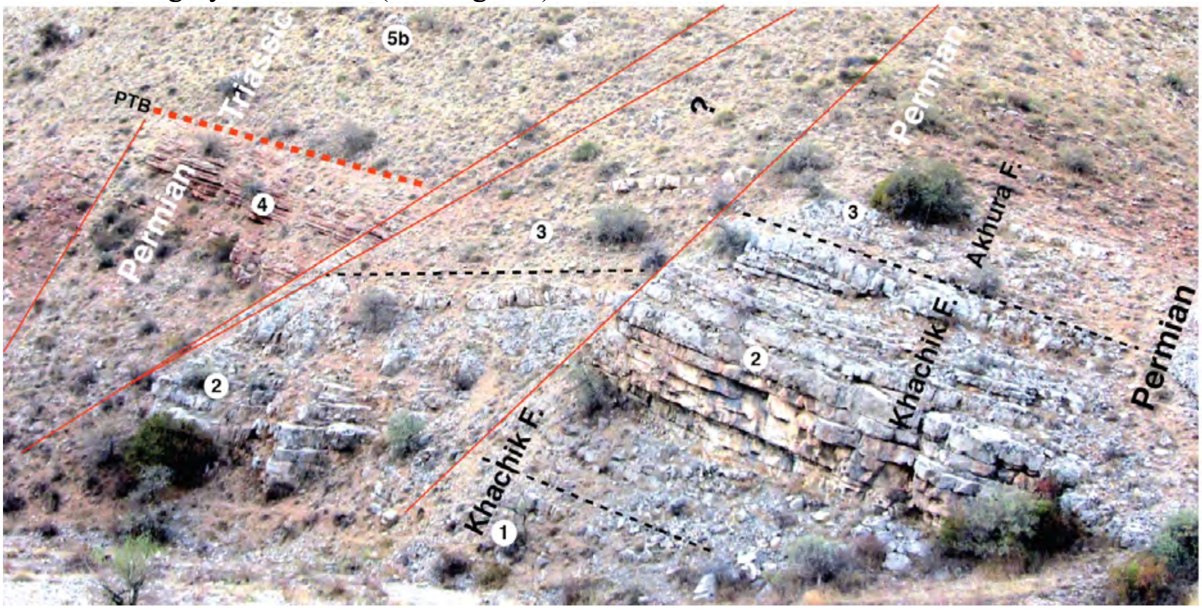

Figure B5: Field picture of stop 1. Right down, outcrop of the Middle to Upper Permian Khachik Formation (Units 1-2); Unit 1, Top of the Middle Permian (Capitanian) dark gray limestones. Unit 2, *Reichelina* - *Araxilevis* beds (Lower Wuchiapingian), gray limestones followed by the Upper Permian Akhura Formation (Units 3-4)). Unit 3, *Araxoceras* and *Vedioceras* beds, gray yellowish marly limestones (Upper Wuchiapingian) . Unit 4, *Phisonites* to *Paratirolites* beds, red nodular marls and limestones (Changhsingian). Unit 5b, Induan thin bedded limestones with SMB. Dashed black line: boundary between lithological units. Dashed red line: Permian-Triassic Boundary (PTB).

From the Kotlyar et al., 1983 levels K2 to K6 (section B in Fig. B6), belonging to our Unit 2 (Upper Khachik Formation), a rich foraminifera fauna is published:

K2- *Neoendothyra* sp., *Climacammina* sp., *Cribrogenerina*? *sumatrina, Globivalvulina graeca, Gl*. sp., *Paraglobivalvulina mira, Dagmarita* sp., *Agathammina* sp., *Nodosaria* aff . *longissima camerata, Geinitzina gigantea, G. postcarbonica, G.* cf. *C. chapmani, Pseudotristix solida, Frondina permica, F.* sp. 1, .*F.* sp.; *Boultonia* cf. *ogbinensis, B*. ex gr. *willsi, B.* sp., *Pseudodunbarula dzhagadzurensis, P. arpaensis,* - *Shubertella* sp., *Codonofusiella ilpovensis, C. dzhagrensis, C.* sp., *Boultonia ogbinensis, B, avushensis, B,* sp,; *Nanlingella*? *ardaglensis, Pseudodunbarula dzhagadzurensis, Reichelina* ex gr. minuta*, Nankinella* sp., *Staffella* sp.

K3- *Climacammina* sp., *Globivalvulina bulloides*, Gl. sp., *Paraglobivalvulina mira*, *Dagmarita chanakchiensis*, D. sp., *Abadehella coniformis*, *Agathammina* sp., *Nodosaria mirabilis caucasica*, *N*. sp., *Geinitzina postcarbonica*, *G*. cf. *caucasica*. *G*. aff. *gigantea*, *G*. sp., *Pachyphloia* sp. *Frondina permica*, F. sp. 2, F. sp., *Rectoglandulina*. sp., *Robuloides* aff, *gibbus*; *Codonofusiella lipovensis*, *C*. cf, *lui*, *C*, cf. *sphaerica*, *C*. sp., . *Boultonia ogbinensis*,

B. avushensis, *Nanlingella*? *ardaglensis*, *Reichelina* ex gr. *minuta*, *Codonofusiella parva*, *C. golubinensis*, *C.* ex gr, *golubinensis*, *C*, sp., *Boultonia* sp.
K4- *Climacammina*. aff. *moelleri*, *Geinitzina* sp., *Pachyphloia* sp., *Frondina* sp. l., *F.* sp. 3, *Codonofusiella* cf. *erki*, *C.* sp., *Boultonia* sp.
K5- *Agathammina* sp., *Pachyphloia* sp., *Codondofusiella* ex gr. *golubinensis*, *C.* ex gr. *kueichowensis*, *C*, sp., *Nankinella* sp.
K6- *Abadehella* sp., *Pachyphlola* sp., *Robuloides* sp., *Reichelina changsingensis*, *R.* sp.
Brachiopods are recorded in Kotlyar et al., 1983, levels K5 and K6 (section B in Fig. B6): *Orthotetina dzhulfensis* (K5). *Orthotetina persica*, *Richthofenia lawrenciana*, *Spinomarginifera spinosocostata*, *Leptodus nobilis*, *Permophricodothyris ovata*, *Araxathyris araxensis araxensis* (K6).

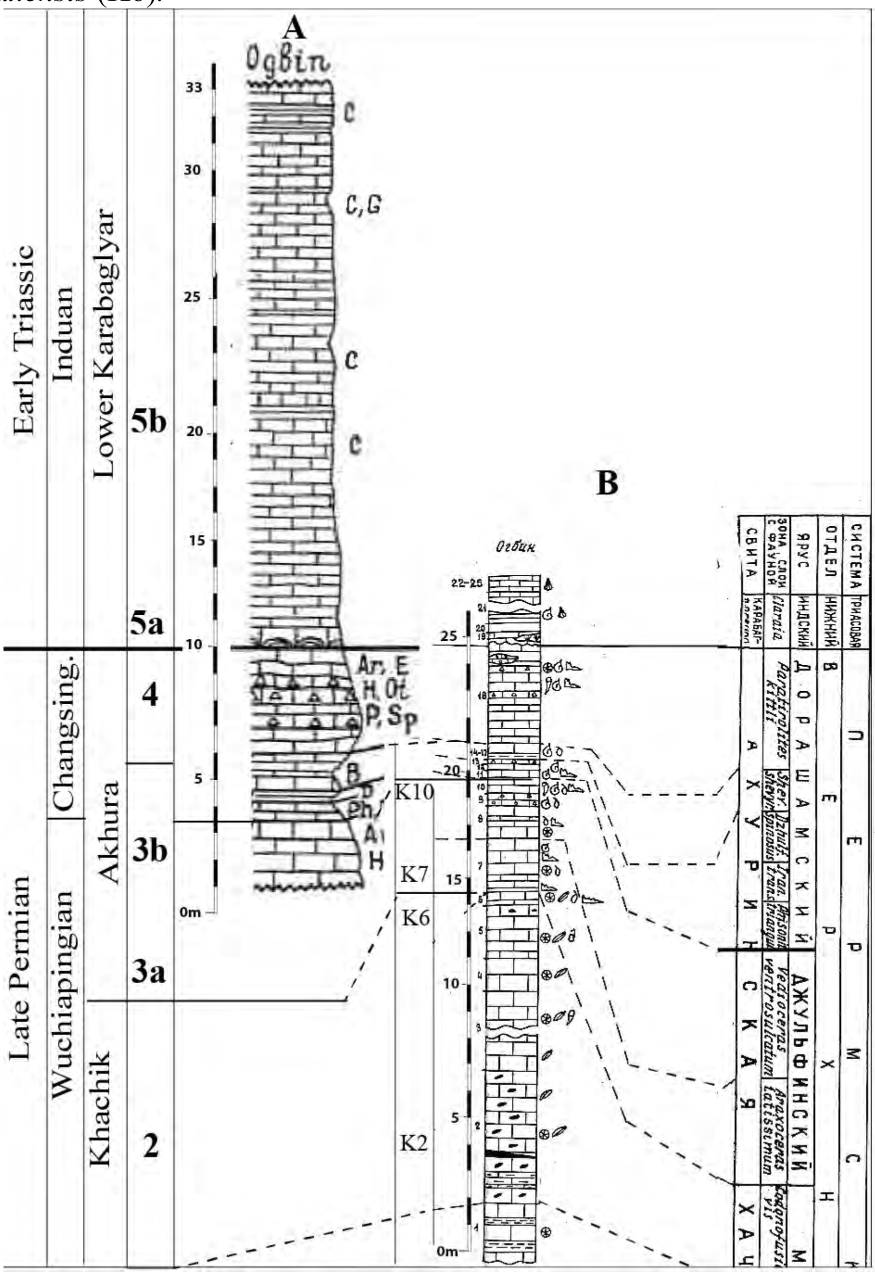

Figure B6: A, Late Permian - Early Triassic lithological profile of Ogbin section published by Rostovtsev and Azaryan (1973). It is interesting to note that 18m above the PTB, G= *Gyronites* sp., is giving a Dienerian age (Upper Induan); B, same profile extended down in the Permian, from Kotlyar et al., 1983 with levels 1-25, here noted K in the reported Kotlyar data.

Stop 2: We will look at the Lower Akhura Formation (unit 3, Middle to Upper Wuchiapingian, Fig. B7) made of light beige limestone and marl, 4.3 m thick.

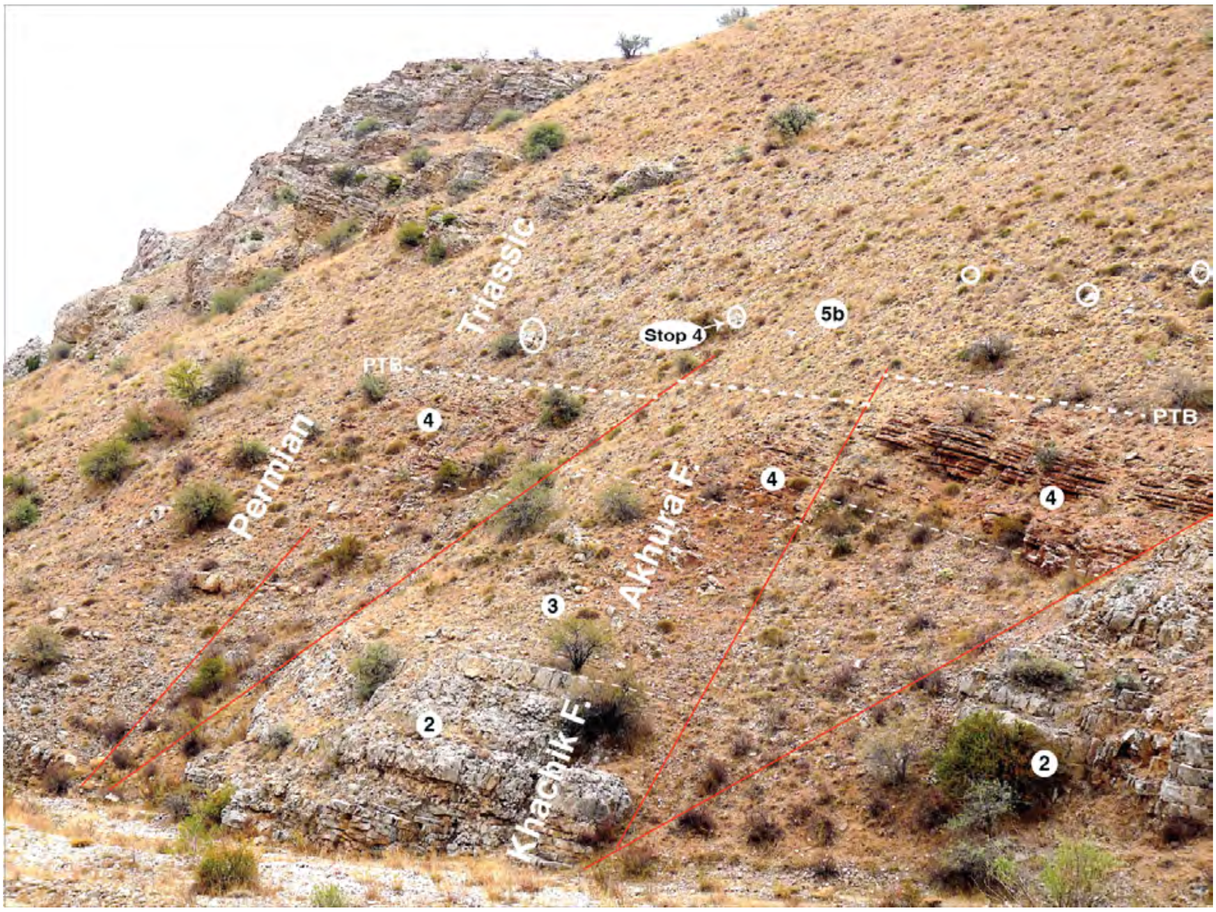

Figure B7: Field view on stops 2, 3 and 4. At stop 2 we will look at the Unit 3 in the middle of the picture (Our Units 2 to 5, see caption in Fig. B5). White circles in unit 5b: SMB.

The Wuchiapingian *Araxoceras* beds, 2 m thick, comprise the level K7, section B in Fig. B6, or our lower Unit 3 in Fig. B7, with, according to Kotlyar et al., 1983, the foraminifera *Nodosaria transcaucasica*, *N.* aff. *piricamerata*, *N*, ex gr. *hoi*, *N.* sp., the brachiopods *0rthotichia minuta, Spinomarginifera helica, S. ciliata, Compressoproductus djulfensis, Leptodus* sp., *Wellerella arthaberi, Permophricedothyris ovata, Araxathyris araxensis araxensis*., and the ammonoids *Pseudogastrioceas sp., Strigogoniatites? sp., Vescotoceras sp., Araxoceras sp., Pseudotoceras djoulfense.*

The 2.3 m thick Wuchiapingian *Vedioceras* beds, (Kotlyar et al., 1983), correspond to levels K8 to K10 (section B in Fig. B6) with the foraminifera *Nodosaria postgeinitzi*, *N*, sp., *Geinitzinita* sp., the brachiopods *Araxathyris araxensis minor, Dorashamia abichi, Tyloplecta yangtzeensis, Spinomarginifera helica, 'l'ransennatia gratiosa, Leptodus nobilis, Gubleria armenica, Haydenella minuta, H. kiangsiensis, H. tumida, Wellerella dorashamensls, W.* sp. 1, *Stenoscisma armenicum Araxathyria araxensis araxensis, Gefonia improvisa* and the ammonoids *Avushoceras jakowlewi, Vedioceras umbonovarum.*
In the level K10 are the brachiopods *Spinemarginifera pygrhaea, Haydenella kiangsiensis, Araxathyris araxensis minor* and the ammonoids *Shevyrevites sp., Avushoceras jakowlewi.*

In the basal Changhsingian 0,25 m thick *Phisonites* beds (level K11), the brachiopods *Comelicania triangularis*, and *Araxathyris araxensis minor* have been determined as the ammonoids *Phisonites* cf. *triangulus*, *Ph*. sp., *Shevyrevites* sp.

Stop 3: At this stop, we will look at the *Paratirolites* beds, red, nodular ammonoid limestone of the Upper Akhura Formation (Unit 4 in Figs B5, B6 and B7) and at the Permian-Triassic Boundary (PTB) red shales.
The *Iranites*, *Dzhulfites* and *Shevyrevites* beds, 0.75 m thick, correspond to levels K12-17 (Kotlyar et al., 1983) and comprise the ammonoids *Iranites* sp. , *Dzhulfites* sp., *Shevyrevites shevyrevi* and *Abichites stoyanowi.*

The Upper Changhsingian *Paratirolites* beds with characteristic red nodular limestones about 3.5 m thick (level K18 in Kotlyar et al., 1983, our unit 4 in Fig. B7 and B8) contain *Paratirolites* cf. *dieneri*, *P*. sp., *Abichites* sp. ammonoids, the brachiopods *Orthotichia* sp., *Araxathyris araxensis minor* and some solitary corals as *Pentaphyllum* sp. 2, *Ufimia differentiata*, *U. armenica*, *Pentamplexus leptoconicus.*

Most often hidden, covered by scree or vegetation, the PTB shale, in order of 10's cm thick is red in color .

Stop 4: at this stop we will look at the Lower Karabaglyar Formation (our unit 5b, the basal part 5a is here hidden) with its significant change in carbonate lithology showing platy, thin bedded yellowish limestone comprising irregularly spaced sponge-microbial build-ups (SMB, see Figs B7 to B9), with different sizes from 0.1 to 5 m thick, and with various external morphologies and internal structures (Figs B8 and B9).

Figure B8: Left, view of about 2 m thick basal Triassic platy limestone; Right, about 1.4 m thick, SMB of an mushroom shaped form. Scale, 1m.

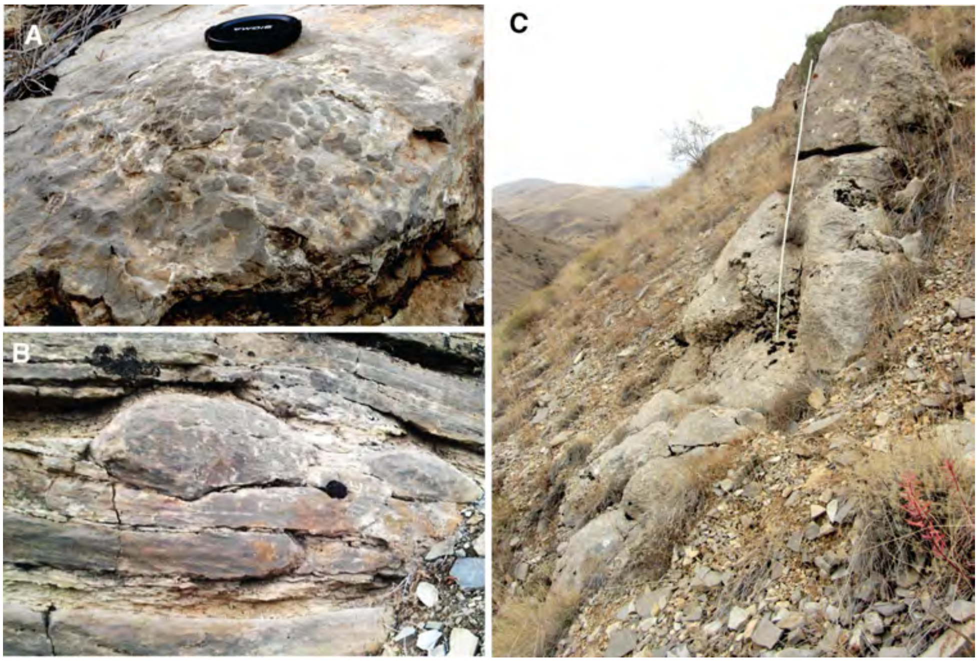

Figure B9: Basal Triassic SMB. (A) Small thrombolitic (dark gray clots) sponge-microbial dome that is about 10 cm thick. (B) Twin SMB, lens- to dome-shaped 10 cm thick, surrounded by platy limestones. (C) An around 5 m high SMB surrounded by platy limestones. Scale = 2 m.

From stop 4, we will move of about 100 m eastward to go to the next stops (S5 to S7, Fig. B10) with the opportunity to have a look at our units 3a, 3b, again 4 and 5a.

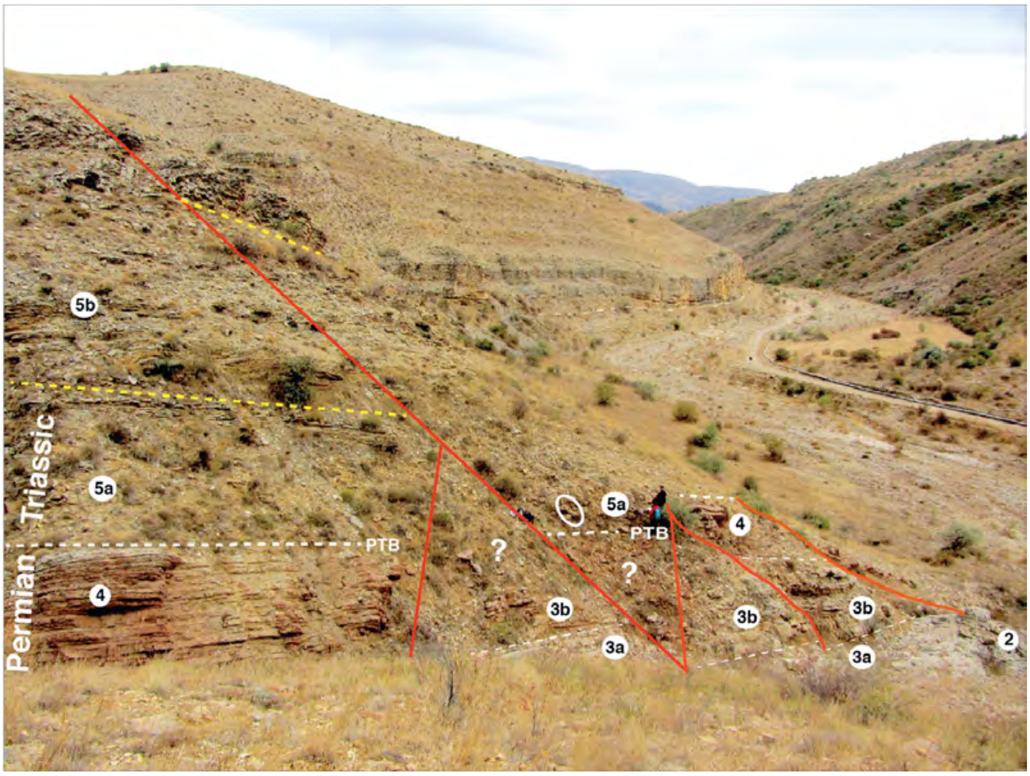

Figure B10: View from above of the Permian-Triassic boundary with stop 5 to the right and stop 6 to the left. (for 2 to 5 units, see caption in Figs B5 and B11).

Stop 5: To complete our observations from the stop 2, we will look (Fig. B11) on the detail and facies changes due to drowning of the carbonate platform between the Upper Khachik Formation and the Lower Akhura Formation (Middle Wuchiapingian) and the overlying facies change between light (unit 3a) and darker yellowish limestone (unit 3b, Late Wuchiapingian). This last boundary was apparently adopted by Bonnet (1920a) for the base of his Triassic stage and described in this outcrop by Bonnet & Bonnet, (1947, p. 70).

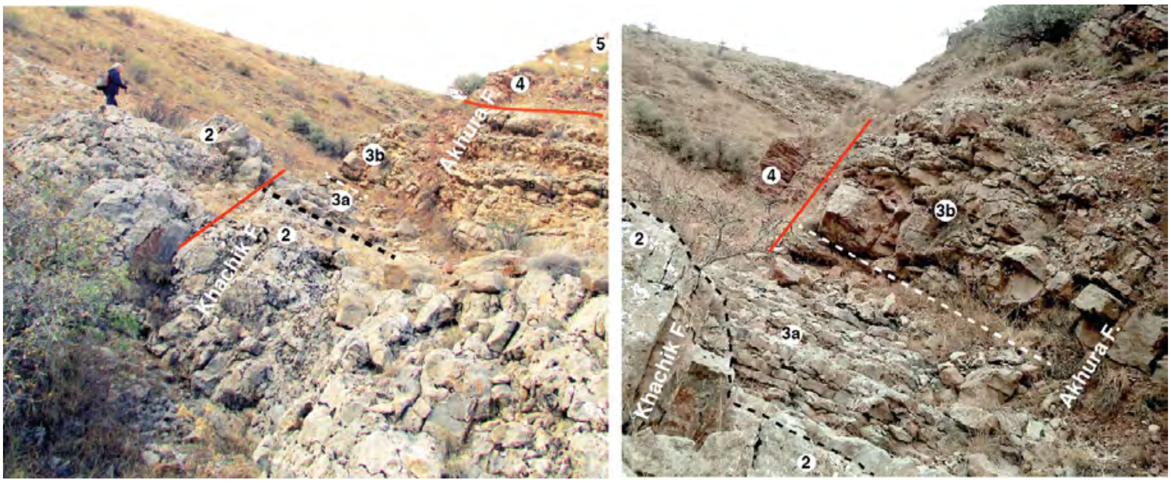

Figure B11:Left, view on the contact (dashed black line) between the shallow water light gray limestone of the Khachik Formation(Unit 2) and the deeper nodular open marine limestone with ammonoids of the Lower Akhura Formation (Unit 3a and 3b, Late Wuchiapingian). Right, detail of left view with the contact (dashed black line) between the Khachik Formation(Unit 2) and the development of the lower Akhura Formation (Unit 3a Late Wuchiapingian). In the background, the Changhsingian Unit 4 (*Paratirolites* beds).

Stop 6: To complete our observations from the stop 3, we will have a close look (Fig. B12) at the detail and facies changes below the *Paratirolites* beds (Lower and Upper Changhsingian).

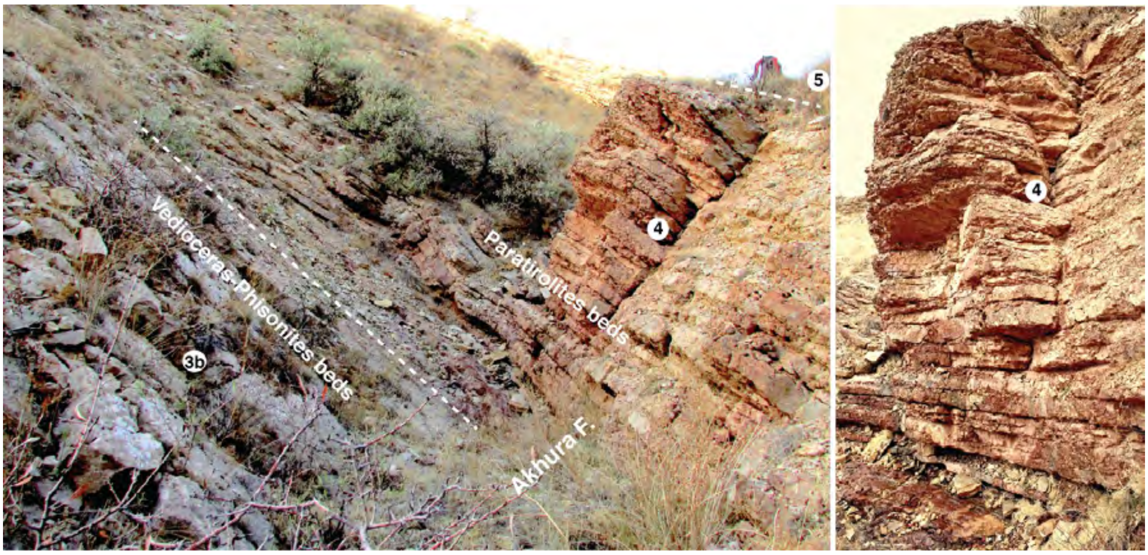

Figure B12: Left, view on the contact between the Upper Wuchiapingian - Lower Changhsingian gray limestone (Unit 3b) and Upper Changhsingian red limestone (*Iranites-Paratirolites* beds) of the Upper Akhura Formation. Right, detail view on the 3.5 m thick *Paratirolites* bed (unit 4).

The area of the stratigraphic sections sampled at Ogbin (Fig. B13) is shown at Fig. B10 left (=B13 A) and right (=B13 B).
The stratigraphic interval concerns only the top of the Permian red limestone and the basal Triassic platy limestone with SMB (our unit 5a, visible only at this outcrop, Figs B10 and B14).

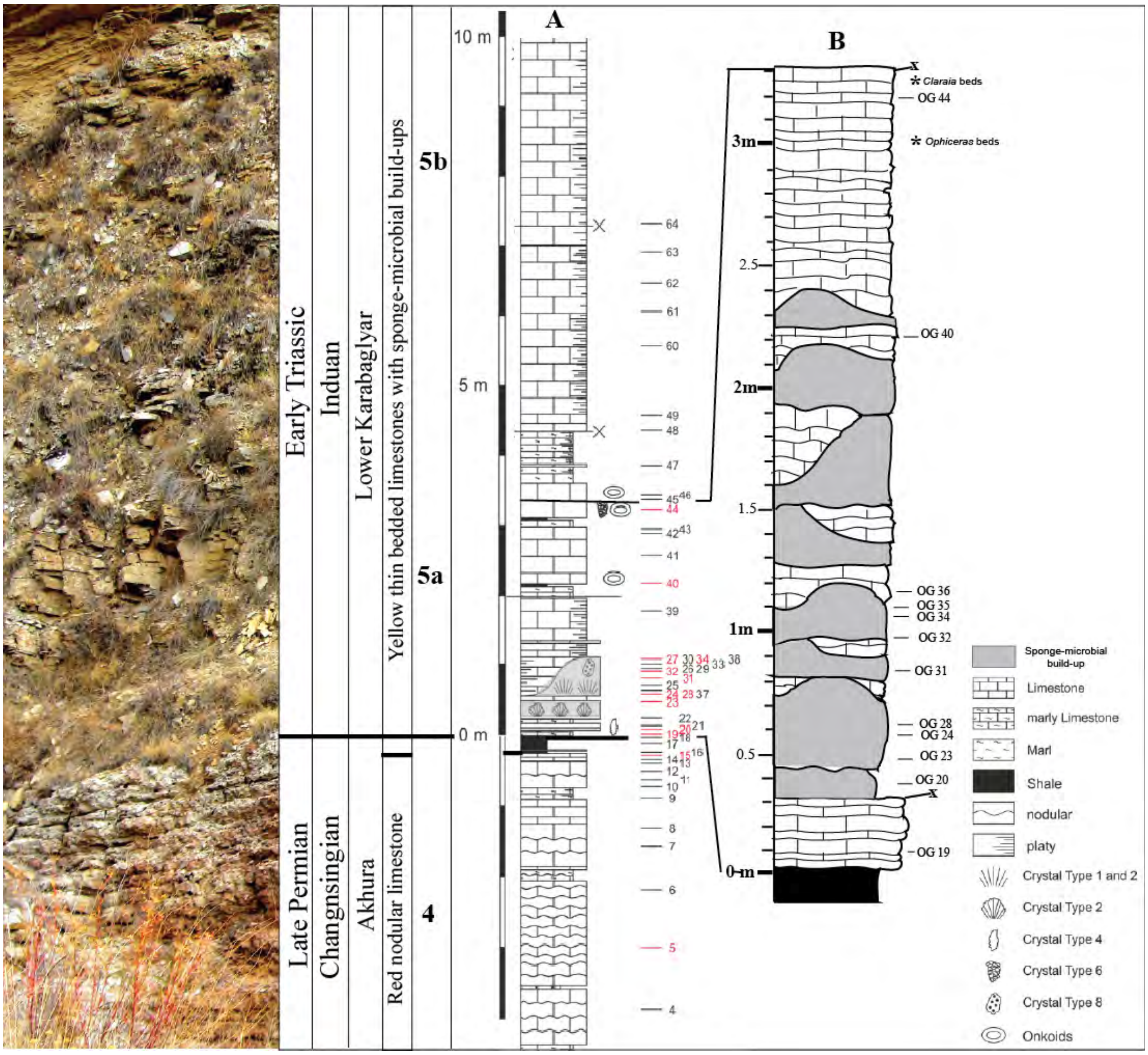

Figure B13: Ogbin's Latest Permian-Earliest Triassic stratigraphic sections. A, section measured and sampled by Friesenbichler and Richoz in Friesenbichler (2016); B, Parallel section measured by Baud, with SMB is visible on the right of the Fig. B14.

Last stop (7): To complete our observations from the stop 4, we will look at the development of the sponge-microbial build-ups (SMB) just above the boundary shales, within the basal Karabaglyar Formation (Lower Induan) and corresponding to the section shown in the Fig. B13, part B and the outcrop in the up-right of Fig. B14 (unit 5a). According to Kotlyar et al., 1983, the first *Claraia* bed crop-out at 4.5m above the boundary with *Claraia claraia, C. auri*ta and the ammonoid *Ophiceras medium*. The Dienerian *Gyronites* sp. ammonoid is at 18 m above the base of the Karabaglyar Formation (Fig. B6 A, Rostovtsev and Azaryan, 1973).

Figure B14: View on the last stop 7 with, on the upper right, the SMB development in the basal Karabaglyar Formation (unit 5a, Lower Induan, section B in Fig. B13). (for units 3 to 5, see caption in Fig. B5 and B11.

The Ogbin irregularly spaced SMB are built by tabular maze-like thrombolites (Fig. B15 left) or by a new group of vertical, branching and coalescent structure here recrystallized (Fig. B15 right). The dark lime mud matrix seen in thin section is rich in calcified keratose sponge fibers.

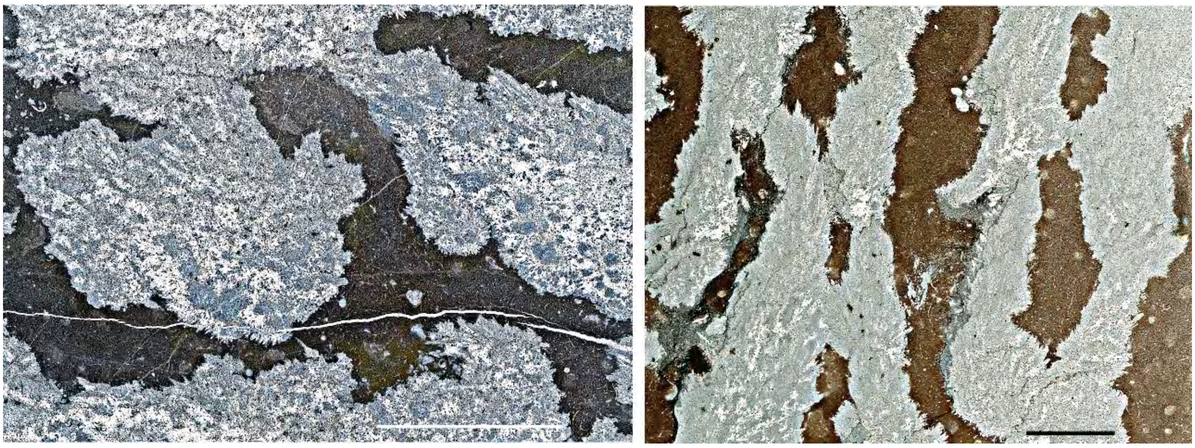

Figure B15 -Thin sections of SMB: Left, tabular maze-like thrombolite clots in a dark lime mud matrix rich in calcified keratose sponge fibers (sample OG 32, scale bar 10 mm). Right, columnar and coalescent structure with same lime mud matrix rich in sponge fibers (sample OG 34 scale bar 5 mm).

4.3 To resume

The main interest of the Ogbin section is the easy access to the Middle - Late Permian Khachik Formation and to the Akhura Formation with the good outcrops and development of the red nodular *Paratirolites* limestone.

Studied by Bonnet, this section allowed us to look at (stop 5) an old Permian-Triassic boundary fixed in 1920 and detailed in Bonnet and Bonnet (1947).

Looking or sampling lithological section, we have to take care of some fault networks and internal thrusting due to a hardness contrast. In our field views (Figs B2, B3, B5, B7, B10 and B14) we draw some of them.

A nice Lower Triassic section with well controlled sedimentary cycles is situated on the hill downstream, as shown on the right of Figs B2, B3 or Fig. B10 up, with expected Induan - Olenekian boundary (IOB), that needs to be studied.

Notes

5. The Chanakhchi section (previously known as Sovetashen)

<u>**12th October**</u>: Vayk to Zangakatun (section Chanakhchi, 48 km, 50 min by bus). Return to the Amrots Hotel. See Fig. B1.

5.1 Geological setting

This section is located on the right bank of the Gortun river, 2.5 km, NNW of Zangakatun village (Figs B16, B17, B18).

Figure B16: Google Earth view on the Zangakatun village and of the Chanakhchi site.

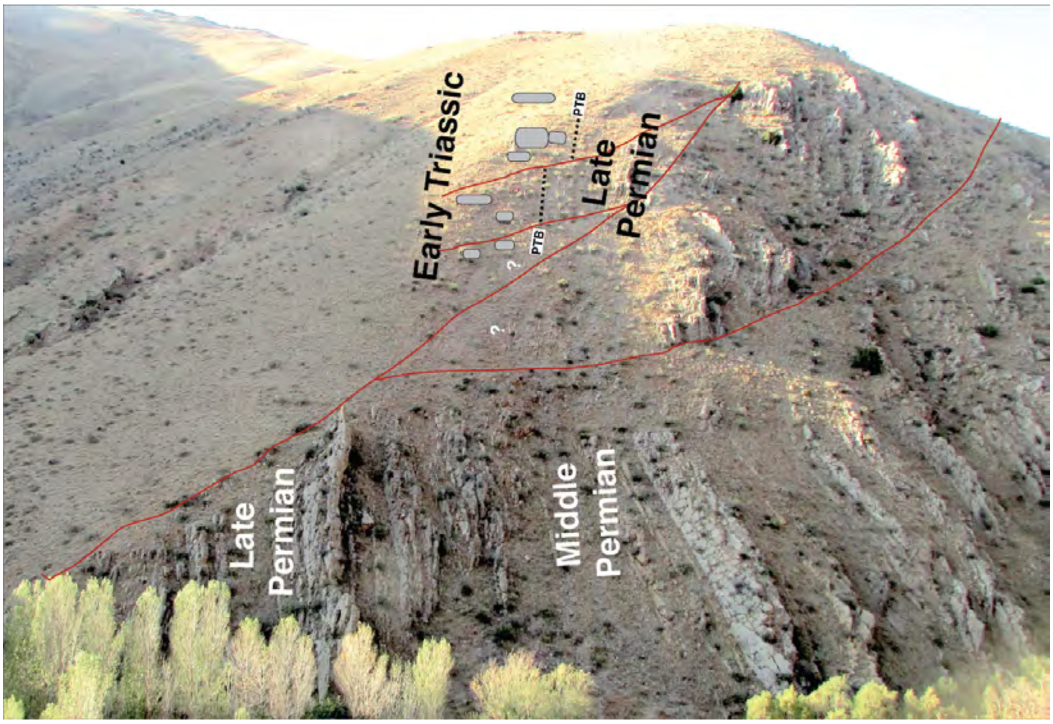

Figure B17: View on the Chanakhchi hill from the opposite side. The vertical bedding of the Permian to Lower Triassic limestone is cutted by large faults. The visited outcrops are in the upper part of the hill. Small gray surfaces =SMB. Dashed black line =PTB.

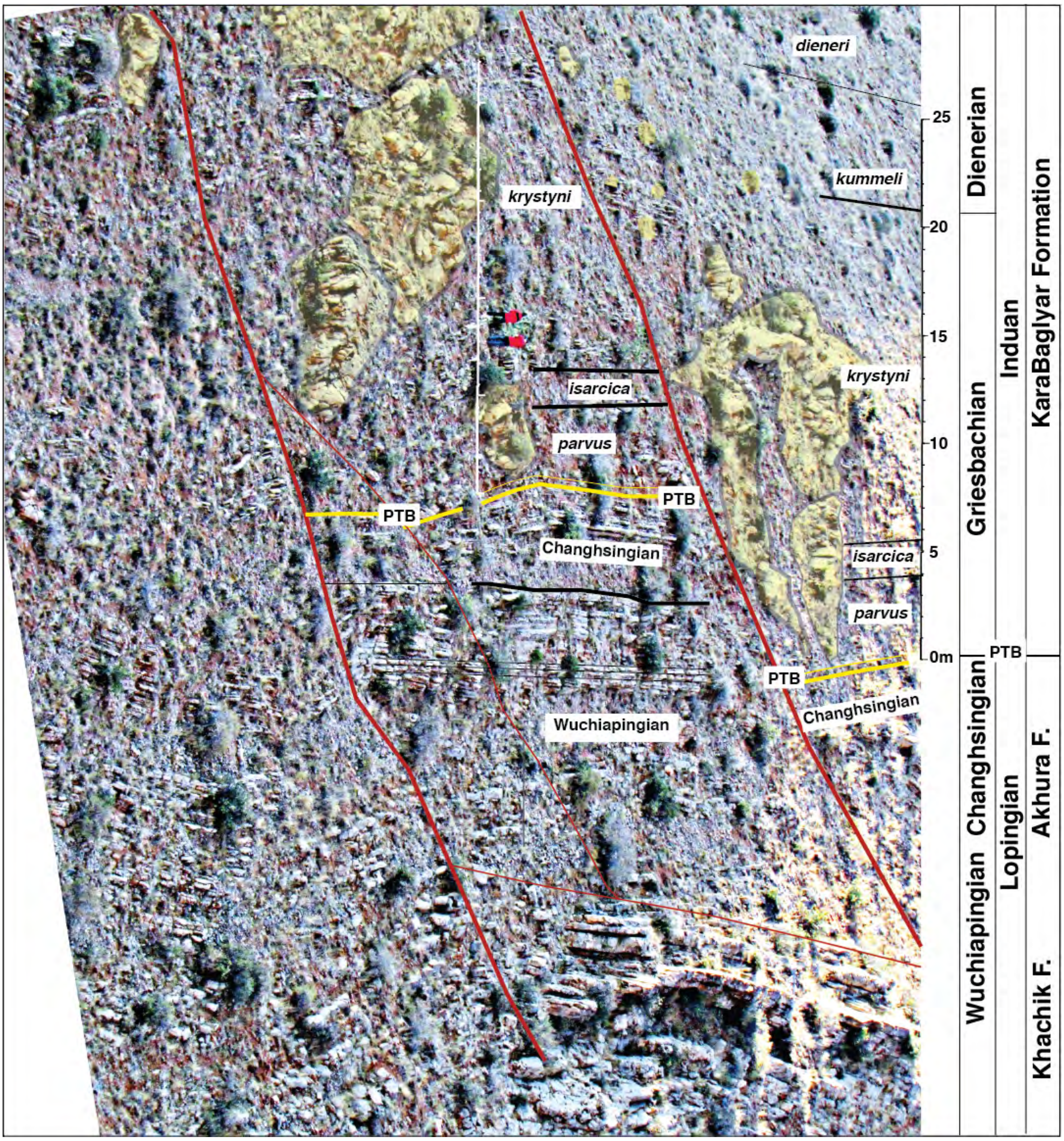

Figure B18: Face view of the basal Triassic giant sponge-microbial buildups (highlighted in yellow), but the vertical bedding is here turned horizontally with the lithology and the biochronological data (conodont zones after Zakharov et al., 2005, modified: see note, p.24 down), and distances above the PTB (yellow line). Red lines: faults.

5.2 The Late Permian to basal Triassic succession at Chanakhchi

As the other South Armenian sections, the Upper Permian succession at Chanakhchi comprise the Khachik and the Akhura Formations. A main facies change occurs at the top of the Khachik Formation (Middle Wuchiapingian) due to drowning of the carbonate platform: the light gray nodular open marine limestone with ammonoids (Lower Akhura Formation) overlains the thick bedded shallow water light gray bioclastic limestone (Upper Khachik Formation). According to Zakharov et al. (2005), the Wuchiapingian succession is about 20 m thick and the Changhsingian one is very condensed with only 5 m thick. A list of Upper Permian foraminifera is published by Kotlyar et al., 1983 and more recently, Jenny et al., 2009, showed a table of Permian-Triassic main bioclasts estimate from thin sections (Fig.

B19) and an inventory of the Upper Permian foraminifers from the Chanakhchi (Sovetachen) section (Fig. B20). The basal Triassic bioclasts in thin section have been worked by Friesenbichler (2016) and will be published in Friesenbichler et al., submitted, (Fig. B21).

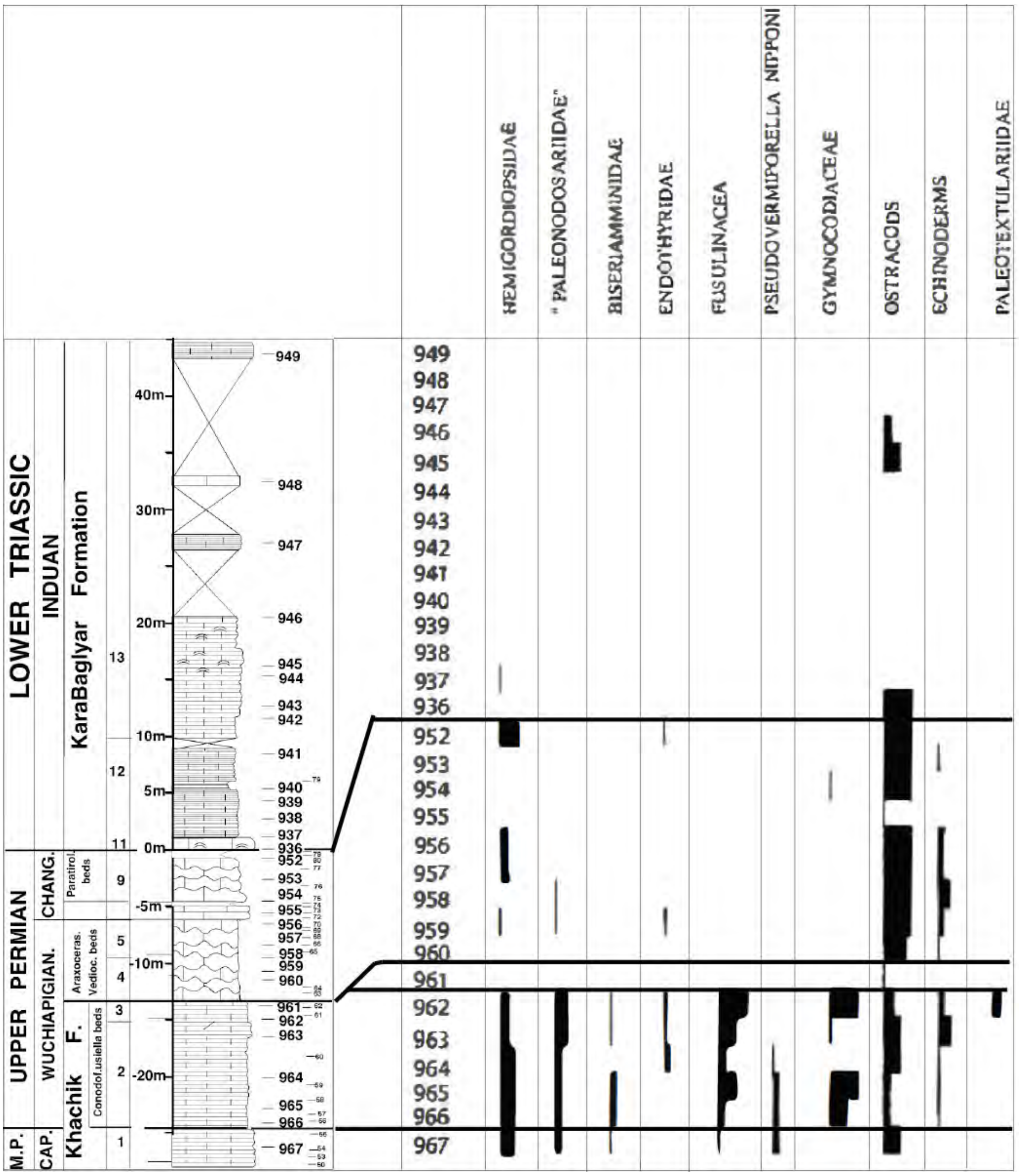

Figure B19: Inventory of the bioclasts from thin sections of the Late Permian-Early Triassic, Chanakhchi (Sovetachen) section, according to Jenny et al., (2009, fig. 1.5.5 modified).

According to Zakharov et al., 2005 (Fig. B22) the base of the Triassic is well dated by conodont with a full succession of Griesbachian zones up to the *kummeli* zone of Dienerian age, according to Brosse (2017) and to Orchard, (2007). On Zakharov et al. section (Fig. B22), *kummeli* is found between 16 and 17 m above the PTB, but after L. Krystyn (written com.) the FO must be 21m above PTB. On Fig. B18, we agree with the 21 m FO and we propose a basal Dienerian age in accordance to the above citations.

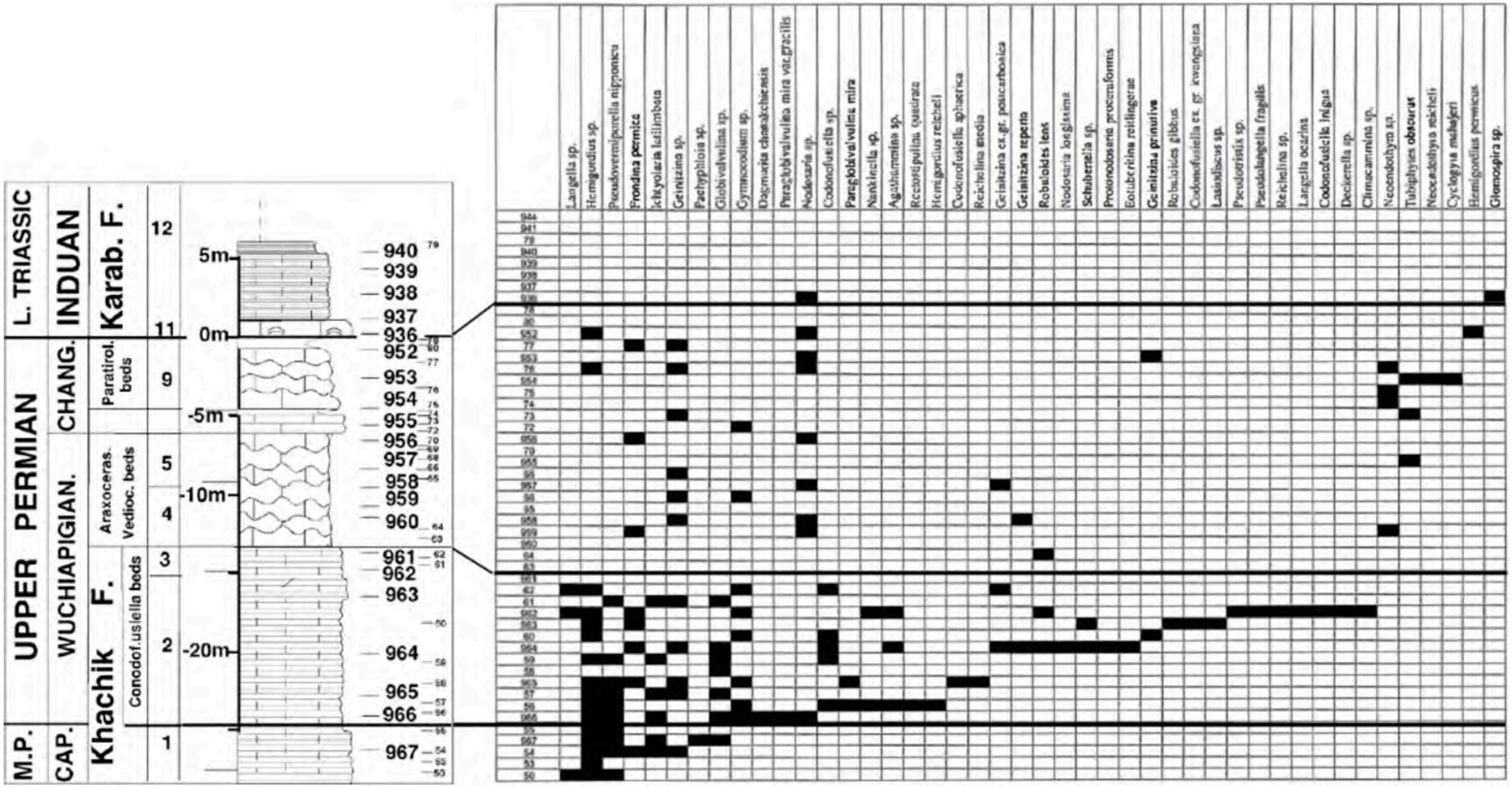

Figure B20: Inventory of foraminifera and calcareous algae of the Upper Permian Chanakhchi section. The first occurence of *Paraglobivalvulina mira*, a rich foraminiferal fauna in the Lower Wuchiapingian and the impoverishment of the micro-fauna after the drowning of the carbonate platform in the Middle Wuchiapingian with the disappearance of the calcareous algae should be stressed. The main extinction happened at the top of the Boundary shale (level 10). Modified after Jenny et al. (2009).

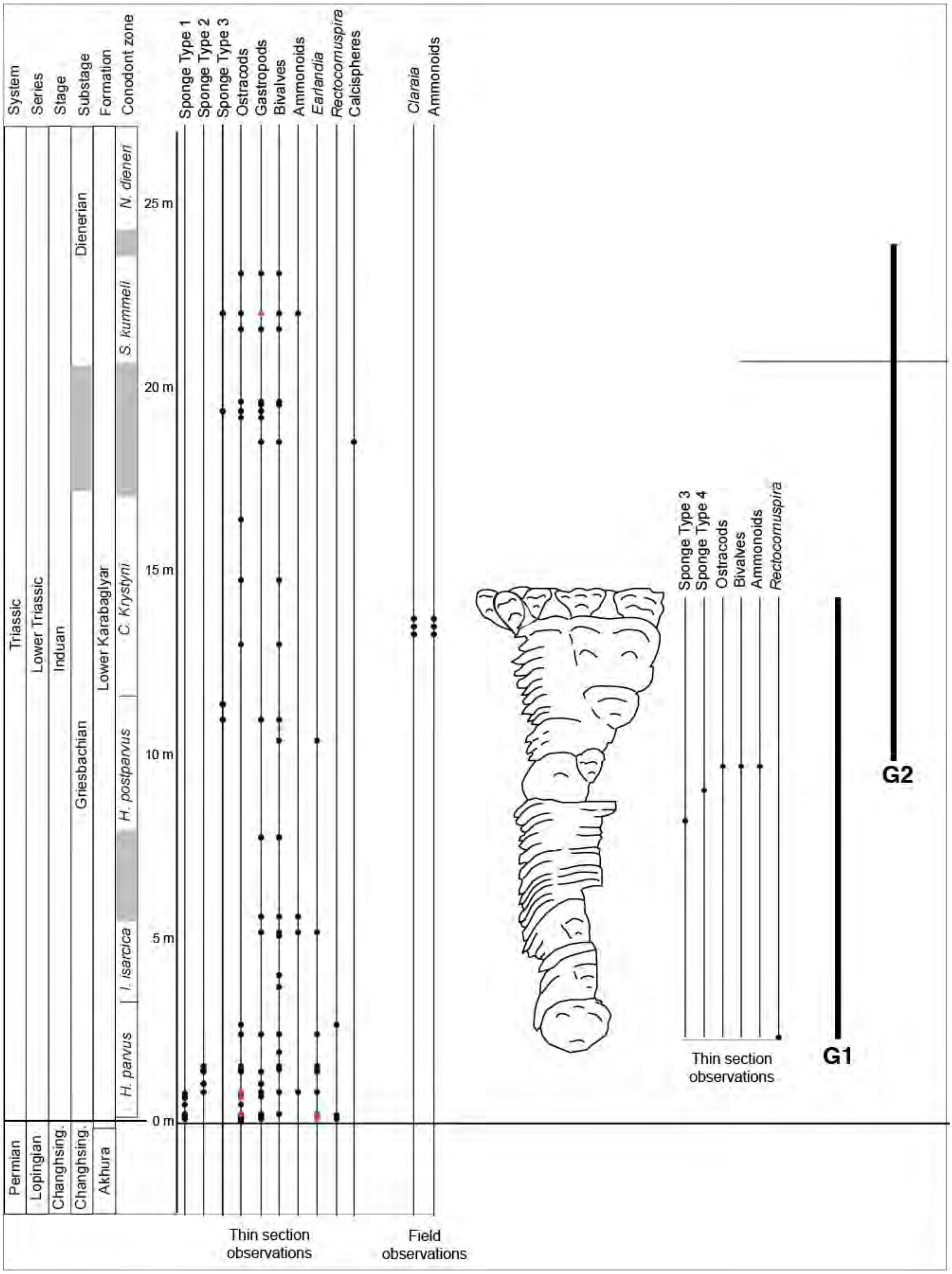

Figure B 21: Inventory of bioclasts from thin sections of the Lower Karabaglyar Formation at the Chanakhchi section. Modified after Friesenbichler (2016). A giant sponge-microbial build-up (GSMB) is illustrated with its time extension (G1) from *parvus* to *krystyni* conodont zone. G2 is the time extension of an upper hill GSMB, from *postparvus* up to *kummeli* conodont zone.

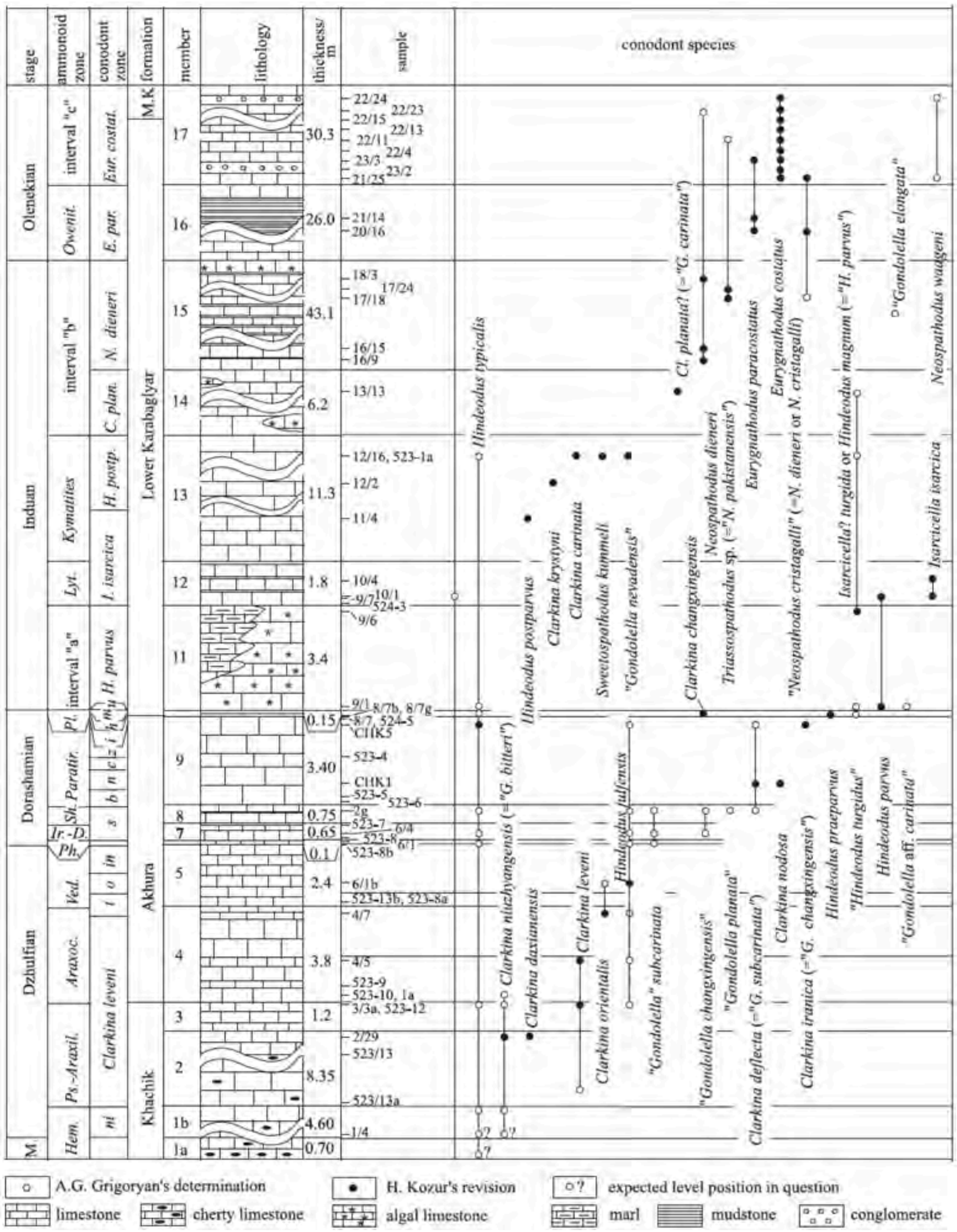

Figure B22: Conodont distribution in the Permian and Lower Triassic rocks of the Chanakhchi (Sovetachen) section. From Zakharov et al. (2005, Fig. 1).

5.3 Geochemical studies

For the first Carbon isotope study, a detailed boundary section of the Upper Permian to Lower Triassic succession at Chanakhchi was sampled on the upper hill section during the IGC fieldtrip 1984 in Armenia. The C isotope results have been published by Baud et al. in 1989. With this spaced sampling studied more than 30 years ago (Fig. B 23) we had shown that the Upper Permian limestones are enriched in heavy Carbon ($\delta^{13}C > +3‰$,), and the Lower Triassic rocks were comparatively depleted with $\delta^{13}C$ values between 0 and + 1‰. Zakarov et al., 2005 took account of the Baud et al., 1989 C isotope results in their Fig. 3. A detailed sampling from the uppermost Permian unit up to the lower 30 m of the Karabaglyar Formation have been done in 2014 by Friesenbichler and Richoz and the C isotope results is discussed in Friesenbichler (2016) and will be published in Friesenbichler et al., (submitted).

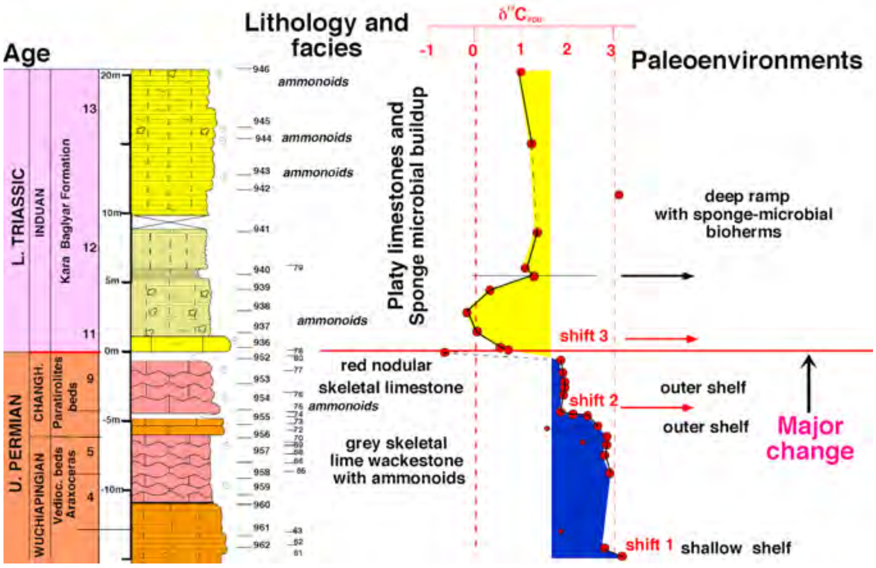

Figure B23: $\delta\ ^{13}C_{carb}$ isotope curve of the Upper Permian to basal Triassic succession at Chanakhchi (Sovetachen) section (Baud et al,. 1989, modified).

For accessory elements geochemistry, Sr, Mg, Mn and Fe have been studied on the same Chanakhchi (Sovetachen) samples as Baud et al., (1989) by Zerari-Leduc (1999), and her results are shown below in the Fig. B24.

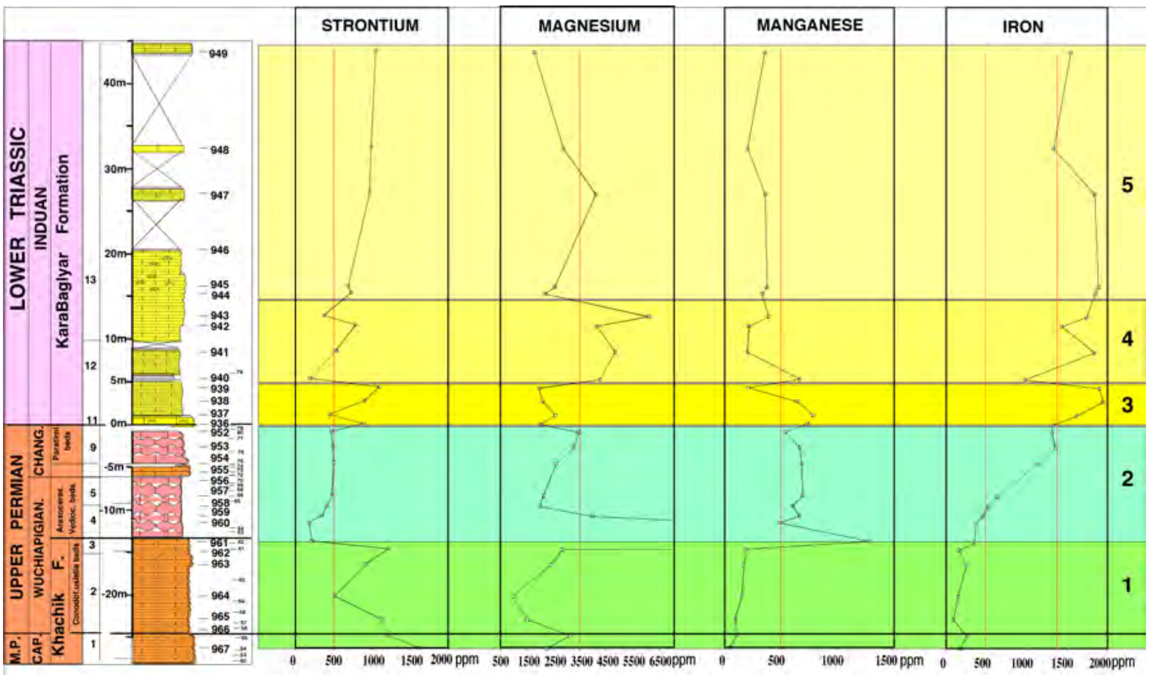

Figure B24: Analyses on the accessory elements Sr, Mg, Mn and Fe of the Upper Permian to basal Triassic sucession at the Chanakhchi (Sovetachen) section. Modified after Zerari-Leduc (1999).

We note the downshift value of Sr at the Khachik -Akhura Formation boundary with the drowning of the carbonate platform and facies change. To the contrary, the Iron content value increases from 200 to 1500 ppm up to the top of the Paratirolites beds and increases again within the lower SMB up to 2000 ppm.

Before visiting the stops of the day, it is interesting to look at the geological map given below, where one can observe a big gap in the Paleozoic succession and, except for Lower Triassic and Upper Cretaceous sediment, all the Mesozoic is missing! (Fig. B 25)

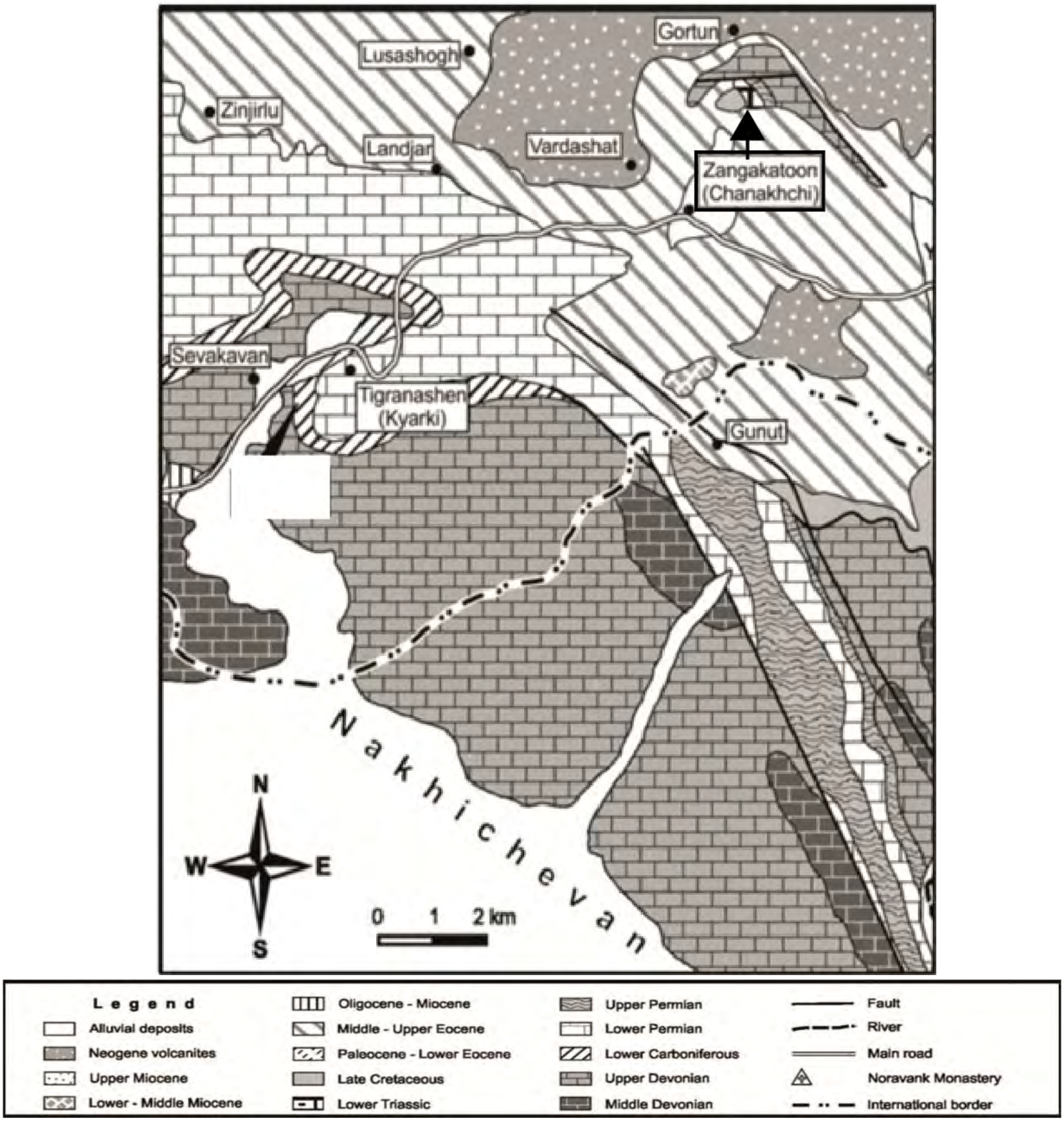

Figure B25: Simplified geological map of the Chanakhchi area (right up) in SW Armenia (modified after Ginter et al., 2011).

5.4 The six stops of the day (S1 to S6, Fig. B26)**.**

Located on the right bank of the Gortun river, 2.5 km to NNW of Zangakatun village, the section is shown in Figs B16 to B18, and the visited outcrops are in the upper part of the hill.

Six stops are planned during the day.

The stops 1 and 2 will focus on the Upper Permian successions. At the third stop we will focus on the Permian/Triassic boundary and the onset of the SMB. The last three stops will be devoted to the SMB, from small to giant shapes and their relationship to the surrounding thin bedded, platy limestone.

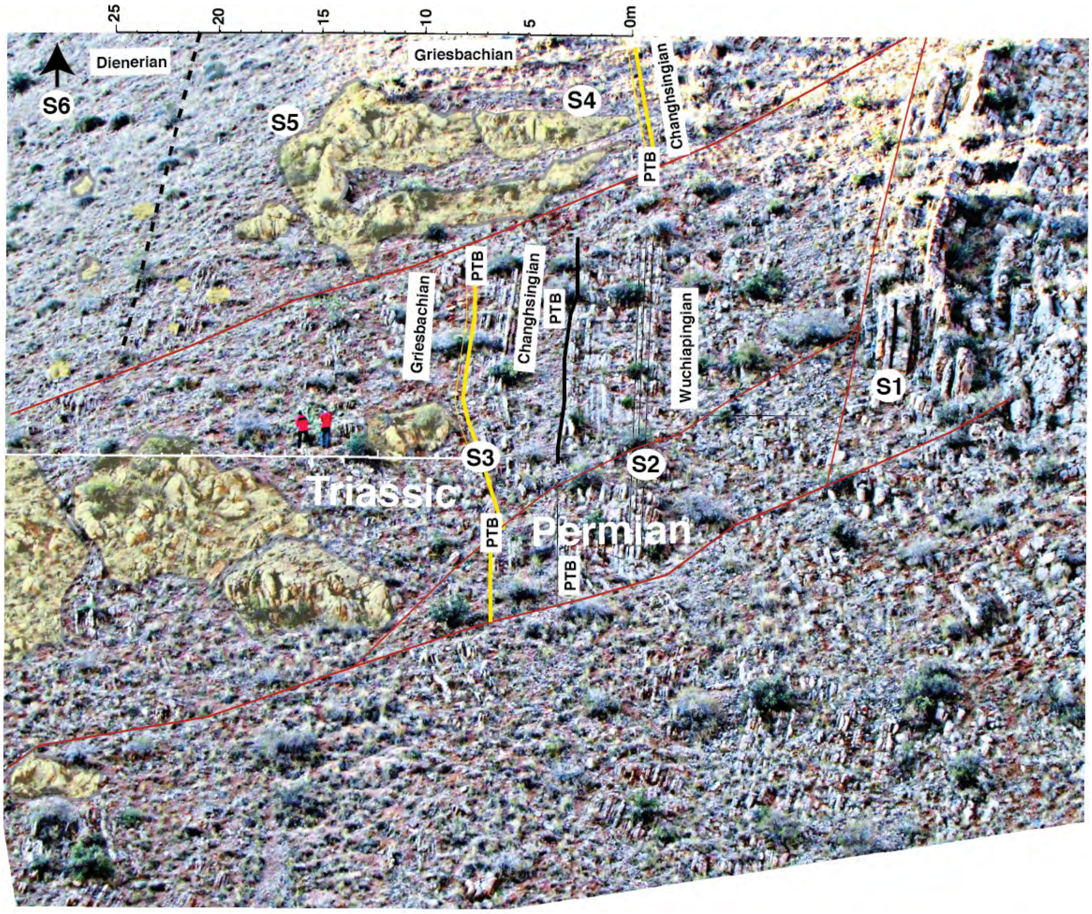

Figure B26: The planned stops S1 to S6 on a field picture of the Chanakhchi section. (see Fig. B18 for details and caption).

Stop 1: Our first stop will be the top of the Late Permian Khachik Formation with thick bedded gray limestones that are vertically cropping-out (Figs B26, B27, members 1-2 of Zhakharov et al., 2005, Fig. B22).

Figure B27: Field picture of the top of the Late Permian Khachik Formation (stop 1).

According to Zhakharov et al. (2005 with ref. to Grigoryan, 1990), the lithology consists of dark-gray and black limestone with rare chert boulders at the base. The conodonts listed are: *Clarkina leveni, Gondolella bitteri, Hindeodus typicalis, Hindeodus julfensis* which indicate an Early to Middle Wuchiapingian age.

Stop 2: we will go up to the Akhura Formation with the main facies change to deeper water thin bedded nodular limestone and we will look in detail to the Uppermost Permian *Paratirolites* limestone, here of partly gray to partly pink colors (Figs B28 to 30).

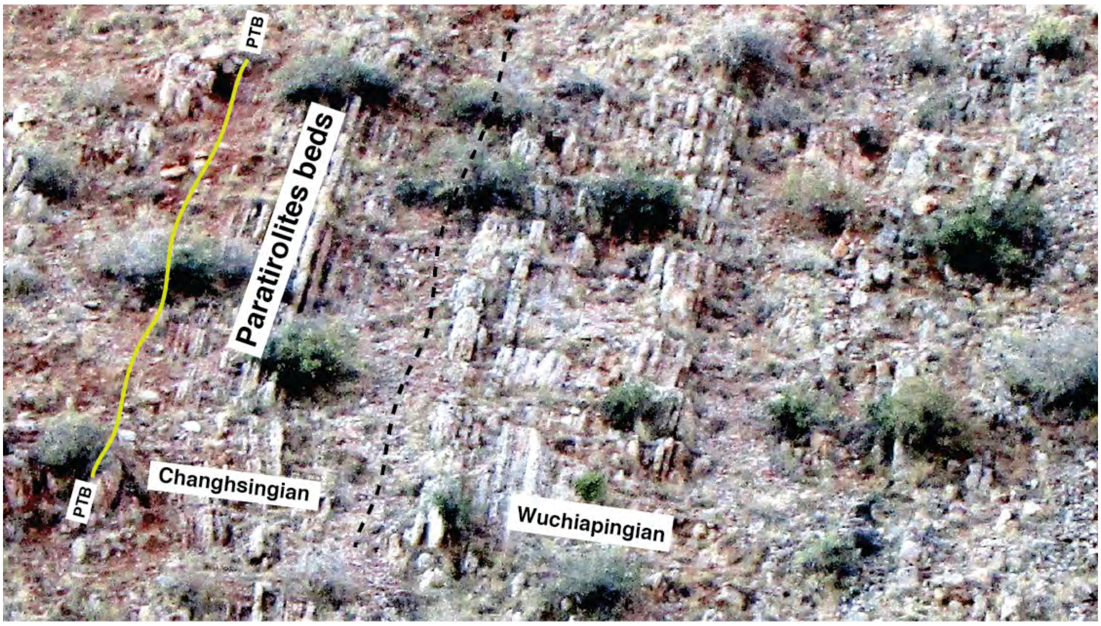

Figure B28: Field picture of the Akhura Formation (stop 2) with the *Paratirolites* beds and the Permian-Triassic Boundary (PTB, yellow line).

The lithology of the *Paratirolites* beds, 3.4 m thick, consists of red to pink and gray, thin bedded limestone, nodular in part. The determined ammonoids are: *Paratirolites kittli*, *P. vediensis*, *Abichites mojsisovicsi*, and *A. stoyanovi* . The brachiopods, *Araxathyris araxensis minor*, and the conodont, *Clarkina deflecta*, *C. nodosa, C. iranica, Hindeodus typicalis* and *H. julfensis.* These Paratirolites beds are overlain by the boundary shale (Fig. B29), a reddish-brown mudstone 0.1 to 0.2 m thick, with small *Haydenella* sp. brachiopod and the following conodonts: *Hindeodus praeparvus, H. turgidus, H. typicalis, Gondolella carinata* and *Clarkina changxsingensis,* Zhakharov et al. (2005 with ref. to Grigoryan, 1990).

Stop 3: From the PTB shale, we will have a look at the onset of the SMB that appear just above the shale (Fig. B30). The partly red, partly gray thin bedded platy limestone contains the following conodonts: *Hindeodus parvus, H. turgidus*, and the long ranging *H. typicalis,* that confirm the basal Induan age (Zhakharov et al. 2005 with ref. to Grigoryan, 1990). Most of the basal SMB are built by a new group of columnar structures (Fig. B31 left) made of coalescent pointed calcite stromatolite also called acicular stromatolite in Friesenbichler et al., (submitted). These acicular stromatolite are surrounded by a dense lime mud matrix rich in keratose sponge fibers. Due to calcium carbonate oversaturated sea-water, the growth of these acicular stromatolite is followed by calcite (original aragonite) needles or fans (CCFs) at the base, on the side or at the top (Fig. B31 right).

Figure B29: Field picture of the top of the *Paratirolites* beds and, on the left, the Permian-Triassic Boundary red shale. Note the partly gray and partly red limestone color. Scale, 40 cm.

Figure B30: Field picture of the Permian-Triassic transition, from right to left: top of the *Paratirolites* beds , in red the boundary shale (with 1 m scale along) and above a SMB of about 2 m thick.

Figure B31: Left, detailed view on the basal part of a lower SMB with his vertical light structures up to 25 cm high in red lime mud matrix; Right, thin section with the vertical structure of coalescent calcite pointed stromatolite and abiotic aragonite crystals on the side. Scale bar 5 mm.

Stop 4: The development of a giant sponge-microbial build-up (GSMB, Fig. B32). According to Zakharov et al. (2005) this development go through the *isarcica*, *postparvus* up to *krystini* conodont zones (Figs B18, G1 in B21, B22) and therefore formed during the whole Griesbachian.

Figure B32: Field picture of the lower GSMB of more than 12 m of vertical extension with asymmetrical sides due to steady bottom current.

Stop 5: The development of small sized SMB above the giant SMB, within the *kummeli* conodont zone (Fig. B33), and the surrounding thin bedded platy limestone (Fig. B34) with two picked out microfacies (Fig. B35) .

Figure B33: Selection of small size SMB. Their main builders are thrombolites and sponges: a) globular mushroom shape; b) umbrella shape; c) and d) cylindrical dome shape, 20 cm of diameter; e) 10 cm high domal bulge.

Figure B34: Field view on thin bedded platy limestone. Left, partly nodular. Right, really platy with a small, ball shaped SMB, 10 cm thick,.

Figure B35 Scanned thin sections of the platy limestone (scale 5 mm): Left, thinning upward micro-cycles of lime packstone-siltstone with millimetric spheroids (sponge tissue? Ch 58). Right, lime wackestone-siltstone with rare bivalves, ostracods and microgastropodes (Ch 61).

Last Stop 6: Time permitting, we will take a look at the extended GSMB, corresponding to G2 in Fig. B21, that is cropping-out in the upper part of the Chanakhchi hill. (Fig. B36) Its base is at 9 m above the PTB , its top is at 24 m and is overlain by small SMB up to 26 m above the PTB shale. Its time extension is from *postparvus* up to *kummeli* conodont zone.

Figure B36: Field picture of the upper hill GSMB of near 15 m of vertical extension. Stop 6, backpack for the scale!

5.5 Sponges in the Chanakhchi giant microbial build-ups (Fig. B37)

The Armenian basal Triassic tabular maze-like thrombolite (Fig. B37a), build-up forming structures, are characterized by often recrystallized micro-sparitic textures within lime mud rich in sponge fibers belonging to putative keratose sponges (Friesenbichler et al., submitted).

It is interesting to note that, according to Luo & Reitner (2014), the organic skeletons of horny or keratose sponges can be preserved in the same way as the rapidly calcified siliceous sponges found in Phanerozoic carbonates. Due to calcium carbonate oversaturated seawater, the spongin skeleton has been preserved as a calcified fiber network within lime mud, within thrombolite or within spar spheroid (former sponge body?) in these basal Triassic Armenian build-ups.

In some case the sponge fibers preferentially oriented parallel to crystal margins indicating that the sponges settled down between columnar, acicular stromatolite or thrombolite after their formation. In many other cases as in the large build-ups, the sponges fibers are highly abundant and binding the lime mud matrix. It is likely that the sponges stabilized the overall framework and impeded disintegration during extreme storm events.

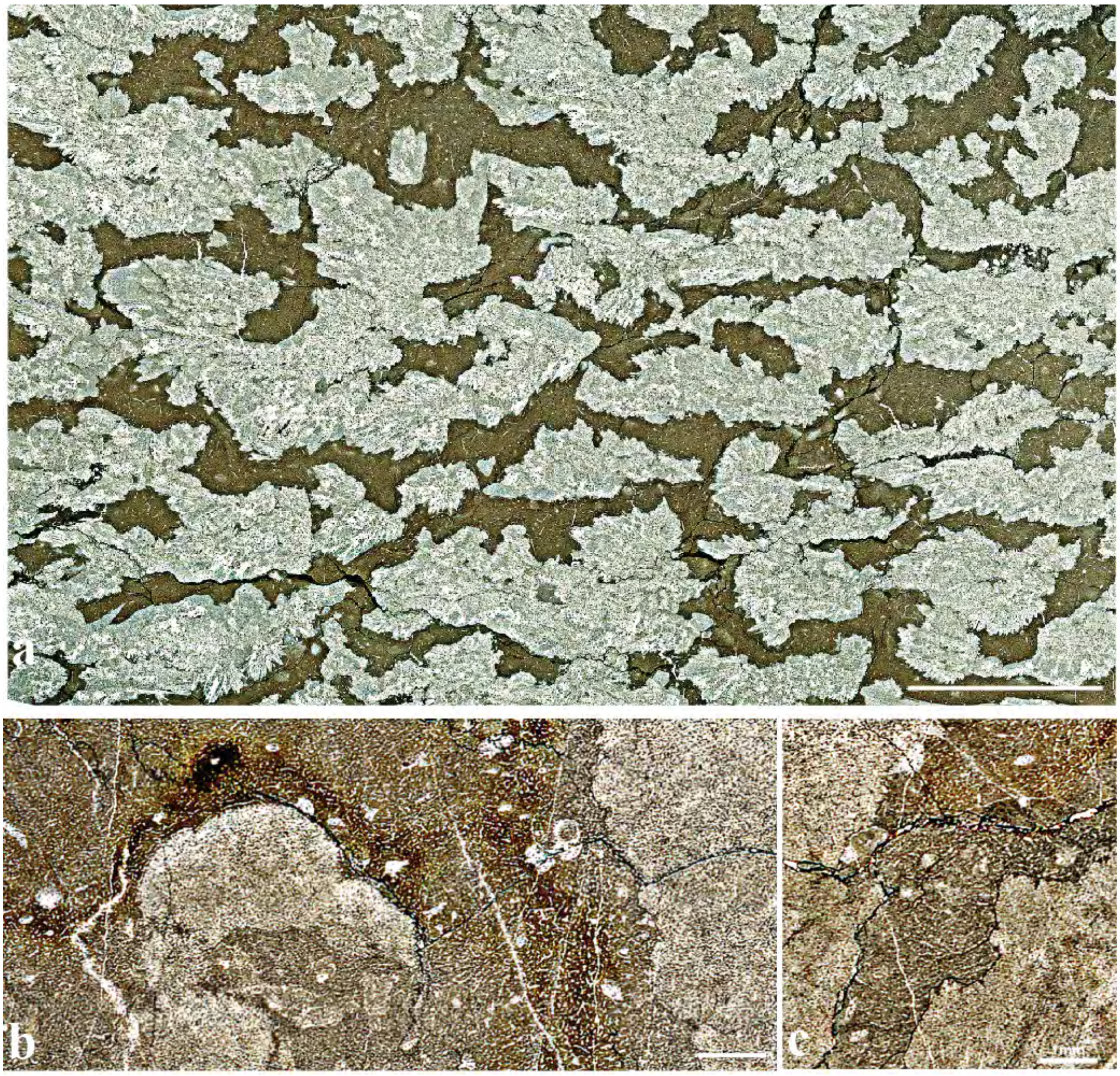

Figure B37 Scanned thin sections: a) Tabular maze-like thrombolite in a dark lime mud matrix with dispersed sponge fibers (scale 5 mm). b) c build by keratose? sponge fibers. c) Preserved framework of calcified keratose sponge fiber in a dark lime mud matrix (b and c, scale 1 mm).

5.6 To resume

The Chanakhchi section is unique in terms of the development of the basal Triassic giant SMB up to 15 m of vertical extension with asymmetrical sides due to steady bottom current. The overturned cone-shaped buildup geometry has a top head diameter up to 8 m width, that consists of numerous thrombolite domes (Fig. B32).

The basal bioherms are built by a new group of columnar structures (Fig. B31 left) made of coalescent pointed calcite stromatolites or "acicular stromatolites".

Keratose sponges, as metazoan play an important part in the bioherm building. Due to the calcium carbonate oversaturated sea-water, the spongin skeleton has been preserved as a calcified fiber network within lime mud that stabilizes the overall framework.

Changes in palaeoenvironments during the basal Dienerian *kummeli* conodont zone suddenly break-off the thrombolite's growth. The overall duration of these post-extinction SMB is estimated at 700'000 years.

Notes

6. The Vedi sections

<u>13th October</u>: Vayk to Vedi (86 km, 1h 25 min by bus), Vedi to Yerevan (67 km, 1h 20 min by bus).

6.1 Geological setting

Permian carbonates are exposed in the middle and upper part of the Vedi river valley (Figs B38-B41) in the core of an anticline known as the Terterasar structure (also known as Keshish-*dag* or hill). The NW flanks of the anticline and the pericline are composed of Lower Triassic limestones (Arakelyan, 1964). Triassic units are exposed on the SW flanks and the NW nose of the plunging Terterasar structure (Arakelyan, 1964), and rest conformably on the Permian units. Triassic strata include thin-bedded, pale gray limestones passing upwards into greenish and yellowish-gray colors. The top of the Lower Triassic units is here tectonically truncated.

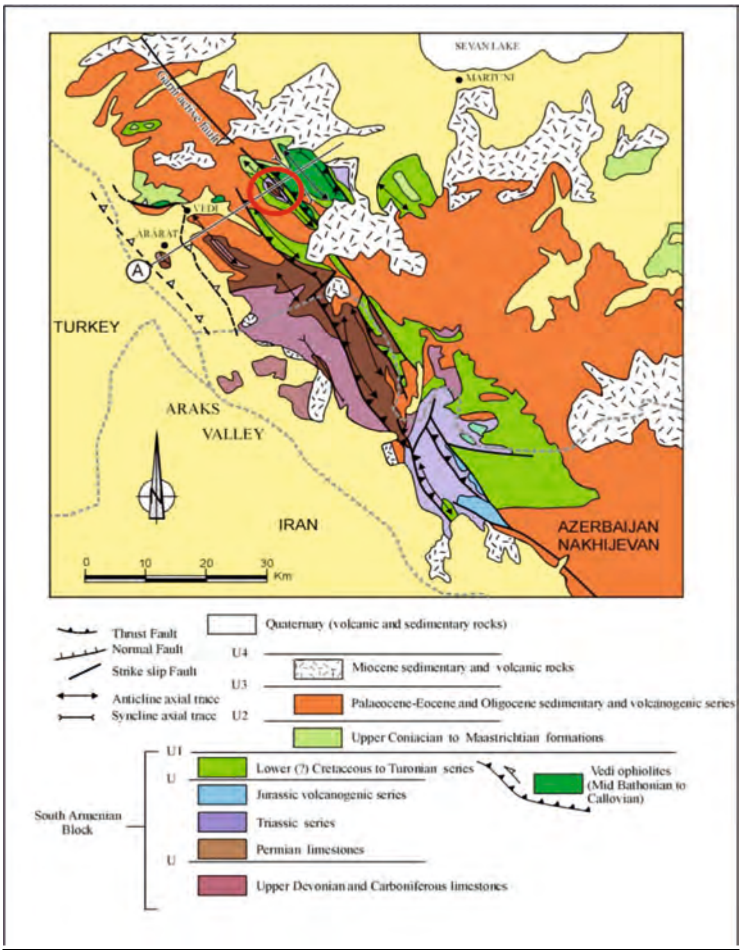

Figure B38: Structural map of the Vedi area, southern Armenia (Sosson et al., 2010) The Permian-Triassic succession is located by the red circle.

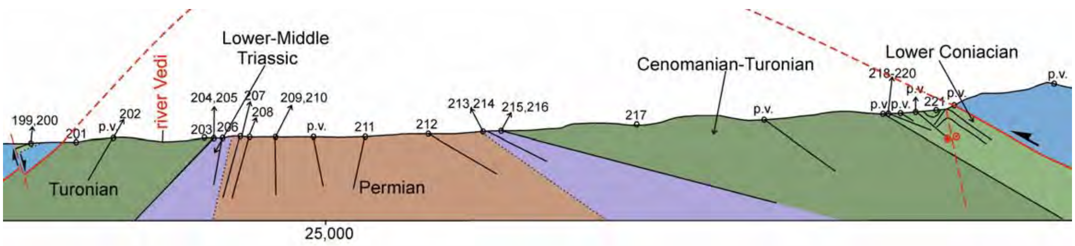

Figure B39: Cross section through the Vedi river basin anticline (Sosson et al., 2010).

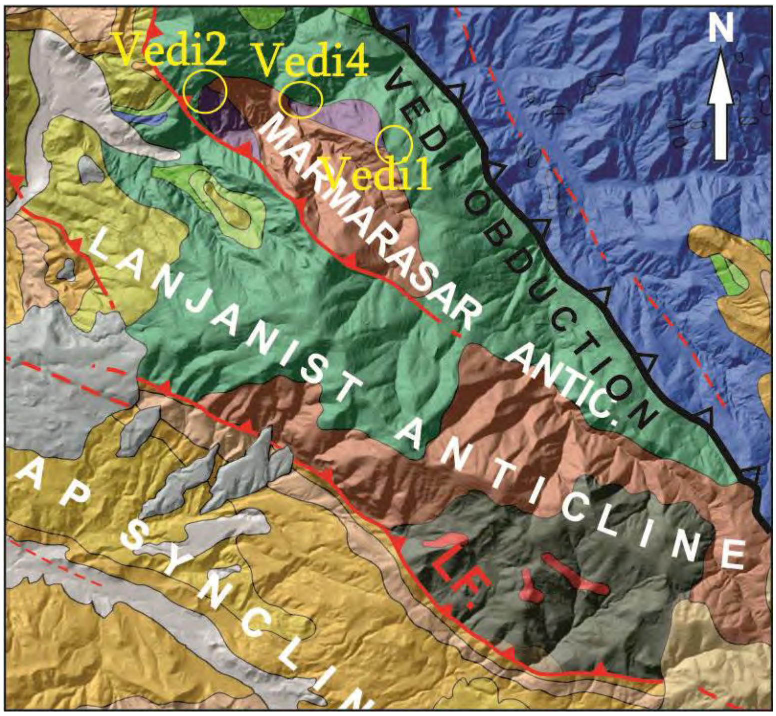

Figure B40: Geological map of the Vedi area (Avagyan et al., 2015), with the Marmarasar (or Terterasar) anticline and the Vedi localities 1, 2 and 4 (yellow circles). Vedi 1 access is not easy and we will not visit it.

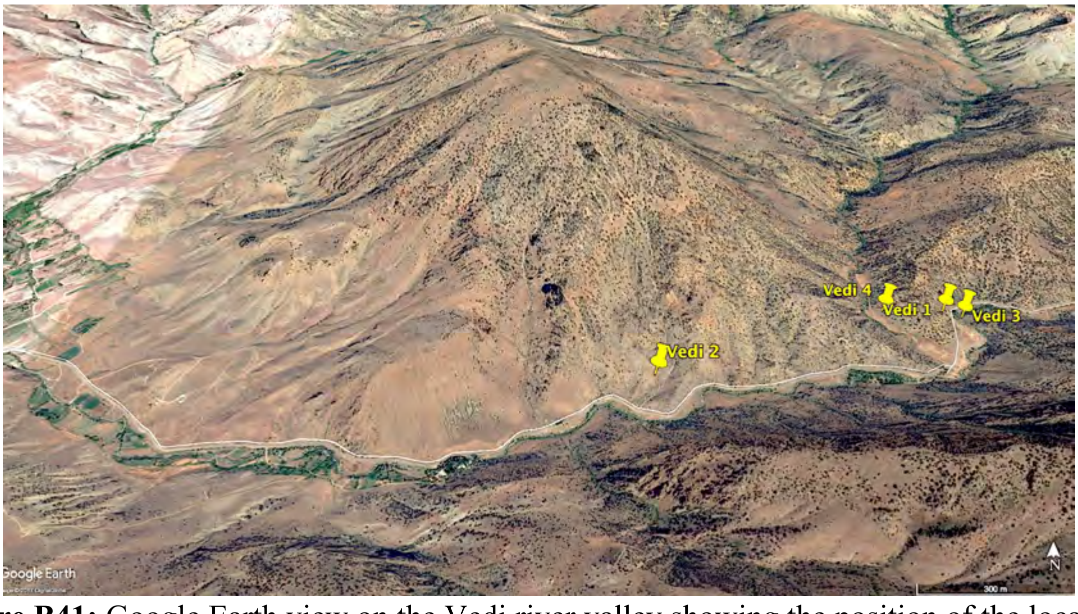

Figure B41: Google Earth view on the Vedi river valley showing the position of the localities Vedi 1 to 4.

6.2 The Late Permian to basal Triassic succession at Vedi 2 section.

This section occurs on the right bank of the Vedi valley, l.5 km downstream the Spitakajur river (Akhsu) mouth and is the first PT section we cross moving up the Vedi river. As the other S Armenian sections, a main facies change occurs at the top of the Khachik Formation (Middle Wuchiapingian) due to drowning of the carbonate platform between the Upper Khachik Formation and the Lower Akhura Formation. A list of Upper Permian foraminifera is published by Kotlyar et al., 1983 and we are giving below the lithological section of Vedi 2 with the faunal content published by Aslanian, 1984 (Fig. B42, levels 1 to 7).

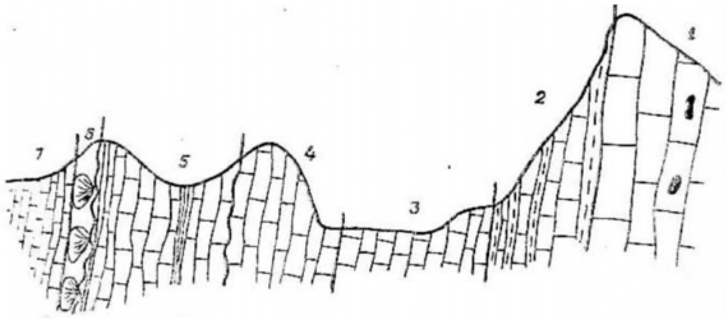

Figure B42: The Permian to basal Triassic rocks of the Vedi 2 section (Aslanian,1984, modified) with first the units 1 and 2 of Capitanian age (Middle Permian): 1) Limestones dark-gray and black, massive and medium-bedded 5 m thick, with interlayers of sandy limestones and mudstones and inclusions of black and dark-brown flints with *Miliolida* and *Codonofusiella* sp. foraminifera. 2) Limestones dark-gray, black, medium-bedded, 0,5 m thick, with rare thin (0.1·0.15 m) interlayers of gray schistose with brachiopods *Orthtetina dzhulfensis*.

Above is the Upper Permian Wuchiapingian units with *Condonofusiella-Araxilevis* beds, 2.3 m thick; 3) Limestones dark-gray, massive-bedded with the foraminifera *Paraglobivalvulina mira*, *Dagmarita* sp., *Langella* cf. *ocarina* (lower part); *Geinitzina gigantea*, *Pachyphloia* sp., *Prodina* sp., *Robuloides* sp. (upper part) *Codonofusiella ussuriensis*, *G*. aff. *kueichowensis*, *C. golubinensis*, *C*. sp., *Pseudodunbarula apraensis*, *Nanlingella* aff. *palaeofusulinaeformis*, *N*.? *ardoglensis*, *Reichelina* aff. *changshingensis* (throughout the bed); the brachiopods - *Araxilevis intermedius* (0.3 m from the basal bed), *Enteletina. ruzhencevi Orthotetina dzhulfensis, Araxilevis intermedius, Haydenella kiangsiensis, Leptodus nobilis*, *Araxathyris araxensis* (0.5 m from the basal bed), *Araxilevis intermedius* (upper part of the bed).

The Akhura Formation starts with the *Araxoceras lasium* and *Vedioceras ventrosulcatum* beds: 4) Limestones gray and light-gray, laminated, brecciated, with rare interlayers of yellow mudstones, 8.3 m thick; the conodont species *Gondolella leveni*, *G. orientalis*, (2,5 m from the base); in the upper half, the brachiopods: *Araxathyris araxensis. araxensis*; the nautiloids: *Pleuronautilus dzhulfensis* and the ammonoids: *Pseudotoceras armenorum, Pseudotoceras* sp*., Vediceras ventroplanum, V. umbonovarum, Godthaabites ruzhencevi*.

The top Permian, *Phisonites Triangulus - Paratirolites kittli* beds, 6.1 m thick (Changhsingian): 5) Limestones gray, pink and lilac-coloured, mottled, thin-bedded with interlayers of mudstones in the upper part ; nautiloids: *Foordiceras* (?) cf. *grypoceroides*, and ammonoids: *Shevyrevites* sp., *Paratirolites dieneri, P. kittli , P. waageni, P. vediensis, P. trapezoidalis, Abichites mojsisovicsi, A. stoyanowi*, *A. abichi*.

The Lower Triassic, Karabaglyar Formation, *Claraia* beds (lower part, Induan).

6) Limestones yellowish, clayey, microbial, forming bun -shaped bodies, -1.4 m thick

7) Limestones gray, 5 m thick, with *Ophiceratidae* gen. et sp. indet.; bivalves *Claraia aurita*.

It is interesting to note that, according to Rostovtsev and Azaryan (1973) *Gyronites* sp. was found in the platy limestone, 18 m above the PTB, which should give a Dienerian age (Upper Induan). Leopold Krysyn (written com.) however mentioned that the fauna described by Rostovtsev and Azaryan (1973) could be rather “*Kymatites*”, a fauna, which co-occur with Ophiceratids in Iran and Oman and probably still Griesbachian. Conodont data are still needed to precisely define the Griebsachian-Dienerian Boundary here.

Jenny et al., 2009, present a table of Permian-Triassic main bioclasts, estimate from thin sections (Fig. B43) and an inventory of the Upper Permian Foraminifers from the Vedi 2 section (Fig. B44) based on a collection made with A. Baud during the IGC fieldtrip 1984 in Armenia. More recently, the basal Triassic bioclasts in thin section have been worked by Friesenbichler, 2016 (Fig. B45).

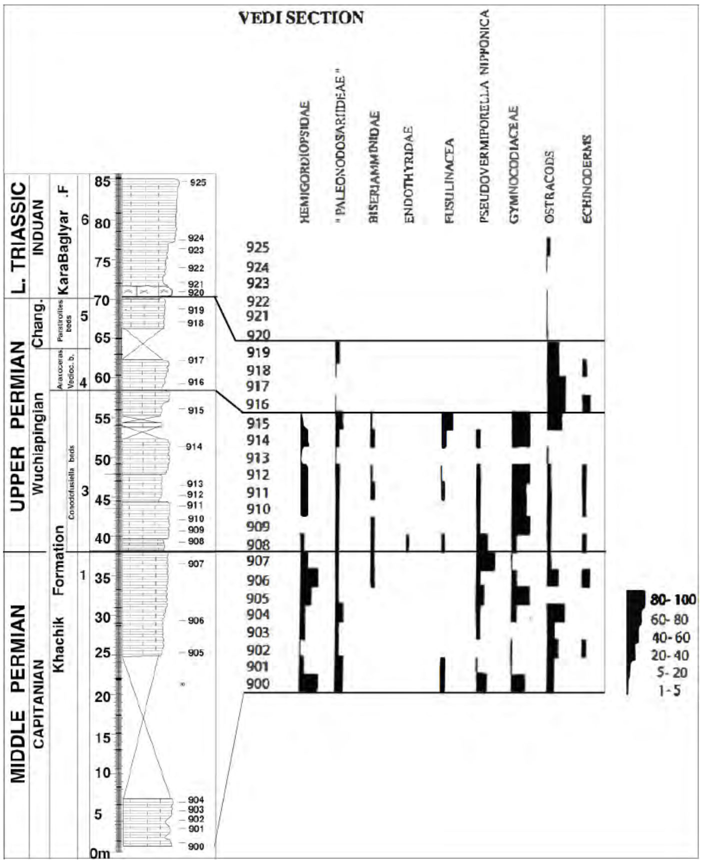

Figure B43: Inventory of the bioclasts from thin sections of the Late Permian to Early Triassic from the Vedi 2 section according to Jenny et al., (2009, Fig. 1.5.5 modified).

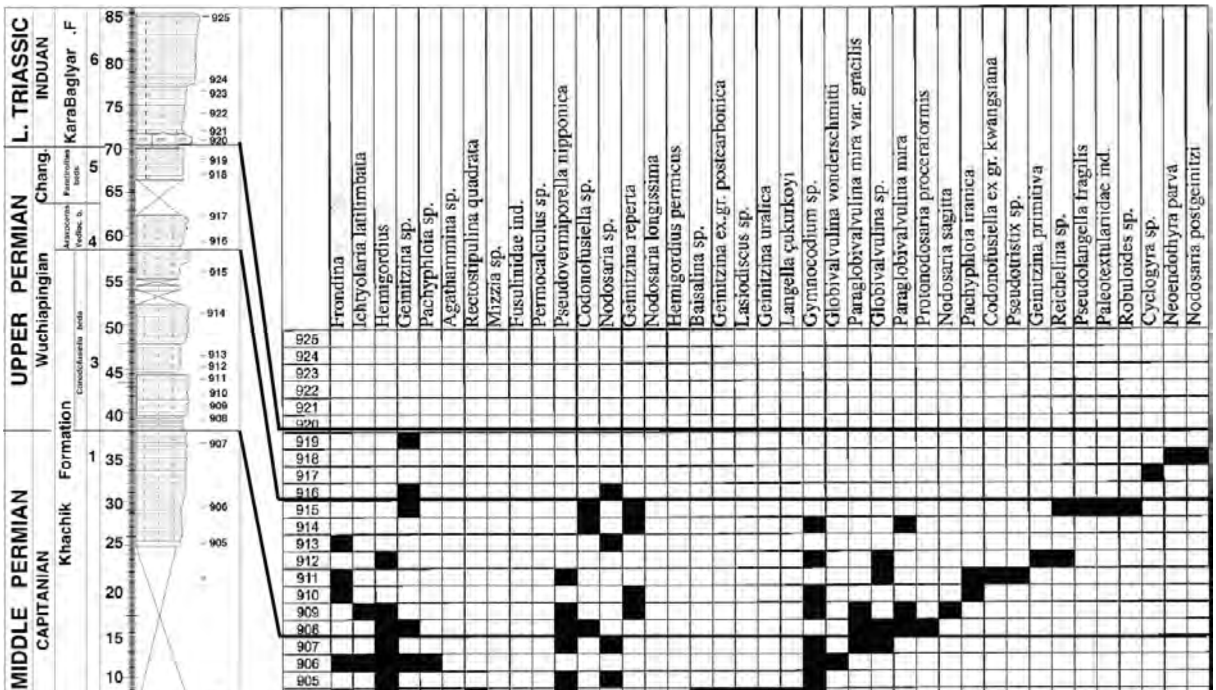

Figure B44: Inventory of the foraminifera and calcareous algae of the Late Permian to Early Triassic from the Vedi 2 section according to Jenny et al., (2009, Fig. 1.5.3 modified).

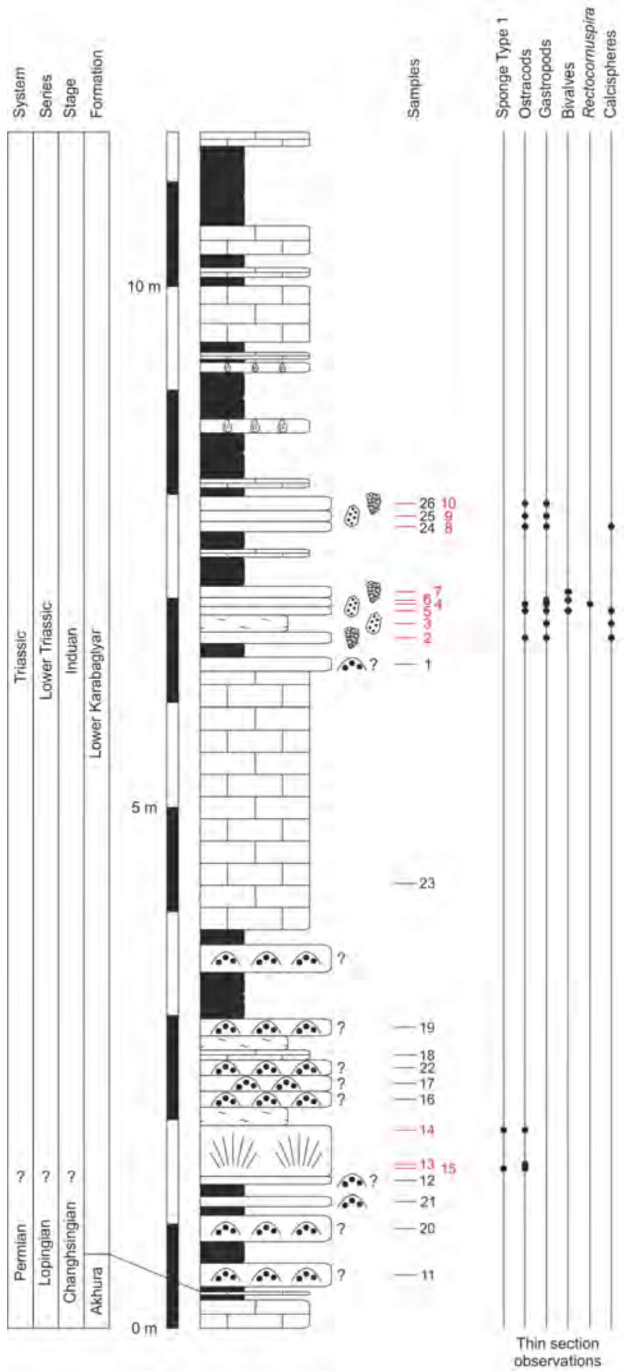

Figure B45: Inventory of the bioclasts from thin sections of the Lower Karabaglyar section at Vedi 2 section according to Friesenbichler, 2016.

6.3 Geochemical studies

For the first stable Carbon isotope study, a detailed section of the Upper Permian to Lower Triassic succession at Vedi 2 was sampled during the IGC fieldtrip 1984 in Armenia. The results have been published by Baud et al. in 1989. We point out (Fig. A4) that the Middle Permian limestones are enriched in heavy Carbon ($\delta^{13}C > +4‰$,) and the first shift of 1‰ occurs at the Guadalupian-Lopingian Boundary. A second shift of 1‰ occur at the facies change between Khachik and Akhura Formation in the Middle Wuchiapingian and the third, well known larger shift, here of more than of 2‰, occur at the Permian-Triassic transition. Lower Triassic rocks were comparatively depleted with $\delta^{13}C$ values between 0.2 and + 1.2‰ (Fig. B46).

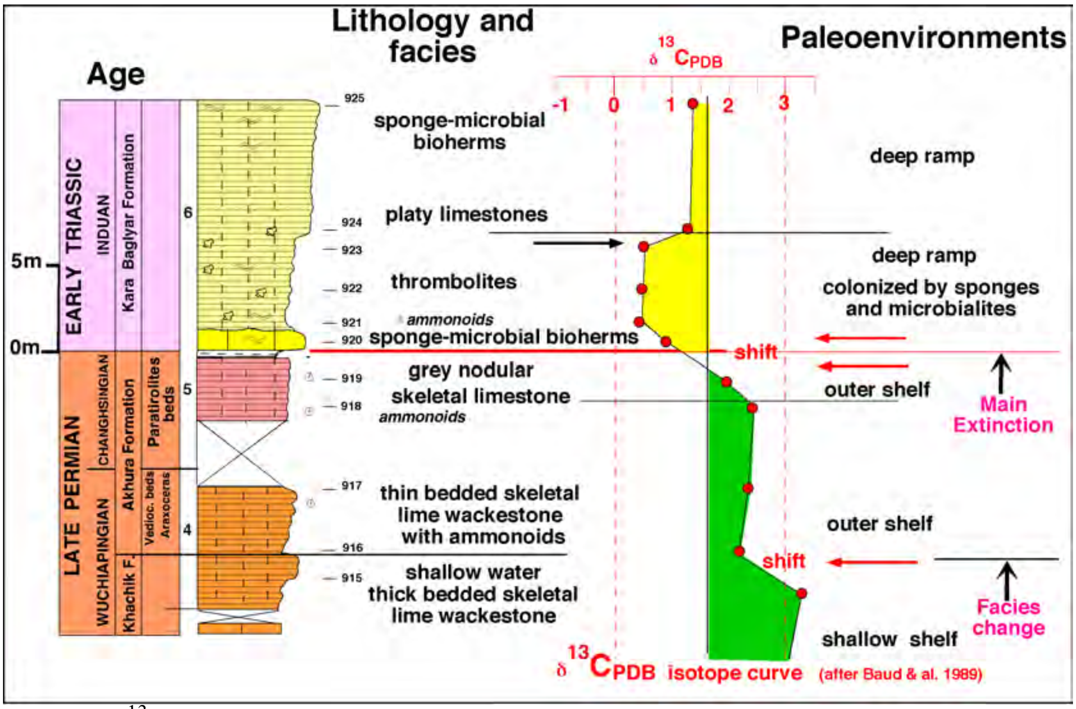

Figure B46: $\delta^{13}C_{carb}$ isotope curve of the Upper Permian to basal Triassic succession at the Vedi 2 section (Baud et al,. 1989, modified) with special focus on the main facies and palaeoenvironnments.

6.4 The five stops of the day.

The best outcrop to look at the Upper Permian and the basal Triassic is the Vedi 2 section (Fig. B47), where the first four stops are planned.

Figure B47: The Vedi 2 section with on the right the well visible thick bedded limestone of the Permian Khachik Formation. The entire slope, grass covered on the left, consists of the basal Triassic thin bedded limestone of the Karabaglyar Formation.

- Stop 1: Our first stop will be the top of the Late Permian Khachik Formation cropping-out vertically with thick bedded gray limestones (Figs B47, B48).

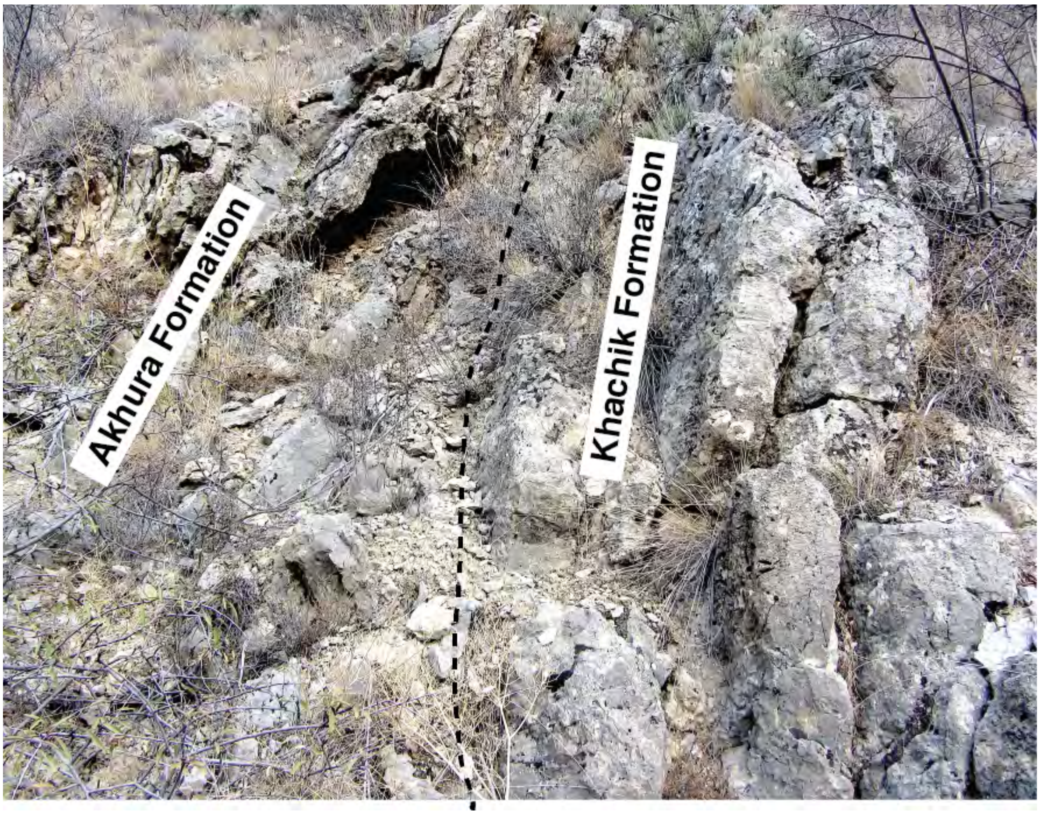

Figure B48: The boundary between the shallow water thick bedded Khachik Formation and the deeper thin bedded Akhura Formation.

- Stop 2: we will move to the Permian-Triassic transition and have a close look at the Uppermost Permian *Paratirolites* limestone, exclusively of gray color here (Fig. B49). A rich nautiloid and ammonoid fauna has been reported by Aslanian (1984) with the nautiloids *Foordiceras* (?) cf. *grypoceroides*, as well the ammonoids *Shevyrevites* sp., *Paratirolites dieneri, P. kittli , P. waageni, P. vediensis, P. trapezoidalis, Abichites mojsisovicsi, A. stoyanowi*, *A. abichi*.

Figure B49: Left, view on the top of the thin bedded *Paratirolites* limestone, here in gray color; Right, main part of the nodular *Paratirolites* limestone. Hammers for scale!

Stop 3: This stop focuses on the onset of the basal Triassic SMB that directly overlies the Permian-Triassic Boundary shale (Figs B50-B52).

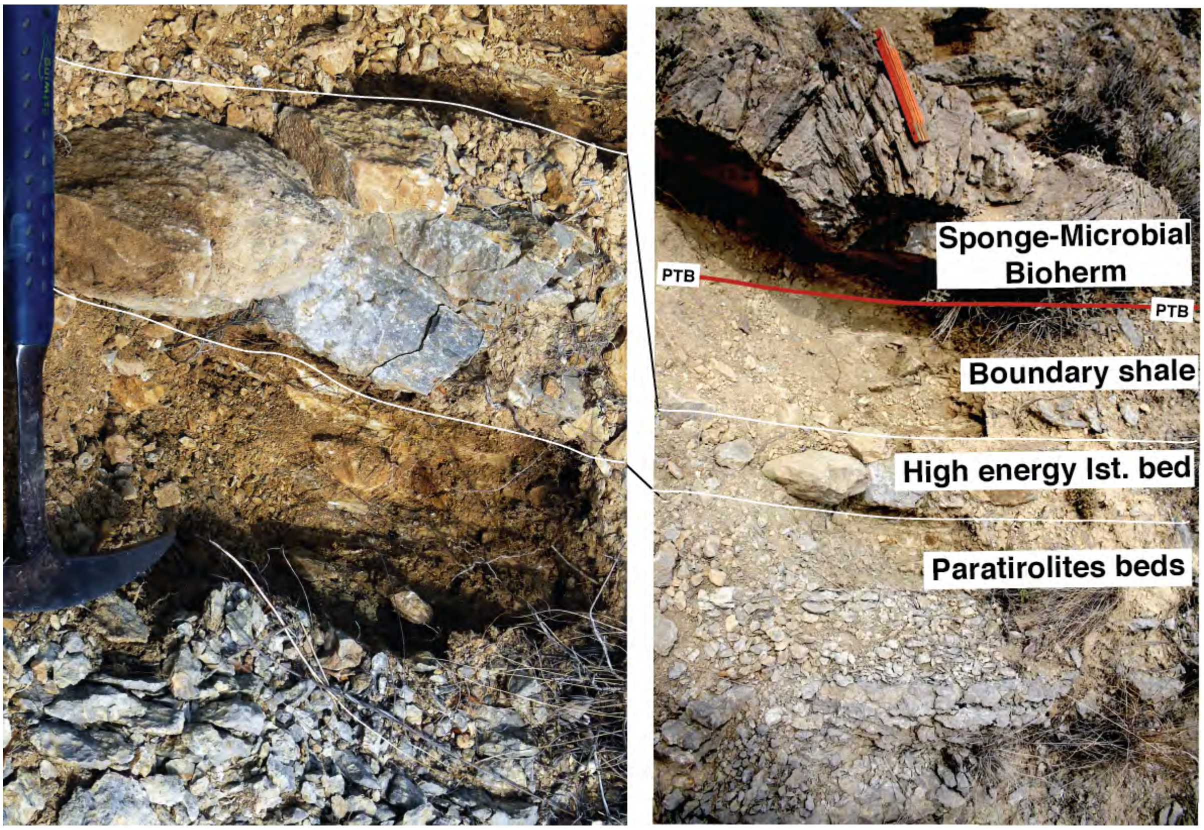

Figure B50: The Permian-Triassic transition turned horizontally. Left, detailed enlargement of the picture on the right showing an high energy lime packstone at the top of the Paratirolites bed. Right, the basal Triassic SMB that directly overlie the boundary shale. Scale (yellow), 20 cm.

Figure B51: Pictures turned horizontally showing two types of structures overlying the basal Triassic SMB, 40 cm thick. Left, straight shaped bioherm. Right, domal shaped bioherm.

Figure B52: The basal Triassic SMB. Left, detailed view on part of its fan structures up to 30 cm high. Right, thin section scan view on the vertical structure of coalescent pointed calcite stromatolites and rare calcified acicular aragonite crystals on the side. Scale bar, 1 cm

Stop 4: Following the horizontal path dig-out for a better outcrop, we will have a close look at the development of the thin bedded platy limestone (Fig. B53) that contain different trace fossil networks on some bedding planes (Fig. B54) and at small sized SMB (Fig. B55).

Figure B53: Five meters of the thin bedded, platy limestone above the basal Triassic SMB along the new dig-out path.

Figure B54: Ichnofacies types on bedding surface of platy limestone. Left, *Thalassinoides* type. Right, *Spongeliomorpha* type.

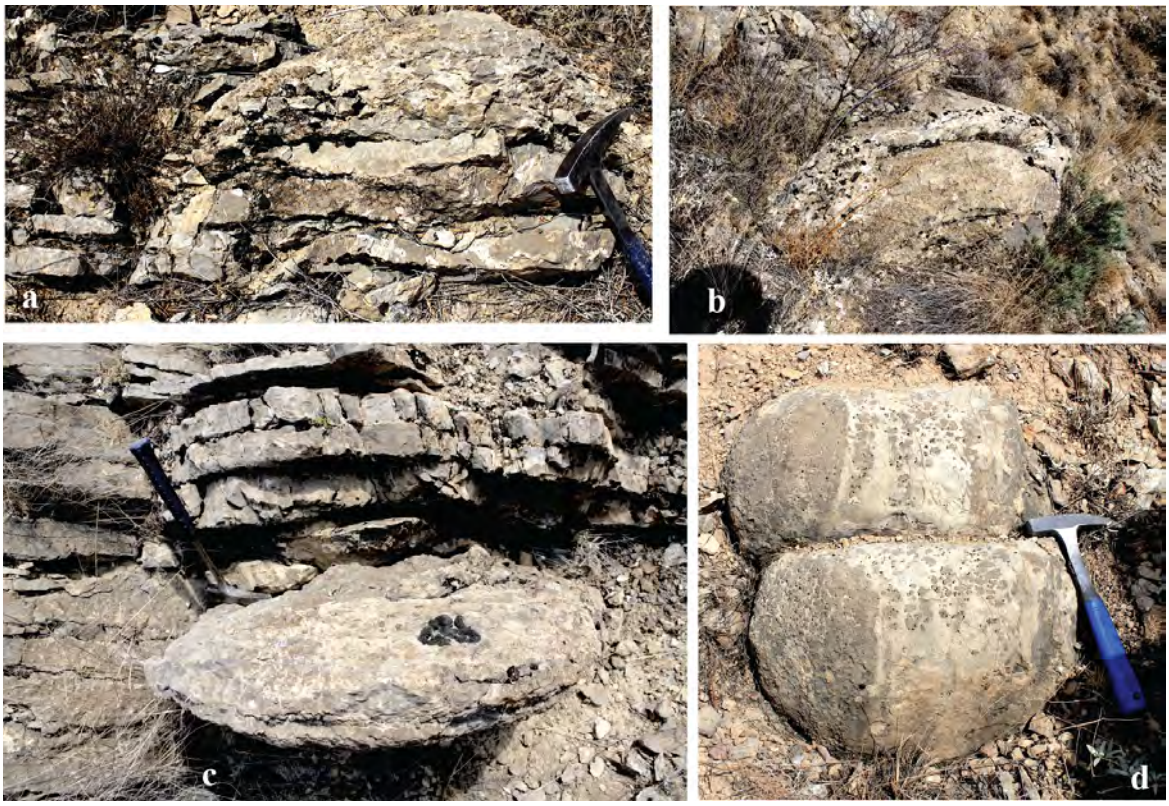

Figure B55 -Collection of selected small sized SMB: a) Small domal structure inside platy limestone; b) Caped spheroid structure, half a meter thick; c) Disk shaped, half a meter thick; d) superposed spheroidic cylinder shaped.

Time permitting, we will move to Vedi 4 locality (position illustrated at Figs B40 and 41 and view at Fig. B56) and have a close look at some large sized SMB (Fig. B57).

Figure B56: The mouth of the Spitakajur river valley looking North; on the right, large sized SMB have been found (Vedi 4 locality).

Stop 5: On the left side of the Spitakajur river mouth, the main part of the platy limestone is covered and only some hard and large-sized SMB are cropping-out (Fig. B57). In the nearby Vedi 1 section the contact between the *Paratirolites* beds and the basal Triassic SMB seems faulted and there is no boundary shale (Fig. B58).

Figure B57: Complex, partly dome-shaped basal Triassic SMB up to 12 m thick, on the left side of the Spitakajur river mouth (Vedi 4 area).

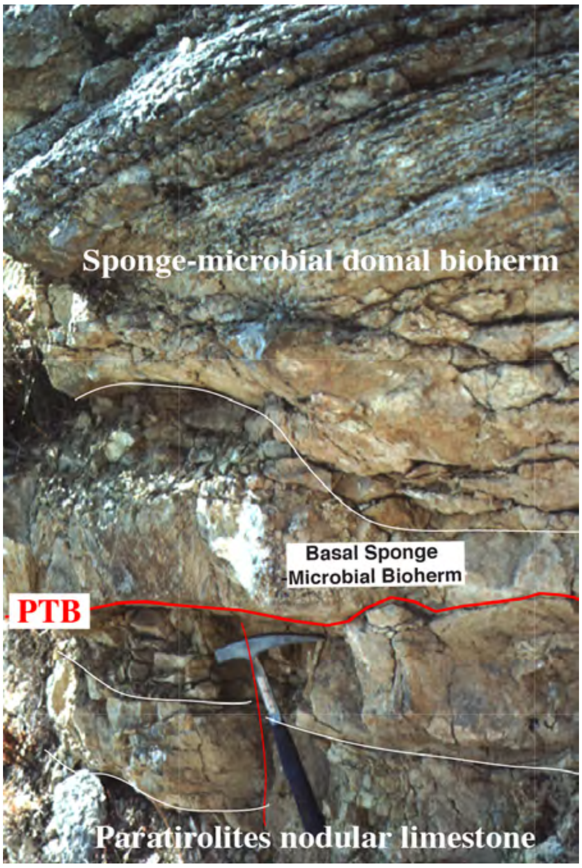

Figure B58: A 1984 field picture of the Vedi 1 Permian-Triassic transition with a new key (Baud et al., 1997, Fig. 2 and Baud et al., 2007, Fig. 2).

6.5 To resume

Within a short distance along Vedi River, there are at least four Vedi PTB sections showing their own features. In the Vedi 1 area, the sponge-microbial crystal fans are directly overlying the Paratirolites nodular limestone without boundary clay followed by large dome-shaped mounds up to 4 m high as shown by Fig. B58.

In the Vedi 2 area, the PTB shale is well visible but the overlying SMB is less developed as shown in the Figs B51 and B53 right. New ichnofacies are present in the Induan Lower Karabaglyar Formation (Fig. B54) but are not yet studied in detail.

A great variety of SMB shapes are cropping-out in the Lower Karabaglyar Formation of the Vedi area (a selection is illustrated in Fig. B55) and can be observed in all Vedi sections (1 to 4) but the largest SMB were discovered in the Vedi 4 area.

Notes

ACKNOWLEDGEMENT

We are grateful to Leopold Krystyn to his help in the field, to his new data sent and the long discussion on the Lower Triassic stratigraphy and his corrections proposal.
discussion on the Lower Triassic stratigraphy and his corrections proposal.
Thanks also Armenian colleagues, in particular Prof. Dr. Arkadi Karakhanyan for providing all facilities to work out the sections, Dr. Sargis Vardanyan for his kind help in the field. We wish to thank Christopher Tiratsoo (Editor of Journal of Petroleum Geology) for his sincere help.

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