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Conodont biostratigraphy from Carboniferous and Permian successions of Pamir, Central Iran and Tunisia

Ph.D. Thesis

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Ieri mi sono comportata male nel cosmo.
Ho passato tutto il giorno senza fare domande,
senza stupirmi di nulla.

Wisława Szymborska

Yesterday I acted bad in the cosmos.
I spent all day without asking questions,
without be surprised by anything.

Wisława Szymborska

CONTENTS

Abstract

My PhD thesis regard the study of conodont faunas from key- areas for the comprehension of the evolution of Cimmerian orogeny. In fact, conodonts are the most useful stratigraphic tools for biocronostratigraphy during Carboniferous and Permian.

The main objectives of my thesis are:

- correlation between conodonts and fusulinids biozones in key areas like Central Iran and SE Pamir in order to correlate Tethyan and International timescales;
- correlation, using conodonts, among areas belonging to different Cimmerian Blocks (N and SE Pamir, Central Iran), Tunisia and the global scale;
- individuation of paleobioprovinces, defining them on the basis of the conodont fauna found;
- taxonomical revision of Carboniferous and Permian conodonts, particularly the gondolellids group which shows problems on identification.

During Upper Carboniferous and Permian a strong provincialism, due to particular paleogeographic and paleoclimatic conditions, develops interesting both flora and fauna and resulting in many problems in biostratigraphic correlation.
Three major conodont bioprovinces have been detected during Permian while mixed fauna zones are very rare.

Sections located in the Cimmerian Terranes, during Lower and Middle Permian, were placed in a mixed fauna area between cool and warm paleobiopriovinces, while Tunisia was located in a warm water province.
These studied areas have been chosen for their position during Upper Carboniferous and Permian assemblage of the supercontinent Pangea: during these periods Central Iran, SE and N Pamir belongs to Cimmerian Terranes while Tunisia was located in the Tethyan gulf.
Tethyan gulf and particularly the Cimmerian Terranes were located in a mixed fauna zone.

In order to reconstruct the evolution of these four areas during the displacement of Cimmerian Terranes throughout Upper Carboniferous and Permian, conodont data have been integrated with paleomagnetic, lithostratigraphic and biocronostratigraphic data from other fossil groups, particularly from fusulinids.

Central Iran: the Upper Carboniferous and Permian of Tabas area have been studied in five stratigraphic sections.

The most significant section is Bagh-e-Vang that is very rich both in conodonts and fusulinids. The age of Bagh-e-Vang section is Early Sakmarian/ Upper Wordian. It was observed that the increasing of *Mesogondolella*, a deep-water genus, specimens respect to *Sweetognathus*, a shallow- water genus, from base to the top of the section reflect a deepening trend.

A rich conodont fauna have been recovered from this section: particularly significant are the species *Mesogondolella monstra* (Chernykh, 2005), that was found also in SE Pamir and is typical of warm water in the Urals, *Sweetognathus subsymmetricus* (Wang, Ritter & Clark, 1987), that was recovered also in SE Pamir sections and is typical of the Warm Water Province and *Mesogondolella siciliensis* (Kozur, 1975) that is a deep- water species whit a wide distribution (S. China, Texas, Oman and Sicily) .

According to the presence of *M. monstra* and *S. subsymmetricus* is possible to recognize an affinity to the warm Boreal Realm (Urals, Russian Platform, Yukon Territory and Carnic Alps): the species *M. siciliensis* indicate the presence of deep water and is coherent with the deepening trend detected throughout the Bagh-e- Vang section.

Conodonts from the other four sections (Shesht- Angosht. Zaladou, Rahdar and Anarak 3) are very rare but the presence of fusulinids allow a correlation among these sections but a global scale correlation is actually impossible and further studies are needed.

Tunisia: three stratigraphic section have been studied from the Permian outcrops of Djebel Tebaga de Medenine.

Merbah-el- Oussif section was completely barren but a well preserved population of the species *Sweetognathus iranicus hanzongensis* (Wang, 1978) was found in Halq Jemel section, the same species have been recovered too in Tebaga *sensu strictu* section.

Sweetognathus iranicus hanzongensis is typical of shallow and warm water ad his presence is coherent with the paleoenvironmental reconstruction of the Djebel Tebaga area (Angiolini *et al.*, 2008).

Sweetognathus iranicus hanzongensis ranges throughout the Guadalupian and was found also in N. Pamir: it is typical of Warm Water Province (like S. China) and signal the presence of shallow and warm water environment.

The presence of both fusulinids and conodonts in sample HJ32 from Unit V in Halq Jemel section point to a Wordian age for this Unit.

N Pamir: two stratigraphic sections have been studied for this area. Gundara section was barren, while a poor conodont fauna was recovered from Bolorian Stratotype section. *Sweetognathus iranicus hanzongensis* and *Sweetognathus modulatus* (Chernykh, 2006) are present in the lower part of the Bolorian Stratotype section and point to a Kungurian age.

The presence of *Sweetognathus iranicus hanzongensis*, that is present in Tunisia too, point to a shallow warm water environment.

SE Pamir: four sections have been studied and a rich conodont fauna have been recovered from them. The presence of both conodonts and fusulinids make this area crucial for the correlation between International and Tethyan timescales. In three of the studied section (Kubergandy, Kutal 2 and Kurteke) a correlation between conodonts and fusulinids has been possible.

The age of Kubergandy section, based on conodonts, is Kungurian to Wordian (International timescale). The correlation with fusulinids allows to identify a Bolorian to Kubergandian (Tethyan timescale) age for the lower part of this section (Kubergandy Formation).

The age of Kutal 2 section is Kungurian to Wuchapingian integrating data from both conodonts and fusulinids.

The Kungurian- Roadian age of the lower part of the section was detected using conodonts, while the age of the top of the section was identified whit fusulinids because no conodonts were founded samples from this part of the section.

The base Kurteke section is Kungurian/early Roadian on the basis of conodonts and latest Kubergandian/ early Murgabian for fusulinids. In this case the age of conodonts and fusulinids does not perfectly correlate, making crucial to carry out for further studies in this area.

The age of the upper part of Kurystyk section is Lower Triassic (Induan/ Olenekian) on the basis of conodonts. No conodonts were founded from the lower part of the section.

Specimens from SE Pamir can be correlated with Oman, S. China, Texas, Sicily and Central Iran for the presence of *M. siciliensis* and transitional form to *Mesogondolela omanensis;* to South China, for the presence of *Mesogondolella pingxiangensis*; to the Altuda and Word Formations (U.S.A.) for the presence of *Jinogondolella altudaensis*, *Hindeodus wordensis* and *Hindeodus excavatus* and to Urals for the presence of *Sweetognathus withei* and *Mesogondolella monstra*.
The presence of such a differentiated fauna suggest that SE Pamir was located in a mixed fauna zone during Permian.

For what concern taxonomical studies the abundant conodont fauna from SE Pamir allow a detailed investigation, particularly for the Middle Permian gondolellids group.
In fact, one of the principal characteristics of Middle Permian conodont fauna from SE Pamir is the absence of serrations in almost all specimens.
Serrations are a morphological character of great importance for Middle Permian conodonts: Permian gondolellids contains both serrated and non- serrated forms and the base of Roadian and Guadalupian have been defined on the base of the First Appearance Datum (FAD) of the serrated species *Jinogondolella nankingensis*.
But the Permian profound provincialism and the recognition of geographic clines throughout conodonts open many question on conodont taxonomy: almost all the specimens of *Jinogondolella* present in the studied fauna of SE Pamir does not shows serrations and few specimens show some trace of this character.

This is a very interesting data that support the hypothesis that serration are under ecological control.

The main results of this thesis may be summarized as follows:

Central Iran: although several samples have been studied from this area the recovered conodont fauna is very poor, except for the section of Bagh-e-Vang that yielded a more rich conodont assemblage. Because of this, a tentative correlation between conodonts and fusulinids, a paleoenvironmental reconstruction, the recognition of the faunal affinity with the Warm Water Equatorial paleobioprovince and correlations with Cimmerian Terranes and to a global scale have been possible only for Bagh-e-Vang section, while some taxonomical revision have been possible for conodonts from the Carboniferous sections of Zaladou and Anarak3.

Tunisia: many samples from three sections have been studied but, unfortunately, one of this section (Merbah- el- Oussif) was completely barren, while in the other two sections only the species *Sweetognathus iranicus hanzongensis* have been reported only from two samples.
The presence of *Sw. iranicus hanzongensis* allows paleoenvironmental reconstruction, recognition of faunal affinities and global scale correlation.

N Pamir: several samples from two sections have been studied but one of them (Gundara section) was completely barren, while for the Bolorian Stratotype section only one sample from the lower part of the section yielded conodonts.
Because of the poorness of conodont fauna no correlation with fusulinids or taxonomical study have been possible, but a paleoecological reconstruction, recognition of paleobioprovinces affinity and global scale correlations have been possible.

SE Pamir: numerous samples have been studied from four section in this area and a rich conodont fauna have been recovered. Thanks to the abundance of conodonts it was possible to make correlations between conodonts and fusulinids, recognize paleobioprovincial affinity and make taxonomical revision of Permian conodonts.

In Central Iran, Tunisia and N Pamir the poorness and bad preservation of conodont faunas prevent exhaustive analyses while the main objectives of this thesis have been achieved in SE Pamir, where a rich conodont fauna have been found.

Chapter 1

Introduction and objectives

1.1 Conodonts as primary group for Upper Carboniferous and Permian biostratigraphy

Conodonts represent one of the most abundant fossil group into marine sediment from Cambrian to the end of Triassic: they were almost ubiquitously diffused from lower to higher latitudes and their biostratigraphic power is well known. Their abundance and distribution make them an irreplaceable tool for construction of bio- and chronostratigraphic scales for Paleozoic and Mesozoic. Still, they are ideal biomarkers for global scale correlations and for GSSPs (Global Stratotype Section and Point) definitions.

In fact 19 of the 48 Paleozoic Stages were defined on the basis of a conodont bioevent and three are in phase of definition while, for the Triassic, 3 of the 7 Stages are based on conodonts (Shen *et al.*, 2013).

The global importance of conodonts as biomarkers make indispensable the prosecution of an extremely detailed study of their biostratigraphy, especially for Upper Carboniferous and Permian that are periods of great climatic and evolutionary changes. It is so very important to make a precise systematic and evolutionary study.

Conodonts are still useful to directly evaluate the thermic history of a sedimentary basin by the analysis of CAI (Color Alteration Index), a thermic alteration index of the conodont residual organic matter (Epstein *et al.*, 1977).

CAI makes conodonts useful index for the thermic maturity of the rocks and makes possible to draw isogrades maps, very useful for specialized researches like individuation of possible hydrocarbons reservoirs, mining exploration, identification of thermic flux, rifting zone or thrusts and preservation of original paleomagnetic signal.

1.2 Significance of study areas for reconstructing Cimmerian Terranes displacement during Neotethys opening

Four areas have been studied: North and South- East Pamir (Tajikistan), Central Iran and Tunisia.

For N Pamir Gundara Valley, between Charymdara, Zidadara and Gundara Valley, was studied: this area extended southward of Mionadus into Obikhingou Valley, into Darvaz area.

For SE Pamir, the study area is represented by the region placed south to the city of Murgab, SE Pamir (Angiolini *et al.*, 2014).

For Central Iran, several sections were studied into the Tabas area.

Finally, for Tunisia, were studied the Permian outcrops located along a small range of hills named Medenine Jebel Tebaga, near the village of Dkhilet Toujane.

These areas are very important during Permian, particularly for their role during the displacement of Cimmerian Terranes during the assemblage of the supercontinent Pangea.

In fact, among Permian period Se Pamir, Central Iran and the other Cimmerian Terranes separate from Gondwana due to the Neotethys opening and Paleotethys closing: in Upper Triassic the Cimmerian Terranes collide to the Asian margin of Laurasia, triggering the Cimmerian Orogeny (Sengör, 1979; Gaetani, 1997; Muttoni *et al.,* 2009; Zanchi *et al.*, 2000).

According to recent paleogeographic reconstruction (Muttoni *et al.*, 2009) the Cimmerian Blocks (Central-Northern Iran, Afghanistan, Karakorum, SE Pamir and Qiangtang) moves differently the ones from the others. For example during Lower Permian Central-Northern Iran was located to a lower and more meridional latitudes respect to the other blocks but to higher latitudes during Middle and Upper Permian (Angiolini *et al.*, 2007).

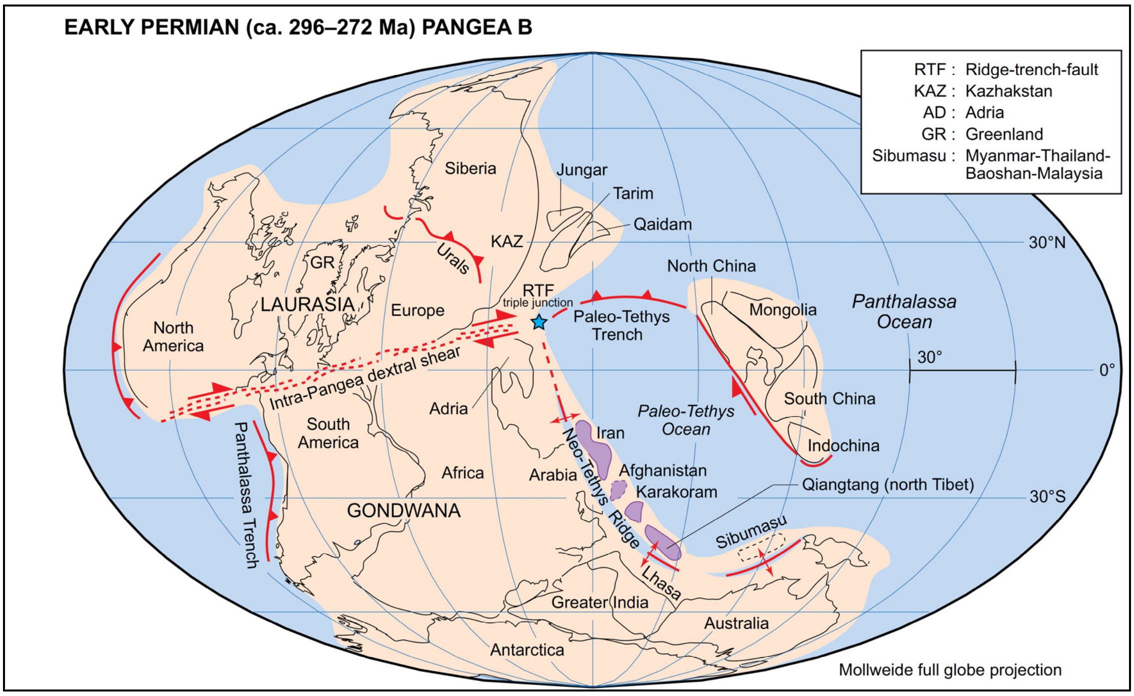

Fig. 1. Paleogeographic reconstruction of Pangea B for the Early Permian (from Muttoni *et al.*, 2009). Blue star: hypothetical location of a ridge-trench-fault (RTF) triple junction adjoining the Gondwana, Laurasia, and Paleo-Tethys plates. Solid triangles: trenches. Small diverging arrows: ridges. Half arrows: transcurrent plate motion. Dashed lines: terranes of uncertain position.

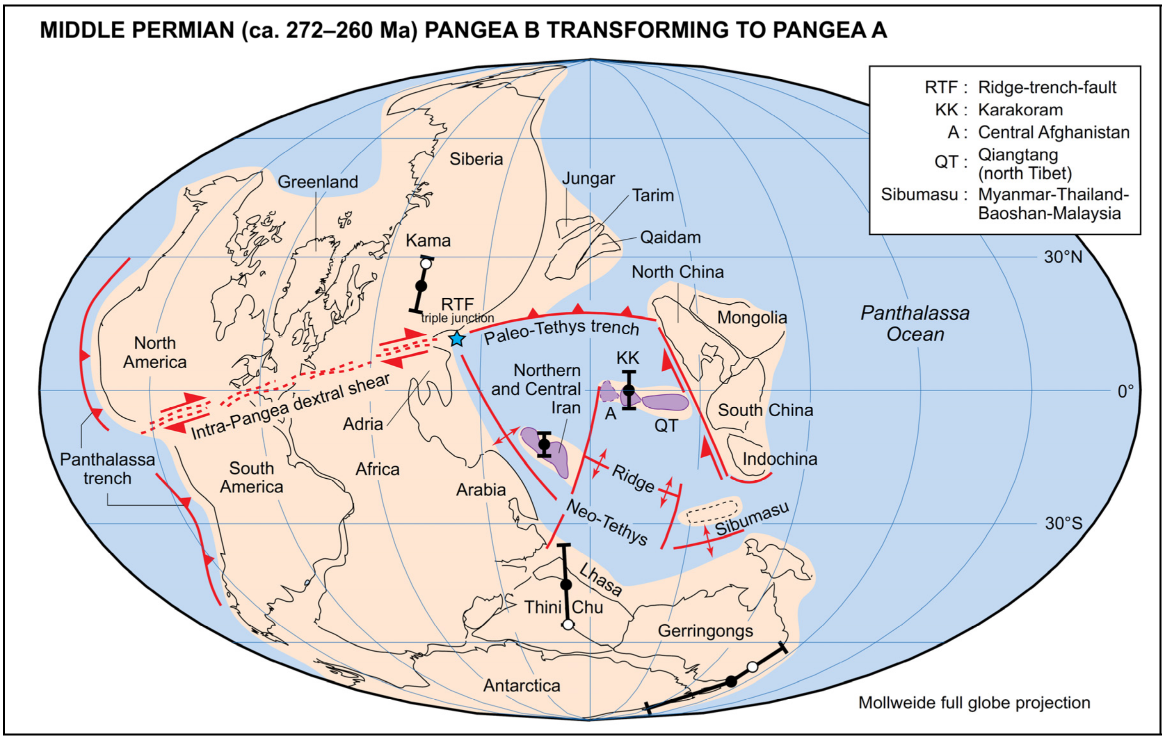

Fig. 2. Paleogeographic reconstruction of Pangea undergoing transformation from Pangea B to Pangea A during the Early Permian (from Muttoni *et al.*, 2009).

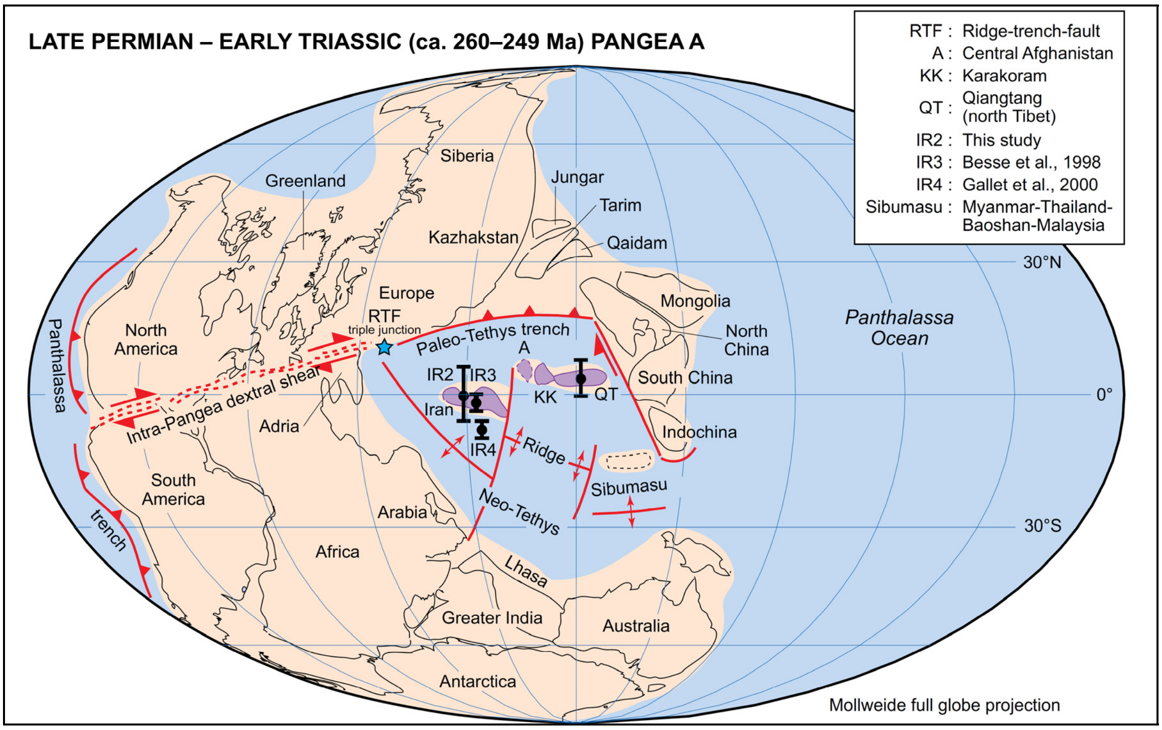

Fig. 3. Paleogeographic reconstruction of Pangea A for the Late Permian – Early Triassic (from Muttoni *et al.*, 2009).

1.3 Permian provincialism and correlation between conodonts and fusulinids: its importance for correlation between Tethyan timescale and International Permian Timescale

Dramatic climate changes during Permian results in profound provincialism that affected many Permian fossil groups (Henderson & Mei, 2003; Henderson & Mei, 2007). Conodonts are affected too from this provincialism even if they were used to define many Permian boundaries. Conodonts shows an increasing provincialism from Kungurian to Upper Permian (Henderson & Mei, 2003) that reflects in their morphology. Particularly Mei & Henderson (2001) shows that warm-water gondolellids have small cusps relative to posterior denticle height and high, fused anterior denticles, whereas cool-water taxa have larger cusps and lower, discrete anterior denticles.

Mei *et al* (1999a, b) and Mei & Henderson (2001) recognized three major conodonts paleobioprovinces: the Northern Cool Water Province (NCWP), the Equatorial Warm Water Province (EWWP) and the peri-Gondwana Cool Water Province (GCWP).

As reported in Henderson & Mei (2003) each of these provinces are marked by a specifically conodonts association:

NCWP- is marked by the presence of gondolellids into early Cisuralian, dominance of *Neostreptognathodus* Clark, 1972 and no or rare *Sweetognathus* Clark, 1972 in the late Cisuralian, dominance of *Merrillina* Kozur, 1975 and *Mesogondolella* Kozur, 1975 and absence of *Sweetognathus* in the Guadalupian, and dominance of *Merrillina* and *Mesogondolella rosenkrantzi* (Bender & Stoppel, 1965) and absence of *Iranognathus* Kozur, Mostler & Rahimi- Yazd, 1975 in the Lopingian.

EWWP- is characterized by the absence of gondolellids and *Vjalovognathus* (Kozur, 1977) in the Cisuralian, abundance of *Sweetognathus* and *Pseudosweetognathus* (Wang *et al.*, 1987) in the Kungurian (late Cisuralian), *Jinogondolella* Mei & Wadlaw, 1994 and *Sweetognathus* in the Guadalupian, and *Clarkina* Kozur, 1989 and *Iranognathus* in the Lopingian.

GCWP- is marked by *Vjalovognathus* and rare *Merrillina* in the Cisuralian, *Vjalovognathus, Merrillina* and *Mesogondolella* in the Guadalupian and *Vjalovognathus* and *Merrillina* or *Mesogondolella sheni* in the Lopingian.

Mixed fauna are very rare and recognized in region bordering between the EWWP and GCWP like Western Timor during Artinskian, Pamir during Kungurian and Salt Range during Guadalupian and Lopingian (Henderson & Mei, 2003).

This particular condition that affects Permian flora and fauna makes Paleotethys an ideal area for correlation of Permian sequences between different surroundings areas (as southern Urals, Russia or North America) because of the presence of various complete Permian successions and highly diverse faunas (Shen *et al.*, 2013). All stage of the Permian System in the Tethyan region (except for the uppermost two) were identified because of fusulinid assemblages because this group is the most abundant, widespread and well studied in the region (Shen *et al.*, 2003).

Leven proposed a Tethyan fusulinid- based Permian timescale in 1980 and then this timescale was refined by Leven (1993, 2003, 2004).

Studies carried out in the last years showed that conodonts are the most important fossil group for biostratigraphy and have a great potential to provide high-resolution stratigraphic correlation for Permian successions among different continents: thus, an international timescale of the Permian System was elaborated by Jin *et al.* (1997) based on conodonts.

The Subcommission on Permian Sratigraphy (SPS) has defined all six established GSSPs for the Permian stages based on conodonts (Shen *et al.*, 2013) and the proposal of the remaining three GSSP candidates of the Cisuralian stages are also based on conodonts (Chuvasov *et al.*, 2002) and the International Permian Timescale (Shen *et al.*, 2013) is based on conodonts.

The correlation between conodonts and fusulinids (and consequently the correlation between the Tethyan and International timescale) is one of the most controversial issues because of the strong provincialism that developed during Permian and because pelagic and deep- water conodonts such as gondolellids usually are not associated with fusulinids (Shen *et al.*, 2013).

Our studies on Permian SE Pamir (SE Pamir is the type area for the Tethyan Permian Timescale) and Iran conodonts are crucial for understanding correlation between the two timescales

Because of the strong development of provincialism, Permian gondolellids are affected by many taxonomic problems and have been subjected to many interpretations during last 25 years. Kozur (1989a, 1989c) divided Permian gondolellids into two genera: *Mesogondolella* e *Clarkina*. Mei *et al.* (1994a, 1998) regarded to the serrated *Mesogondolella* from equatorial areas (like S. China and West Texas) as *Jinogondolella*. Furthermore Wardlaw & Mei (1998) proposed *Pseudoclarkina* to include previous *Mesogondolella bitteri* and *Mesogondolella wilcoxi* from the Phosphoria Basin: Mei *et al.* (1998, 1999a) expanded the genus *Pseudoclarkina* to include all the species of the cool-water Guadalupian gondolellid lineage from Phosphoria Basin.

Orchard & Rieber (1999) consider *Clarkina* as a synonym of *Neogondolella* based upon a study on the multielemental configuration.

Mei & Henderson (2001) regarded *Pseudoclarkina* as a synonym for occasionally serrated *Mesogondolella* from cool-water faunas because of their configuration of platform and denticulation.

There is therefore a serious problem and confusion in Permian gondolellids taxonomy that has not been solved yet. For this thesis, the generic level classification that was applied is the one suggested by Henderson & Mei (2003):

Mesogondolella for all the Kungurian and older Permian gondolellids and for the cool-water Guadalupian and Lopingian gondolellids with non-serrated and gently tapering platforms;

Jinogondolella for all the warm-water serrated gondolellids;

Clarkina for the warm-water Lopingian gondolellids with non-serrated platforms that taper rapidly anteriorly.

1.4 Objectives

The main objectives of this PhD are:

- correlation between fusulinids and conodonts in key areas like Central Iran and SE Pamir in order to correlate Tethyan and International timescales;
- correlations, using conodonts, among areas belonging to different Cimmerian Blocks (N and SE Pamir, Central Iran), Tunisia and the global scale;
- individuation of paleobioprovinces, defining them on the basis of the conodont fauna found;
- taxonomical revision of Carboniferous and Permian conodonts, particularly the gondolellids group which shows problems in identification.

Chapter 2

Materials and methods

2.1 Materials

For this thesis I've processed and studied several conodont samples from the studied areas:

- 43 samples from Central Iran (Bagh-e-Vang, Zaladou, Anarak 3 and Rahdar sections);
- 86 samples from SE Pamir, Tajikistan (Kurteke type section, Kuristyk, Kutal II and Kubergandy sections);
- 30 samples for N Pamir, Tajikistan (Gundara and Bolorian Stratotype sections);
- 31 samples from Tunisia (Halq Jemel, Merbah el Oussif and Tebaga *sensu strictu* sections).

2.2 Methods

Conodont samples treatment generally lasts a month. Each rock sample (about 5 kg in weight) was mechanically crushed and then the fragments were collected into a plastic bucket and signed with the code of the sample (using an alphanumeric code).

For each samples a fragment was collected and preserved in order to make thin sections. All the thin sections fragments were signed and putted into a plastic bag.

The plastic buckets containing the crushed samples were filled with a mixture of hot water and formic acid (80%) and putted into armchairs with extractor fans.

Formic acid is used for treating conodont samples because it melts carbonates without corroding phosphatic elements: hot water is used in order to accelerate the reactions.

To increase the rate of reaction the solution of acid and water was substituted two times for week. For every substitution, each sample was filtered using three sieves with different mesh decreasing in size (2 mm, 150 µm and 63 µm): finest fraction could be rinsed in order to remove clay and collected into a filter paper cone. The cone was signed with the number of the sample and allowed to dry.

After a month, the buckets were completely and definitely emptied still filtering the content with the sieves: three fractions (fine, medium and coarse) were collected, dried and placed into plastic or paper bags signed with the number of the sample.

Avoid contamination between samples is crucial and for these reason thoroughly clean the sieves and the sink between the treatment of one sample and the other is very important.

Once dry, coarse and medium fractions were put away while the fine fraction was further treated with lithium heteropolytungstates dissolved in water (LST) if needed. Not all samples were subjected to this phase: only the major residues were separated using LST in order to reduce the time for the picking phase.

LST treatment request a number of funnels with hose and faucet which is the same of the number of the processed samples and a number of funnels and beckers which is double respect to the number of samples.

The biggest samples were divided into different funnels in order to avoid clogging.

After closing the faucet of the funnel a quantity of LST was pour out into the funnel: the finest fraction was poured into the LST stirring with a glass rod. In order to avoid contamination for each sample was used a different glass rod.

Each samples must be stirred each 30 minutes for at least two hours. Then, after waiting for at least another hour, the heavy fraction will be separated from the lighter one and the faucet can be open to allow the heavy fraction to filter into a filter paper cone positioned into a funnel. The funnel is positioned onto a becker.

Before open again the faucet in order to filter the lighter fraction a new filter paper cone with a new funnel and a new becker were putted under the LST funnel. The all the lighter residues was filter.

Sometimes the two fractions (heavy and light) did not separate the one from the other: in this case we didn't have a significant density difference inside the residue.

The two fractions (light and heavy) treated with LST must be carefully washed with distilled water in order to remove all the residues of LST.

The heavy fraction is the one that could potentially contain conodonts, so is the one that was observed to the microscope.

Used LST was recovered by boiling it in order to eliminate the distilled water.

After the laboratory treatment samples were observed using stereomicroscope: all residues were observed and any conodont was picked and putted into a micropaleontological slide. The presence of any other fossil (ostracods, fish teeth, gastropods etc.) was annotated.

All the found conodonts were identified using papers and asking to experts. After identification, the best preserved and most significant conodonts were prepared for the SEM (Scanning Electron Microscope). Thanks to the great SEM magnification (max 300000X) and resolution (3,5 nμ) capacity and to the great depth of field we can obtain high resolution 3d photos. Treatment for SEM consist in positioning the conodont onto a button covered with special scotch: the specimens were place on the button surface using a small paintbrush in upper, lateral or lower view. The button with the specimens on top was covered with a thin film of gold in order to favor the reflection of the electrons. The photos were saved in digital like .jpeg files. After capturing all the upper view photos is necessary to extract the button from the SEM in order to remove the specimens, polish the button, place new scotch and place again the conodonts on top of the button in the new position, for example lateral view. Then is necessary to gild them again in order to catch new photos. This whole process is repeated for the last view.

SEM photos are necessary in order to correctly identify conodonts: they allow us to see tiny details such as pustulose ornamentation of the nodes, denticulation etc.

Photos were modified with Photoshop program in order to make plates: all the pictures were contoured and placed on a black background, furthermore they were resized in order to have the same scale (usually 100 or 500 μm).

Chapter 3

Geological setting of Central Iran

3.1 Introduction

Nowadays Iran is composed by several blocks: Northern Iran- Alborz, Central Iran- Lut, Sanandaj-Sirjan and Zagros.

Northern and Central Iran shared a common geological evolution for most of the Paleozoic (Angiolini *et al.*, 2007): in fact, they are characterized by a substantial continuity of Paleozoic sedimentary rocks and a uniform distribution of biota (Berberian & King, 1981; Leven & Gorgij, 2006).

The Sanandaj-Sirjan zone is metamorphic and shows an affinity to Central Iran (Rachidnejad-Omran *et al.*, 2002), while the Zagros belt is part of Arabia (Angiolini *et al.*, 2007 *cum lit.*).

Stöcklin *et al.* (1974) considered Northern and Central Iran as being located along the Arabian margin during the Paleozoic. The authors based their reconstruction on several evidences: (1) the pre-Paleozoic basement was affected by the Pan- African orogeny; (2) Precambrian- Cambrian sedimentary rocks are continuous between Arabia and Northern and Central Iran; (3) the Variscan deformation is lacking.

Angiolini *et al.* (2007) provide to reconstruct a broader paleogeographic context in which they place Iran using selected Late Carboniferous- Early Permian paleomagnetic data.

These data support a Pangea B configuration (Irving, 1977, 2005; Muttoni *et al.*, 1996, 2003; Torcq *et al.*, 1997) in which Africa is placed south of Asia and South America is south of Europe. According to Muttoni *et al.* (2003) Pangea B continued to exist well into the Early Permian and transformed into a Wegenerian type of Pangea A in the Late

Permian- Early Triassic by means of ≥3000 km of dextral motion of Laurasia relative to Gondwana taking place essentially along the Variscan suture.

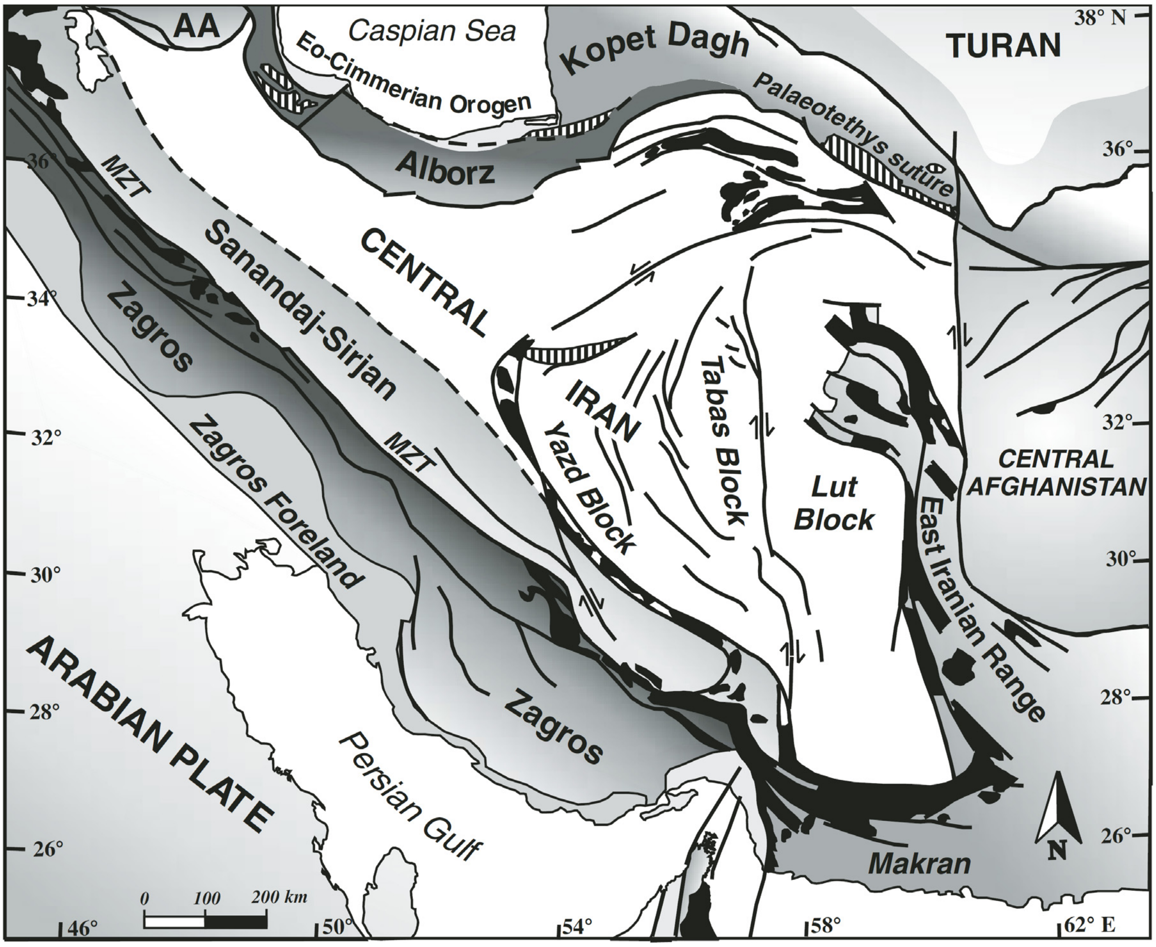

Fig. 4. Tectonic scheme of Iran (from Angiolini *et al.*, 2007). Black: Mesozoic ophiolites along Main Zagros thrust (MZT) and around Central Iran. Hachures: ophiolites and metamorphic rocks related to Cimmerian orogeny. AA: Astara-Adzerbaijan block.

The study of the faunal affinities carried out on brachiopods, fusulinids, corals, pollen and conodonts confirm that Iran was surrounded by a warm water stream during Permian. Particularly the Lower Permian brachiopod assemblage from Northern Iran studied by Angiolini & Stephenson (2008) showed a strong affinities with the coeval biota from warm Boreal Realm (Shi, 1998) of the Urals, Russian Platform, Yukon Territory and Carnic Alps. This fauna is clearly different from the poorly diversified assemblage of Gondwana (Western Australia, India, Oman) and Perigondwanan regions (Karakoram, Central Afghanistan and Sibumasu with Thailand and Baoshan: Angiolini *et al.*, 2005).

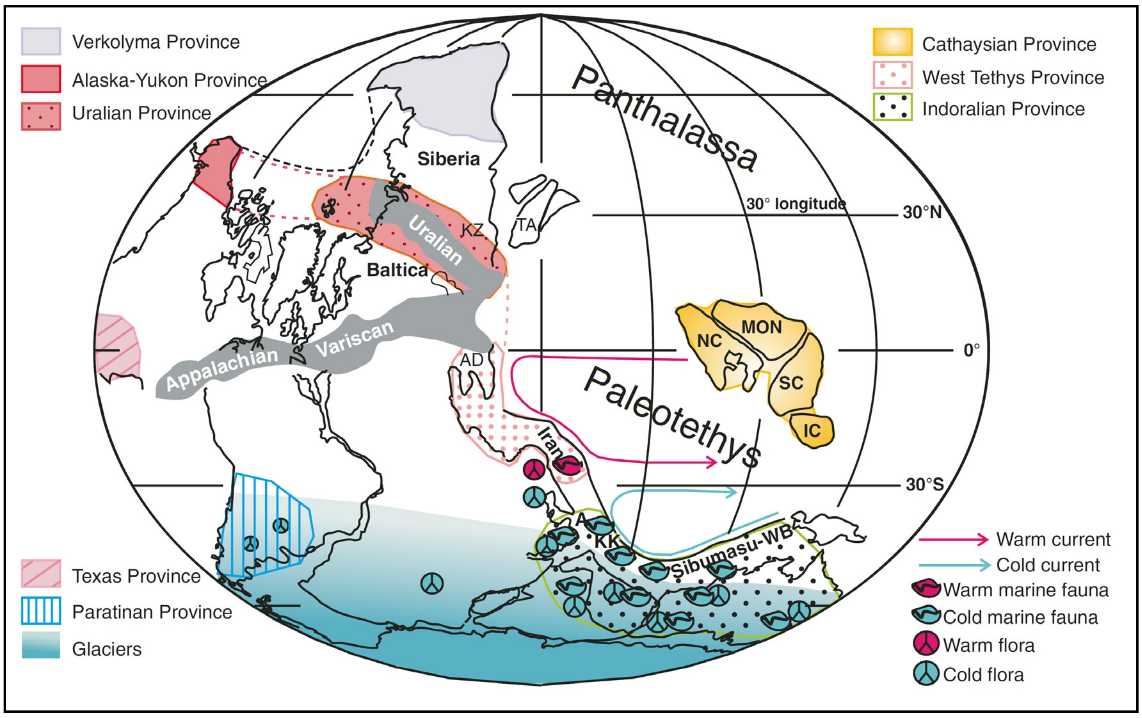

Fig. 5. Distribution of bioprovinces and oceanic circulation pattern plotted on a Pangea B configuration of 300 m.y. ago (from Angiolini *et al.*, 2007). Bioprovinces distribution modified from Shi (1998).

Leven & Gorgij (2006) showed that Pennsylvanian- Lower Permian fusulinid assemblages of Northern and Central Iran are similar to those of Eastern Europe and northern Paleotethys (Carnic Alps, Uzbekistan, and Tajikistan).

The palynomorph assemblage of Northern Iran studied by Angiolini & Stephenson, 2007 is dominated by monosaccate pollen with very few spores and is quite different from those recorded from the Asselian- Sakmarian *Granulatisporites confluens* biozone (ubiquitous in the Gondwana region).

According to Angiolini *et al.* (2007) paleontological evidence from both marine and terrestrial realms suggest that during the Carboniferous- Permian northern and central Iran had a clear Eurasian affinity rather than a Gondwanan affinity.

This affinity is consistent with the Pangea B configuration that place the Urals to the north of western Tethys Gulf, allowing a potential genetic flux from the Boreal Realm (Russia- North America) to the western Tethys (Angiolini *et al.*, 2007). The effects of the Southern Hemisphere glaciation prevent the warm Boreal taxa to colonize the

Gondwanan and Perigondwanan regions to the south of Iran (*id est* central Arabia, central Afghanistan, Karakoram, Baoshan, Thailand) (Angiolini *et al.*, 2007).

Comparing Permian data with modern analogs in the Cenozoic global cooling (Crame & Rosen, 2002) Angiolini *et al.* (2007) reconstructed that around 300 m.y. ago the earth's climate was characterized by a narrow near- equatorial current gyre sweeping the western Tethys Gulf down to Iran. This compressed warm current gyre was sharply bounded to the south by an extended southern latitude cold belt caused by the effects of Gondwana glaciation.

3.2 Carboniferous-Permian of the Tabas area, Central Iran

Almost all the formations of Carboniferous and Permian documented from the Sanandaj-Sirjian to the eastern Iran were defined in the 1960's in the area comprised between Shotori Range and Ozbak-Kuh respectively East and North East of Tabas. Tabas area, then, is historically crucial for the definition of the late Paleozoic stratigraphy of Iran and the best area to attempt to reconstruct the sedimentary evolution of the Cimmerian blocks during their breakup of Gondwana and the following drifting (Balini *et al.*, 2010).

All formations therein reported have been described by Balini *et al.* (2010).

Shishtu Formation

The type locality is in the Ozbak-Kuh Mountains, however no description of the type section is available. Ruttner *et al.* proposed the unit in the 1960s, however the explanatory notes of this sheet have never been published (see also Wendt *et al.,* 2005 for discussion).

Afterwards the unit has been recognized in a very wide area of Central Iran, with several sections shortly described mostly in explanatory notes of the Geological Survey of Iran geological maps (exempli gratia Shotori Range: Stöcklin *et al.*, 1965; Shirgesht area: Ruttner *et al.*, 1968).

In a recent general review of the Devonian-Early Carboniferous of Iran Wendt *et al*. (2005) include the Shishtu Formation into the Bahram Formation. Thickness is of some hundreds of meters (about 500 in the Shotori Range: Stöcklin *et al.,* 1965). Lithology is reported (Stöcklin *et al.,* 1965) as consisting of shales, limestones and sandstones in the Shotori range, with a distinct interval named “Cephalopod Beds”, that is also recognized in the Shirgesht area (Ruttner *et al.*, 1968). In the 1960s (e.g ., Stöcklin *et al.*, 1965) the unit was dated as Frasnian-Early Carboniferous.

Sardar Formation

The type locality is on the western foothills of the Kuh-e-Shotori, south of Sardar Valley, Shotori Range (Stöcklin *et al.* 1965), where the unit is about 660 m thick. Light green shales, with sandstones and limestone intercalations, dominate the lithology of Sardar Formation. Age is Early Carboniferous, but the upper boundary is not well calibrated.

Jamal Formation

Type locality is on the south wall of Kuh-e-Mehdi, southern promontory of Kuh-e-Jamal, Shotori Range (Stöcklin *et al.,* 1965). The formation is up to 473 m thick at the type locality, where it consists of limestones with corals, gastropods, brachiopods and crinoids, and dolomites. The unit, in the southern part of the Shotori Range was originally attributed to the Permian, with occurrence of Middle Permian corals (Stöcklin *et al.,* 1965).

The Sardar and Jamal formations, as noted by Balini *et al*. (2010, 2011, 2012) show a wide variety of facies in time and space that suggests a lithostratigraphic revision of both the units. Moreover the two units seems to be more similar to lithostratigraphic groups than to formations.

Some authors have recently tried to separate some subunits (e.g., the Bagh-e-Vang Member: Leven & Vaziri Mohaddam, 2004), however much more work has still to be done.

Khan Formation

This formation is present only in the Kalmad Tectonic Unit and slightly west of it. The formation takes the name from the village of Robat-e-Khan (West of Tabas); the most complete sections are in the Halvan Mountain, but in literature (e.g., Davydov & Arefifard, 2007) the outcrop in the Bakshi Mountains is referred as type section. The formation is up to 300 m thick consists of three transgressive-regressive cycles, each one beginning with sandstones and ending with marine, fossiliferous limestones (Aghanabati, 1977). On the basis of fusulinids the unit is referred to the ?Sakmarian-Artinskian (Davydov & Arefifard, 2007) or to the Sakmarian (Leven & Gorgij, 2007).

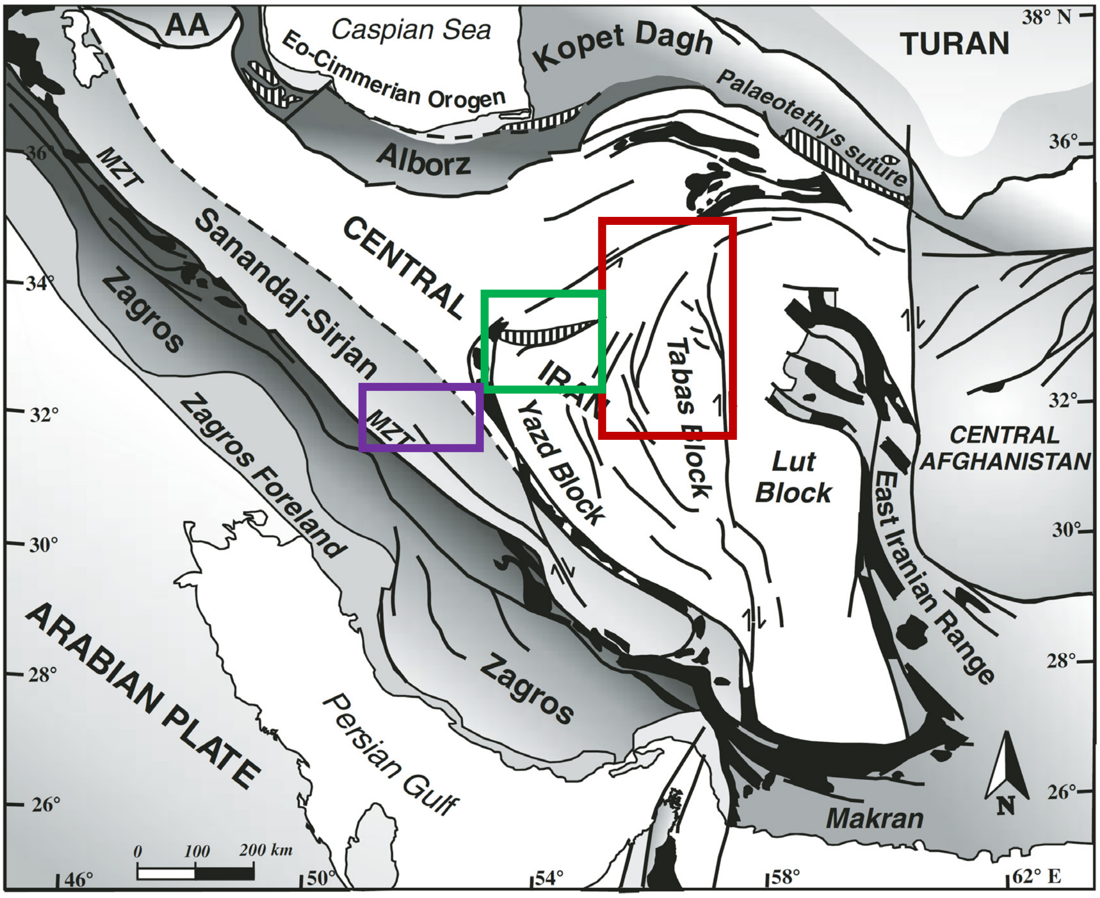

Fig.6. Studied areas in Central Iran (modified from Angiolini *et al.*, 2007). Red rectangle: area studied in 2010. Green rectangle: area studied in 2011. Violet rectangle: area studied in 2012.

In Central Iran area I have studied conodont samples from four sections: Bagh-e-Vang, Shesht- Angosht, Zaladou, Anarak 3 and Rahdar, in order to define the age of these section, to correlate conodonts with fusulinids and to study conodont assemblage of this paleoprovince.

3.3 Bagh-e-Vang section

The section of Bagh-e-Vang (about 175m thick), located in the Kuh-e-Bagh-e-Vang, North of Tabas, was sampled during the Darius project in 2010 and 2011 (see Balini *et al.,* 2010, 2011).

The exposed section contain the upper part of the Sardar Group and the overlying Jamal Group.

The succession exposed on the northwestern slope of Kuh-e-Bagh-e-Vang is folded and faulted but Balini *et al.* (2011, 2012) have selected the outcrop where tectonics does not affect the lithostratigraphic boundaries between the Sardar and Jamal groups and between the members of the Jamal Group.

Ruttner *et al.* (1968) originally described Bagh-e-Vang Section recognizing both the Sardar and Jamal formations. Partoazar (1995) described three formations for the Bagh-e-Vang section dividing the lower part of the Jamal Group as the new Bagh-e-Vang Formation. There is no agreement between different authors in recognizing two or three formations: the unit of Bagh-e-Vang have been accepted in literature, but sometimes only as a formal Member of the Jamal Group (e.g. Leven & Vaziri Mohaddam, 2004).

In this thesis, we follow Balini *et al.* (2010, 2011, 2012) considering the unit of Bagh-e-Vang as a formal Member of Jamal Group.

Recently some works have been carried out on paleontological fauna of Bagh-e-Vang Section: Leven & Vaziri Mohaddam (2004) described fusulinids and few conodonts (Leven *et al.*, 2007) from both the "Bagh-e-Vang Member" and the Jamal Group. Some paleontological papers have been published on bryozoans, Algae and Porifera from the "Bagh-e-Vang Member" (Senowbari-Daryan *et al.*, 2005; Ernst *et al.,* 2006).

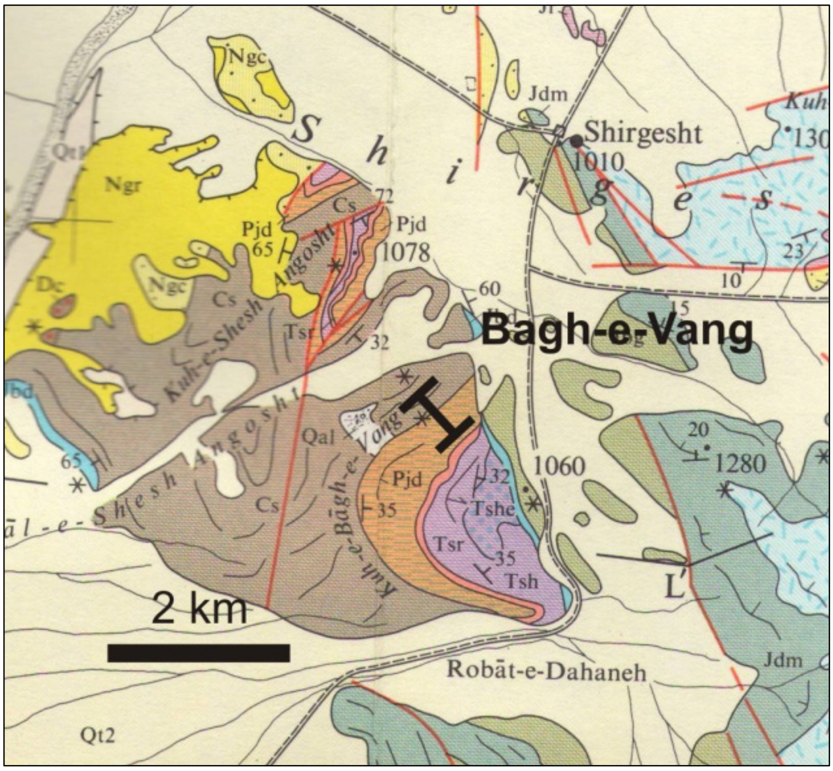

Fig. 7. Location of the Bagh-e-Vang section, shown on the geological map 1:100.000 "Shirgesht" (from Balini *et al.*, 2010).

Sedimentary evolution (from Balini *et al.*, 2011)

The 37 m of the Bagh-e-Vang Member consist of marls with a variety of calcareous intercalations, from thin to medium bedded grainstones up to 3-4 m calcareous olistoliths rich in Algae, bryozoans and Porifera (Senowbari-Daryan *et al*., 2005; Ernst *et al*., 2006) that point to an unstable carbonate platform (probably affected by tectonics).

The overlying 100 m of the section are represented by medium to thin bedded often recrystallized cherty limestones: a facies referred to a rather deep marine environment with relatively abundant supply of fine grained calcareous sediment. In the last 20 m of this lithologic interval there were some thin bedded grainstones documenting a regressive trend, that ends with the onset of a carbonate platform.

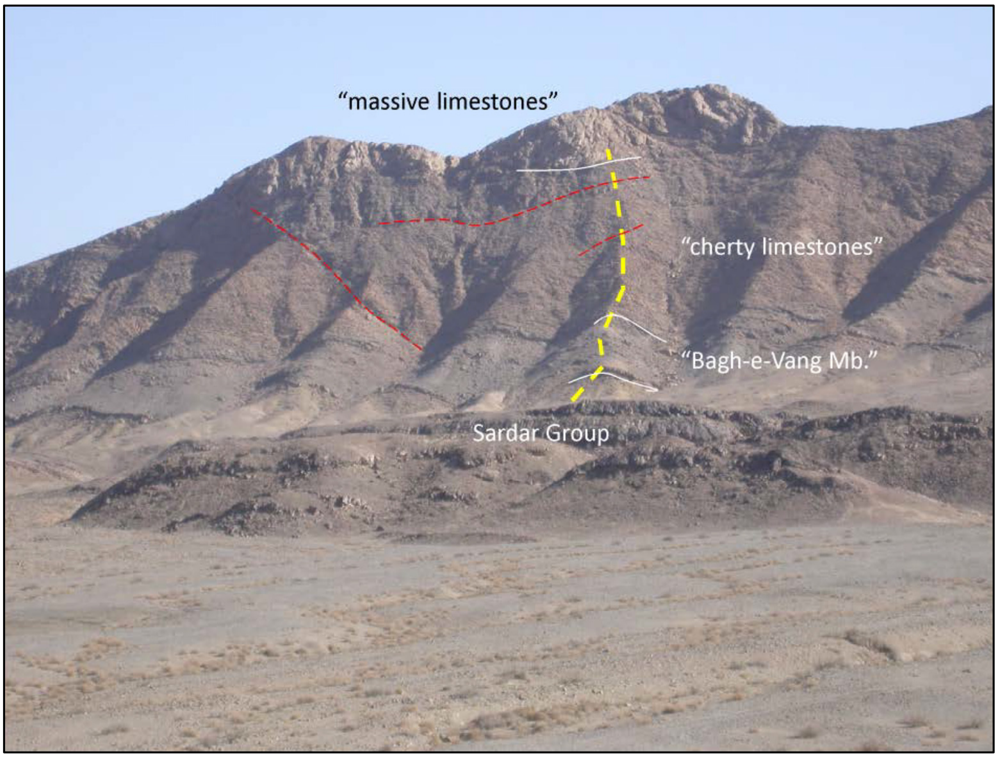

Fig. 8. Northwestern ending of the Kuh-e-Bagh-e-Vang (from Balini *et al.*, 2010). Yellow dashed line: position of the studied section. Red dashed line: main faults.

The uppermost Sardar Group is made by fine-grained greenish siltstones with very rare very thin bedded and fine-grained sandstones: the paleoenvironmental interpretation of this facies is rather uncertain but is actually attributed to a transitional to marine environment with fine grained siliciclastic supply.

In "Bagh-e-Vang Member" a transgression is documented by medium to coarse grained bioclastic grainstones that at the very base (see fig. 9) referred to a subtidal environment because of herringbone lamination.

The conglomerates reported in literature (see Leven & Vaziri Mohaddam, 2004 and Leven *et al.*, 2007) do not occur at the very base of the grainstones, but about 2 m above.

This level actually consists of breccia (fig. 10b) composed of bioclastic grainstones similar to those from the underlying levels reflecting synsedimentary tectonic activity.

The topmost bed of grainstones is very rich in fossils and especially in brachiopods, echinoderms, solitary Rugosa and rare ammonoids. This level marks a drowning and is probably condensed: the red shaly marls overlying the fossil rich level also support the deepening trend.

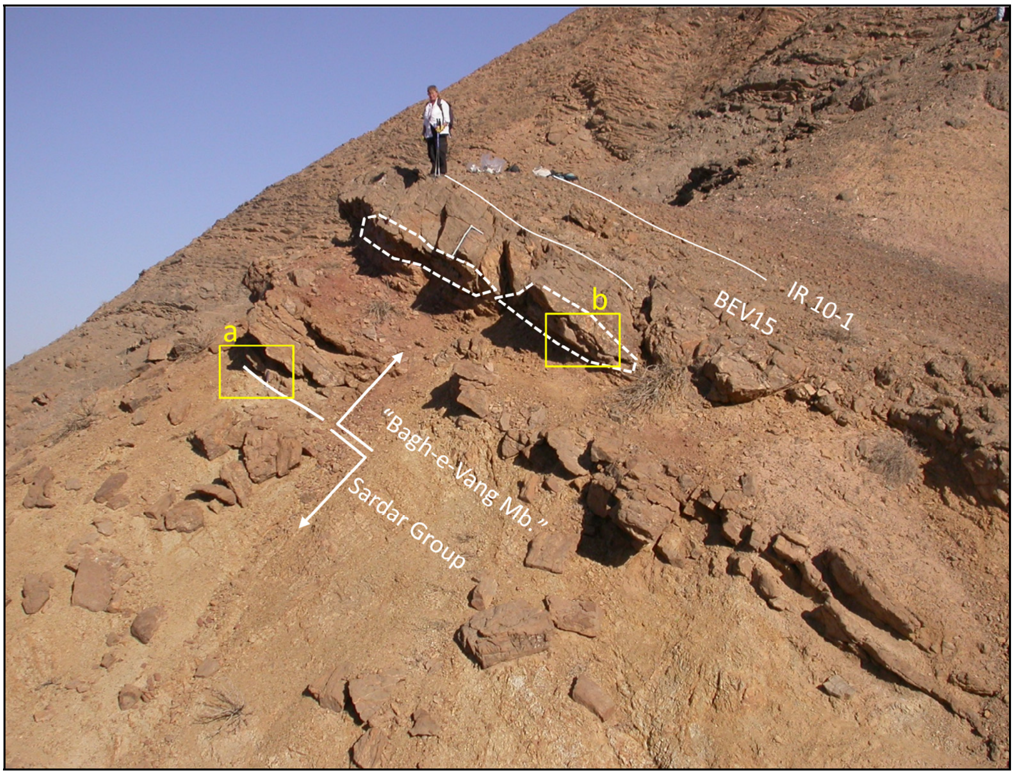

Fig 9. The boundary between Sardar and Jamal Groups (from Balini *et al.*, 2010). Yellow: position of the close up pictures of the next figure. White dashed line: lenses of breccias.

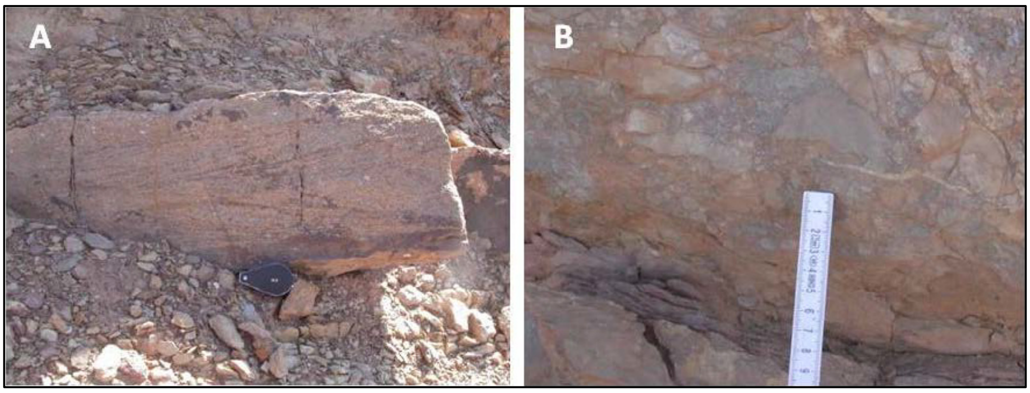

Fig 10. Close up pictures of some facies of the lower part of the "Bagh-e-Vang Member" (from Balini *et al.*, 2010). A) Herringbone cross lamination in the first sandy limestone. B) Detail of the calcareous breccias.

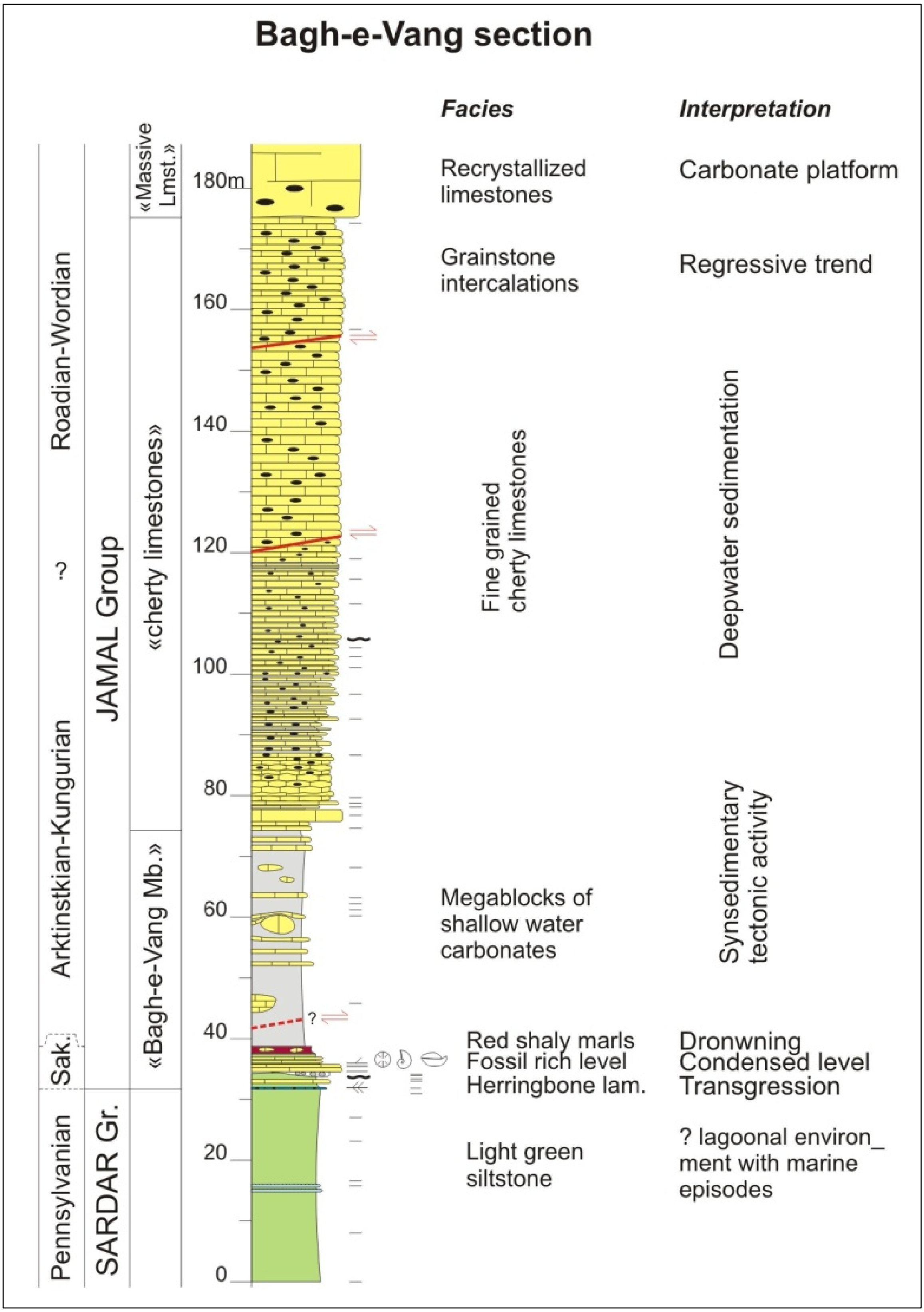

Fig. 11. Stratigraphic revision and reconstruction of paleoenvironmental evolution of the Jamal Group at Bagh-e-Vang - Shirgesht, Central Iran (from Balini *et al.*, 2010).

Bio-chronostratigraphy (from Balini *et al.*, 2011)

Even if Bagh-e-Vang section has a rich paleontological record, still the dating of the succession is very complex.

Most of the macrofossils reported from the whole interval (e.g., Ruttner *et al.*, 1968) actually come from the top of the of the 2,5 m thick calcarenites overlying the breccias (fig. 9).

During the field works carried out in 2010 and 2011 Balini *et al.* collected brachiopods, ammonoids, solitary Rugosa and crinoids from the lowermost part of the Bagh-e-Vang Member. Particularly from a fossil-rich level (IR10- 1), located at a lithologic change where one of the major unconformities of the succession was recorded (Balini *et al.*, 2012).

The middle part of the "Bagh-e-Vang Member" consists of marls and thin bedded limestones including olistoliths up to 3 meters in rise. These olistoliths consist of shallow water limestone bodies yielding the Porifera and Algae studied by Senowbari-Daryan (2005).

The brachiopod association of Bagh-e-Vang (level IR010-1) comprises few specimens of undetermined species of five genera: *Cartorhium* Cooper & Grant, 1976; *Spiriferella* Tschernyschew, 1902; *Hustedia* Hall & Clarke, 1893; *Elivella* Fredericks, 1924, and *Hunzina* Angiolini, 1995. The specimens are not well preserved, hampering a specific determination.

The genera *Hunzina* and *Elivella* are instead restricted to the Early Permian. The former in particular has been found up to now only in the Sakmarian of Karakorum and W Australia (i.e. Angiolini, 1995, 2001). Thus, the suggested age for this assemblage is Early Permian, more probable Sakmarian.

The biogeographic affinity of this fauna is paleoequatorial, in agreement with the one suggested by Angiolini *et al*. (2007) and Angiolini & Stephenson (2008) for the Asselian brachiopods of the Dorud Group of the Alborz Mountains (N Iran).

The presence of the genus *Hunzina* in an association otherwise dominated by paleoequatorial taxa suggests enhanced faunal exchanges between Iran and the more southerly located peripheral Gondwanan blocks (i.e. Central Afghanistan, Karakorum) and Australia in the Sakmarian, after the demise of the Gondwana glaciations and the interruption of sharp climatic barriers (Angiolini *et al*. 2007).

The level IR010-1 of Bagh-e-Vang section yielded also ammonoids preserved as internal molds, and often consisting of fragments of phragmocones. The most common group is represented by the subfamily Propinacoceratinae, genus *Bamyaniceras* Termier &Termier 1970. One specimen of Popanoceratidae has also been collected. These groups are not strictly age-diagnostic, ranging from Artinskian to Wordian.

Leven *et al.* (2007) report few conodonts from the middle to upper part of the Bagh-e-Vang member as well as from the overlying "cherty limestones".

Conodont fauna

For my PhD thesis, I have processed and studied several conodont samples collected from key-intervals (Balini *et al.*, 2010, 2011) during the DARIUS Project.

Thirteen conodont samples have been collected and processed for Bagh-e-Vang section: six from the Bagh-e-Vang Member and seven from the Jamal Formation (see appendix I, table 1). CAI of the conodont faunas reported from Bagh-e-Vang ranges from 3.5 to 4, documenting a temperature between 190° and 200° degrees.

Samples 37 and 47 only contains a small conodont fragment but the other samples contains a quite rich conodont fauna, somewhere very abundant like in samples BEV 41 or BEV 43.

Samples BEV 10, 40, 41, 42, 43 and 15 comes from the Bagh-e-Vang Member, from the lower part of the section (fig. 12). The conodonts genera yielded in these samples, *Streptognathodus* Stauffer & Plummer 1932*, Sweetognathus* Clark, 1972 and *Mesogondolella* Kozur, 1988, pointed to a subtidal environment according to the sedimentary evolution of this member (Balini *et al.,* 2010, fig. 11).

A deepening trend, showed by lithology, can be appreciate by the increasing in *Mesogondolella/ Sweetognathus* ratio in the BEV 42, 43 and 15 samples.

Streptognathodus postconstrictus Boardman, Wardlaw & Nestell, 2009, *Streptognathodus* affinis *lanceatus* Chernykh, 2005 and *Mesogondolella manifesta* Chernykh, 2005, present in sample BEV40, indicate a Lower Sakmarian age.
According to Boardman *et al.* (2009) *S. postconstrictus* and *S.* aff. *lanceatus* occur into Tastubian substage of Sakmarian stage in Kansas. In the western slope of southern Urals. *M. manifesta* occur, as reported in Chernykh (2006) and Boardman *et al.* (2009), into *merrilli* Zone of the Sakmarian stage.

In sample BEV 10 the co-occurrence of *S. postconstrictus,* whose range is from Upper Asselian to Sakmarian (Chernykh, 2006; Boardman *et al.,* 2009), *Mesogondolella monstra* Chernykh, 2005 and *M. manifesta* (Tastubian substage of Sakmarian Stage; *merrilli* Zone; Lower Permian; western slope of Ural Mountains, Chernykh, 2005) indicate a Lower Sakmarian age for this association (see Chernykh & Reshetkova, 1987; Chernykh, 2005, 2006; Boardman *et al.* 2009).

In sample BEV 41 and 15 *Sweetognathus binodosus* Reimers, 1999 and *Mesogondolella bisselli* (Clark & Behnken, 1971) point to a Middle/Upper Sakmarian age.
Sw. binodosus was found by Chernykh (2205, 2006) from the Upper Tastubian Horizon of Sakmarian Stage to the Irginian Horizon of Artinskian Stage in the Urals.

It is also reported from the Schroyer Limestone of Wreford Formation to the basal part of Florence Limestone of Barneston formations of Chase Group in Kansas, North America that is Sakmarian in age (Boardman, 2009); and from *Pseudosweetognathus costatus* zone, section in Ziyun County, Guizhou Province, China (see Chernykh, 2006). Sample BEV 42 has a monospecific fauna characterized by the species *M. bisselli* which indicate a Middle-Upper Sakmarian age (Chernykh 2006; Boardman *et al.*, 2009). Chernykh (2006) found *M. bisselli* into *Sweetognathus anceps* zone, Sakmarian age, in the Urals.

In sample BEV 43 the presence of transitional forms between *Sw. binodosus* and *Sweetognathus anceps* and *Mesogondolella gujioensis* (Igo, 1981) suggest an Upper Sakmarian/Lower Artinskian age (Igo, 1981; Kozur & Mostler, 1991; Wang, 1994).

Samples BEV44, BEV25, BEV46, BEV47, BEV48, BEV49 and BEV37 are from the Jamal Group (fig. 14).

Samples BEV 44, 46 and 47 are from the cherty limestones from the middle and upper part of the Bagh-e-Vang Section. The lack of *Sweetognathus* and the presence of the *Mesogondolella siciliensis* (Kozur, 1975) and transitional forms between *M. siciliensis* and *Mesogondolella omanensis* point to a deep-water marine environment, according to the interpretation of the sedimentary evolution of this part of the Jamal Group reported in Balini *et al.* (2010).

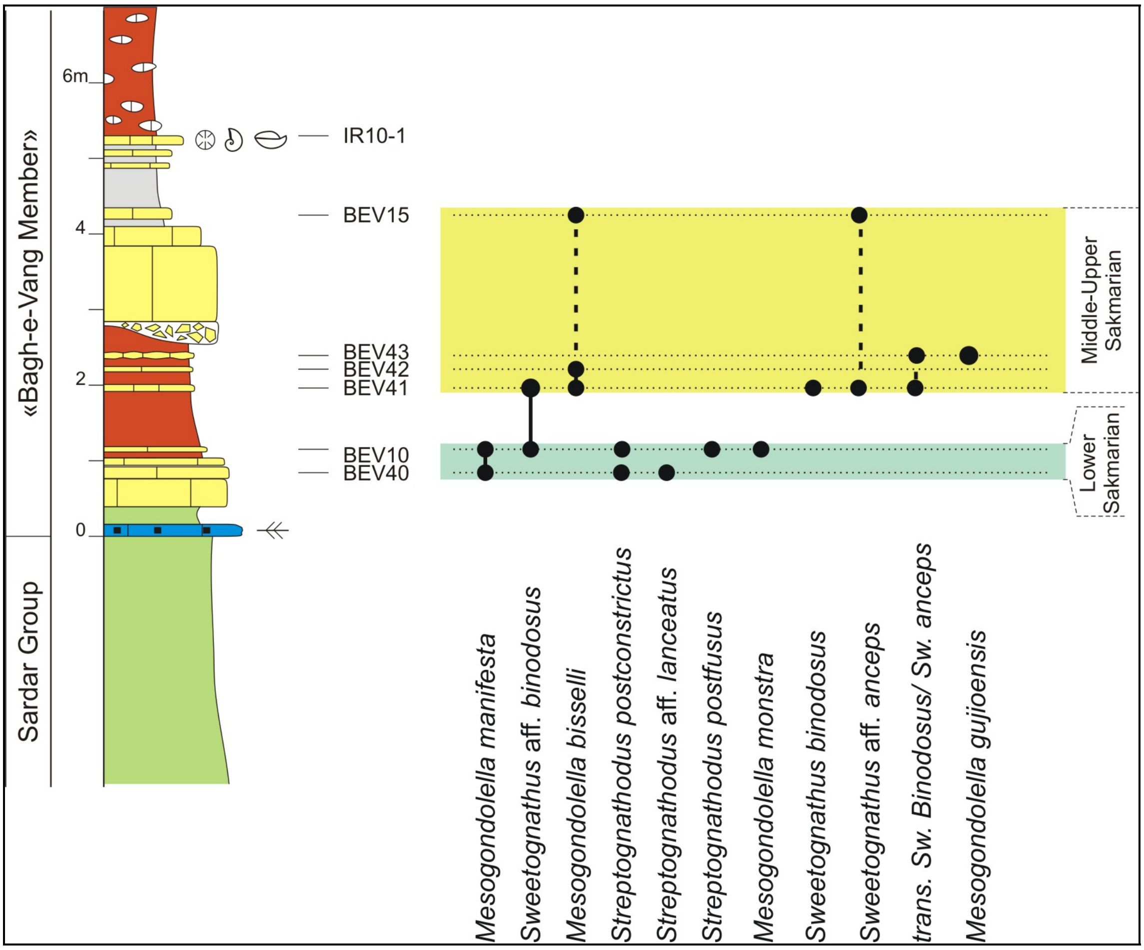

Fig. 12. Range chart of conodonts for the base of Bagh-e-Vang Section.

Samples Bev 48, 49 and 37 are very poor in conodonts but the presence of the genus *Sweetognathus* is coherent whit the regressive trend showed by the presence of thin bedded grainstones reported by Balini *et al.*, 2010.

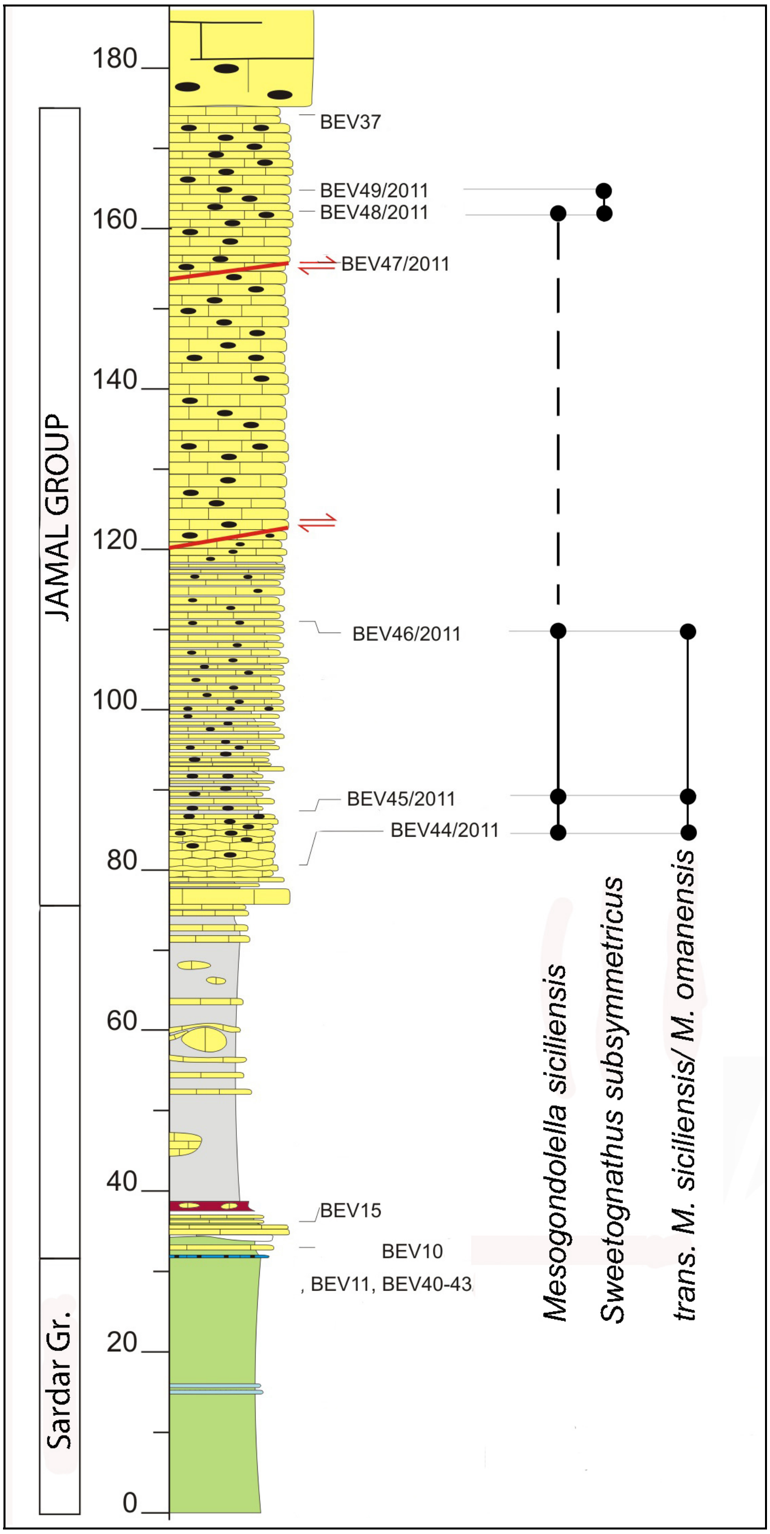

Fig. 13. Range chart of conodonts from the middle and upper part of Bagh-e-Vang section.

Conodont assemblage in sample BEV 44 and BEV 45 is represented by *M. siciliensis* and transitional forms between *M. sicilensis* and *Mesogondolella omanensis. M. siciliensis*, according to Kozur & Wardlaw (2010), ranges from the middle Roadian to the Wordian-Capitanian boundary interval. The holotype of *M. siciliensis* is from the Rupe del Passo di

Burgio block in the Sosio Valley, Sicily which is Wordian in age (Kozur, 1975; Kozur & Wardlaw, 2010).

In sample BEV45 some transitional forms between *M. siciliensis* and *M. omanensis* are present along with a specimen of *Pseudohindeodus ramovsi* Gullo & Kozur, 1992 that is a long- range species that goes from Roadian to Wordian (Gullo & Kozur, 1992; Wardlaw, 2000).

In sample BEV 46 *Hindeodus wordensis* Wardlaw, 2000 and *M. siciliensis* point to a Wordian age. Wardlaw (2000) reported *H. wordensis* from the Word, Altuda and Bell Canyon formations of west Texas and in the Gerster Limestone and the upper part of the Phosphoria and related rocks in the Great Basin and northern Rocky Mountains. The FAD of *H. wordensis* is Mid-Roadian in age (Wardlaw, 2000).

The co- occurrence of *M. siciliensis*, and *Sweetognathus subsymmetricus* Wang, Ritter & Clark, 1987 in sample BEV 48 point to a Kungurian age.

In sample BEV 49 *S. subsymmetricus* point to a Kungurian age according to Wang *et al*. (1987).

On this evidences we consider our Bagh-e-Vang samples age ranging from Sakmarian to Wordian instead of Yaktashan to Murgabian as reported in Leven *et al.* (2007) for the lower and middle part of the section, whereas the upper part, interested by faults, is Kungurian in age (see fig. 13, samples BEV48 and BEV49).

Particularly the Lower Sakmarian age is based on *Mesogondolella* species and although the *Streptognathodus* species are more typical of Upper Asselian, Chernykh (2005, 2006) does indicate they can occur in Lower Sakmarian in reduced abundance prior to their extinction. The Wordian age is indicated by the presence of transitional forms between *M. siciliensis* and *M. omanensis* (Kozur & Wardlaw, 2010).

3.4 Shesht-Angosht section

In 2012, Balini *et al*. found a very good outcrop some km NE from the Bagh-e-Vang: the succession was measured and sampled in detail from the upper part of the Sardar Group to the middle part of the Jamal Group. This new section is well exposed from the lowermost part of the Bagh-e-Vang Member to the middle-upper part of the Jamal Group but the lower boundary of the Bagh-e-Vang Member with the Sardar Group is actually slightly covered by debris while the upper boundary of the Jamal Group is not preserved, as at Bagh-e-Vang.

From bottom to top the lithology is described by Balini *et al.* (2012) as follows:

(base) Sardar Group, green shales and siltstones;

a) bioclastic limestones, intraformational breccias, coarse grained sandstones (probably quartzarenites) with some silty marly interbeds. One olistolith; 9.1 m;

b) gray marls with some bedded limestone; very frequent olistoliths; 22.5 m;

c) sandstones and intraformational breccias; 4.5 m;

d) gray marls with olistoliths, upward increasing of bedded limestones; 17 m e) Coarse grained grainstones and breccias; 2.6 m;

f) chaotic interval consisting of bedded limestones, deeply deformed; 5.8 m;

g) cherty limestones, in 10 to 20 cm thick beds; 26 m h) Massive dolomite; 11.7 m.

Fig. 14. Wide angle view of Shisht- Angosht section (from Balini *et al.*, 2012). Br: breccias; ci: chaotic interval; dol: massive dolomite. Dotted white line: olistholithes. Dashed line: lithologic boundaries. Yellow dashed line: major unconformities.

Conodont fauna

Six conodont samples were collected in order to test the correlation of the Bagh-e-Vang section with Shesht-Angosht: samples SHA1, SHA4, SHA12, SHA15 and SHA16 whose are all from Bagh-e-Vang Member (see appendix I, table 2).

CAI of the conodonts from Shesht-Angosht section is 3, pointing to a thermic gradient between 110° and 200°.

Three samples, SHA1, SHA12 and SHA15 yielded conodonts (fig. 15); samples SHA4 and SHA16 did not contain any conodonts but show a very rich fauna made by corals, bryozoan, ostracods and Foraminifera, moreover the sample SHA16 show some vegetal fragments.

Sample SHA8 that is from the lower olistolith of the Bagh-e-Vang Member is completely barren.

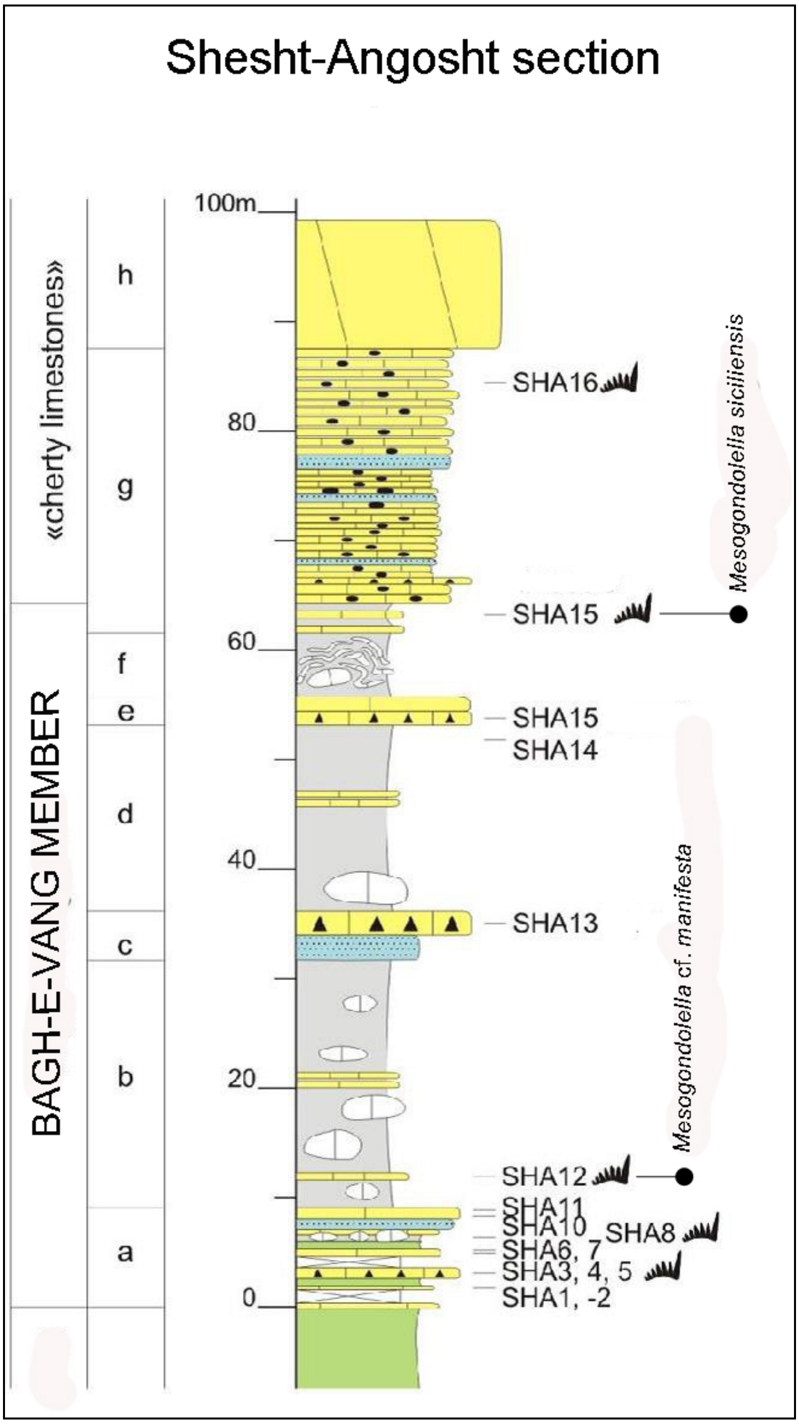

Fig.15. Range chart of conodonts from Sesht-Angosht section.

Only *M. siciliensis* and *Mesogondolella* confer *manifesta* were reported from Shesht-Angosht section.

Sample SHA12 is 12 m above the base of the section (unit B of Bagh-e-Vang Member) and is composed by grey marls with calcareous beds: it yielded only two fragments of *Mesogondolella* cf. *manifesta.* The range of this species is Tastubian substage of

Sakmarian stage (Chernykh, 2006).

Sample SHA12 shows a similar fauna of sample BEV10, in fact in sample SHA12 is present a fragment of *Mesogondolella* cf. manifesta and in BEV10 is present the species *M.* manifesta. The stratigraphic position of those two samples is similar: sample SHA12, in fact, is located few meters upward respect to sample IR10- 1 in Bagh-e-Vang section.

SHA15 was sampled 64 m above the base of the Shesht-Angosht section, on top of the Bagh-e-Vang Member were cherty limestones begins and contains two specimens of *M. siciliensis* and few fragments. *M. siciliensis* is a wide-range species that ranges from the Upper Kungurian to Lower Capitanian (Kozur, 1988, 1989b; Kozur *et al*., 2001).

Sample SHA15 is from the transition between “Bagh-e-Vang Member” and “cherty limestones” and is in a similar stratigraphic position of the sample BEV44.

Both samples yielded the conodont *M. siciliensis* but their correlation does not fit perfectly because of the presence of transitional forms between *M. siciliensis* and *M. omanensis* in sample BEV 44, pointing to a younger age.

3.5 Zaladou section

In the Ozbakh-Kuh mountains the successions are folded and faulted (Wendt *et al*., 2005): however some good exposures with limited tectonic overprint can be found. In particular, a good exposure of Shishtu Formation, Sardar and Jamal groups is located in the Valley of Zaladou river (Balini *et al.*, 2012).

The section, studied by Balini *et al.* (2010, 2011), is located on the northern side of the Zaladou Valley. Balini *et al.* (2010) reported that the northwest dipping succession is well exposed on the southeastern and northwestern slopes of an elongate hill and is affected by several small scale faults but they can be easily solved.

According to Balini *et al.* (2010) the lower boundary of the Zaladou Formation is exposed and the section covers about 100 m of Zaladou Formation and the very base of the Tighe-Maadanou Formation (fig. 16).

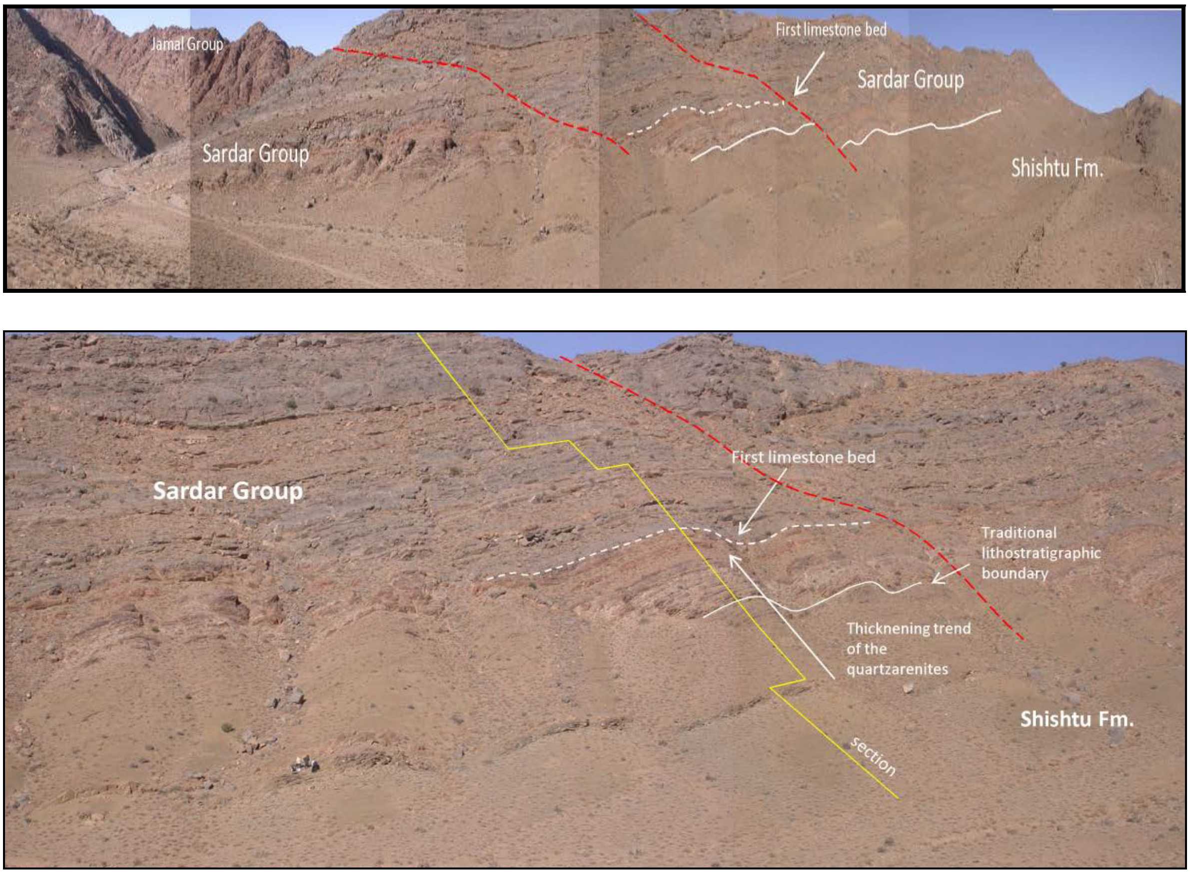

Fig. 16. General and particular views of the lower part of Zaladou section (from Balini *et al*., 2010). Red dashed lines: faults. White line: lower boundary of the Sardar Group. White dashed line: base of the first limestone bed of the Sardar Group. Yellow line: trace of the section.

The correlation of the new log with the log very shortly described by Leven & Gorgij (2006a) is uncertain in some parts. Leven, in cooperation with Davydov and Gorgij (2006) publishes a paper on the Zaladou section, mostly based on fusulinids, but with a new lithostratigraphic subdivision of the Sardar, now considered as a group.

The Sardar Group is then divided into two new formations (Ghaleh and Absheni formations) separated by an important hiatus. The two units are shortly described in Leven *et al*., 2006, but only based on tens of meter thick intervals (Ghaleh Formation: intervals 1-5; Absheni Formation: intervals 6 and 7). An unconformity is hypothesized at the base of the basal quartzarenites of Ghaleh Formation.

Bio-chronostratigraphy (from Balini *et al.*, 2010, 2012)

The Zaladou section has been sampled in 2010 during the Darius project: 81 samples was collected, including thin sections, conodonts and brachiopods samples, furthermore several limestone samples have been collected by Balini *et al.* during the last field trip in 2012.

These new samples are from the middle part of Sardar Group and yielded some good fusulinids pointing to an early- middle Pennsylvanian age like, from lower to higher: *Neoarchaediscus* ex gr. *postmosquensis acutoformis* (lowermost Bashkirian); *Plectostaffella* sp. (Lower Bashkirian, Akavassian); *Staffellaeformes* cf. *staffellaeformis* (uppermost Bashkirian - lowermost Moscovian); *Neostaffella* aff. *syzranica* (Lower Moscovian, Vereian); *Taitzehoella* sp. (Lower Moscovian, Kashirian).

The brachiopod associations of Zaladou section comprises few specimens not well preserved of undetermined species of four genera: *Pterospirifer* Dunbar, 1955; *Alispiriferella* Waterhouse & Waddington, 1982*;* *Hunzina* Angiolini, 1995 and *Hustedia* Hall & Clarke, 1893.

The genus *Hunzina* suggest an Early Permian, Sakmarian age, whereas *Pterospirifer* and *Hustedia* range through all of the Permian. *Alispiriferella* is mostly abundant in the Early Permian, even if a few species may range into the Middle Permian.

The biogeographic affinity is also in this case paleoequatorial if not boreal as *Alispiriferella* occurs in Canada and Russia, whereas most species of *Pterospirifer* have been recorded in Europe, Russia, Canada and USA. The faunal link to peripheral Gondwana is also in this case assured by the occurrence of *Hunzina*.

Conodont fauna

Eleven conodont samples were collected and studied from this section: sample IR10-10 is from Sardar Group while samples ZAL3, IR10-11, IR10-12, IR10-13, IR10-14, ZAL9, ZAL12, ZAL13, ZAL14 and ZAL15 are from Zaladou Formation (see appendix I, table 3). All the specimens show CAI 5, testifying a temperature ranging from 300° to 480°.

Unfortunately almost all of the samples studied are barren: only samples ZAL3, IR10-11, IR10-12 and ZAL12 yielded some rare and bad preserved conodonts (fig. 17).

Particularly sample ZAL3 contains a specimen of *Idiognathodus* sp. Gunnell, 1931 preserved so bad that is impossible to determine the species and samples IR10-12 and ZAL12 only contain ramiforms which are useless for biostratigraphy.

Sample IR10-11 yielded the conodont *Streptognathodus* cf. *plenus*: this species is reported as Asselian in age (Chernykh, 2005) and this is not that we expected based on fusulinids (for discussion on *Streptognathodus* distribution see chap. 7 and chap. 8). Unfortunately the other conodont that I have founded in this sample is only a fragment of *Streptognathodus* sp. that is not useful to solve the question: further samples need to be collected from this part of the section in order to obtain more conodonts.

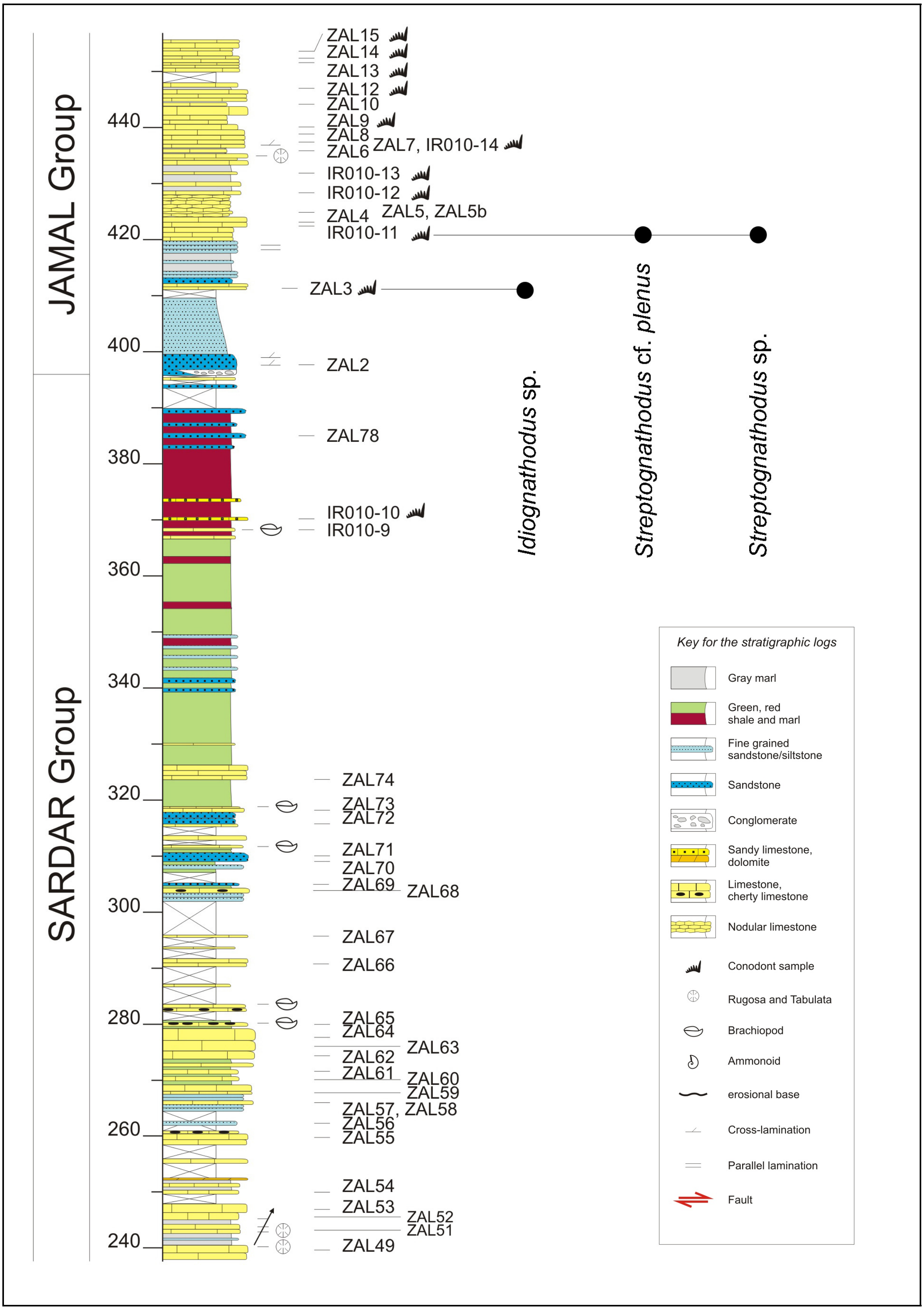

Fig 17. Range chart of conodonts from upper part of Zaladou section, Tabas area, Central Iran.

3.6 Anarak 3 section

Some interesting upper Paleozoic sections from the Anarak area were known by literature (Sharkovski *et al*., 1984; Wendt *et al*., 2005; Leven & Gorgij, 2006a, 2006b, Leven *et al*. 2006): they are all located in the surroundings of a mountain with no name and with 1625 m of elevation, immediately S-SE of the Biabanak fault (20 km SE from the town of Anarak).

Some of those sections are described as affected by faulting, especially for the Carboniferous and Permian part (e.g., Wendt *et al*., 2005; Leven *et al*., 2007).

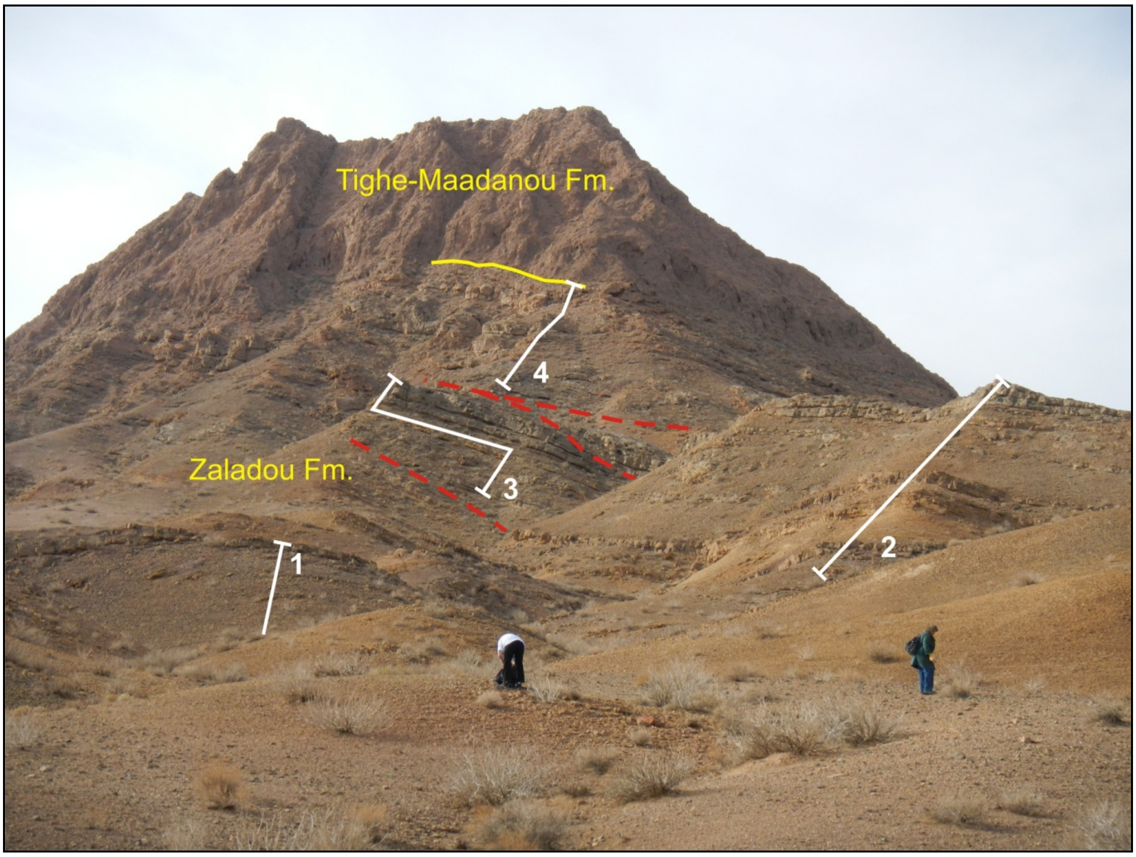

Fig 18. View of the Northwestern slope of the unnamed mountain where the Anarak 3 section has been measured (from Balini *et al*., 2011). Yellow: lithostratigraphic boundary. Red: major reverse faults. White: position of the 4 segments of the composite section.

Balini *et al*. (2011) selected the section described by Leven & Gorgij (2006b) for sampling during the 2011 field trip. This section was chosen because of the apparently lack of tectonic overprint, undisturbed record from the Late Carboniferous to the earliest Permian and possibility to sample a stratigraphic contact between the Tighe-Maadanou and the Jamal formations reported in literature by Leven & Gorgij, 2006b. The location of this section, however, was slightly different from what reported in literature (Balini *et al.*, 2011).

The section has been numbered following Wendt *et al*. (2005), who already described in the area the sections of Anarak 1 and Anarak 2.

The sedimentary succession exposed at Anarak 3 spans from the Zaladou Formation to the base of the Tighe-Maadanou Formation and is affected by several reverse faults: this has made necessary to measure four different partly overlapping segments in order to be able to reconstruct the succession without repetitions of some stratigraphic intervals. Unfortunately, the contact between the Tighe- Maadanou and Jamal Formation, detected in the field, is tectonic.

The Anarak 3 section seems to correlate very well with Zaladou Section, especially as regard its upper part. The lower siliciclastic-dominated part of the Zaladou Formation at Zaladou does not seem to have a counterpart at Anarak 3, but this might be only apparent because the lower boundary of Zaladou Formation is not exposed at Anarak 3. The main significance of Anarak 3 is in the correlation with the Zaladou section and the correlation between conodonts and fusulinids can solve many problems in time correlation. (Balini *et al.*, 2012).

The units A, B and C of Anarak 3 section (fig. 20) seem to be deposited in a more protected environment with respect to Zaladou section. The characterization of the facies will be done by the study of the about 60 samples for thin sections.

Sedimentary evolution (from Balini *et al.*, 2010, 2012)

Notwithstanding the rather good exposure, the section measured by Balini *et al.* is not fully consistent with the log provided by Leven *et al.* (2006).

The thickness of the Sardar Group measured by Balini *et al.* (2010) is about 300 meters, about 50 meters thinner than reported by Leven *et al.* (2006) and the correlations between Leven *et al.* intervals 2, 3, and 4 Balini *et al.* log are not very clear.

The thickness of unit 4, estimated of 15 m by Leven & Gorgij (2006), was probably overestimated by fault repetition.

Unit 5 was reported in literature (Leven & Gorgij, 2006) as 4.5 m of pink marls but has never been found by Balini *et al.* (2010) who reported that some pink marls are visible on the slope, more or less above algal limestones correlative at least in part with Leven & Gorgij unit 4, but they are always in tectonic contact with the rest of the succession.

The base of unit 6, was reported by Leven & Gorgij (2006b) as "overfilled" with fusulinids but such a distinct lithologic marker has never been detected by Balini *et al.* above the pink marls of the supposed unit 5.

The sedimentary evolution observed by Balini *et al*. (2010) is the following:

- lowest 50-54 m of the formation dominated by siltstone and marls with intercalations of a wide variety of rocks, such as bioclastic limestones, nodular limestones, occasionally thin bedded quartzarenites;
- the overlying 15-16 m showing an increasing amount of carbonates, with at least two Rugosa-dominated bioherms ;
- about 5.5 m of algal boundstone, cliff forming;
- a limestone dominated interval with very common grainstones, more or less thick bedded;
- frequent fusulinids, about 24 m.

The boundary with the massive dolomites of the Tighe-Maadanou Formation is very sharp.

Conodont fauna

Fifteen conodonts samples from Anarak 3 composite section were collected, processed and studied (see appendix I, table 4).

All samples are from Zaladou Formation (fig.19): samples ANK6, ANK7, ANK8, ANK11, ANK12, ANK16, ANK20, ANK21 and ANK22 are from segment1 of the composite section. Specimens show CAI 3 pointing to a temperature range comprised between 110° and 200° C.

Sample ANK26 is from segment 2 of the composite section.

Samples ANK35, ANKK38, ANKK42 are from segment 3 of the composite section.

Samples ANK43, ANK49 and ANK53 are from segment 4 of the composite section.

Unfortunately, samples ANK8, ANK11, ANK16, ANK20, ANK35, ANK38, ANK42, ANK43 and ANK49.

Sample ANK 6 contains only one bad preserved specimen of *Streptognathodus* sp. The specimens are too bad preserved to identify them to a specific level.

Sample ANK7 contains a fragment of *Declinognathodus* sp. that is Carboniferous in age.

Sample ANK12 contains a rich and almost well preserved population of *Idiognathodus lobatus* Gunnell, 1933 and *Streptognathodus longus* Chernykh, 2005. Almost all the specimens are broken, especially the blade is missing, but the species are clearly identifiable. *I. lobatus* is Kasimovian in age (Gunnell, 1933) while *S. longus* range from Gzhelian to Asselian Age (Chernykh 2005, Chernykh *et al.*, 2009) the presence of both species in the same sample is atypical, for discussion on *I. lobatus* and *S. longus* ranges see chap. 7. The same association was found in sample ANK26, in the upper part of segment 2.

Samples ANK12 and ANK26 are definitely Upper Carboniferous in age because of the presence of *I. lobatus*. Ranges of the two species do not overlap perfectly and further investigation on both species ranges are needed, but the age of these two samples seems to be Kasimovian/Gzhelian.

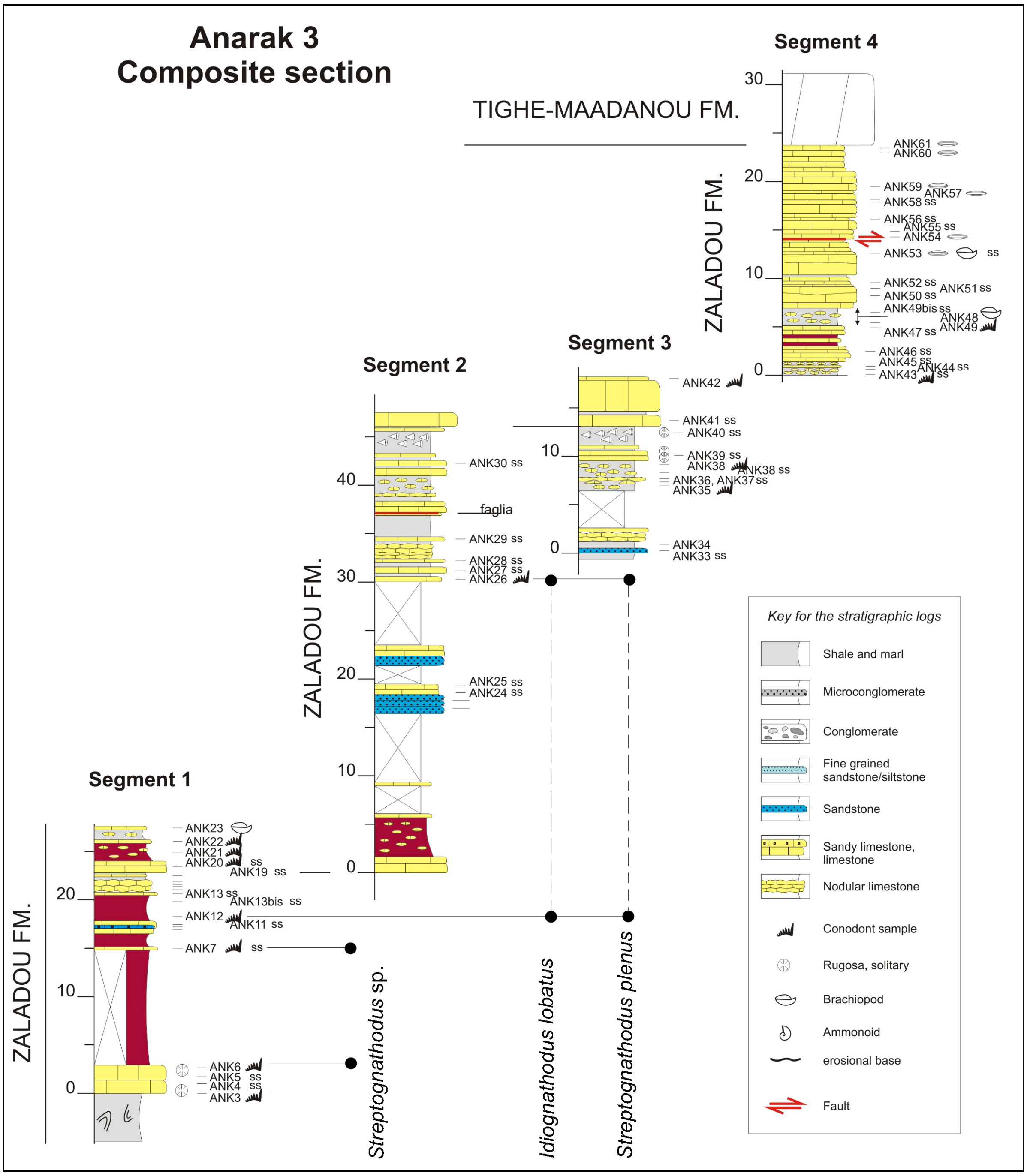

Fig. 19. Range chart of conodonts from Anarak 3 section.

3.7 Rahdar section

Carboniferous to Permian successions (Gachal and Khan formations) are well exposed at several sites of the Kalmard unit, a narrow and extremely elongated tectonic unit sandwiched between the Kalmard and the Rahdar faults. The section exposed in the Kuh-e-Rahdar is probably the easiest to access and has been studied by Aghanabati (1977), Wendt *et al.* (2005) and Davydov & Arefifard (2007).

Aghanabati (1977) reported the upper part of the Khan Formation at Rahdar as lacking by erosional unconformity.

Davydov & Arefifard (2007) identified in the upper part of the section a fusulinid rich interval that is documented in all the other sections of the Kalmard unit.

The three stratigraphic sections reported in literature from this locality do not match each other because of some important differences.

Wendt *et al.* (2005) described 142 m of Khan Formation, with 2 sandstone intervals (on the whole 84 m thick), while Davydov & Arefifard (2007) reported 146 m for the formation, but with 4 sandstone intervals (on the whole 72 m thick).

Differences are reported also for the lithostratigraphic unit capping the Khan Formation by erosional unconformity, in this case Wendt *et al.* (2005) described the late Triassic-Jurassic Shemshak Formation, while Davydov & Arefifard (2007) reported the Early Triassic Sorkh Shale.

The section choose by Balini *et al.* to be sampled during the 2011 field trip was the one described by Wendt *et al.* (2005), which has GPS coordinates. Balini *et al*. (2011) carried out an additional sampling for fusulinids and conodonts in 2012. No information on the location of Davydov & Arefifard (2007) section is available, then it is possible that this section is located on a different slope of Kuh-e-Rahdar.

The exposure of the section is very good, especially for the upper part of the Gachal Formation and Khan formations (fig. 20). The lower to middle part of the Gachal Formation deep with the slope and accurate measurements are more complex.

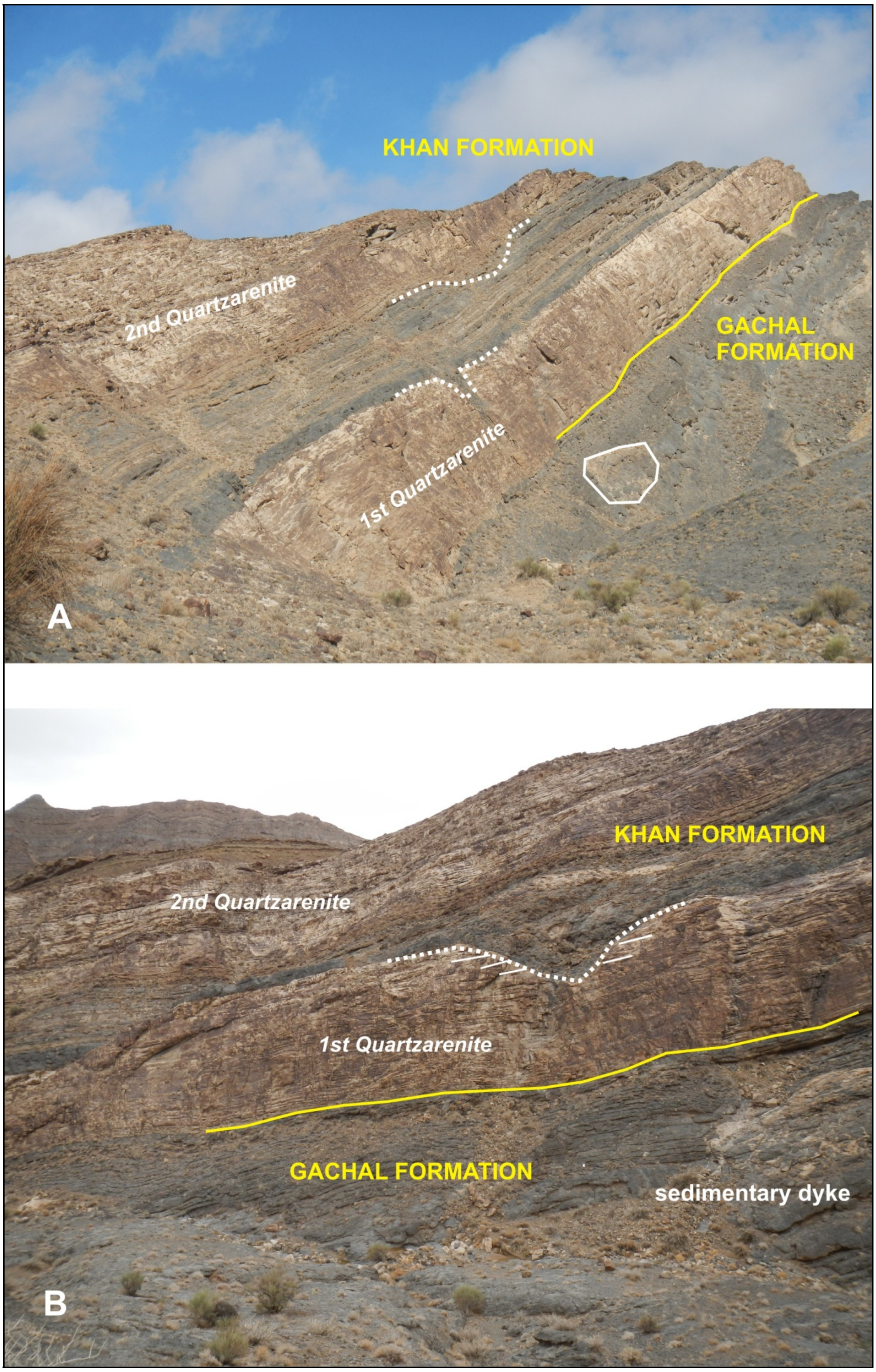

Fig 20. Lower part of the Rahdar section (from Balini *et al.,* 2011). A) The erosional unconformities on top of the 1st quartzarenites and at the base of the 2nd are visible from distance; B) A closer view to the uppermost Gachal and lowermost Khan formations. The impressive disconformity on top of the 1st quartzarenite, was never mentioned in literature.

Sedimentaty evolution (from Balini *et al.*, 2011)

About the last 60 m of the Gachal Formation and about 150 m of the Khan Formation have been measured. The Khan Formation is overlain by greenish siltstones and sandstones attributed to the Shemshak Group, in agreement with Wendt *et al.* (2005). The succession reflect a much dynamic sedimentary evolution with respect to what is reported in literature.

The upper part of the Gachal Formation, from the base of the section to about m 45, mostly consists of dark gray rather fine grained fetid limestones, often thin bedded. Some very thin fine grained sandstone intercalations might occur, but a major 6.5 m thick very fine grained siliciclastic interval is recorded from 12.5 m above the base of the section. This interval consists of greenish shale-silt with rare and thin sandstone layers, and has been sampled for palynomorphs.

These lowest 45 m of the section provide very good evidences of sedimentation on a slope setting with tectonically-controlled instability. A slumping is recorded at about 30 m from the base and at least 3 intervals with monogenic breccias are documented.

The last 20 m of the Gachal Formation, overlying the last breccias, show a slight increasing of energy, and probably a shallowing trend. This part mostly consists of dark gray bioclastic packstones to grainstones, thin to medium bedded, often with solitary Rugosa in life position, brachiopods and some rare Tabulata.

The Khan Formation consists of two types of lithofacies, quartzarenites and limestones, organized in rather homogeneous intervals. In literature (Aghanabati, 1977; Leven & Gorgij, 2007) the intervals are interpreted as sedimentary cycles, starting with quartzarenites e then continuing with carbonates.

Two thick quartzarenite units are documented in the Rahdar Section, but the general organization of facies does not seem to correspond very well with the interpretation by previous authors. The base of the two quartzarenites is disconformable, especially the one of the second unit, but the top of the quartzarenites (especially the 1^{st}) is also a disconformity.

The base of the Khan Formation is transgressive. On the outcrop this boundary is very sharp, and looks to be a paraconformity, followed by deposition of quartzarenites in a rather stable foreshore-like environment. However, the occurrence of sedimentary dykes in the upper part of the Gachal Formation, not reported in literature (cf. Wendt *et al.*, 2005) provides a slightly different picture. The sedimentary dykes are filled with quartzarenitic sediment, but include also blocks up to 1 m in diameter. The lithology of the blocks is mostly qurtzarenitic and recalls the lithology of the upper part of the Gachal Formation. However some blocks of limestones can also be found in the dykes, thus documenting that the extension that controlled the opening of the dykes was at least in part coeval with the beginning of the deposition of the quartzarenites (fig. 21).

The base of the first limestone interval of the Khan Formation is again a disconformity, locally deeply cutting the first quartzarenite. This limestone interval also includes some sandstone and sandy limestone layers, especially in its middle part, and is truncated by a disconformity marking the base of the second quartzarenite. The top of the limestones locally is deeply weathered and possibly capped by a paleosoil.

The upper part of the Khan Formation is characterized by a reduction of the siliciclastic supply, that becomes very fine grained (from 140 to 158 m from the base), then it is replaced by the deposition of shallow water limestones with rather common Rugosa (solitary and colonial), Tabulate, Algae, foraminifers and brachiopods. The uppermost 4 m of the formation are in particular rich in fossils.

The sedimentary evolution documented by the Gachal and Khan formations is clear but there is a scarcity or even the lack of bio-chronostratigraphic data from several key intervals (Balini *et al.,* 2012). With these open problem, every attempt at the reconstruction of the sedimentary evolution of Rahdar would be very subjective. Very important is the correlation between Zaladou, Bagh-e-Vang and Anarak that can be made using fossils contents and thin sections.

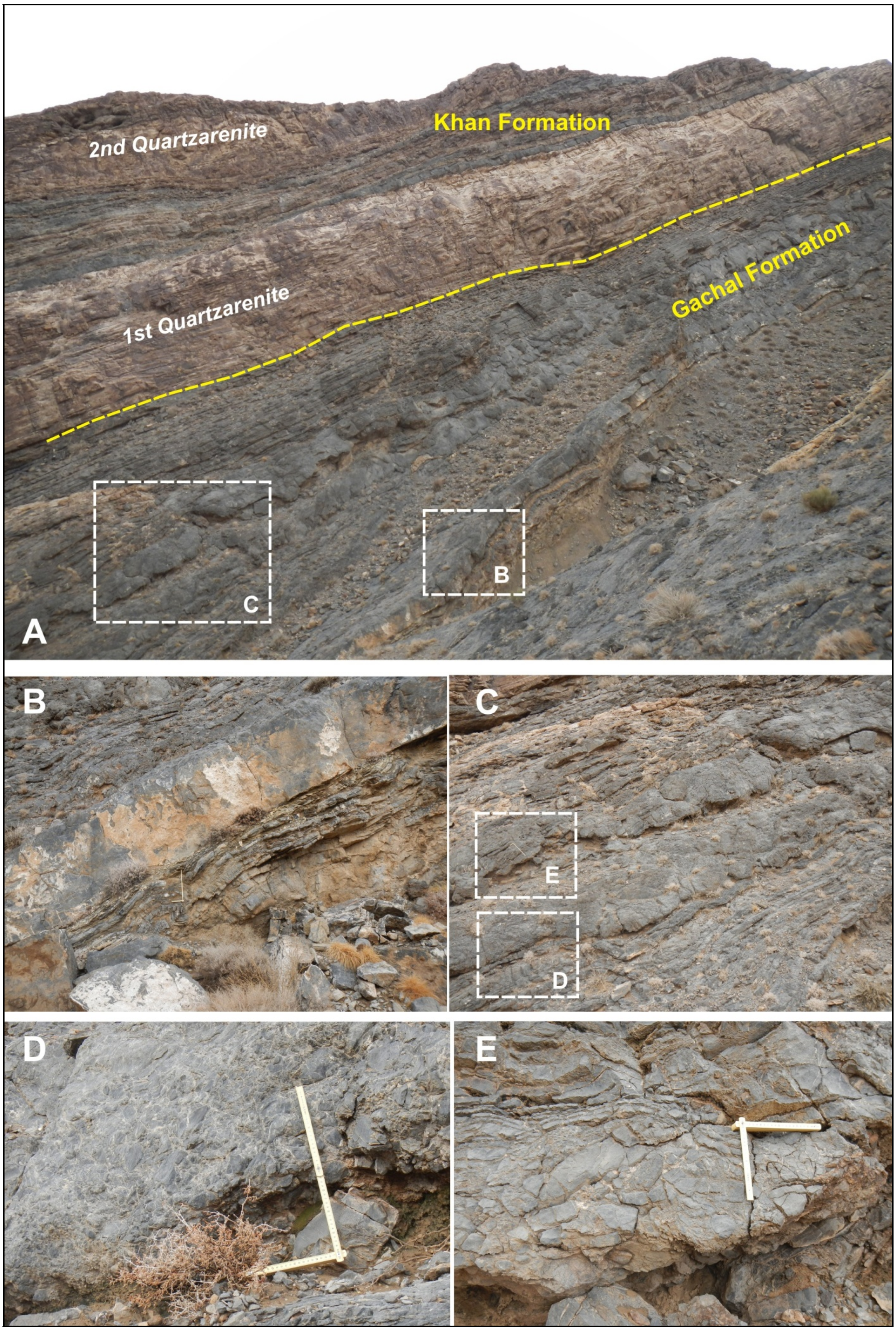

Fig. 21. Evidence of sedimentation on a slope setting, uppermost Gachal Formation, Rahdar section (from Balini *et al.*, 2012). A) View of the lower part of the section; B) slumping affecting thin bedded; C) the two massive monogenic breccias with close up views D and E.

Bio-chronostratigraphy (from Balini *et al.*, 2012)

Brachiopod samples from level RH14, just below the base of the Khan Formation point to a Visean-Serpukhovian on the basis of *Frechella*, while *Syringothyris* ranges from the Upper Devonian to the Serpukhovian.

Fusulinids have been found only in three samples from the upper part of the Khan Formation: RH34, RH35 and RH36. An assemblage of *Nonpseudofusulina aghanabatei* (Davydov & Arefifard, 2007); *N. neglectens* (Leven, 1993); *N.* aff. *tezakensis* and *Anderssonites* sp. has been identified in samples RH34 and RH35. These taxa document the Kalaktasch assemblage, of Sakmarian age. In sample RH36 the fauna consists of *Nonpseudofusulina pamirensis* (Leven, 1993); *N.* ex gr. *fecunda* (Sham & Scherb); *Parazekkia* sp. and belongs to the Halvan assemblage of Sakmarian or early Artinskian age. Sample RH36 also yielded the brachiopod *Neospirifer* aff. *hardmani*.

The Visean-Serpukhovian age of the top of the Gachal Formation suggested by brachiopods is perfectly consistent with the age reported in literature for this unit (e.g., Aghanabati, 1977; Wendt *et al*., 2005). Moreover the Sakmarian or early Artinskian age of the fusulinid faunas identified on top of the Rahdar section are rather consistent with the age of the Khan Formation reported in literature (e.g., Aghabanati, 1977; Davydov & Arefifard 2007; Leven & Gorgij 2007; Leven & Gorgij 2011b; Leven *et al.*, 2011).

Conodont fauna

Four conodont samples were collected during 2011 from the Rahdar section: RH4, RH5 and RH14 from Gachal Formation and RH21 from Khan Formation (see appendix I, table 5) (fig. 22).

Unfortunately 4 of the 5 conodonts samples collected during 2011 were barren. Only sample RH4 yielded a fragment but the specimen is too bad preserved to determine the species.

Eight more samples were collected in 2012: RH4 was sampled again and were collected three more sample from Gachal Formation, RH54, RH15 and RH51. Samples RH63, RH33, RH36 and RH34 are from Khan Formation (fig. 22). CAI of all the specimen is 5, pointing to a thermic gradient between 300° and 400°C.

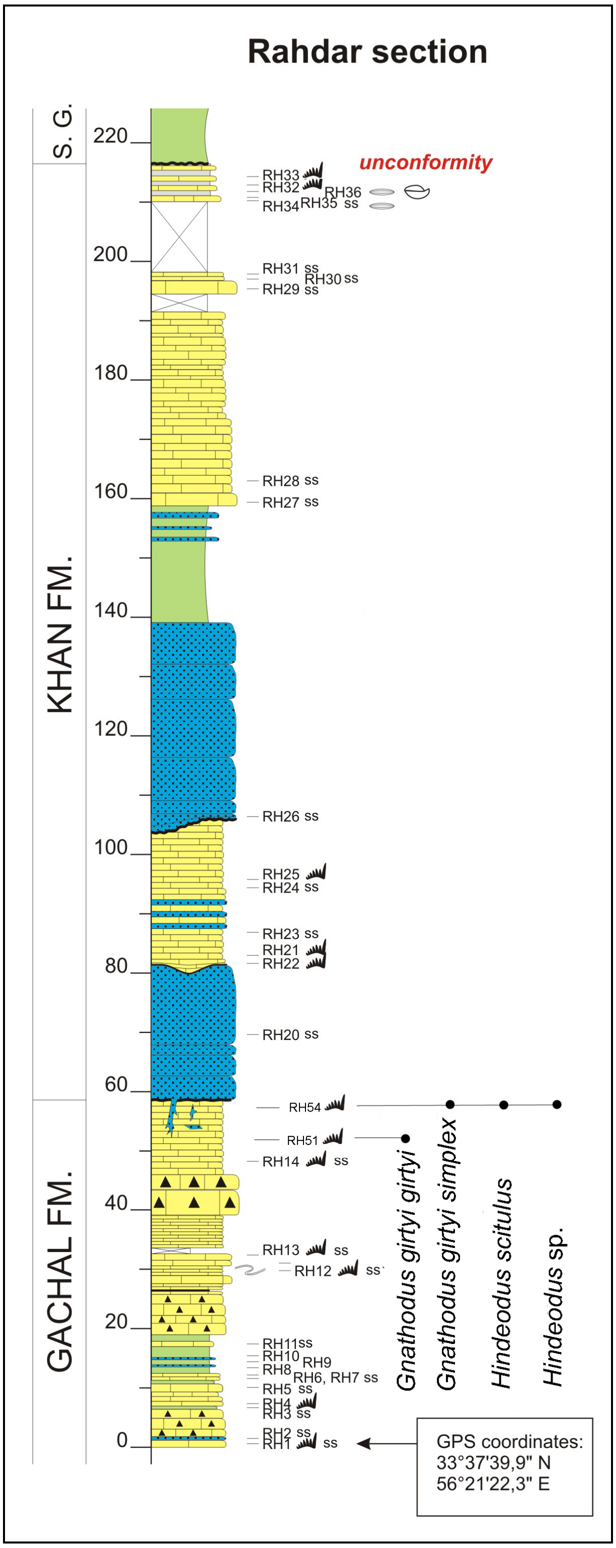

Fig. 22. Range chart of conodonts from Rahdar section.

In RH 51 were found some specimens of *Gnathodus girty girty* (Hass, 1953) which ranges from Serpukovian to Lower Bashkirian (Boncheva, 2007).

Three different species were found in sample RH54: *Gnathodus girty simplex* (Dunn, 1965), *Hindeodus* sp. (Rexroad & Furnish, 1964) and *Hindeodus scitulus* (Hinde, 1900). Both *Gnathodus girtyi simplex* and *Hindeodus scitulus* ranged from the Visean to the Serpukovian (Hinde, 1990).

Chapter 4

Geological Setting of SE Pamir

4.1 Introduction

The tectonic setting that characterizes nowadays Central Asia is the results of a complex evolution that started at the beginning of the Mesozoic with the progressive accretion of several blocks of Perigondwanan ancestry to the Eurasian margin and the closure of the Paleotethys Ocean by subduction beneath the southern Eurasia margin (Zanchetta *et al.*, 2013).

This geodynamic event is known as Cimmerian orogeny and is traceable from Iran to Tibet through Central Asia.

It is bracketed in time between the Late Triassic and the Early Jurassic (e.g. Sengör, 1979; Gaetani, 1997; Schwab *et al.*, 2004; Zanchi *et al.*, 2009; Zanchi & Gaetani, 2011; Robinson *et al.,* 2012; Angiolini *et al.*, 2013a, 2013b) but the events leading to this complex tectonic evolution started much earlier than the Mesozoic, in the Late Carboniferous-Early Permian. Starting from the progressive detachment of the Cimmerian terranes (like Iran, Central Afghanistan, Karakorum, Central and South Pamir and Sibumasu) which broke off from the Gondwanan margin and drifted northward with the opening of Neotethys Ocean (Sengör, 1979; Gaetani, 1997; Angiolini *et al.,* 2003, 2007; Muttoni *et al*., 2009; Domeier & Torsvik, 2014).

South Pamir is one of the main orogenic belts which form the Pamirs (e.g. Yin & Harrison, 2000; Schwab *et al*., 2004; Robinson *et al.,* 2012; Angiolini *et al*., 2013a) and was later deformed by the Cenozoic collision of India (Burtman & Molnar, 1993; Angiolini *et al.*, in press) (fig. 23).

South Pamir is separated from Central Pamir by the Rushan-Pshart zone (Leven, 1995; Burtman, 2010; Robinson *et al.,* 2012; Angiolini *et al*., 2013a). It is bounded southward by Karakoram (fig. 23), but their contact is still debated: some authors considering them to be continuous, (e.g., Schwab *et al.*2004; Robinson *et al.,* 2012), others seeking for a minor suture zone along the Tirich Boundary Zone (TBZ) where serpentinized mantle peridotites may represent the remnants of a secondary suture zone (Zanchi *et al.*, 2000; Zanchi & Gaetani, 2011).

The southwestern part of South Pamir consists of metamorphic rocks exhumed in the Cenozoic following the Indian plate collision (Schmidt *et al.*, 2011) (fig. 24).

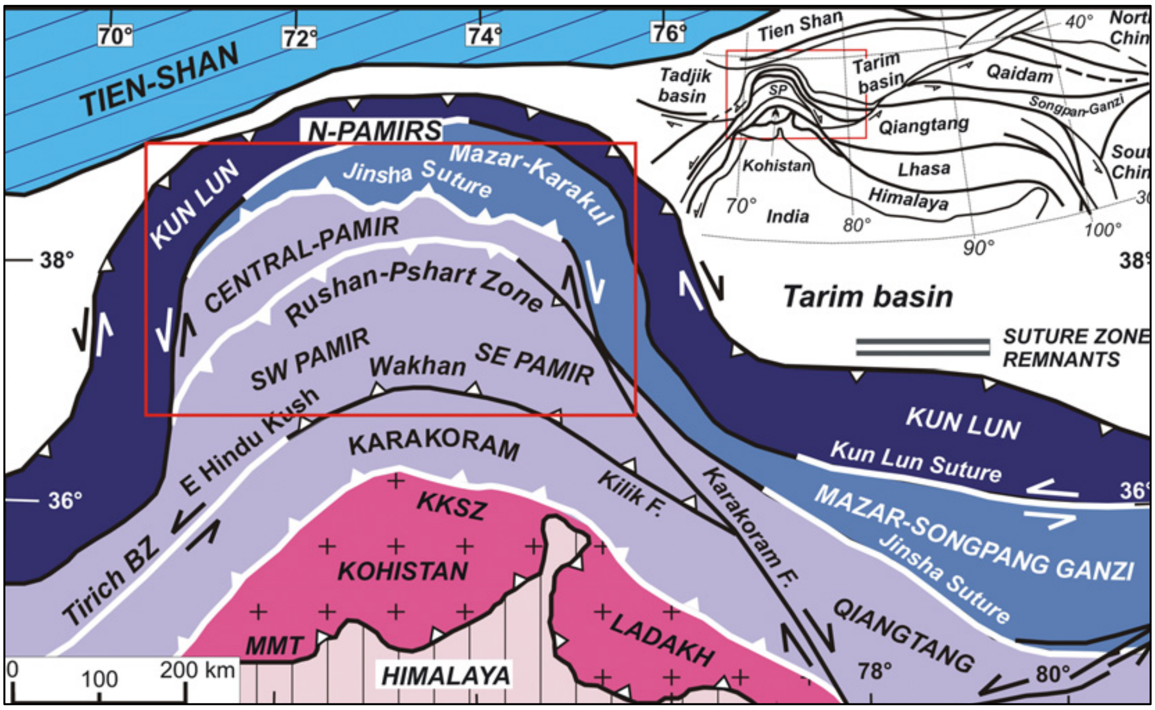

Fig 23. Present tectonic setting of the SE Pamir (from Angiolini *et al.*, 2013). Red square: studied area. KKSZ: Karakoram-Kohistan suture zone. MMT: Main mantle thrust. Modified from Schwab et al. (2004); Zanchi and Gaetani (2011); Robinson et al. (2012).

SE Pamir (Tajikistan) is an area of high significance for biocronostratigraphy: in fact the Darvasian, Murgabian, Pamirian stages (Miklucho-Maklay, 1958), the Kubergandian stage (Leven, 1963), Bolorian stage (Leven, 1979) and Jachtashian stage (Leven, 1980) have been defined in the Darvaz and Pamir with stratotypes in this area.

Jachtashian, Bolorian, Kubergandian and Murgabian are still used as regional stages in the Tethys, whereas the other above stages are no longer used in the present Permian literature (Kozur *et al.*, 1994).

Furthermore, studied sections contain both fusulinids and conodonts, so this is the ideal area to solve the correlation between these two fossil groups (Reimers, 1991; Kozur *et al.*, 1994; Leven 2003, 2004, Angiolini *et al.*, 2012; Shen *et al.*, 2013).

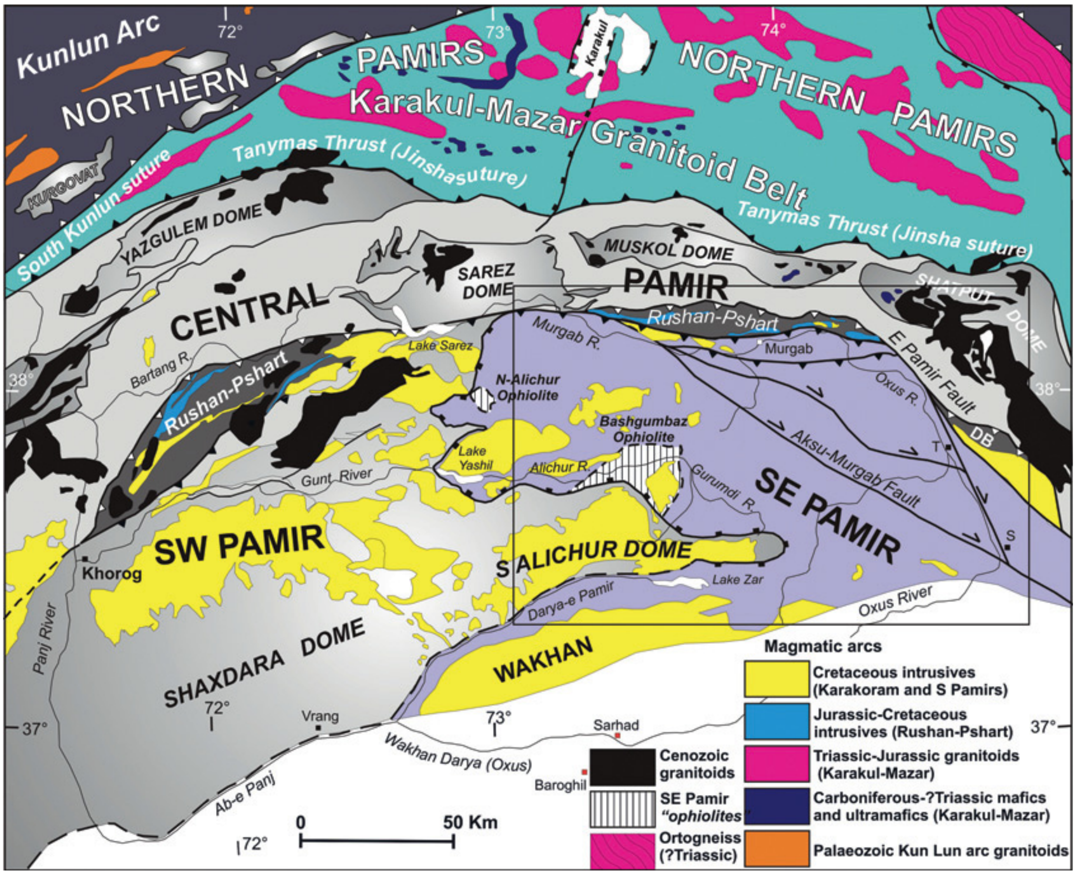

Fig 24. Tectonic setting of the Pamirs that comprises three main units: North, Central and South Pamir (from Angiolini *et al.*, 2013).

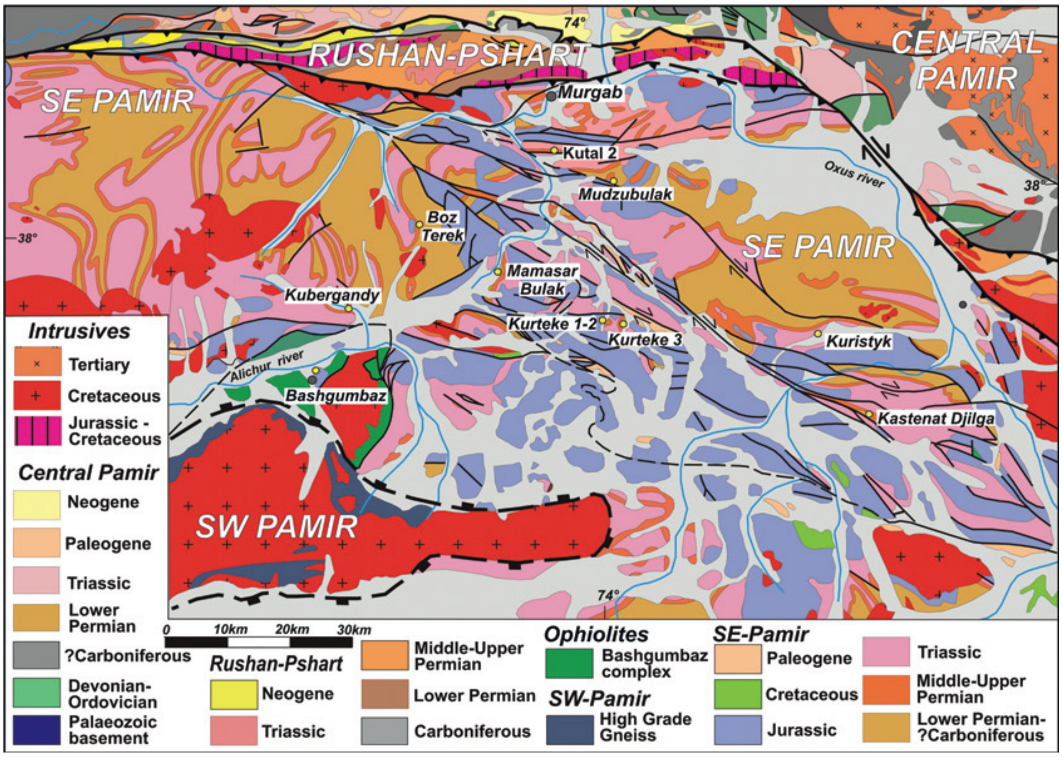

Fig. 25. Geological map of the studied area (from Angiolini *et al.*, 2013

The base of Permian-Lower Triassic succession comprises the Lower Permian Uruzbulak and Tashkazyk formations (Bazar Dara Group), consisting of fine to medium siliciclastic locally fossiliferous strata. They are unconformably covered by an upper Lower to Upper Permian succession: this comprises both platform facies, recorded by the massive limestones of the Kurteke Formation, and slope to basinal facies, which are represented by the Kochusu Formation, Shindy Formation, Kubergandy Formation, Gan Formation, and Takhtabulak Formation (Angiolini *et al.*, in press) (fig. 26). These formations consist of bioclastic limestones, cherty limestones, shales, volcanoclastic rocks, sandstones and conglomerates: the fossil content is locally very rich (fusulinids, ammonoids, brachiopods, corals and conodonts). The lower part of the overlying Triassic succession consists of platform carbonates of the Induan to Anisian Karatash Group (Angiolini *et al.*, in press).

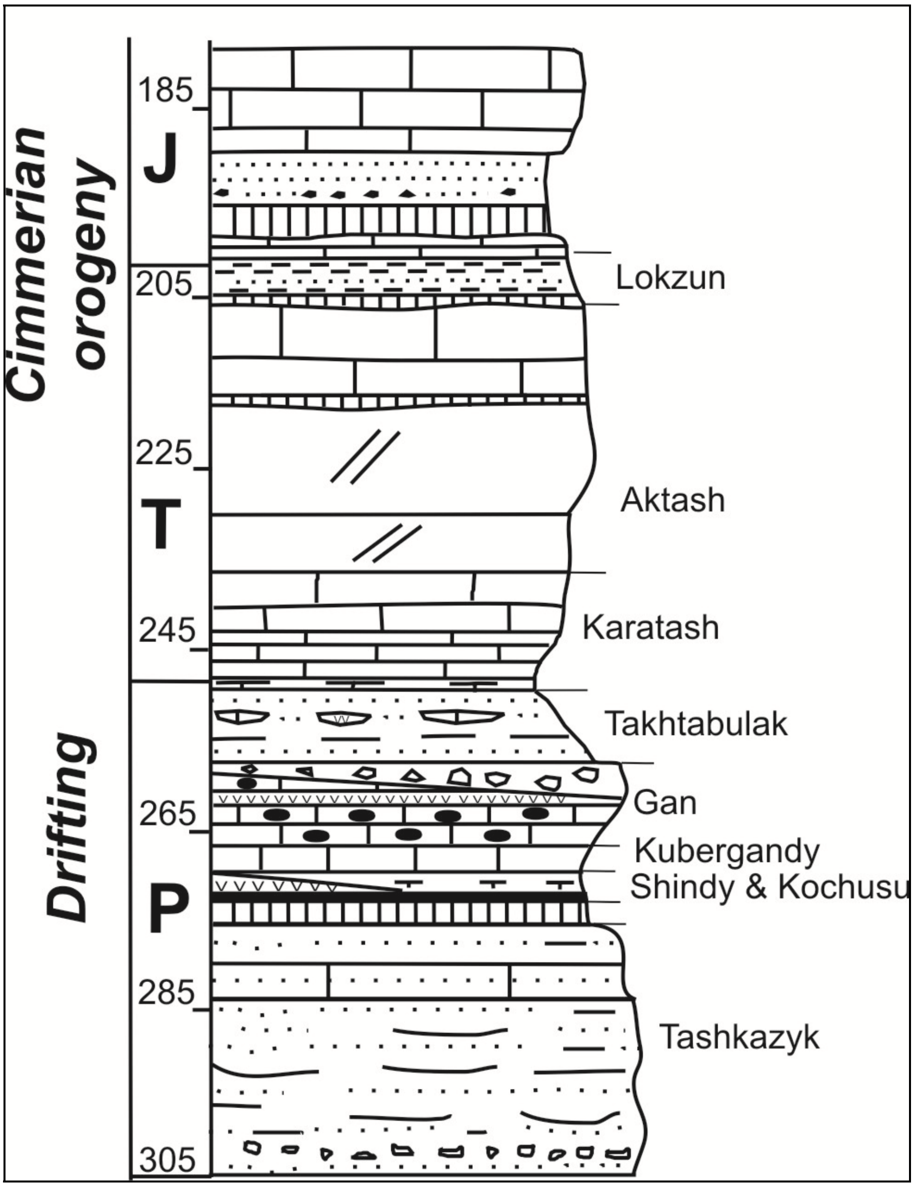

Fig 26. Sedimentary succession of SE Pamir (from Angiolini *et al.*, 2011).

For Darius project the following stratigraphic sections have been sampled in 2010 and 2011: Kubergandy section, Mamasar Bulak, Kutal 2 section, Kurteke 1 section, Kurteke 3 section, Karebeles Valley at Mudzubulak, Kuristyk section and Kastenat Djilga section. 0For this thesis were studied the sections of Kubergandy, Kutal 2, Kurteke and Kuristyk (figs. 27 and 28).

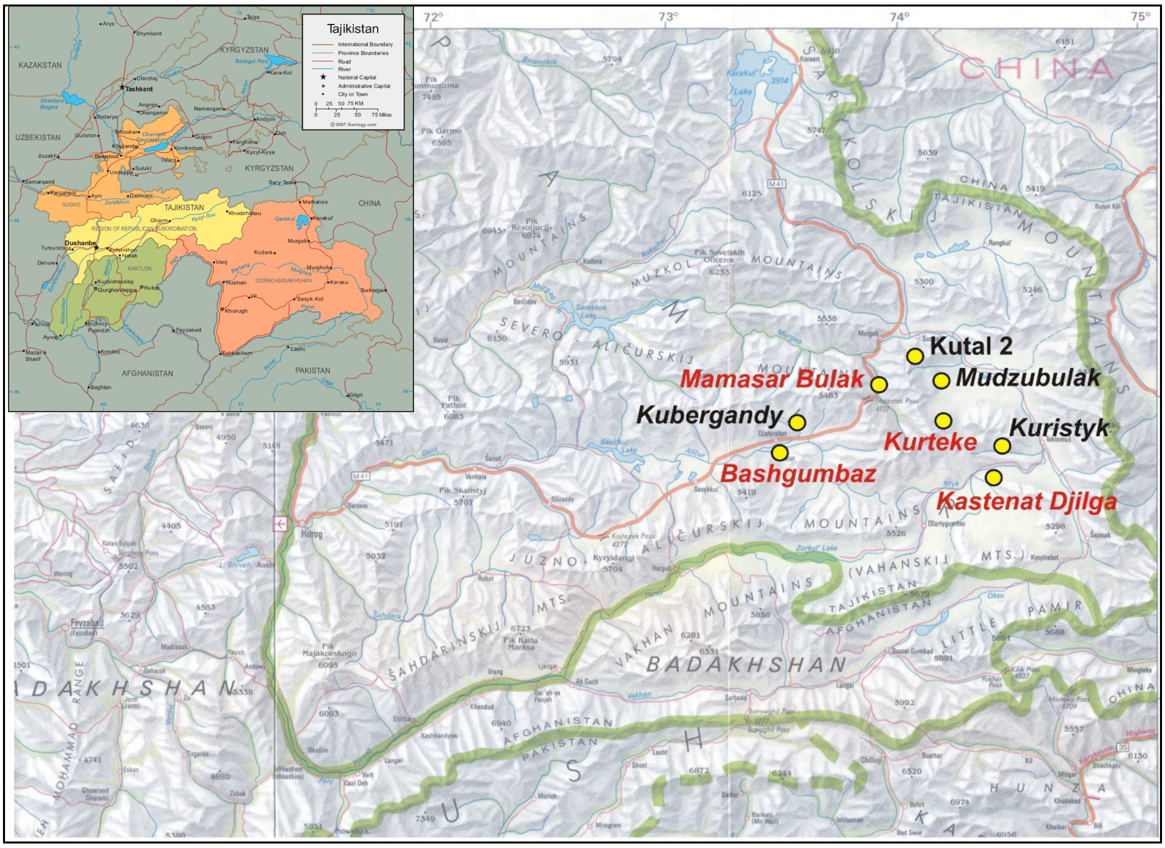

Fig 27. Location of the studied localities. Red: localities studied in 2011 (from Angiolini *et al.*, 2011).

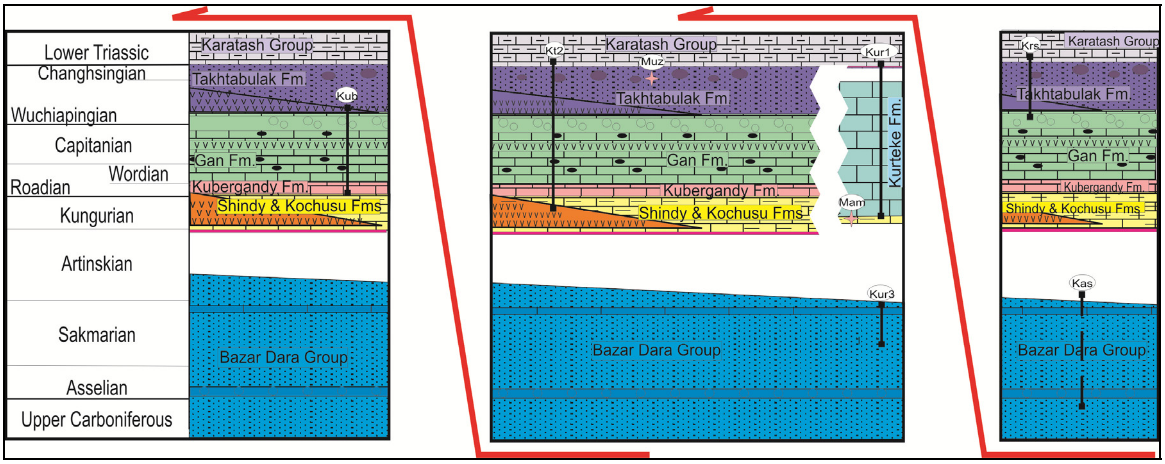

Fig 28. Stratigraphic scheme of the Permian formations with the position of the measured sections (from Angiolini *et al.*, 2013). Kt2: Kutal2. Kub: Kubergandy. Muz: Mudzubulak. Krs: Kuristyk. Kur1: Kurteke 1. Kur3: Kurteke 3. Kas: Kastenat Djilga. Mam: Mamasar Bulak.

Shindy and Kochusu Formations

These formations have been studied during the DARIUS Project by Angiolini *et al.* (2012) and description of lithology and fossil content are from this report.

Only few, mostly covered, outcrops of the Kochusu Formation were observed in the Kuristyk and Kastenat Djilga Valleys.

The Kochusu Formation (Dmitriev, 1976) unconformably covers the Tashkazyk Formation above an emersion surface (fig. 29).

The Shindy Formation conformably overlays the Kochusu Formation and laterally replaces it (Leven, 1958, 1967).

Grunt & Dmitriev (1973) and Leonova & Dmitriev (1989) report a laterite occurring at the base of the Shindy Formation but Angiolini *et al.*, (in press) did not observe that lithology as it is covered or as the contact is tectonized. Good outcrops of the Shindy Formation have been sampled in the Kuristyk Valley, at Mudzubulak and at the base of the Kutal 2 section.

Lithology

The Kochusu Formation consists of 12-60 meters of silty limestones, locally bioclastic, overlain by siltstones with few and thin intercalations of marly limestones. The Shindy Formation consists of massive basaltic lava flows with pillow texture, locally interbedded with breccias and volcaniclastic layers. The space between the pillows is filled with carbonate and carbonate-siliceous material.

Microfacies analysis of the limestones at the base of the Kutal 2 section shows that they are bioclastic packstones with foraminifers, Algae, brachiopods and bivalves.

The Kochusu Formation contains fusulinids as *Monodiexodina shiptoni* (Dunbar), foraminifers as *Multidiscus* sp., Algae, brachiopods, ammonoids, rare Rugosa and conodonts. Ammonoids and Rugosa also occur among pillow lavas in the Shindy Formation.

Fig. 29. Tashkazyk and Kochusu Formations in the Kuristyk Valley (from Angiolini *et al.*, 2011). The Kochusu is the whitish interval in the right. The prominent beds in the foreground are the sandstones of the Tashkazyk Formation.

Fossil content

In 1994 Kozur *et al.* carried on a work on a collection of conodonts from Kochusu Formation owned by prof. Kozur and prof. Barshkov. They recognized two distinct faunal association inside Kochusu Formation.

The first fauna, as reported in Kozur *et al.* (1994), is from the lower member of Kochusu Formation and contains *Mesogondolella bisselli, Mesogondolella shindyensis* Kozur 1991*, Mesogondolella intermedia* (Igo, 1981)*,* very rarely *Mesogondolella asiatica* (Igo, 1981), *Neostreptognathodus sulcoplicatus* (Youngquist, Hawley & Miller, 1951), *N.* ? *foliatus, N.* ? *murgabicus,* very rarely transitional forms *Neostreptognathodus pequopensis*/ *Neostreptognathodus leonovae* Kozur, 1976, *Pseudohindeodus nassichuki* (Kozur, 1976), *Pseudohindeodus oertlii* Kozur, 1975, *Sweetognathus bucaramangus* (Rabe, 1977), *Sweetognathus pamiricus* (Reimers, 1991), *Sweetognathus guizhouensis* Bando *et al.*, 1982, *Sweetognathus iranicus* Kozur, Mostler & RahimiYazd, 1975, *Vjalovognathus shindyensis* (Kozur, 1976). Kozur *et al.* (1994) did not report fusulinids from this member.

The second, distinct, conodont fauna is still in the lower part of the Kochusu Formation: they noticed that a rather rich but monotonous conodont fauna mainly composed by *Mesogondolella idahoensis* (Youngquist, Hawley & Miller, 1951) and *N. leonovae* and only rare presence of *P. nassichuki*, *S. guizhouensis* and *Sweetognathus venustus* Reimers, 1991 (Kozur *et al.*, 1994).

Both faunas belongs to the eastern Gondwana Paleoprovince.

New conodonts from Kutal 2 and Kubergandy sections studied for this thesis and new fusulinids samples collected for DARIUS project added further constrains to the age of Kochusu Formation. Thanks to both fusulinid and conodont data we are able to make some correlation between this two fossil groups in order to better correlate Tethyan and International Biostratigraphic Timescales.

Angiolini *et al.*, (in press) report the presence of fusulinids in the Kochusu Formation like *Monodiexodina shiptoni* (Dunbar) and species of *Chalaroschwagerina*, *Darvasites*, and *Leeina* (e.g. Gaetani and Leven, 2014), smaller foraminifers (*Multidiscus* sp.), Algae, brachiopods, ammonoids, rare rugose corals and conodonts. Ammonoids and Rugosa also occur among pillow lavas in the Shindy Formation.

Kubergandy Formation

This formation has been studied during the DARIUS Project by Angiolini *et al.* (2012) and description of lithology, fossil content, paleoenvironment reconstruction and age are from this report.

Dutkevich (1937) established the Kubergandy Formation. The Kubergandy type section is the stratotype for the Kubergandian Stage of the Tethyan Scale (Leven, 1963, 1981).

Angiolini *et al.* measured and sampled two detailed stratigraphic sections in the Kubergandy Formation: the Kubergandy type section and the Kutal 2 section for thickness of respectively 105 and 107 meters.

Lithology

The Kubergandy Formation comprises mostly bioclastic calcarenites, calcareous siltstones and sandstones and dark shales with a few volcaniclastic sandstones and intercalations of volcanic ashes (fig. 30).

In the lower part, shales are dominating whereas graded calcarenites and subordinate hybrid sandstones form planar to lenticular 20-50 cm-thick beds. In the upper part, calcarenites increase in frequency and thickness, forming m-thick channelized bodies with coarser grained texture.

Microfacies analysis shows that the limestones mainly consist of bioclastic packstones with fusulinids, small foraminifers, algae, echinoderms, brachiopods, and bivalves.

The limestones and the calcareous sandstones show neat sedimentary structures as cross, convolute and parallel laminations and gradation; beds with erosional base, channelized bodies and slumpings occur interbedded within the shales.

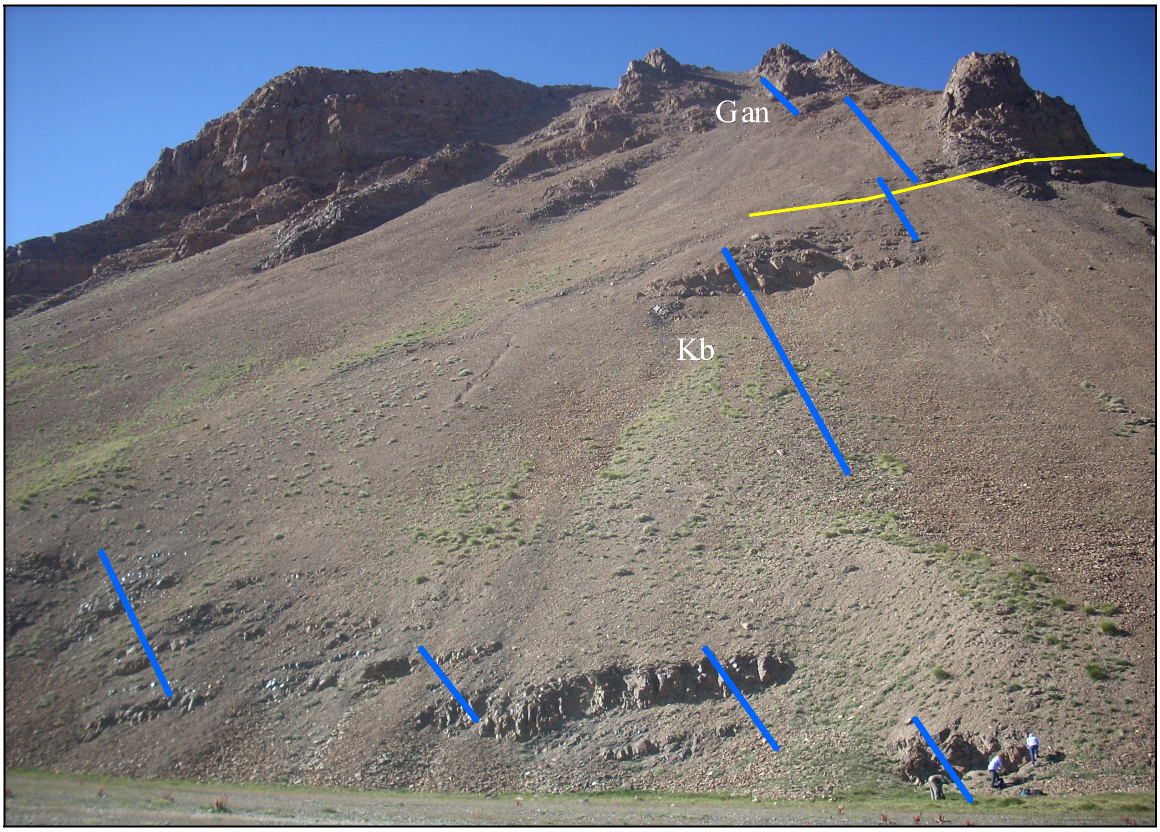

Fig. 30. Kubergandy section (from Angiolini *et al.*, 2011). Blue lines: base and middle part of Kubergandy type-section. Yellow line: limit between Kubergandy (Kb) and Gan formations.

Fossil content

The formation has been reported to contain fusulinids and ammonoids (Leven, 1981; Chediya *et al.*, 1986).

Fusulinids comprise three biozones: *Misellina parvicostata* biozone, *Misellina ovalis-Armenina* biozone and *Cancellina cutalensis* biozone (Leven, 1981; Chediya *et al.*, 1986).

Angiolini *et al.* (in press) collected new fusulinids, foraminifers and conodonts. Fusulinids are mainly represented by *Misellina termieri*, *Misellina* sp., *Neofusulinella* ex gr. *giraudi*, *Parafusulina* cf. *dzamantalensis*, *Yangchienia* cf. *compressa* and primitive species of *Cancellina.*

The majority of the smaller foraminifers (neoendothyrins, palaeotextulariids, globivalvulinids, miliolates and nodosariates) are well known, but the FO (First Occurrence) of *Dagmarita, Graecodiscus*, and *Retroseptellina*? is noticeable. There are also interesting dasycladaceans (*Gyroporella*? sp., *Velebitelleae* gen. sp.), algospongia (*Efluegelia johnsonii*, *Stacheoides* sp.), classical microproblematica (*Archaeolithoporella hidensis* and *Tubiphytes obscurus*), echinoderms, brachiopods, bivalves.

Deep water ostracodes and conodonts are also present. Conodont will be discussed further in the text.

Paleoenvironment

Sedimentary structures (laminations and gradation; beds with erosional base, channelized bodies and slumpings) indicate that the formation was deposited below the storm wave base along a slope. Microfacies analysis of the calcarenites confirms this depositional setting, comprising coarse bioclastic packstones with allochthonous foraminifers, undetermined bioclasts and algal lumps, which are all highly abraded and fragmented indicating they have been transported and resedimented along the slope from a nearby carbonate platform. They are mixed with an autochthonous fauna of bivalves, brachiopods, echinoderms and lagenids, which are typical of slope settings.

Age

According to Leven (1981) and Chediya *et al.* (1986), the lower part of the formation contains fusulinids of late Bolorian age (figs. 31 and 32). Fusulinids and ammonoids in the middle and upper parts of the Kubergandy Formation characterize the Kubergandian Stage, with ammonoids in particular correlating with the assemblage of the Roadian stratotypes. Our new data instead suggest that the base is early Kubergandian in age, based on the fusulinids occurring in TJ37. The middle-upper part of the formation can be late Kubergandian, however fusulinids in TJ14-17 lack the typical representatives of early Murgabian age.

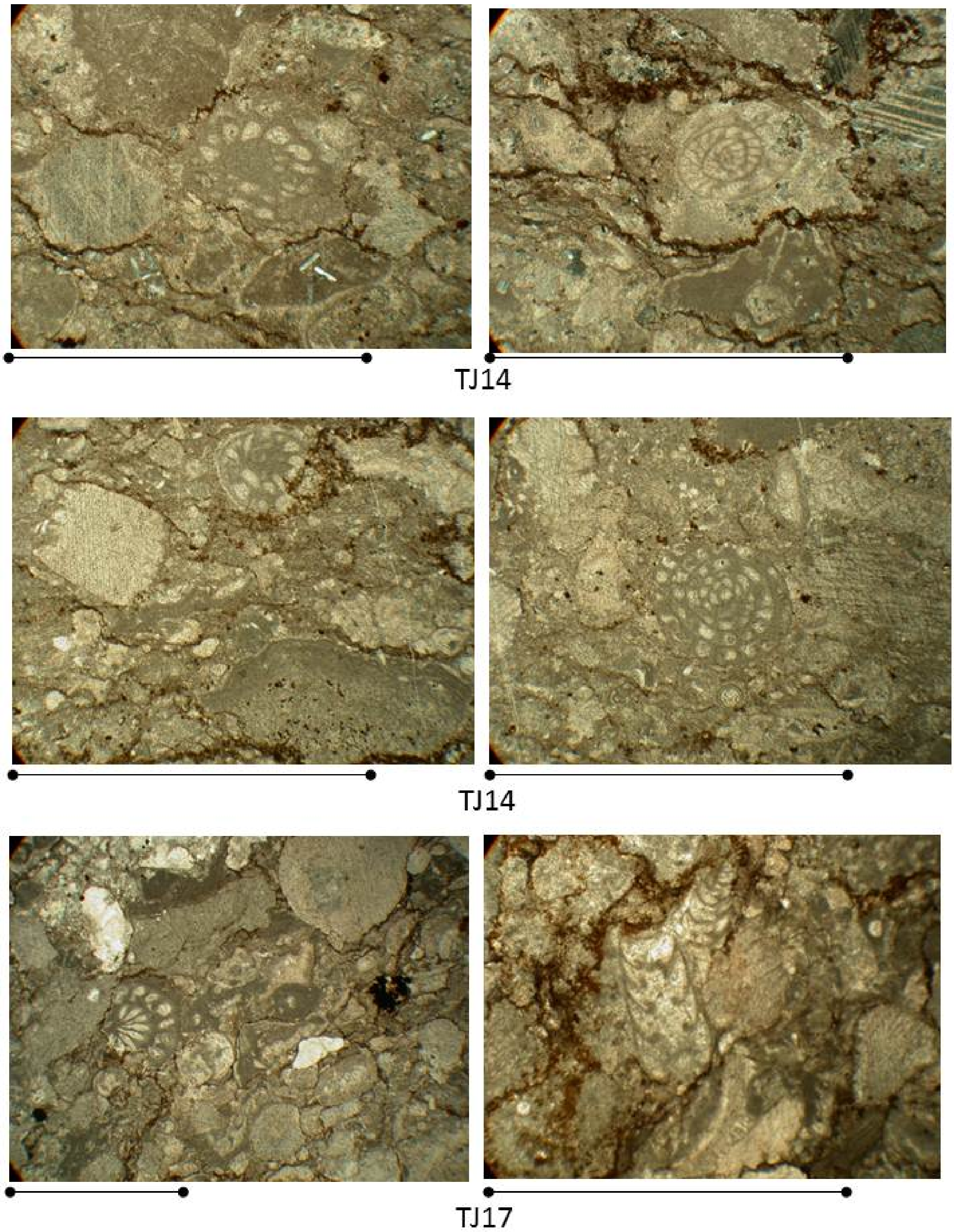

Fig. 31. Fusulinids (*Neofusulinella* ex gr. *giraudi* and *Cancellina* sp.) and foraminifers (*Climacammina* sp.) of the Kubergandy Formation (from Angiolini *et al.*, 2011). Scale bar 2 mm.

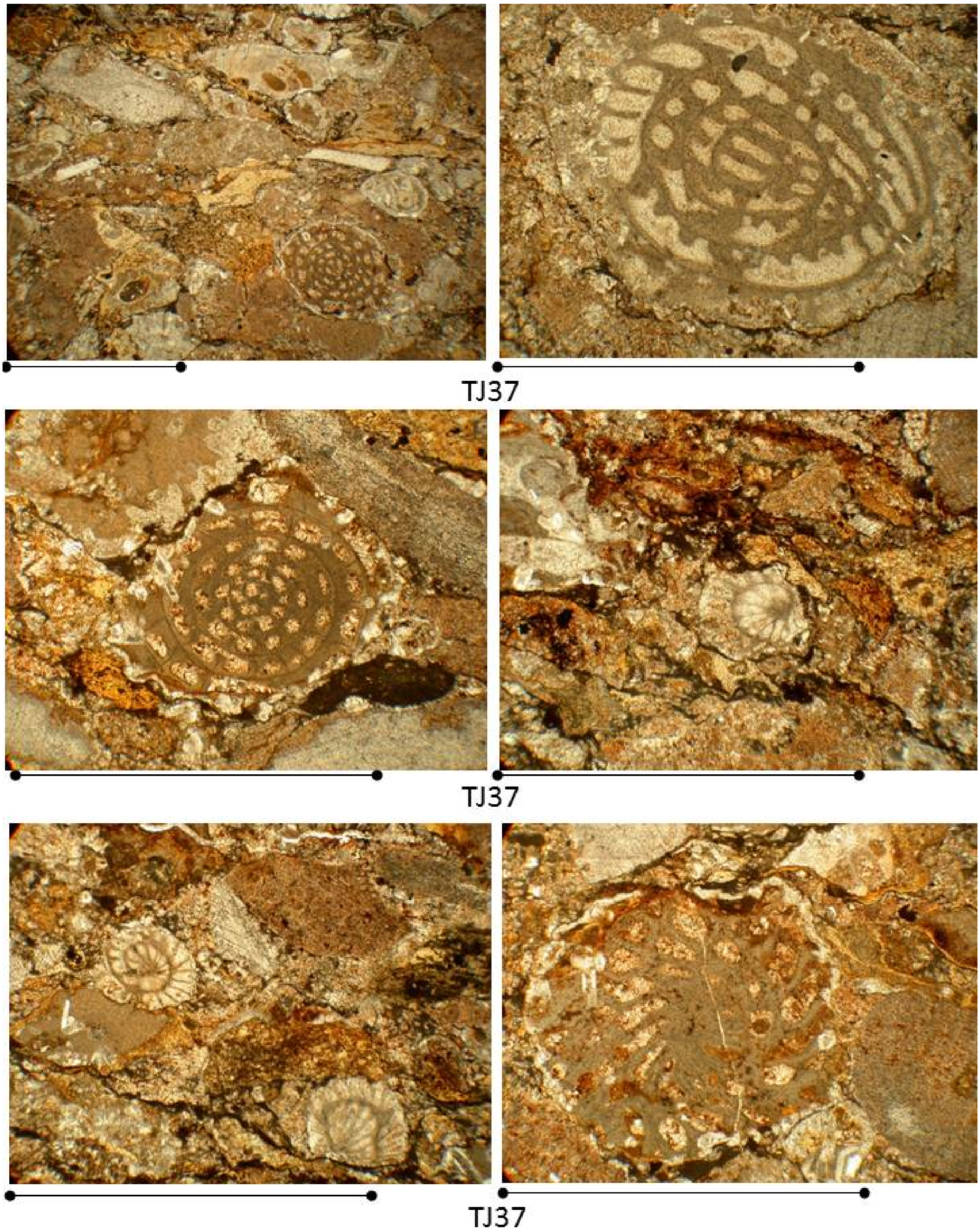

Fig. 32. Fusulinids (*Neofusulinella* ex gr. *giraudi* and a relatively primitive *Cancellina)* at the base (TJ37) of the Kubergandy Formation (from Angiolini *et al.*, 2011). Scale bar 2 mm.

Gan Formation

This formation has been studied during the DARIUS Project by Angiolini *et al.* (2012) and description of lithology, fossil content, paleoenvironment reconstruction and age are from this report.

The Gan Formation was introduced by Leven (1958) for a succession of turbiditic and micritic limestones and cherty siltstones. The formation has been traditionally divided into several units: Agalkhar, Dhzamantal, Deirin, Karasin and Kutal, already recognized by Dutkevich (1937).

Angiolini *et al.* (2011, 2012) have measured and sampled two detailed stratigraphic sections in the Gan Formation: the Kubergandy type section and the Kutal 2 section for a total thickness of 154 and 198 meters respectively. The latter section is very close to the Dzhamantal section, the lectostratotype for the Murgabian Stage of the Tethyan Scale (Leven, 1967, 1981), but Angiolini *et al.* (2011, 2012) discarded it because is strongly affected by faults and faults.

The boundary with the underlying Kubergandy Formation is drawn at the appearance of diffuse chert nodules. Angiolini *et al.* (2011, 20012) decided not to follow the subdivision of the formation into members, as there is a considerable lateral lithological variability. Distinctive are however the conglomerates (Kutal unit) at the top of the formation.

Lithology

The lower part of the formation consists of cherty bioclastic limestones (mostly fine calcarenites), cherts and greenish shales with a greater amount of volcaniclastic ashes with respect to the formation below; intercalation of conglomerates, channelized beds and slumpings occur (fig. 33).

The middle part is dominated by colored volcaniclastic ashes interbedded with thin bedded, nodular limestones and cherts (fig. 34). This part is more distinct in the Kubergandy section than in the Kutal 2 section (fig. 30).

Two distinct microfacies have been recognized in the limestones: 1) a microfacies of bioclastic packstones, finer than those of the Kubergandy Formation, containing foraminifers, peloids, thin shelled bivalves, and echinoderms; 2) a microfacies of wackestones/packstones with radiolarians, sponge spicules and thin shelled bivalves.

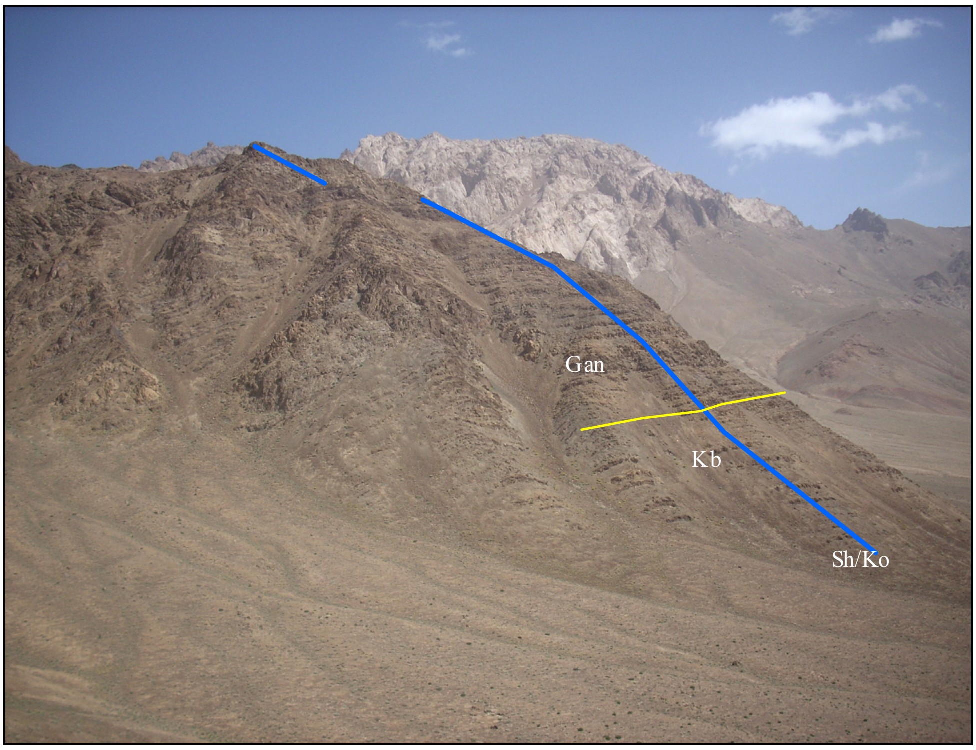

Fig. 33. Kutal 2 section (from Angiolini *et al.*, 2011). Blue line: Kutal2 section. Yellow line: limit between Kubergandy (Kb) and Gan formations.

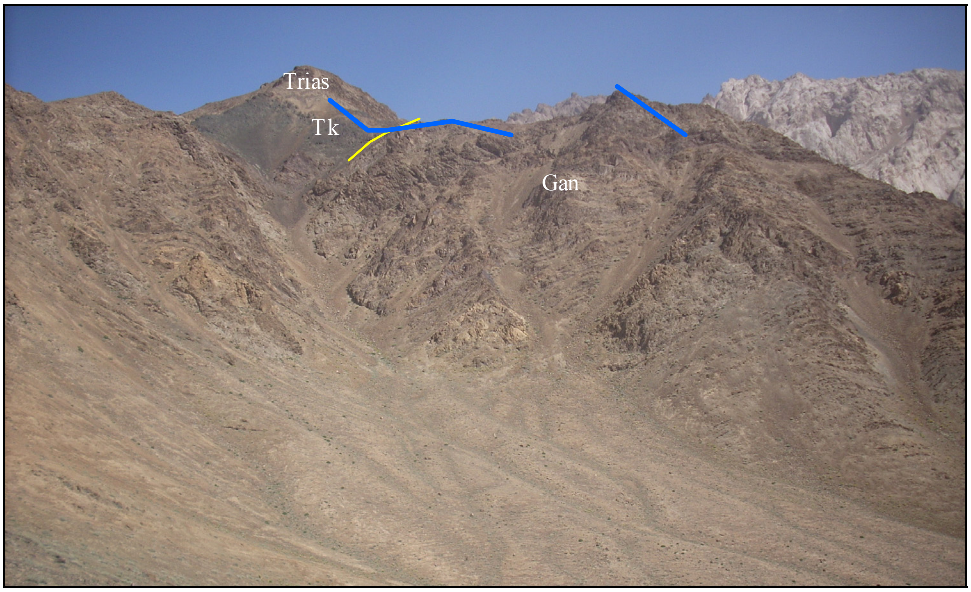

Fig. 34 Kutal 2 section (from Angiolini *et al.*, 2011). Blue lines: Kutal2 section. Yellow Line: limit between Gan and Takhtabulak formations.

The upper part of the formation consists of very thick polymict conglomerates, which are clast-supported, immature, poorly sorted, with both spherical and elongated, rounded and angular clasts of chert, limestone, volcaniclastic rocks which are from 3 to 40 cm-wide. In the lower part of the interval the conglomerates form lenticular bodies with erosive bases, cannibalizing each other; in the upper part they are better organized in meters thick beds. Sporadic intercalation of volcanoclastic ashes, thin bedded limestones (wackestones with radiolarians, sponge spicules and pelagic bivalves) and slumpings are also present. In the Kutal2 section the conglomerates are less thick and the Gan Formation ends with about 30 meters of cherty bioclastic limestones (calcarenites and calcirudites; subordinate calcilutites) and volcaniclastic ashes.

Fossil content

The Gan Formation is characterized by the occurrence of fusulinids, foraminifers, conodonts, algae (Permocalculus sp.), pelagic bivalves,ostracods, echinoderms and Tubiphytes ex gr. Obscures.

Leven (1967) and Chediya *et al.* (1986) reported the occurrence of fusulinids from the Gan Formation both along the Kubergandy and the Kutal 2 sections. From the lower middle part of the section there were species of *Armenina*, *Praesumatrina*, *Verbeekina* and *Neoschwagerina simplex*. 10- 15 meters above there are specimens of *N. schuberti*, *N.* ex gr. *craticulifera*, *Sumatrina brevis* and species of *Afghanella*, *Armenina*, and *Verbeekina*. While at the base of the conglomerates there are specimens of *Dunbarula* ex gr. *schubertellaeformis, N.* ex gr. *margaritae*, and *S. annae*. Primitive Yabeina (*Y.* ex gr. *opima* and *Y. archaica*, two species which are probably synonymous) and species of *Lantschichites*, *Neoschwagerina*, and *Yangchienia* are reported from the conglomerates.

Analysis carried on new samples collected by Angiolini *et al.* (2011, 2012) shows that fusulinids and foraminifers fauna at the base of Gan Formation in Kutal 2 section comprise *Climacammina* sp., *Endothyra* sp., *Eotuberitina reitlingerae*, *Geinitzina* aff. *spandeli*, *Globivalvulina* sp., *Hemigordiellina* sp., *Pachyphloia ovata*, *Polytaxis* sp., *Postendothyra* sp., *Pseudodoliolina*? sp., and *Schubertetella* ex gr. *melonica*; at the top they include *Bidagmarita* sp., *Codonofusiella* sp., *Globivalvulina* sp., *Midiella* sp., *Multidiscus*? sp., *Neogeinitzina* sp., *Pachyphloia ovata*, *Rectostipulina quadrata*, and *Reichelina pulchra*.

In 1986 Movshovich reported strong reworked conodonts from the Upper Kubergandian of SE Pamir: *Mesogondolella idahoensis*, *M. intermedia, P. nassichuki* and *Gullodus siciliensis*. According to Kozur *et al.* (1994) only the later form occurs in the Middle Permian of Sicily: all other species are typical world-wide distributed guide forms for the Cathedralian (*M. idahoensis*) and early Cathedralian (*M. intermedia*) or occur in the lower Bolorian of SE Pamir (*P. nassichuki*) (Kozur *et al.*, 1994). Reimers (1991) reported the loser Bolorian *N. leonovae* from the Early Kubergandian of Darvaz but Kozur *et al.* (1994) coinsider it to be probably reworked.

Paleoenvironment

The main facies of the Gan Formation indicate deposition and resedimentation along a slope, but in a more distal setting than that recorded by the underlying Kubergandy Formation, and a remarkable increase in volcanic activity. As in the Kubergandy Formation, the bioclasts, the fusulinids and the conodonts are highly abraded and fragmented, indicating considerable transport.

The maximum depth is recorded by the radiolarian and sponge wackestones intercalated to cherts and colored volcaniclastic ashes, just below the conglomerates.

The thick conglomerate bodies indicate a marked reprisal of tectonic activity possibly related to syn-depositional block-faulting and formation of debris flow along steep fault scarps, during a major regression which occurred at the end of the Capitanian.

They are thus correlatable to similar debris flows which occur in the late Middle Permian Kundil Formation of Karakorum, Pakistan (Gaetani *et al*., 1995). This suggests that this tectonic activity coupled with regression is a global event recognizable in the most of the Cimmerian blocks.

Age

The lower-middle part of the formation has been considered to be Murgabian to Midian (=late Roadian -Capitanian) in age (Chediya & Davydov, 1980; Chediya *et al*., 1986). The conglomerates (Kutal Member, figs. 35 and 36) are poor in fusulinids and has been conventionally placed in the Midian, even if a Late Permian age could not be excluded (Leven, 1998).

Fig. 35. Conglomerates above the volcanoclastic interval at 205-212 meters above the base of the Kubergandy section (from Angiolini *et al.*, 2011).

Fig. 36. Conglomerates 252 m above the base of the Kutal2 section (from Angiolini *et al.*, 2011).

Takhtabulak Formation

This formation has been studied during the DARIUS Project by Angiolini *et al.* (2012) and description of lithology, fossil content, paleoenvironment reconstruction and age are from this report.

The Takhtabulak Formation was established by Dutkevich (1937) and later subdivided into three units by Grunt & Dmitriev (1973).

Angiolini *et al.* (2011, 2012) have measured and sampled two detailed stratigraphic sections in the Takhtabulak Formation: the Kutal 2 section (fig. 37) and Kurystyk section (fig. 39) for a total thickness of 110 and 119 meters respectively.

The boundary with the underlying Gan Formation has been drawn at an ash bed (frequently covered) which marks the disappearance of limestones (fig. 37). In the Kutal2 section the formation starts with a huge olistrostrome enclosing meter-sized boulders of basaltic lavas and limestones covered by green volcaniclastic sandstones, whereas in the Kuristyk section the base of the formation consists of volcaniclastic sandstones.

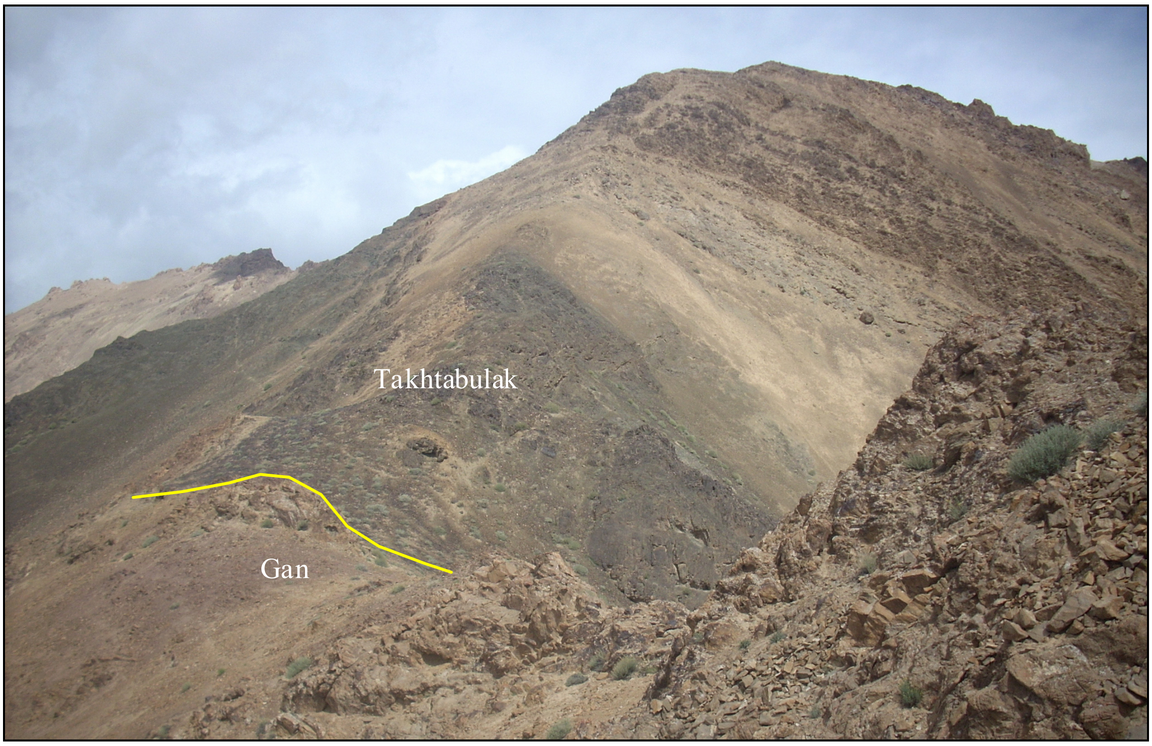

Fig. 37. Kutal 2 section: top of the Gan Formation and base of the Takhtabulak Formation. Yellow line: limit between Gan and Takhtabulak formations (from Angiolini *et al.*, 2011).

Lithology

Most of the formation is made of dark green volcaniclastic sandstones, shales and subordinate conglomerates, with sedimentary structures as parallel lamination and gradation; rare intercalations of sandy calcarenites occur.

At the base of the formation in the Kutal 2 section, meter-sized boulders of basaltic lavas and limestones are embedded in volcaniclastic sandstones (fig. 37).

In the middle part of the formation in the Kuristyk section and at Mudzubulak (fig. 39), meter-sized boulders of stratified bioclastic limestones and algal, coral, and sponge biostromes occur.

Microfacies analysis of the bioclastic limestones indicates that they are coarse packstones with foraminifers as *Colaniella* sp., Rugosa and tabulate corals, sphinctozoans, brachiopods, echinoderms, ostracods and carbonate and volcanic extraclasts.

Fossil content

The intercalation of bioclastic limestones and the biostrome boulders embedded in the formation contains a very rich biota of fusulinids, small foraminifers (*Colaniella* sp.), algae, brachiopods, bivalves, echinoderms, bryozoans, tabulate and rugosa corals and sponges (sphinctozoans) (fig. 38).

Age

According to Grunt & Dmitriev (1976), fusulinids and brachiopods in the lower part of the formation suggest a late Wuchiapingian-early Changsingian age. Moreover the foraminifer genus *Colaniella* Likharev is in agreement with this attribution being known from the late Midian to the Changhsingian.

Kozur *et al.* (1994) reported the conodont *Clarkina subcarinata* (Sweet, 1973) from the upper unit indicating a Changhsingian age.

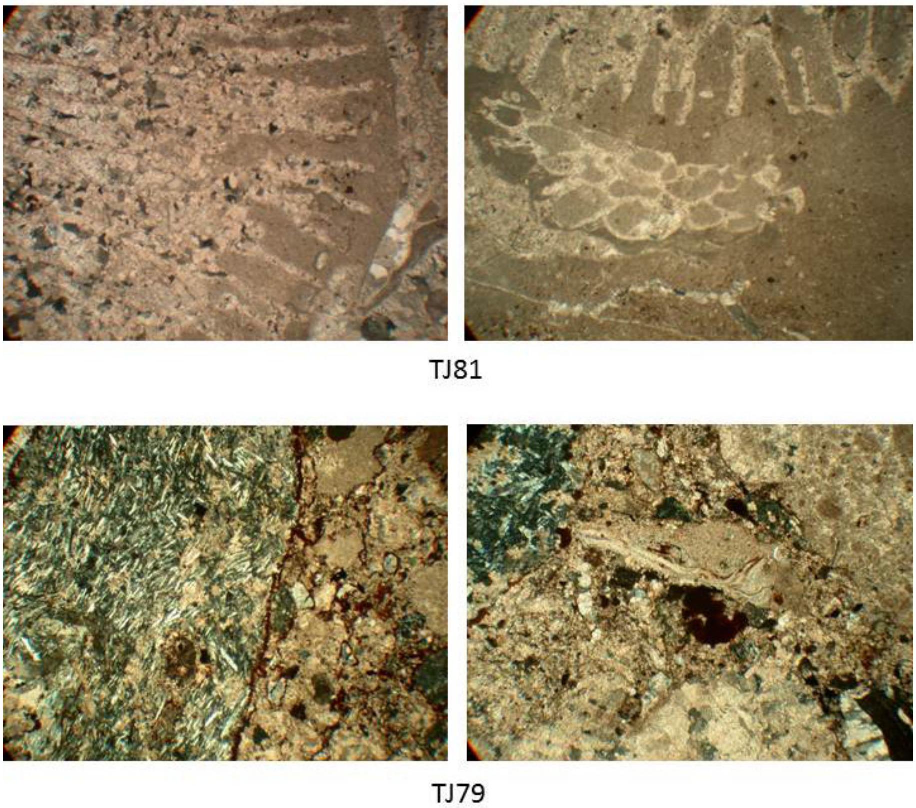

Fig. 38. Microfacies of the coral-sphinctozoan boundstones of the Takhtabulak Formation (from Angiolini *et al.*, 2011). Note volcanic extraclasts in TJ79.

Palaeoenvironment

Sedimentary structures in the volcaniclastic sandstones and conglomerates are still indicative of resedimentation along a slope. Tectonic activity should have been intense, with slope instabilities causing resedimentation of meter-sized olistoliths of bioclastic limestones, biostromes and basaltic lavas.

There are several features which suggest that both the bioclastic limestone boulders and the biostromes are olistoliths transported along the slope. The limestone boulders are in fact stratified discordantly to the S0 of the formation. The build-ups are not growing on the sandstones of the slope as suggested by Grunt & Dmitriev (1973), as most reef organisms are in life position but they are discordant with respect to the polarity of the succession.

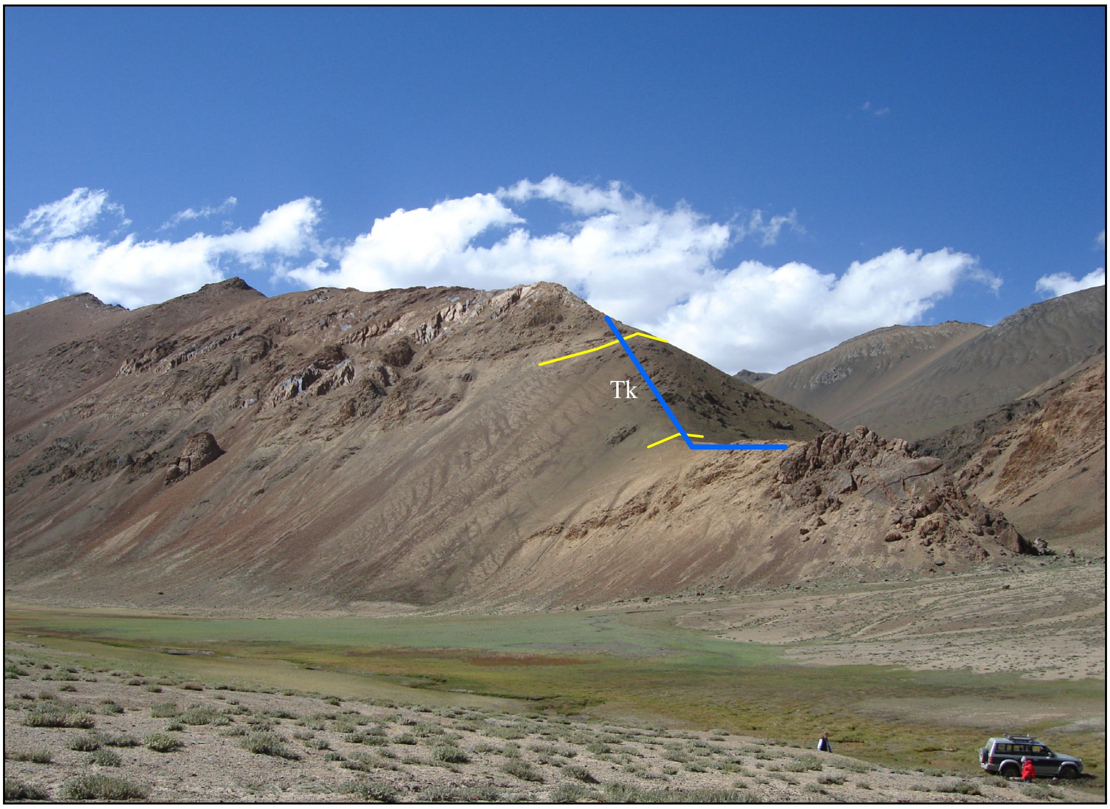

Fig. 39. Kurystyk section (from Angiolini *et al.*, 2011). Blue line: Kuristyk section. Yellow lines: limits of the Takhtabulak (Tk) Formation.

Kurteke Formation

This formation has been studied during the DARIUS Project by Angiolini *et al.* (2012) and description of lithology, fossil content, paleoenvironment reconstruction and age are from this report.

The Kurteke Formation was introduced by Leven (1967) for a succession of bioclastic and massive microbialitic limestones.

Angiolini *et al.* (2011) have measured the Kurteke 1 section at Kurteke (fig. 40) on the right hydrographic side of the valley which is the second left inflow of the Kurteke River (type section of Leven, 1967). The total thickness of the formation is 86 meters.

At Kurteke 1 (fig. 40) the base is not exposed, the talus covering the very few and scanty outcrops of the Tashkazyk Formation, which however is reported as outcropping by the Russian authors.

Lithology

The lower part of the Kurteke Formation consists of partly covered red bioclastic limestones with crinoids and fusulinids which crop out discontinuously: they pass to cherty bioclastic calcarenites mostly in 15-25 cm-thick beds with rare volcaniclastic ashes. These grade in turn to massive limestones locally microbialitic, more bioclastic towards the top. At the top, the massive limestones are eroded by a laterally discontinuous conglomerate and pass to a mostly covered succession which according to the Russian authors (e.g. Leven, 1967; Chediya & Davydov, 1980; Grunt & Dmitriev, 1973) contains a laterite and then black limestones of Triassic age. This succession, however, is laterally cut by a thurst surface stacking the Gan Formation on top of the measured section. Along the thrust surface a foliated cataclasite is present.

Microfacies analysis shows that the formation comprises at the base grainstones and packstones with fusulinids, small foraminifers, echinoderms, brachiopods, algal lumps and bryozoans. The microfacies associated to the microbialites comprises peloidal packestones with brachiopods, whereas in the upper part there are again bioclastic packstones with fusulinids, small foraminifers, algal lumps, and echinoderms.

Fig. 40. Kurteke section (from Angiolini *et al.*, 2011). Blue lines: Kurteke 1 section.

Fossil content

The formation contains fusulinids (*Chusenella*, *Praesumatrina*, *Cancellina* ex gr. *neoschwagerinoides*) (figs. 41 and 42), small foraminifers (*Climacammina* sp., *Tetrataxis* sp., *Graecodiscus* sp., *Neoendothyra* sp., *Earlandia* sp. *Palaeotextularia* sp., *Tuberitina* sp., large hemigordiids; lagenids are rare), Algae, echinoderms, brachiopods (species of the genera *Martinia, Overtonina, Retimarginifera, Costiferina, Magniplicatina, Boloria, Labaia, Spiriferella*), bryozoans and *Tubiphytes* sp.

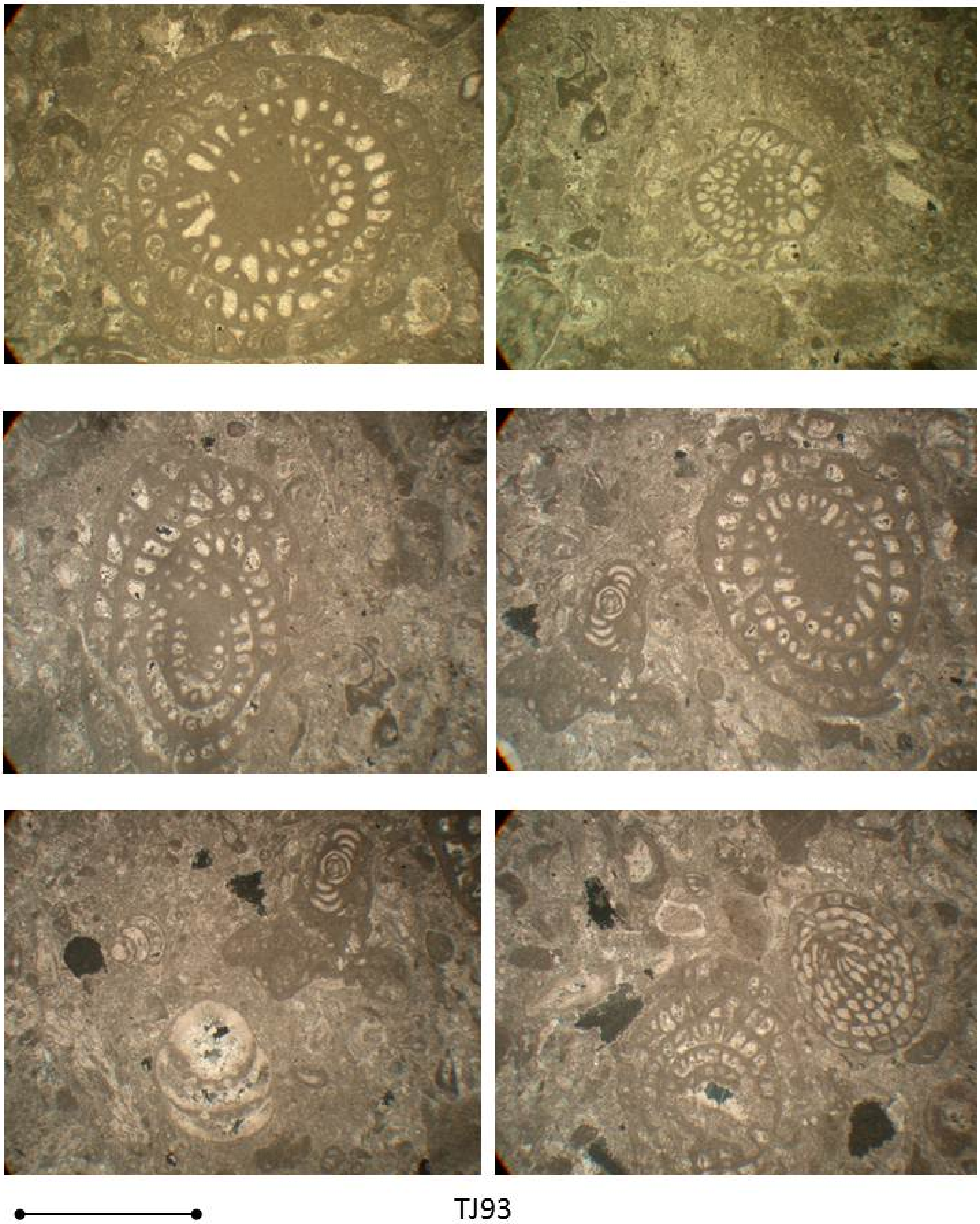

Fig. 41. Fusulinids (*Chusenella* sp., *Praesumatrina* sp., *Cancellina* ex gr. *neoschwagerinoides)* and foraminifers (*Climacammina* sp., *Hemigordius* sp.) at the base (TJ93) of the Kurteke Formation (from Angiolini *et al.*, 2011). Scale bar 2 mm.

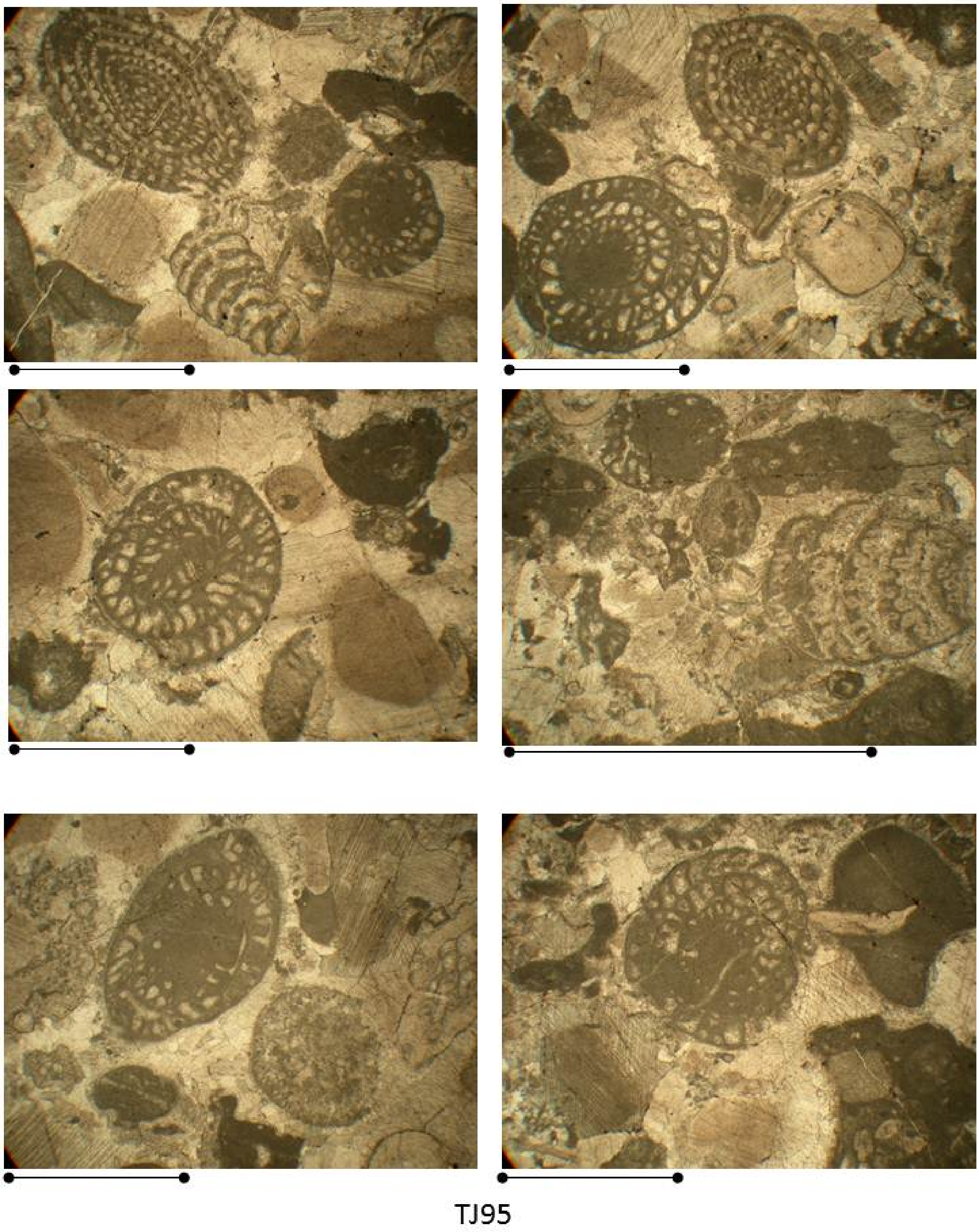

Fig. 42. Fusulinids (*Chusenella* sp., *Praesumatrina* sp., *Cancellina* ex gr. *neoschwagerinoides*) and foraminifers (*Climacammina* sp.) at the base (TJ95) of the Kurteke Formation (from Angiolini *et al.*, 2011). Scale bar 2 mm.

Palaeoenvironment

The Kurteke Formation represents several carbonate platform environments from the inner shelf with microbialites and peloidal packstones to higher energy platform margin settings where bioclastic shoals were deposited.

Age

The Kurteke Formation have been reported to span the Middle-Late Permian time interval by the Russian authors (Leven, 1967; Chediya & Davydov, 1980), based on fusulinids.

New data from fusulinids collected by Angiolini *et al.* (2011, 2012) allow to better refine its age, especially for the base, which is constrained to the Roadian (= late Kubergandian).

In SE Pamir area I have studied conodont samples from four section: Kubergandy type section, Kutal 2 section, Kurteke section and Kurystyk, in order to define the age of these section, to correlate conodonts with fusulinids and to study conodont assemblage of this paleoprovince.

4.2 Kubergandy type section

Thirty- one conodont samples were studied for this section (see Appendix I, tables 6 and 7). All specimens shows a CAI comprised from 4,5 and 5, pointing to a thermic gradient that ranges from 250° to 480 °C.

Samples TJ1, TJ2, TJ3, TJ4, TJ5, TJ6, TJ7, TJ8,TJ9, TJ10, TJ11, TJ12, TJ13, TJ15, TJ16 and TJ17 are from the Kubergandy Formation (fig. 43).

In sample TJ1 the presence of *Mesogondolella siciliensis* (Kozur, 1975) and *Mesogondolella idahoensis idahoensis* (Youngquist, Hawley & Miller, 1951) point to a Kungurian age. The same fauna was found in sample TJ6, while in samples TJ4 and TJ5 only *M. idahoensis* was recovered.

M. siciliensis is a long- range specimen which ranges from Kungurian to Upper Wordian/Lower Capitanian: Kozur designated this species a Guadalupian index taxon (Kozur 1988, 1989b, Kozur et al. 2001), but in South China, Texas and Oman it appears in the upper Kungurian (Henderson & Mei 2003). While *M. idahoensis* is restricted to Upper Kungurian (Ning *et al.*, 2010). The presence of genus *Mesogondolella* is coherent with the reconstruction of a slope environment for the base of the Kubergandy section (Angiolini *et al.*, in press).

In sample TJ7 a rich fauna composed by several specimens of *Pseudohindeodus ramovsi* Gullo & Kozur, 1992, *Hindeodus excavatus* (Behnken, 1975), *Pseudohindeodus* sp. A and *Sweetognathus subsymmetricus* Wang, Ritter and Clark, 1987 is present together with the species *M. siciliensis.* All this species are long-ranging species (Kozur, 1995; Wang, 1994; Wardlaw, 2000) that lived from Upper Kungurian/Roadian to Lower Capitanian (*S. subsymmetricus*) or Capitanian (*P. ramovsi*).

Sample TJ8 contains the same association of sample TJ1 with the species *M. siciliensis* and *M. idahoensis*. Several fragments and ramiforms are still present. The age of this sample is Kungurian for the presence of *M. idahoensis*.

A similar fauna to sample TJ7 was found in sample TJ9 were we found the species *H. excavatus*, *M. siciliensis* and *Mesogondolella idahoensis lamberti* Mei & Henderson, 2002*,* a Kungurian species (Mei & Henderson, 2002; Ning *et al.*, 2010).

Preservation of specimens in sample TJ10 is bad: they are broken and encrusted but is possible to recognize the species *M. siciliensis* together with few fragments and ramiforms.

Sample TJ11 shows the same bad preservation of the previous sample TJ10, but there are more specimens: the co-occurrence, in sample TJ11, of the species *H. excavatus* and *M. siciliensis* point to a Kungurian age for this sample.

In sample TJ12 there is a rich fauna composed by *Mesogondolella pingxiangensis* Zhang, Henderson & Xia, 2010, *M. siciliensis* and *Sweetognathus* cf. *bicarinum* pointing to an Upper Kungurian/ Roadian age for the co-occurrence of the species *M. pingxiangensis* and *S.* cf. *bicarinum* (Ning *et al.*, 2010; Wardlaw, 2000).

Unfortunately, samples TJ15, TJ16 and TJ17 contains only few, broken specimens of *M. siciliensis*.

According to conodonts all this samples are Kungurian in age, in fact all the specimens founded ranges from Kungurian to Roadian and, for the case of *M. siciliensis,* to Wordian. Samples TJ12 and TJ17 are considered to be Roadian in age thanks to the FO of *Cancellina*, according to Leven (1967) and Angiolini *et al.* (in press).

In this section, the base of Kubergandy Formation is Kungurian according to conodonts and Bolorian for the Tethyan timescale based on fusulinids.

Samples TJ18, TJ19, TJ20, TJ21, TJ22, TJ24, TJ25, TJ27, TJ28, TJ29, TJ30, TJ31, TJ32, TJ33 and TJ34 are from Gan Formation (figs. 43 and 44).

Unfortunately, sample TJ18 is barren.

In samples TJ19 and TJ20 there were only fragments that can be classified as *Mesogondolella* sp.

A monospecific fauna of *M. siciliensis* is present in sample TJ21. The long range of this species does not allow us to strictly constrain the age of this sample.

Conodonts in sample TJ22 are better preserved and the association is composed by transitional forms *Sweetognathus guizhouensis*/ *S. subsymmetricus* and *M. siciliensis*. Transitional forms *S. guizhouensis*/ *S. subsymmetricus* point to a middle Kungurian age for this sample (Shen *et al.*, 2013).

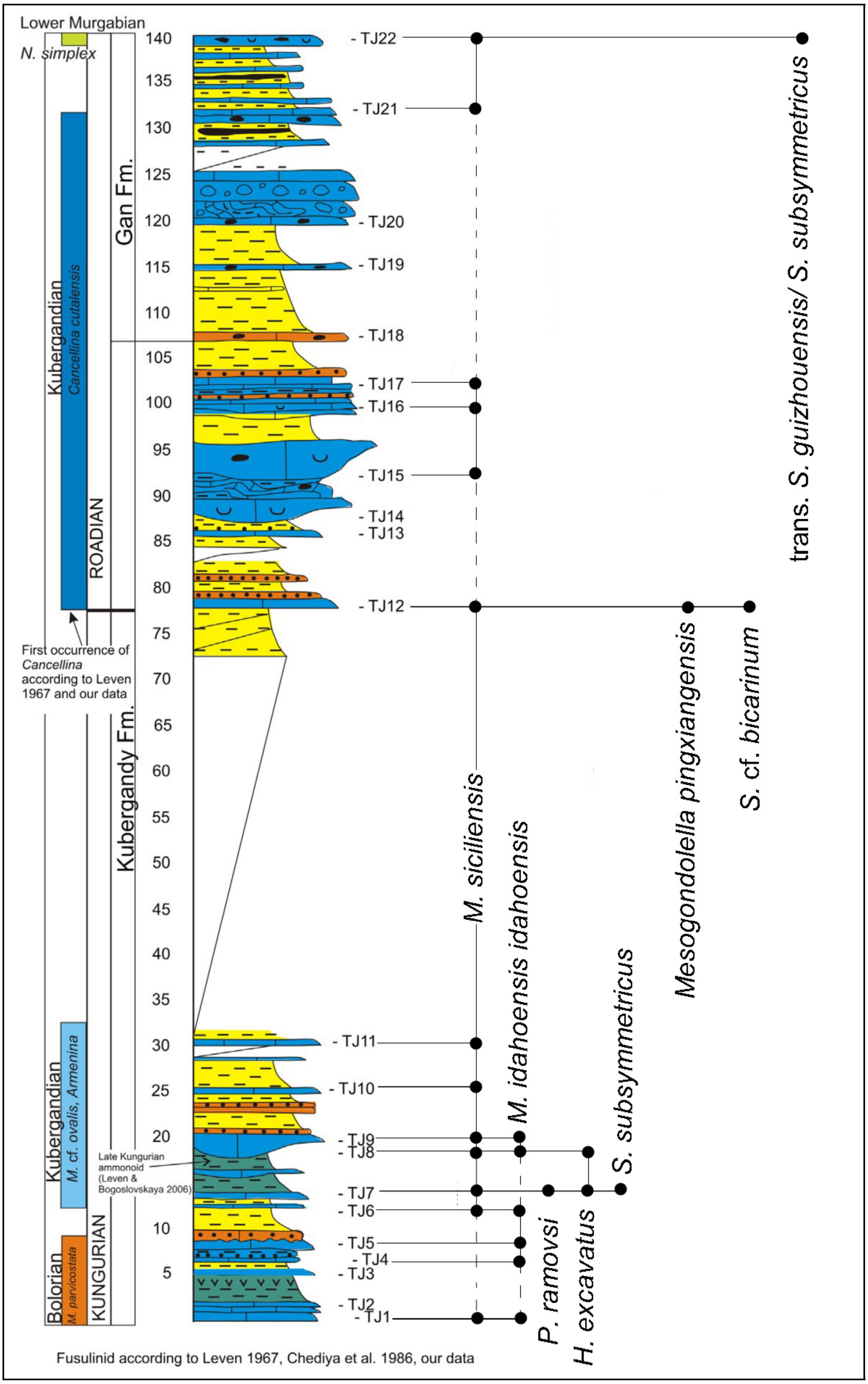

Fig. 43. Range chart of conodonts with fusulinids data from Kubergandy type section, SE Pamir (part1). (Stratigraphic log from Angiolini *et al.*, in press).

Samples TJ 24 and TJ 25 contains a monospecific fauna composed by several specimens of *M. siciliensis*.

Sample TJ26 contains a rich fauna composed by transitional forms *Sweetognathus subsymmetricus/ Sweetognathus iranicus hanzongensis*, *M. siciliensis* and *M. pingxiangensis*. The co- occurrence of those specimens point to an upper Kungurian/ Lower Roadian age.

In sample TJ27 conodonts *M. siciliensis* and *M. pingxiangensis* are present but the preservation of the specimens is really bad.

Unfortunately sample TJ28 is barren.

In sample TJ29 is remarkable the presence of *Sweetognathus fengshanensis* Mei & Wardlaw, 1998 and *M. siciliensis* and *Jinogondolella altudaensis* (Kozur, 1992), the presence of both *S. fengshanensis* and *J. altudaensis* Point to a Capitanian (Upper Guadalupian) age (Mei *et al.*, 1998; 2002). *J. altudaensis* is typical of pelagic shallow-water facies or intraplatform basins (Wardlaw, 2000) and *S. fengshanensis* is a shallow-water species (Jin *et al.*, 2003).

Sample TJ30 contains a rich conodont fauna composed by *M. siciliensis, Jinogondolella aserrata* (Clark & Behnken, 1979), few specimens of transitional forms *M. siciliensis/ Mesogondolella omanensis, Hindeodus wordensis* and a fragment of *Sweetognathus* sp. Those species still point to a Capitanian age because of the presence of *J. aserrata* and *M. omanensis* (Shen *et al.*, 2013; Kozur & Wardlaw, 2010).

In sample TJ31 several specimens of *J. aserrata* are present and there are few specimens very slightly serrated. The species *H. wordensis* is still present. The age of this sample is still Capitanian.

Conodonts from sample TJ32 are broken and identified as fragments of *Mesogondolella* sp. Unfortunately, sample TJ33 is barren.

In sample TJ34 almost all the specimens are juveniles, making the identification very hard. One specimen of *P. ramovsi* is present together with the species *J. altudaensis*.

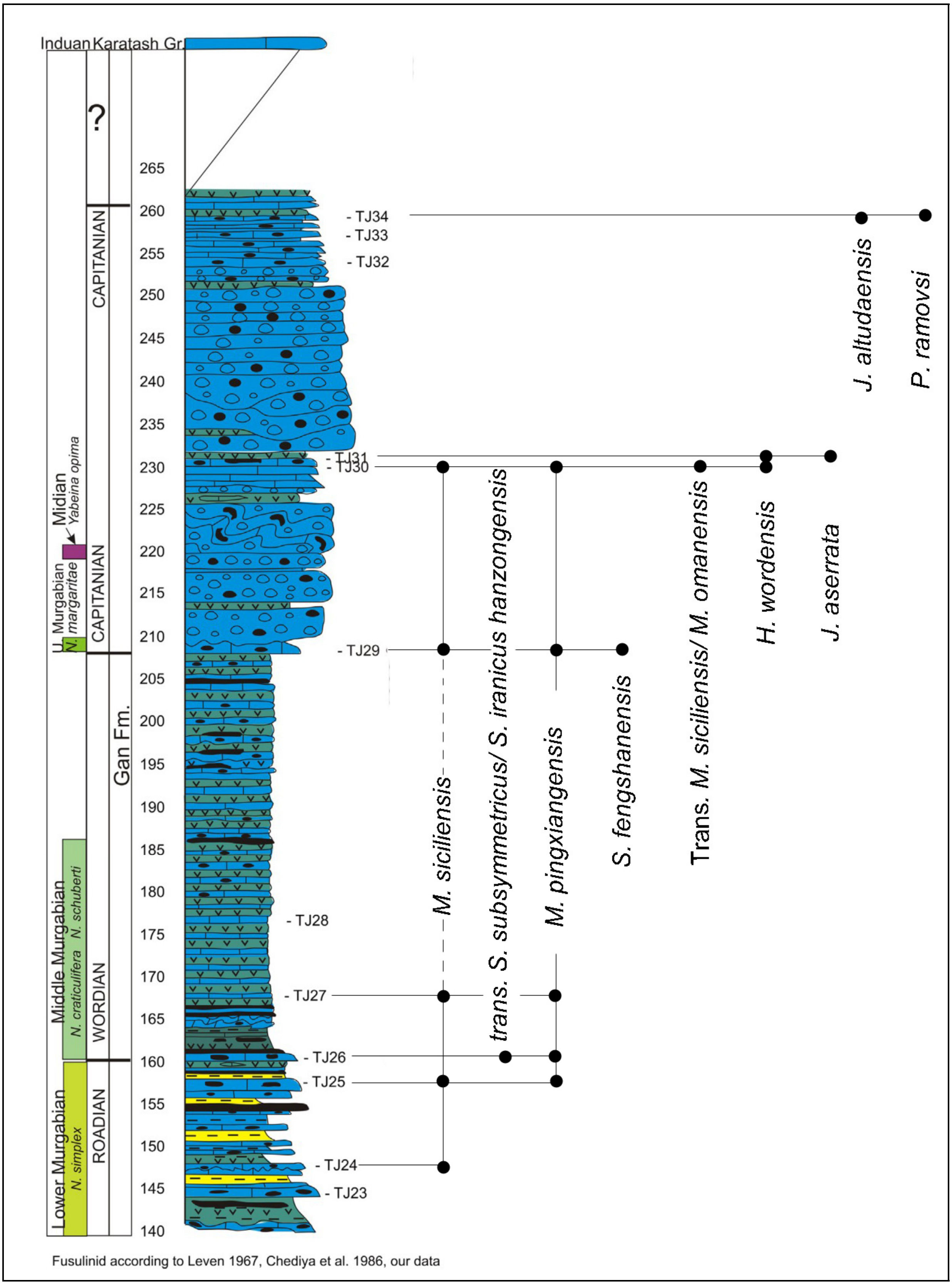

Fig. 44. Range chart of conodonts with fusulinids data from Kubergandy type section, SE Pamir (part. 2). (Stratigraphic log from Angiolini *et al.*, in press).

The presence of *J. altudaensis* point to a middle- upper Capitanian age (Shen *et al.*, 2013).

According to conodonts the age of this section ranges from Kungurian to Capitanian.

4.3 Kutal 2 section

For Kutal 2 section thirty- three conodont samples have been collected and studied (see Appendix I, table 7). All specimens shows a CAI comprised from 4,5 and 5, pointing to a thermic gradient that ranges from 250° to 480 °C.

Sample 35 is from the Shindy formation and contains only broken specimens that can be identified only a generic level as *Mesogondolella* sp.

Samples TJ36, TJ37, TJ38, TJ39, TJ40, TJ41, TJ42, TJ44, TJ45, TJ46, TJ47, TJ48, TJ49, TJ50 are from the Kubergandy Formation (fig. 45) (Appendix I, table 8).

In sample TJ36 is present one specimen of *Mesogondolella* sp.

Sample TJ37, unfortunately, is barren while sample TJ38 contains only one fragment. Fusulinids from samples TJ37 and TJ38 point to a Bolorian age because of the presence of *Misellina* sp. (Angiolini *et al.*, in press).

In sample TJ39 two fragments of *Mesogondolella* sp. are present. The same specimen is present in sample TJ40.

Sample TJ41 is barren.

In sample TJ42 I have found a slightly well preserved fauna respect to previous TJ39 and TJ40 samples with the presence of the species *M. idahoensis lamberti* that point to an Upper Kungurian/ Roadian age.

Sample TJ44 is barren.

In sample TJ46 few specimens of *M. idahoensis lamberti* are present. Several broken specimens of *M. idahoensis lamberti* are present in sample TJ47 together with species *M. siciliensis* and few ramiforms.

Sample TJ48, unfortunately, is barren while *M. idahoensis lamberti* is present once again in sample TJ49.

In TJ50 there are some specimens of transitional forms *Sweetognathus guizhouensis/ S. subsymmetricus* together with some broken *M. pingxiangensis* and *M. idahoensis lamberti.* The age of this fauna is Upper Kungurian.

Unfortunately, sample TJ51 is barren.

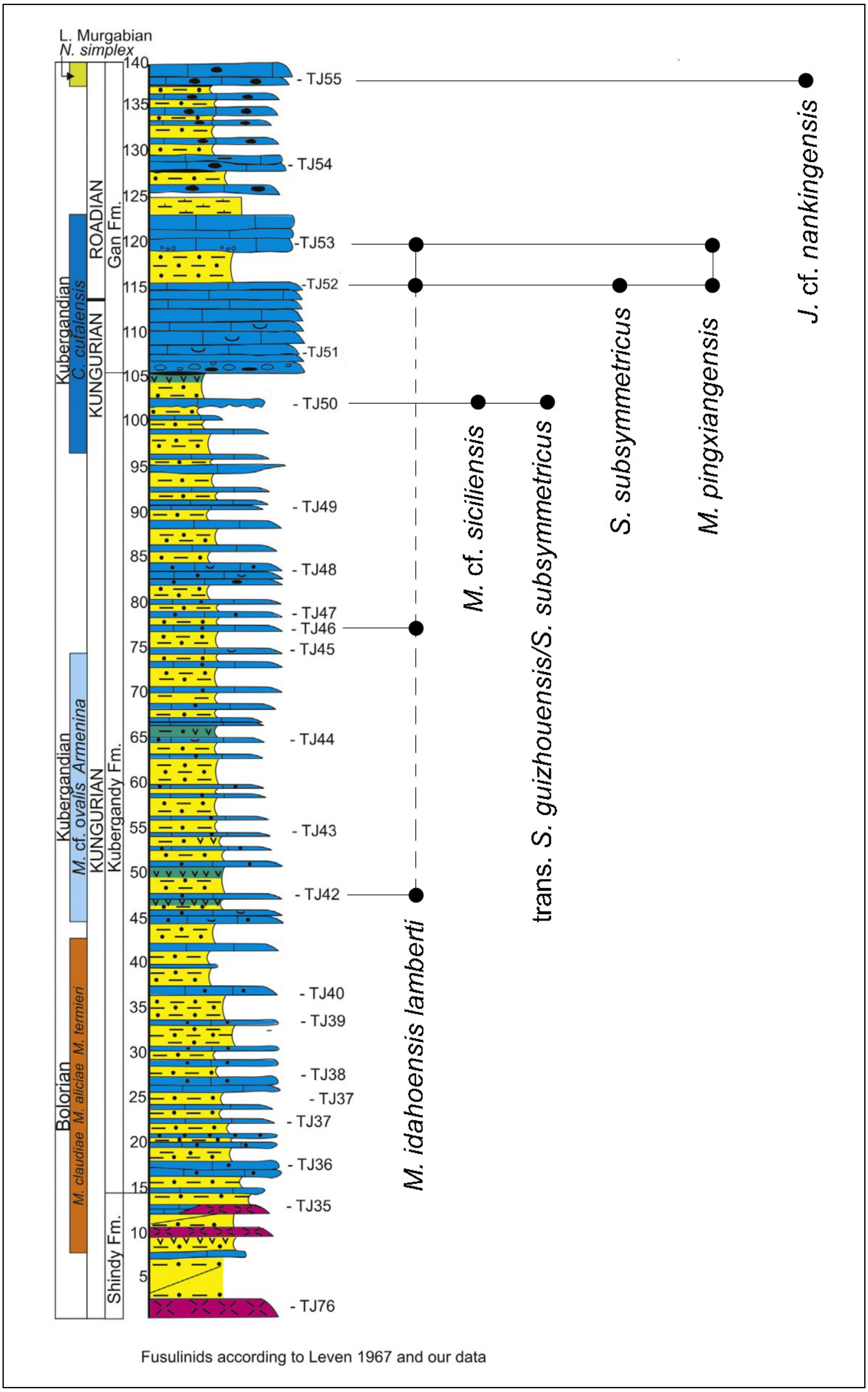

Fig. 45. Range chart of conodonts from Kutal 2 section, SE Pamir with fusulinids data (part 1). (Stratigraphic log from Angiolini *et al.*, in press).

Samples TJ52, TJ53, TJ54, TJ55, TJ56, TJ57, TJ58, TJ59, TJ60, TJ61, TJ62, TJ63, TJ65, TJ66, TJ67, TJ68, TJ69, TJ70, TJ71, TJ72, TJ73, TJ74 and TJ75 are from the Gan Formation (figs. 45 and 46) (Appendix I, table 9).

Preservation of specimens in sample TJ52 are similar to those of TJ50 whit a lot of tiny fragments. Specimens in this sample are *S. subsymmetricus, M. idahoensis lamberti* and *M. pingxiangensis*. This association point to a Roadian age because of the presence of *S. subsymmetricus*, which is Roadian in age (Metcalfe & Sone, 2008).

In Sample TJ53 the conodont association is composed by *M. pingxiangensis, M. idahoensis lamberti* and two specimens of *Sweetognathus* sp.

Unfortunately, no conodonts were found in sample TJ54.

In sample TJ55 was found the species *Jinogondolella* cf. *nankingensis*: in fact the morphology of this specimens is very close to *Jinogondolella nankingensis* (Ching, 1960) but there are no serrations. Shen *et al.* (2013) report the FO of *J. nankingensis* to be Roadian in age.

Sample TJ56 contains only fragments of *Mesogondolella* sp.

Sample TJ57 contains some specimens of *M. idahoensis* and *H. excavatus*, pointing to a Roadian age.

M. siciliensis and a juvenile specimen of *Hindeodus* sp. are present in sample TJ58, while in sample TJ59 only *M. siciliensis* is present.

Samples TJ60 and TJ61 are barren.

Specimens in sample TJ62 are poorly preserved and contains *Hindeodus* sp. and some fragments.

Conodont fauna in sample TJ63 is better preserved and contains specimens of *P. ramovsi, H. wordensis* and *Jinogondolella* cf. *postserrata*. This association is supposed to be Wordian in age according to the presence of *J.* cf. *postserrata* (Shen *et al*., 2013).

Sample TJ64 contains specimens of *J. altudaensis* and a juvenile of *Mesogondolella* sp.

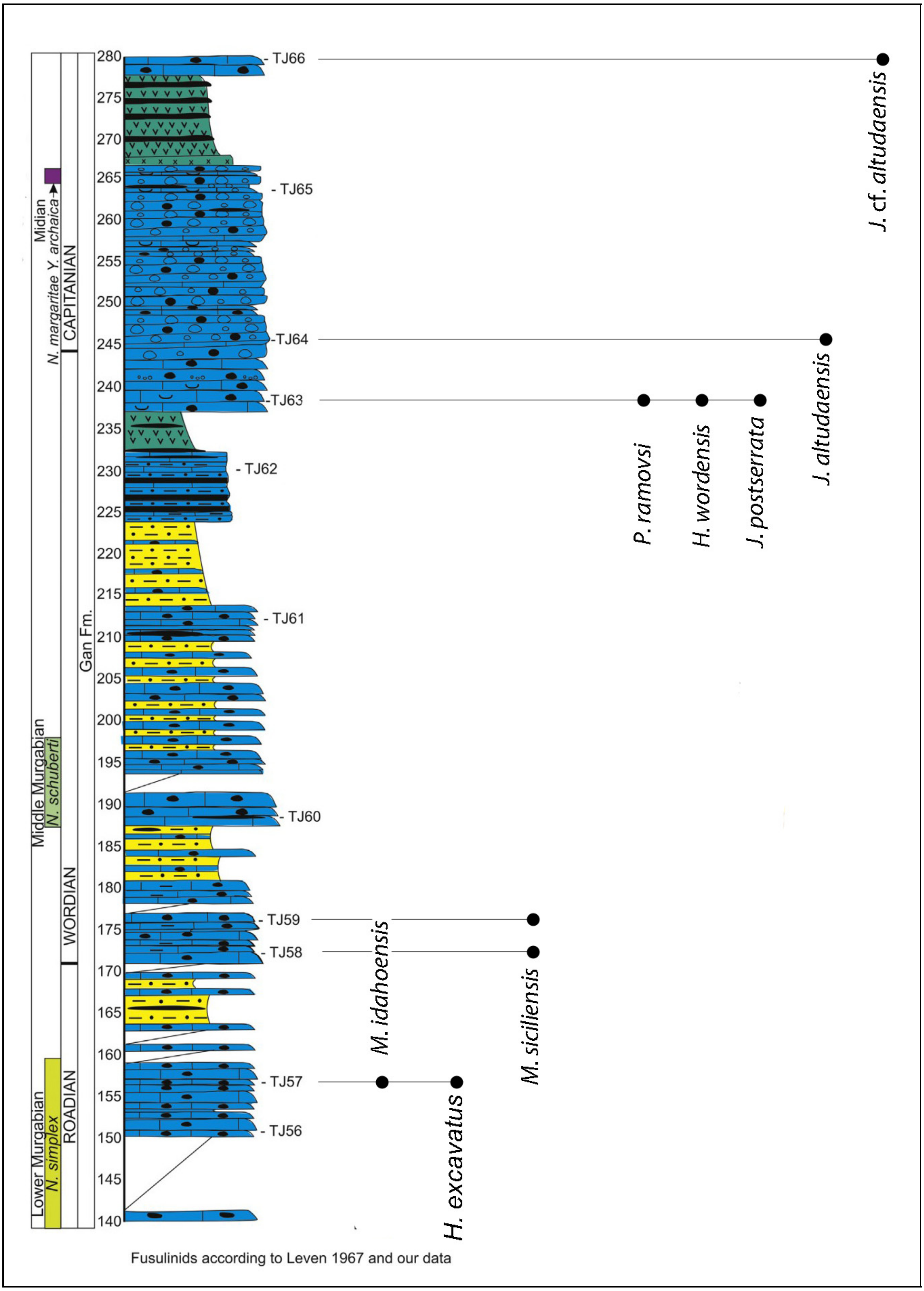

Fig. 46. Range chart of conodonts from Kutal 2 section, Se Pamir with fusulinids data (part 2). (Stratigraphic log from Angiolini *et al.*, in press).

In sample TJ65 there are only some fragments that can be identified as *Mesogondolella* sp.

In sample TJ66 is present only *Jinogondolella* cf. *altudaensis.*

Iranognathus movschovistchi Kozur & Pjatakova, 1975*, Iranognathus punctatus* Wardlaw, 2000 and *Clarkina* sp. were found in sample TJ67. *I. punctatus* is reported from the Wargal Formation, Pakistan (Wardlaw, 200) that is Murgabian in age (Zia-ul-Rehman & Masood, 2008).

Samples TJ68, TJ69, TJ70, TJ71, TJ72, TJ73 and TJ74 are from the Takhtabulak Formation (see Appendix I, table 9), which is composed mainly by sandstones. No conodonts were found in those samples.

Sample TJ75 is from Karatash group and should be Induan in age but unfortunately no conodonts were found.

According to conodonts the age of lower and middle part of the section ranges from Kungurian to Roadian. No conodonts have been recovered from the upper part of the section (Takhtabulak Formation, see fig. 47).

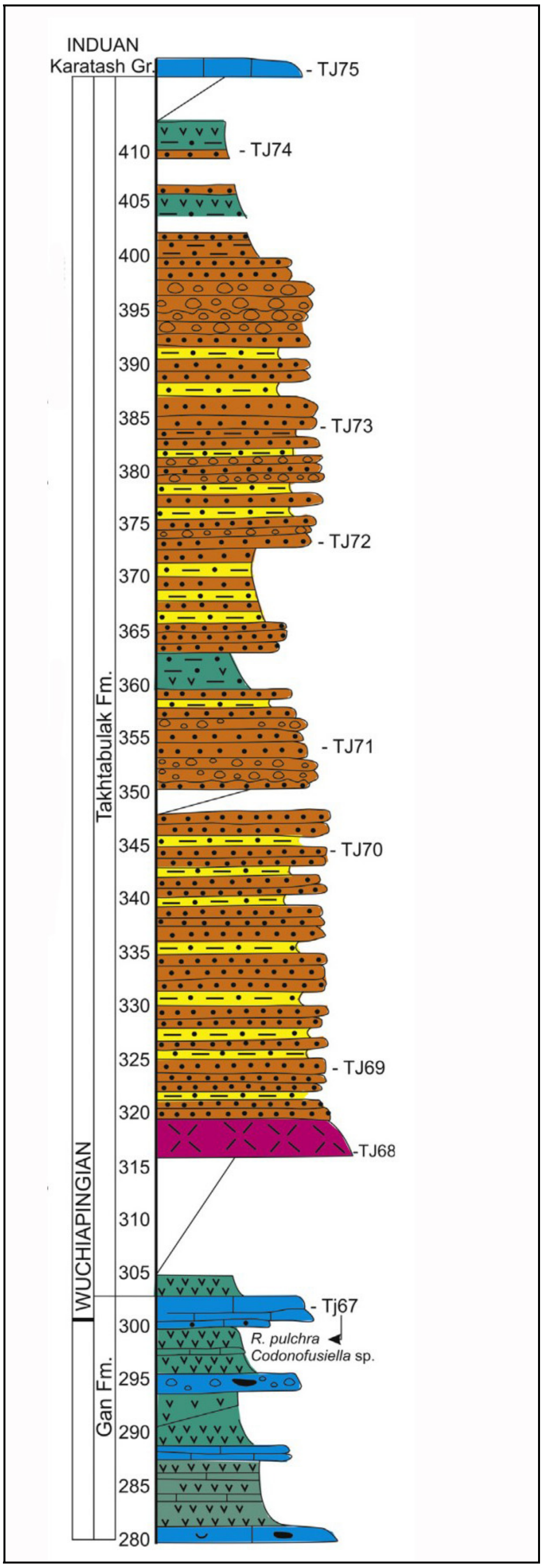

Fig. 47. Conodont samples from Kutal 2 section, Se Pamir with fusulinids data (part 3). (Stratigraphic log from Angiolini *et al.*, in press).

4.4 Kurystyk section

For Kurystyk section nine conodont samples have been studied (see Appendix I, table 10): samples TJ86, TJ87 and TJ84 are from the Tashkazyk Formation, while samples TJ88, TJ89, TJ90 and TJ91 are from the Karatash Group. All specimens shows a CAI comprised from 4,5 and 5, pointing to a thermic gradient that ranges from 250° to 480 °C.

Sample TJ86 contains only some fragments of *Mesogondolella* sp.

Samples TJ81, TJ83, TJ84, TJ85 and TJ87 are from Takhtabulak Formation: unfortunately, they are all barren.

Samples TJ88, TJ90 and TJ91 are from the Karatash Group which should be Induan in age (fig. 48).

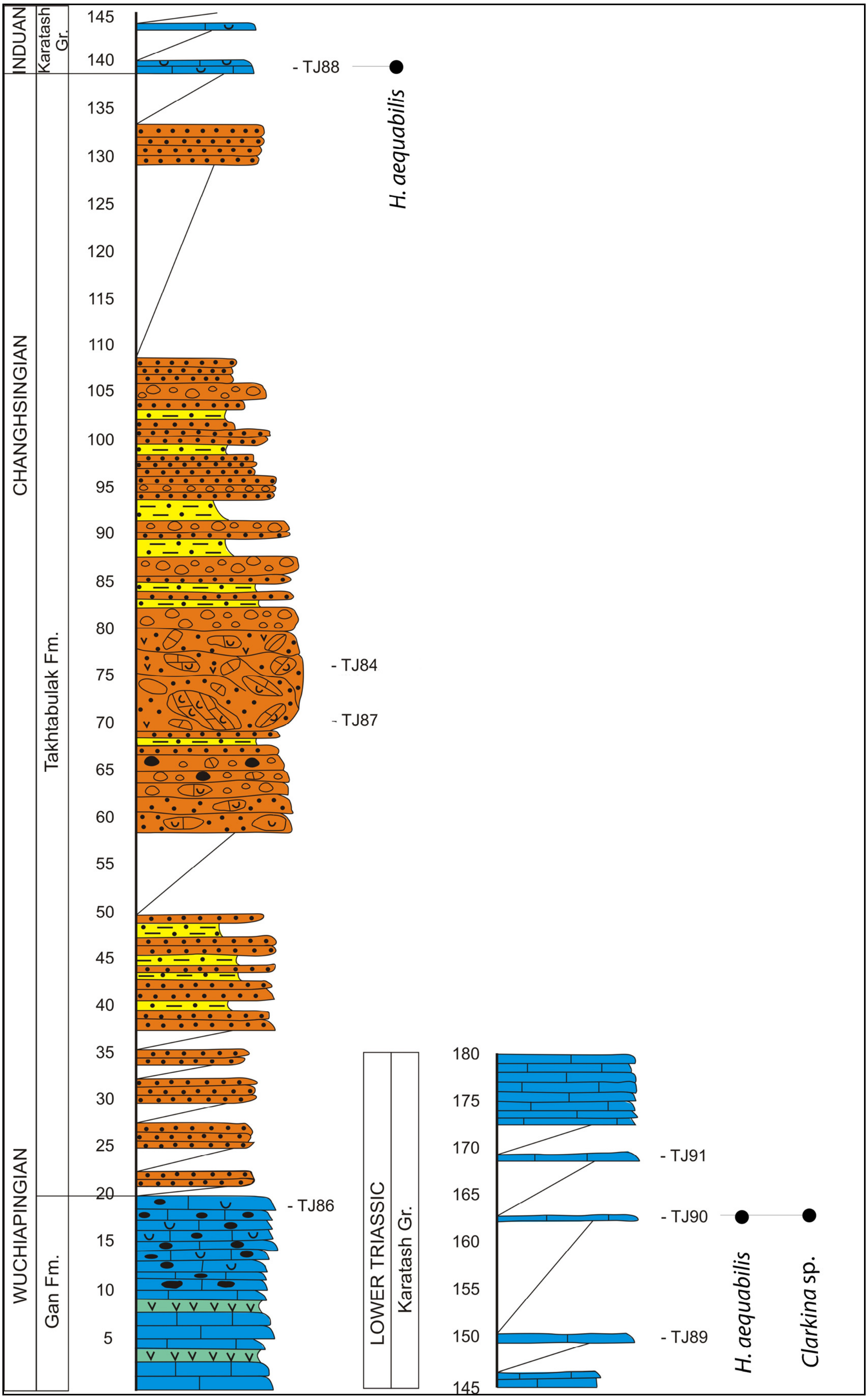

Fig. 48. Range chart of conodonts of Kurystyk section, SE Pamir. (Stratigraphic log from Angiolini *et al.*, in press).

4.5 Kurteke section

For Kurteke section six conodont samples have been studied (see Appendix I, table 9). All specimens shows a CAI comprised from 4,5 and 5, pointing to a thermic gradient that ranges from 250° to 480 °C.

Samples TJ92, TJ93, TJ94, TJ95, TJ96 and TJ97 are from the Kurteke Formation (fig. 48).

A well preserved fauna was found in sample TJ92 which contains: *Sweetognathus subsymmetricus*, *M. idahoensis lamberti* and *M. siciliensis*. Those specimens point to a Kungurian/Roadian age.

Sample TJ94 contains only fragments of *M. siciliensis* while sample TJ95 only fragments of *M. idahoensis lamberti*.

Samples TJ896 and TJ97 are barren.

Samples TJ98 and TJ99 are from the Karatash Group and should be Induan in age but, unfortunately, they are barren.

According to conodonts the age of the base of the section is Kungurian/ Roadian.

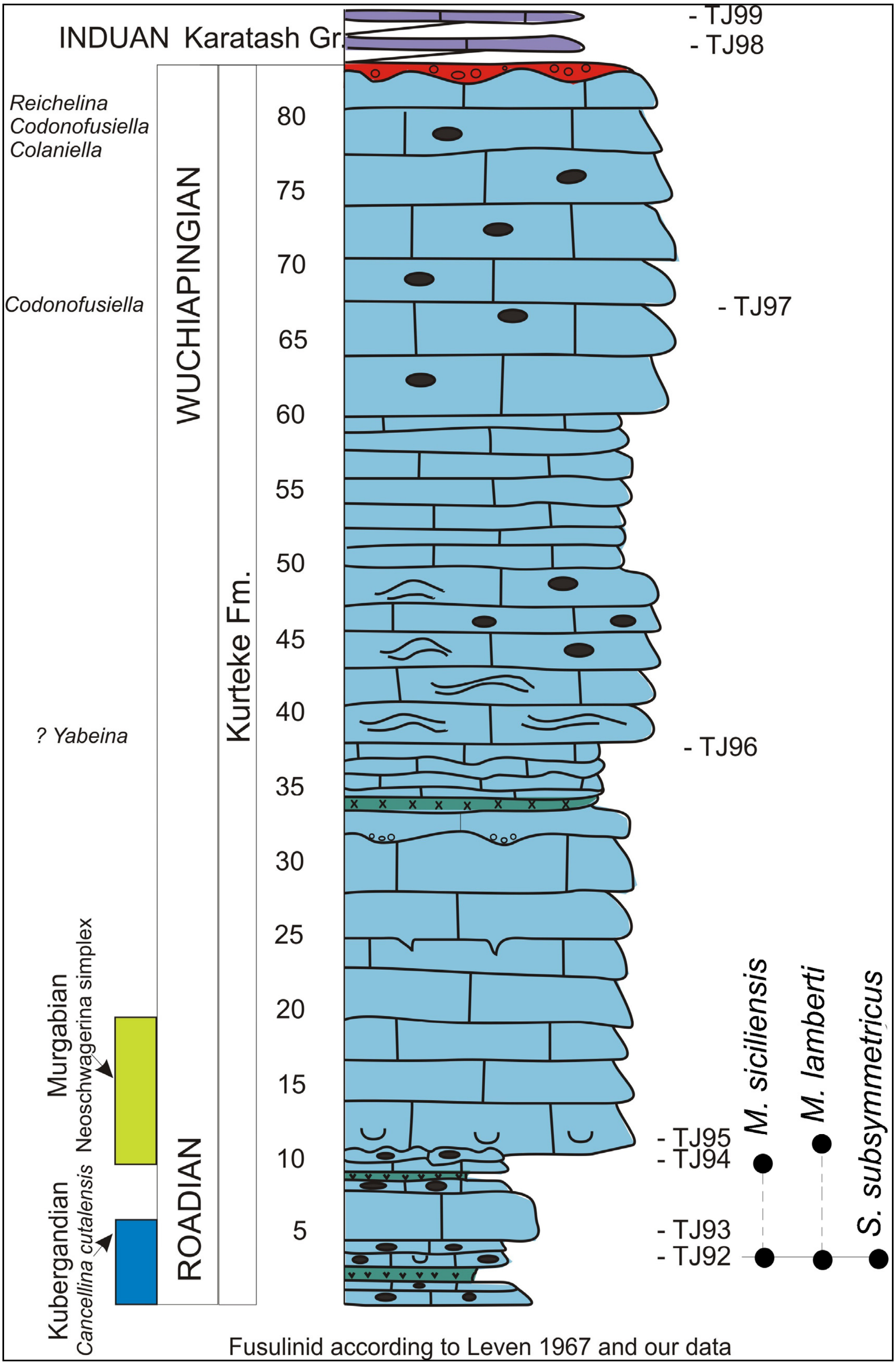

Fig. 49. Range chart of conodonts from Kurteke section, SE Pamir with conodonts data. (Stratigraphic log from Angiolini *et al.*, in press).

4.6 Tashkazyk Formation

Three sparse samples have been collected from Tashkazyk Formation, in the Bazar Dara Group.

Samples TJ88 and TJ 90 contain some *Hadrodontina aequabilis* Staesche, 1964 pointing to an Upper Induan- Lower Olenekian (Lower Triassic) age for this samples. Sample TJ 90 contains also a fragment of *Clarkina* sp.

TJ 91 contains only some fragments.

Sample TJ82 (see Appendix I, table 11) was collected in the upper part of the Cisuralian Tashkazyk Formation of the Bazar Dara Group and yielded a well preserved conodont fauna comprehending: *Mesogondolella monstra* (Chernykh, 2005), *Streptognathodus* sp., *Sweetognathus* cf. *bucaramangus*, *Sweetognathus* cf. *merrilli*, *Sweetognathus* cf. *behnkeni*, and *Sweetognathus whitei* Rhodes, 1963. According to Chernykh (2005), *M. monstra* is typical of the Tastubian (early Sakmarian) and *Sw. merrilli* has been correlated with the early Sakmarian (Chernykh & Chuvashov, 2014) in its type region pointing to a Sakmarian age for this sample. The presence of *Sw. withei* together with typical Sakmarian specimens like *M. monstra* and *Sw. merrilli* is controversial (Chernykh & Chuvashov, 2014; Chuvashov *et al.*, 2013; Lucas 2014; Henderson *et al.*, 2014; Vuolo *et al.*, 2014) and so is the overlapping of the two genera *Streptognathodus* and *Sweetognathus*. In fact they overlap only for a short period in the Lowermost Sakmarian in the Urals, but for a long period in the mid-west USA (Henderson, 2014). For further discussion see chap. 8.

Chapter 5

Geological setting of N Pamir

5.1 Introduction

In 2012 two stratigraphic sections have been sampled in Gundara Valley (south of Mionadus, Obikhingou Valley, Darvaz, N Pamir) (fig. 49): the stratotype of the Bolorian at the junction of the watersheds between the Charymdara, Zidadara and Gundara valleys and a section along the left side of the Gundara Valley (see Angiolini *et al*., 2012).

The geological setting of the Gundara Valley up to the watersheds with the Charymdara and Zidadara Valleys seems to be very different both from the one shown in the geological map of Darvaz and from that of Leven *et al.* (1983): there are at least three tectonic units repeating the upper Lower Permian succession (Tchelamtchi, Safetdara and Gundara formations) which are dissected by northeast south- west directed strike-slip faults. This makes the reconstruction of the stratigraphic relationships very hard also due to the poor exposure of the tectonic contacts.

Bedding attitudes of the studied succession shows a general NW dip direction and a NE-SW trend parallel to the regional structures of Darvaz showing a marked oroclinal bending of the structural trend of the belt in front of the Indian-Pamir indenter. A few data collected in the area on mesoscopic faults suggest that a N-S compression was active in the region after the imbrication of the main thrust sheets (Angiolini *et al*., 2012).

As reported in Angiolini *et al.* (2012) and according to the Russian maps and literature, the main deformation event occurred in the area before the Jurassic, as most of the Permian to Triassic succession is sealed by the Jurassic succession with a local well-preserved unconformity showing coal beds at the base. Andesitic dikes and stocks, attributed in the literature to the base of the Jurassic, are widespread in the area. Another major unconformity is well recognizable at the top of the Gundara Valley between the Permian successions and the Neogene units which form the southernmost portion of the Pamir foredeep.

Both Gundara and the Bolorian Stratotype sections were sampled mainly for conodonts, fusulinids and brachiopods.

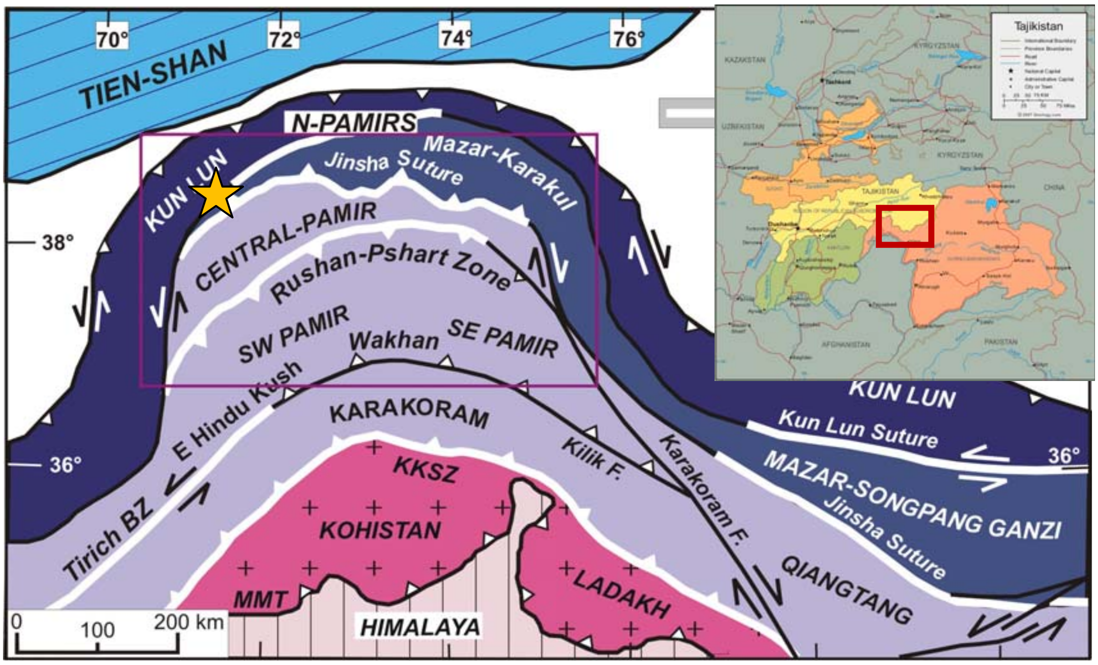

Fig. 50. Geological setting of Pamir. Yellow star: position of Darvaz. (from Angiolini *et al.*, 2012).

The sections have been measured through part of the Permian succession of Darvaz that, according to Leven and Shcherbovich (1978), Leven et al. (1992), Leven (1997) comprises:

- the Asselian to lower Sakmarian Sebisourkh Formation consisting of bioclastic limestones (0–450 m);
- the Sakmarian Khoridje Formation consisting of flyshoid shales and sandstones (300–750m);
- the Artinskian Zygar Formation with conglomerates, sandstones and shales interpreted as a flysch (300–400 m);
- the Artinskian-lower Bolorian Tchelamtchi Formation consisting of alternating claystones, siltstones, sandstones, conglomerates, and limestones (>1000 m);
- the upper Artinskian-Bolorian Safetdara Formation consisting of reefal limestones (0–1000 m);

- the upper Bolorian to Kubergandian Gundara Formation consisting of sandstones, shales and limestones (0−700 m);
- the Bolorian- Kubergandian Kuljaho Formation comprising varicolored volcaniclastic and terrigenous deposits (0–1000 m);
- the Murgabian Daraitang Formation with multicolored volcaniclastics (800 m);
- the Murgabian Valvaljak Formation with red sandstones and conglomerates (>1000 m);
- the Midian Kaftarlmol Formation consisting of gypsum (at the base), sandstones, and shales (400 m);
- the Midian–Dzhulfian Kafirbacha Formation consisting of carbonates and mudstones (50– 230 m).

As reported by Angiolini *at al.* (2012) exposed formations in the study area are Tchelamchi, Safetdara and Gundara formations. The stratotype of the stage Bolorian (Leven, 1979) spans the top of the Tchelamchi Formation, the Safetdara Formation and the base of the Gundara Formation which were sampled for conodonts, fusulinids and brachiopods.

5. 2 Gundara section

A good outcrop of the Gundara Formation along the left side of the Gundara Valley provided the opportunity to measure a short log also in this formation, which here consists of marly bioclastic limestones in 10-40 cm-thick beds, locally nodular, with a rich silicified biota (Angiolini *et al.*, 2012) (figs. 50 and 51). The fossils comprise mainly brachiopods (spiriferids, richthofeniids, terebratulids), crinoids, gastropods, bryozoans, and colonial corals which however are not preserved in life position, indicating limited transport of the assemblages in peri-reefal facies. The upper part of the formation is mostly covered (fig. 51), but Angiolini *et al*. (2012) managed to sample a fossiliferous bed about 100 metres above the section. At the top, the formation is dissected by a fault. According to Leven (1979) and Leven et al. (1983, 1992) the age of the Gundara Formation is late Bolorian-Kubergandian.

Fig. 51. Gundara section (pink line) (from Angiolini *et al.*, 2012).

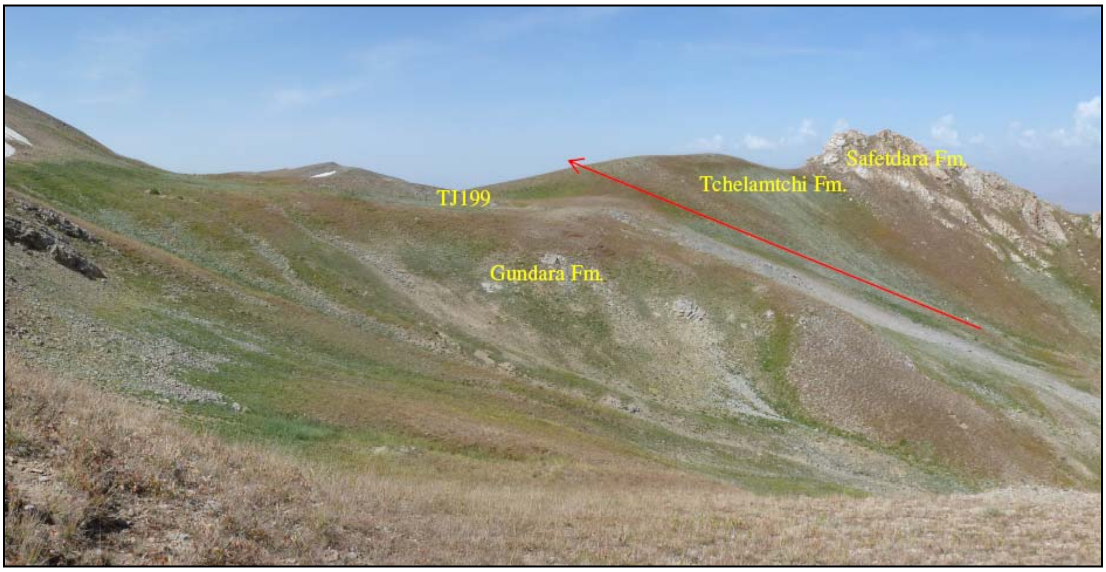

Fig. 52. Gundara section (from Angiolini *et al.*, 2012). Red arrow: fault.

Conodont fauna

Several conodont samples have been collected and studied for this section. All the samples of Gundara section are from Gundara Formation (fig. 53).

For this sections were studied samples: TJ192, TJ195, TJ196, TJ197, TJ198 and TJ199, all from Gundara Formation but, unfortunately, none of them yielded conodonts.

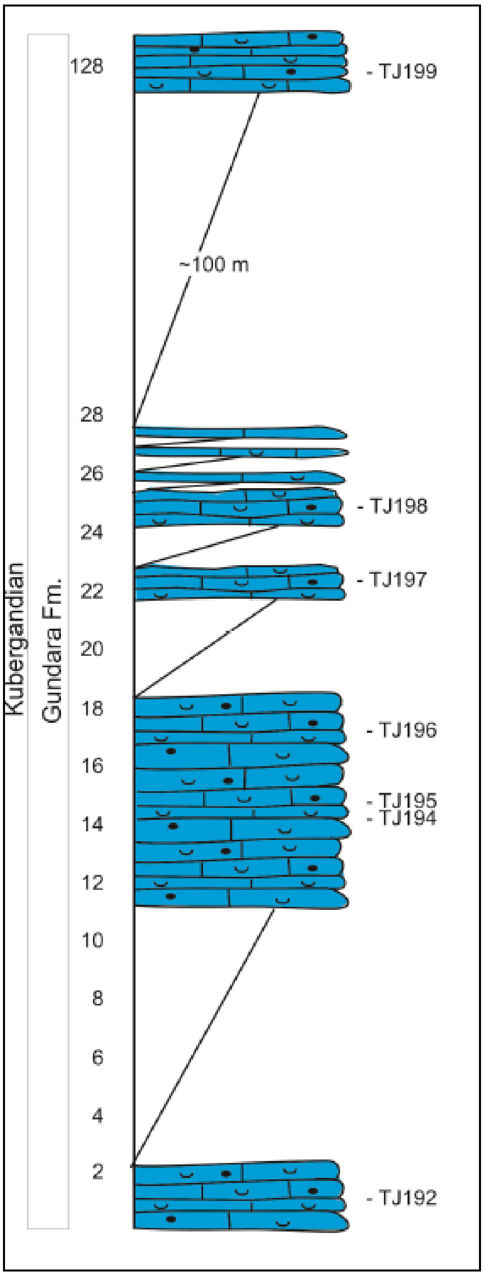

Fig. 53. Conodont samples from Gundara section (from Angiolini *et al.*, 2012).

Chapter 6

Geological setting of Djebel Tebaga de Medenine, Tunisia

6.1 Introduction

Permian outcrops of Djebel Tebaga de Medenine

Permian outcrops of Djebel Tebaga de Medenine (South Tunisia) have been known for their rich and well preserved since 1950 (see Angiolini *et al.*, 2008).

The outcrops are exposed in a series of hills extending for about 15 km WSW-ENE, 30 km W-NW of Medenine, near the village of Dkhilet Toujane (fig. 57). The Permian Succession is an E-W monoclonal structure, gently dipping S-SE, overlain with a spectacular angular unconformity by Jurassic to Cretaceous carbonates.

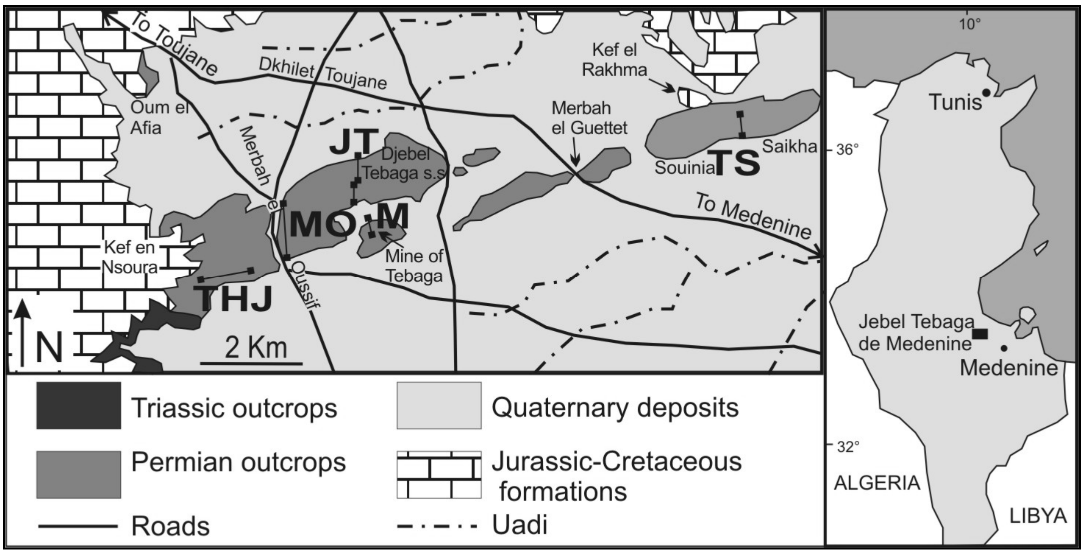

Fig. 57. Position of studied sections in Djbel Tebaga de Medenine area, Tunisia. TS: Tebaga Section. THJ: Halq Jemel section. MO/M: Merbah- el- Oussif section.

Several different lithostratigraphic subdivisions of the Permian outcrops of Djebel Tebaga de Medenine have been presented (Mathieu, 1949; Baird, 1967; Newell *et al.*, 1976; Termier *et al.*, 1977; Khessibi, 1985; Memmi *et al.*, 1986, Chaouachi 1985, 1988; and Toomey, 1991) because of the discontinuous nature of the outcrops and the significant lateral changes in facies and thickness which make the correlation between different units very hard.

Angiolini *et al.* (2008) and Verna *et al.* (2010) have chosen to follow the stratigraphic subdivision of Chaouachi (1998) which divided the Permian outcrop rocks into six distinct lithologic units:

- Unit I (Bateun Beni Zid sandstone), consisting of 50 meters of shallow water sandstone with bioclastic limestone, oncoid limestone and oolitic limestone capped by regressive sandstone.
- Unit II (lower reef complex at Djebel Tebaga *sensu stricto*), comprising about 70 meters of lenticular dolomitized algal/*Tubiphytes* boundstone and bioclastic limestone laterally and vertically delimited by sandstone.
- Unit III (intermediate shale), quite variable in thickness from about 40 meters-thick in the east to about 280 meters- thick westward; it has a very articulated and laterally variable lithostratigraphic framework with diversified sponge and algal bioherms and well bedded bioclastic limestone interbedded with sandstone and green shale.
- Unit IV, consisting of 120 meters of dolomitized algal/*Tubiphytes* boundstone and bioclastic limestone; it forms the second cliff of Djebel Tebaga.
- Unit V (only at Halq Jemel), comprising about 40 meters of bioclastic limestone, oncoidal limeston, dolomitic limestone, shale and fewer algal and sponge patch reefs than the unit below, as well as sandstone with cross stratification, current ripples and wood fragments.
- Unit VI (Cheguimi sandstone), initially sandstone and shale of marginal marine to coastal environments, which grade upwards into fluvial red sandy beds and shale.

Units I to III represent a continuous stratigraphic succession, which can be easily laterally traced: these units are capped by thick biohermal limestone and dolostone ascribed to Unit IV by Chaouachi (1988).

The outcrops of Souinia and Saika are considered to also represent Unit IV, even if the succession there is different from the typical lithology of Unit IV at Djebel Tebaga s.s., comprising about 43 meters of well bedded bioclastic limestone, lateritic beds, sandstone with dolostone only at the top. Unit V at Halq Jemel is separated by a major fault from the remaining units and it is overlain by sandstone and shale of Unit VI, which are thought to be the uppermost part of the Permian succession in this region.

Units I to V have been interpreted by Chaouachi (1988) as having been deposited on a shallow marine shelf characterized in its inner part by mixed channelized siliciclastics and the northeast, the shelf comprises patch reefs behind a prominent barrier reef delimited by a slope and a relatively deep basin. By the end of the Permian succession, the shelf was progressively covered by the prograding Cheguimi siliciclastics.

The first and most detailed studied group are the Fusulinids (e.g. Douvillé, 1934; Ciry, 1948, 1954; Glintzboeckel & Rabaté, 1964, Skinner & Wilde, 1967; Lys, 1988; Vachard & Razgallah, 1993) and the age of the Djebel Tebaga de Medenine outcrop has been established using fusulinids and generally was considered to be Murgabian- early Midian (Vachard & Razgallah, 1993), Wordian- Capitanian (Newell *et al.*, 1976) or Capitanian (Vachard *et al.*, 2002).

Vachard *et al.* (2002) correlated the entire Tebaga succession with the Capitanian of the International Time Scale.

Conodonts have been reported from the Halq Jemel section (Djebel Tebaga outcrops) by Angiolini *et al.*, 2008 pointing to a Wordian- early Capitanian age for the succession.

6.2 Halq Jemel section

This section have been measured in Unit V.

According to Verna *et al.* (2010) it corresponds to Newell *et al.* (1976) section B beds 22 to 35 (upper Biohermal complex, “Bellerophon lmst” and lower part of Cheguimi sandstone facies of the authors).

The reported lithology and evolution of this section is from Verna *et al.* (2010).

Five parasequences can be detected into this section: the first sequence is composed only by the transgressive term ad showas four carbonates bar. Few centimeters of clay occurs below HJ107, reflecting the deepening of the shelf margin. The deposition is continuous and shallow-shelf open-marine carbonate type.

The second sequence starts with thin sandy beds intercalated by argillaceous terms and followed by a carbonate bed represents the transgressive systems tract. The upper boundary of this sequence is represented by dolomites.

The third sequence begins with silts and sandstones which mark the relative regression. Two bars of sandstone intercalated by sandy dolostone are followed by a clayey term which represents the transgressive system tract.

The fourth sequence is made by sandy limestone; centimetric sandstones bedsare intercalated with clays reflects neither the instability of energy. The shelf- edge facies consist of aggrading reef lenses which are stacked, changing laterally into bedded carbonates. All are sealed by a clayey term closing this sequence.

The fifth sequence commences by nearly a meter of sandstone boundary. The upper part of this sequence is represented by a clayey term, a dolomitized bioclastic limestone with brachiopods, gastropods, bivalves, fusulinids which are followed by continental red sandstone and shale.

Permian deposits are characterized by a progressively shallowing upward character. The depositional profile of the basin reflects this shallowing trend with the change from the initially open marine deposing clays and sandstones, into mixed clastic- carbonate, to rimmed shelf and finally into mixed clastic-carbonate reef-rimmed shelf. This follows an increasing steepening of the shelf-margin directly resulting from basin starvation with the shallowing trend.

Lithology

Halq Jemel section, according to Verna *et al.* (2010) is composed, from the base by:

- 7 m of well bedded bioclastic limestone (packstone- grainstone) with abundant echinoderms and fusulinids and rarer smaller foraminifers, algae, brachiopods, gastropods, bivalves and sponges (THJ1-2).
- 7 m mostly covered, with sporadic occurrence of bioclastic and oncoidal limestone and claystone.
- 2.30 m of well bedded bioclastic limestone (packstone-grainstone) with abundant fusulinids and brachiopods, associate to smaller foraminifers, algae, echinoderms,bivalves, sponges, conodonts (THJ3).
- 0.3 m of yellow marly limestone with brachiopods (THJ4) at the base passing to bioclastic limestone (packstone) with fusulinids, articulated brachiopods, gastropods (THJ5).
- 2 m green, red and yellow bioclastic claystone with brachiopods, echinoderms, gastropods (THJ6).
- 0.8 m of withe, light grey fine sandstone with flaser indicating tidal influence.
- 0.3 m of claystone with fine sandstone.
- 0.3 m sandy limestone with brachiopods.
- 2.5 m green, red and yellow claystone.
- 0.3 (laterally up to 0.5) yellow dolomitized silty limestone with echinoderms, brachiopods, oncoids at the top.
- 0.6 m bioturbated siltstone with seven fine sandstone layers at the top.
- 0.3 brown fine sandstone with irregular top and wood logs.
- 0.5 bioturbated siltstone.
- 0.4 brown medium sandstone with FE-OX at the top ad wood logs.
- 0.3 m (westward up to 1 m) fining upward dolomitized silty limestone with articulated, non oriented brachiopods and encrusting algae (*Ottonosia*) (THJ7).
- 0.6 m red claystone laterally (westward)passing to 0.2 m of green claystone capped by 0.4 m of fine sandstone with flaser. In the upper part sandstone layers an thinning up.
- 0.25 m sandy bioclastic limestone with oncoids, algae, gastropods.
- 1 m fine sandstones and green claystone.

- 0.3 m fine laminated sandstone.
- 0.2-0.5 small sponge patch reefs laterally interfingering with dolomitized silty limestone.
- 2.8 m silty bioclastic limestone with brachiopods and algae passing to sponge and algal (occasionally with briozoans) patchy reefs up to 1-2 m thick. At the top pockets of red claystone occur between the patches.
- 0.3 m (laterally up tp 1 m) medium qz-sandstone with wood logs, lithoclasts and low angle cross laminations.
- 6 m red claystone, greenish at the top.
- 0.15 m dolomitized limestone.
- 0.15 m yellow-red dolostone.
- 0.2 m dolomitized bioclastic limestone with brachiopods, gastropods, bivalves, smaller foraminifers (THJ8).
- 0.4 m dolomitic siltstone with gastropods and bivalves.
- 0.4 m bioclastic limestone (packstone) with abundant fusulinids associated to smaller foraminifers, echinoderms, brachiopods, sponges (THJ9).
- 1 m red claystone with gypsum.
- 0.2 m yellow dolostone.
- Sandstone and shale.

Fossil content

From samples THJ1 and THJ 2 Verna *et al.* (2010) reported one specimen of *Chusenella rabatei* Skinner & Wilde, 1967 and *Dunbarula ex* gr. *nana.* In THJ 1 were found rare foraminifers such as *Neodiscus* sp. and *Climacammina grandis* Reitlinger, 1950 in association with the fusulinids.

Foraminifers are still rare in THJ 2 whit the presence of *Globivalvulina* sp. and *Ciclammina* cfr. *C. tenuis* Lin, 1978. Both samples consist of packstone with abundant echinoid fragments, thick shelled bivalves and brachiopods, bryozoans and algal lumps (Verna *et al.*, 2010). The presence of the dominant biseriamminid genera *Climacammina*, *Globivalvulina* in association with rare and small sized miliolids can be referred to the leeward shoals as stated by Insalaco *et al.*(2005).

Dunbarula ex gr. *nana* is characteristic for the lower Midian and Upper Wordian: this species occur in many section along with late Wordian ammonoids and conodonts throughout the Tethys.

Dunbarula mathieui Ciry, 1948, few *Staffella* sp. and *Neoschwagerina* aff. *glintzboeckeli* were found into sample THJ 3 while sample THJ9 yielded the specimen *Dunbarula mathieui* Ciry, 1948.

In THJ3 there is a significant change: grainstone with thick shelled brachiopods, Dasycladacean algae bioclasts in association with abundant fusulinids and different porcelaneous foraminifers such as *Glomomidiellopsis*? sp., *Neodiscus* sp., *Neodiscopsis* sp., *Hemigordius* spp., *Multidiscus* sp., *Midiella* sp., *Brunsispirella linae* (Vachard & Galliot, 2005). Accordin to Verna *et al.* (2010) this assemblage can be referred to the sandwaves shoals and oolitic shoals sensu Insalaco *et al.* (2005)

Dunbarula nana is a very primitive representative of the genus, whereas *Dunbarula mathieui* Ciry, 1948 is most advanced species in this lineage; there is no transitional forms in between the two recorded in the Halq Jemel section (Verna *et al.*, 2010).

Three species of the brachiopods genus *Permophrycodothyris* have been recorded from sample THJ3 to sample THJ7.

Conodont fauna

Several conodont samples have been collected and studied from this section (see Appendix I, table 14): samples HJ30-395, HJ32-397, HJ33-398 and HJ36- 401 from Unit V (fig. 58). CAI of the conodonts is about 3, pointing to a range between 110° and 200° C for the rock thermic gradient.

Sample HJ30- 395, unfortunately, was barren.

Sample HJ32-397 contains a nice population of well preserved specimens of *Sweetognathus iranicus hanzhongensis* (Wang, 1978); during previous study carried on this area (see Verna *et al.*, 2010) this species have been reported from the same section. Our sample confirm the presence of the species in this Unit and the Guadalupian age of the sample, according to the Wordian age assigned using fusulinids and brachiopods. The presence of *S. iranicus hanzongensis* is coherent with the reconstruction of the paleoenvironment based on lithological evidences and brachiopods (Angiolini *et al.*, 2008): this species, in fact, is typical of shallow and warm waters during Guadalupian (Mei *et al.*, 2002).

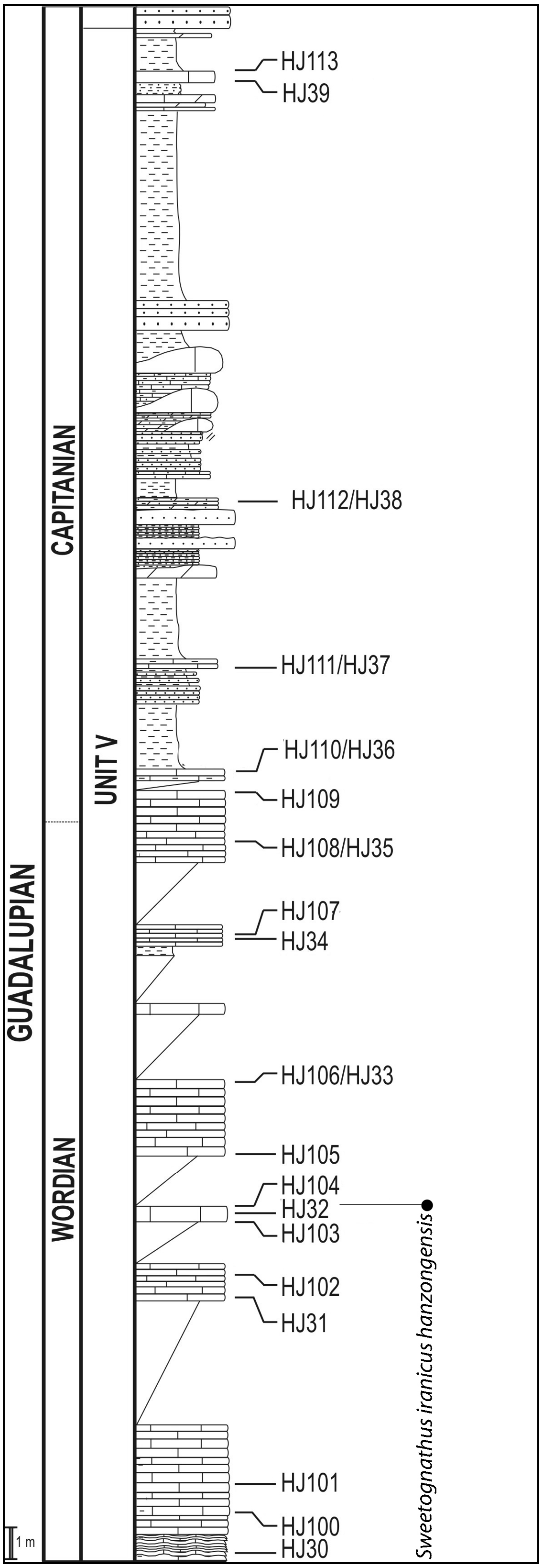

Fig. 58. Range chart of conodonts from Halq- Jemel section, Tebaga de Medenine, Tunisia

6.3 Merbah-el-Oussif

For the section of Merbah- el- Oussif ten conodont samples have been studied (fig. 59) but, unfortunately, none of them yielded condonts. Few benthonic foraminifera were founded in samples MO5 and MO2 and in sample MO5 also some bryozoans were present. All the samples from this section are from Unit V (see fig. 59).

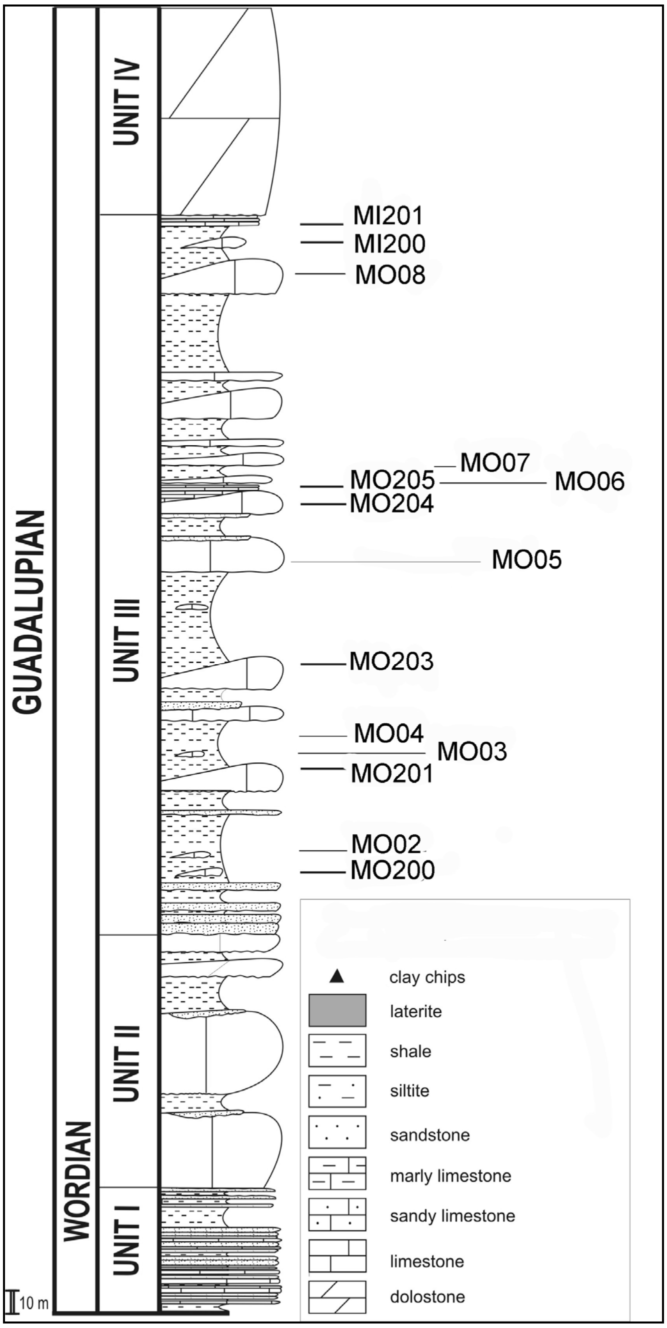

Fig. 59. Merbah-el- Oussif section (from Verna *et al.*, 2009). All the samples reported are conodont samples.

6.4 Tebaga *sensu strictu* section

For the section of Tebaga S.S. eight conodont samples have been collected and studied (see Appendix I, table 15). Samples: TSS1, TSS2, TSS3, TSS6 are from Unit I, while samples TSS7, TSS9, TSS10 and TSS11 are from Unit II.

Only samples TSS9 and TSS11 contains conodonts: sample TSS9 contains some fragments of ramiforms, while sample TSS11 (see fig. 60) contains a fragment of *Sweetognathus iranicus hanzongensis* that ranges throughout the Guadalupian (Mei *et al.,* 2002).

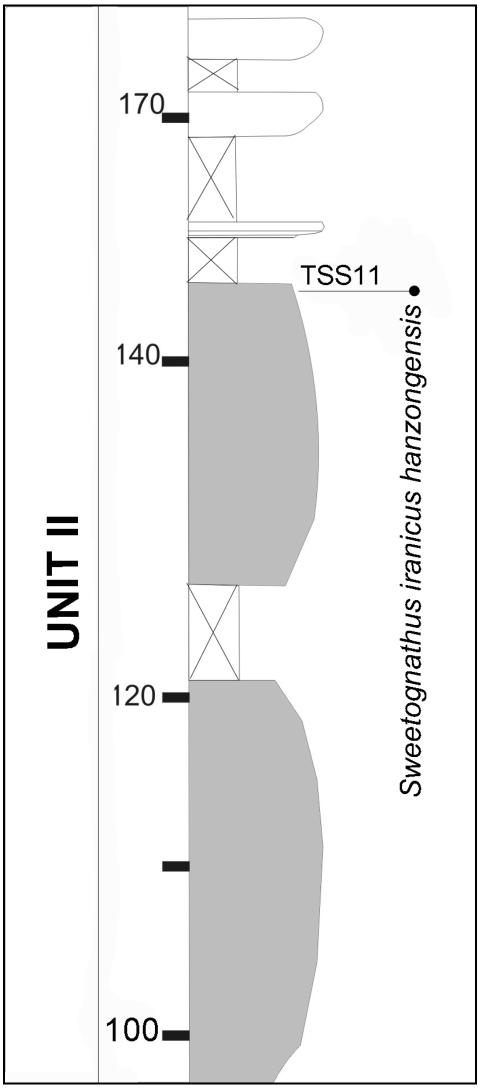

Fig. 60. Position of sample TSS11. Unit II, Tebaga *sensu strictu* section.

Chapter 7

Systematic paleontology

PREMISE: conodont taxonomy for Carboniferous and Permian is complex. For several specimens the original diagnosis are not available and most authors wrote their papers in Russian or in Chines, making harder to understand the description of single species.
I have tried to report, when it was possible, the original diagnosis and the holotype for each species. When this have not been possible I have reported the description of the most reliable author.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Gondolellidae, Lindström 1970

GENUS ***Clarkina*** Kozur, 1989

1975 *Gondolella leveni* Kozur, Mostler & Pjatakova - in Kozur

Type species: *Gondolella leveni* Kozur, Mostler & Pjatakova in Kozur (1975).

Diagnosis (Kozur, 1989): typical, not modified gondolellid apparatus. Platform not reduced, shape variable, but generally broad. Anterior free blade is distinct. Broad part of platform ends mostly rather abruptly. Non sculpture. Micro-reticulation distinct, with exception of the smooth adcarinal furrows. Lower surface with flat keel, but marginally in general with narrow, low ridge. The keel ends subterminal, the basal cavity is subterminal with respect to both end of platform and end of keel. Secondary elevation around the basal cavity is rather high.

Carina anteriorly high; in the posterior part it is low and in adult specimens mostly totally fused. Cross-sections of the denticles are round, but in the anterior part, the denticle are laterally compressed. The carina ends terminal or subterminal. Narrow to broad platform brim behind the end of carina may be present. Main cusp indistinct to prominent, often subterminal and then followed by a distinct platform brim.

Emended diagnosis (Henderson *et al.*, 2006): the lateral processes of the S_0 element extend from the cusp and the S_3 element bears a bifid anterior process as in *Jinogondolella*. The P_1 platform narrows and is downward deflected in the anterior 1/3; in some cases, this feature may form a free blade in adult forms. Juvenile P_1 elements all have a distinct platform over their entire length.

Remarks: specimens illustrated in plate 25 (figs. 7a, b, c; 8a, b, c) looks quite similar to the genus *Clarkina:* they have expanded and flat platform, wider in the middle part of the platform, platform tapers anteriorly and the free blade is slightly longer than the platform end. Cusp is of the same height or slightly higher than the other denticles and is on a subterminal position with only a narrow posterior brim.
Denticles of the carina are low, laterally compressed, almost of the same height and fused at the base. Denticles of the blade appears to be higher and almost completely fused.
On the lower surface the keel ends subterminal and the basal cavity is subterminal too.
These specimens occurs in a Capitanian sample (TJ67, Gan Formation) from SE Pamir in association with the Murgabian species *Iranognathus punctatus.*

Clarkina sp.

(plate 25, figs. 7a, b, c)

Description: a fragment of Pa element of *Clarkina* from sample TJ90 (Kurteke section, SE Pamir). The platform is broken both in the anterior and posterior parts, and the cusp is lacking. Denticles are massive, discrete and almost of the same height. The platform is widest in the half and posterior third and abruptly tapers in the anteriormost part.

Occurrence: sample TJ90, Lower Triassic (Induan?), Kurteke Formation, Kurteke section, SE Pamir, Tajikistan.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Idiognathodontidae Harris & Hollingsworth, 1933

GENUS ***Declinognathodus*** (Ellison & Graves, 1941)

1966 *Declinognathodus* (Ellison & Graves, 1941)- Dunn

1977 *Declinognathodus* (Ellison & Graves, 1941)- Ebner

1978 *Declinognathodus* (Ellison & Graves, 1941)- Nemirovskaya, in Kozitskaya *et al.*

1983 *Declinognathodus* (Ellison & Graves, 1941)- Park

1990 *"Declinognathodus"* (Ellison & Graves, 1941)- Grayson *et al.*

1999 *Declinognathodus* (Ellison & Graves, 1941)- Nemirovskaya

Type species: *Cavusgnathus nodulifera* Ellison & Graves, 1941

Description: scaphate, symmetrically paired platform elements with elongate narrow platform, two unequal parapets and median position of junction of free blade with a platform. Median carina declines from the longitudinal axis and fuses with the outer parapet that can be reduced down to one or two nodes near the anterior margin of the platform. Basal cavity is deep, wide and slightly symmetrical (Nemirovskaya, 1999).

Remarks: Nemirovskaya (1999) noticed that *Declinognathodus* differs from *Gnathodus* and *Neognathodus* by declination of carina to the outer parapet and mergence with the latter. It differs from *Idiognathoides* by median junction of the blade with the platform.

Occurrence: reported this genus from Middle Carboniferous of eastern Europe, Urals and Central Asia; Namurian- Westphalian of Western Europe; Lower Pennsylvanian (Morrowan- Atokan) of North America; the Kodani Formation of Japan; the Weiningian of China (see Nemirovskaya, 1999)

Declinognathodus sp.

(Pl.7; figs. 4a, b, c)

Description: a fragment of *Declinognathodus* sp. was found in sample ANK7. The specimens is broken (see plate 7, figs. 4a, b, c) and the blade is missing.

Carina appears to be formed by two rows of nodes separated by a well developed median groove. The platform ends asymmetrically with a rounded point. Nodes are irregular in shape and dimensions but appears to be elongated.

The blade is asymmetrically jointed with the platform and appears to be formed by a single row of small nodes, almost in the posteriormost part. The rest of the blade is missing.

Occurrence: this genus is reported from Middle Carboniferous (Lower Pennsylvanian) (Nemirovskaya, 1999).

ANK7 sample, Zaladou Formation, Anarak 3 section, Tabas area, Central Iran.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY *Idiognathodontidae* Harris & Hollingsworth, 1933

GENUS ***Gnathodus*** Pander, 1856

1856 *Gnathodus* Pander

1974 *Gnathodus* Pander- Lane & Straka

1978 *Gnathodus* Pander- Nemirovskaya in Kozitskaya *et al.*

1979 *Gnathodus* Pander- Lane & Ziegler

1983 *Gnathodus* Pander- Park

1984 *Gnathodus* Pander- Lane & Ziegler

Type species: *Polygnathus bilineatus* Pander, 1856.

Remarks: because of the original type species *Gnathodus mosquensis* (Pander, 1856) has been lost the species *Gnathodus bilinieatus* (Roundy, 1926) was designed by Tubbs (1986) as the new type species for the genus *Gnathodus*.

Gnathodus girtyi girtyi Hass, 1953
(Pl. 9, figs. 1a, b, c; 2a, b, c)

1953 Gnathodus *girtyi* - Hass, p.80, pl.14, figs.22-24.

1956 *Gnathodus girtyi* Hass- Elias: 118, Pl.3,figs.30,01.

1957 *Gnathodus girtyi* Hass- Bischoff*, p.24,Pl.4, figs.16-23.*

1957 Gnathodus girtyi Hass- Lys & Serre*, p.1043, Pl.2, fig.7.*

1960 *Gnathodus clavatus* Clarke, p.25, Pl.4, figs.4-9.

1961 *Gnathodus girtyi* Hass- Higgins*: 220, Pl.10, fig.4.*

1961 *Gnathodus girtyi* Hass- Rexroad & Jarrell*: 2015.*

1962 *Gnathodus girtyi* Hass- Higgins, pl.3, fig.31.

1967 *Gnathodus girtyi* Hass- Wirth*, p*.210, figs.4-9.

1969 *Gnathodus girtyi simplex* (Dunn)- Webster, Pl.5,figs.10(non fig.B)

1969 *Gnathodus girtyi simplex* (Dunn)- Rhodes, Austin & Druce, Pl.16,figs.1-4.

1969 *Gnathodus girtyi girtyi* Hass- Rhodes, Austin&Druce*, p.98, Pl.17,figs. 9-12.*

1974 *Gnathodus girtyi* Hass- Matthews & Thomas, pl. 51, figs. 16-17, 28-31.

1975 *Gnathodus girtyi girtyi* Hass- Higgins, p.11, pl.10, figs.5,6 (cum.syn).

1982 *Gnathodus girtyi girtyi* Hass- Belka, pl. 1, figs. 2-7, pl. 2, figs. 3, 7.

1982 *Gnathodus girtyi girtyi* Hass- Higgins & Wagner- Gentis, p. 334, pl. 34, fig. 9.

1982 *Gnathodus girtyi* Hass- Von Bitter & Plint-Geberl, p. 200, pl. 6, fig. 5 [non fig. 7].

1985 *Gnathodus girtyi girtyi* Hass- Belka, pl. 4, figs. 4, 9.

1985 *Gnathodus girtyi girtyi* Hass- Varker & Sevastopulo, p. 202, pl. 5.6, figs. 1-2.

1985 *Gnathodus girtyi girtyi* Hass- Higgins, p. 220, pl. 6.2, fig. 2.

1993 *Gnathodus girtyi girtyi* Hass- Perret, p. 334, pl. CV, figs. 32, 36.

1996 *Gnathodus girtyi girtyi* Hass- Krumhardt *et al.* p.40, Pl.2, figs.20-22.

1996 *Gnathodus girtyi girtyi* Hass- Skompski, pp. 198-199, pl. 1, figs. 8-9.

1996 *Gnathodus girtyi girtyi* Hass- Krumhardt *et al.*, pp. 40- 41, pl. 2, figs. 20-22, 29.

1999 Gnathodus girtyi girtyi Hass-Yadzi, p.194, Pl.12, figs. 9,11,12.

1999 *Gnathodus girtyi* Hass- Somerville, pl. 2, figs. 4-7.

1999 *Gnathodus girtyi* Hass- Somerville & Somerville, pl. 1, fig. 10.

2002 *Gnathodus girtyi girtyi* Hass- García-López & Sanz-López, Pl. 4, Fig. 15.

Holotype: United States National Museum USNM 115097; Hass, 1953, p. 80, pl. 14, figs. 22- 24.

Diagnosis: Dunn (1970) consider this diagnostic character for this species: in oral surface the platform has a large inner parapet and a smaller outer parapet that are positioned on either side of a median carina; small outer parapet contains at least four or five nodes or lateral ridges and does not extend as far posteriorly as inner parapet.

Remarks: Boncheva *et al.* (2007) report that Iranian specimens have well developed transversely ridged anterior inner parapet continuing closing to the posterior end of the platform. The carina is straight to slightly deflected, central, and continues to the posterior end of the platform forming a tip.

Dunn (1970) noticed that *Gnahodus girtyi girtyi* can be distinguish from *Gnathodus girtyi simplex* because of a major development of the small external platform, while in the second one the platform is constituted only by one or two nodes.

Specimens from sample RH51 are well preserved (plate 9, figs. 1a, b, c; 3a, b, c): outer parapet is clearly separated from the inner one and carina is well developed and goes to the posteriormost end of the platform where the crests are very evident.

Occurrence: Barnett Formation (Chesterian- Upper Mississipian), Lampas County, Texas; Indian Springs Formation, Clark County, Nevada (Dunn, 1970)

Nemirovskya (1999) reported this species from the Upper Viséan-lowermost Serpukhovian of Europe and Upper Mississippian of North America.

Samples 8459-8477, 8791A (Section 1), 8479-8490 (Section 2) and 8495-8499 (Section 3); upper Viséan through lower Serpukhovian, *Lochriea nodose* through *L. ziegleri* zones (Nemirovskaya, 1999).

Iranian specimens are all from *muricatus* zone (Boncheva *et al.*, 2007) in the Sardar Formation.

Sample RH54, Serpukovian/ Bashkirian, Gachal Formation, Rahdar section, Tabas area, Central Iran.

Gnathodus girty simplex Dunn, 1965
(Pl. 9, figs. 5a, b, c)

1965 *Gnathodus girtyi simplex* Dunn, p.1158, pl.140, figs,2,3,12.

1974 *Gnathodus girtyi simplex* Dunn- Pierce & Langenheim, pl. 1, figs. 17, 18.

1975 Gnathodus girtyi simplex Dunn- Higgins, p.33, pl.10,figs.3,4.

1975 *Gnathodus girtyi collinsoni* Higgins, pp. 30, 31, pl. 10, figs. 1, 2.

1975 *Gnathodus girtyi simplex* Dunn- Higgins, p. 33, pl. 9, figs. 6,7, 11.

1980 *Gnathodus girtyi collinsoni* Higgins- Tynan, p. 1301, pl. 1, figs. 10, 11.

1980 *Gnathodus girtyi simplex* Dunn- Tynan, p. 1303, pl. 1, figs. 5-7.

1984 *Gnathodus girtyi collinsoni* Higgins - Qiu, pl. 2, figs. 17-19.

1984 *Gnathodus girtyi simplex* Dunn- Qiu, pl. 2, figs. 15, 16.

1986 *Gnathodus girtyi simplex* Dunn- Ji, pl. 1, figs. 15-17.

1991 *Gnathodus girtyi simplex* Dunn- Higgins *et al*., pl. 3, figs. 6, 12.

1991 *Gnathodus girtyi simplex* Dunn- Morrow & Webster, pl. 3, fig. 8.

1992 *Gnathodus girtyi simplex* Dunn - Morrow & Webster, pl. 1, fig. 4.

1993 *Gnathodus girtyi simplex* Dunn- Dumoulin & Harris, fig. 8C.

1996 *Gnathodus girtyi simplex* Dunn- Krumhardt *et al*., p. 41,42, pl.2, figs.25- 27.

Diagnosis: Dunn (1970) recognize that the reduced from one or two nodes outer parapet distinguish this species from *Gnathodus girtyi girtyi.*
Pa elements shows two parapets: the inner one is most developed and extend posteriorly with a series of nodes fused with the carina.

The external margin of the platform is ornamented by one or two nodes. A narrow blade merge with the platform in a median position and continues towards the posterior end with a series of nodes. Basal cavity is asymmetric and width.

Remarks: this subspecies was recognized as a distinct species by Meischner (1962).

The subspecies is considered by Dunn (1970) as an ancestor of *Idiognathoides noduliferus*.

Specimen from sample RH54 (Rahdar Formation, Central Iran) is well preserved (Pl. 9, figs. 5a, b, c) and the two parapets are clearly visible. The blade is missing while the carina extends until the middle part of the platform: afters the end of the carina four nodes are positioned in the posterior part of the platform.

Occurrence: Dunn (1970) reported this subspecies from the Chesterian (Upper Mississipian) of Indian Springs Formation, Clark County, Nevada.

This subspecies is reported from Krumhardt *et al.* (1996) s from the Upper Visean to Serpukovian.

Sample RH54, Visean/ Serpukovian, Gachal Formation, Rahdar section, Central Iran.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Ellisonidae, Clark 1972

GENUS ***Hadrodontina*** Staesche, 1964

Type species: *Hadrodontina anceps* Staesche, 1964

Hadrodontina aequabilis Staesche, 1964
(plate 29, figs. 3a, b, c; 4a, b, c; 5a, b, c; 6a, b, c)

1964 *Hadrodontina aequabilis* - Staesche, pp.275 – 276, figs. 11, 43 – 44.

1995 *Hadrodontina aequabilis* Staesche- Samankassou, p. 253, figs.8, 9

Description: sesquimembrate apparatus with Pa angulate element, Pb digyrate, M digyrate, Sa alate without posterior process, Sb digyrate and Sc bipennate (Staesche, 1964).

Pa element bears 6 discrete denticles, the attachment surface is wide, flat or slightly concave. The basal cavity is in the middle part of the element.

Remarks: few broken specimens have been found in samples TJ88 and TJ90 in SE Pamir (plate 29, figs. 3a, b, c; 4a, b, c; 5a, b, c; 6a, b, c). The specimens are fragmented but clearly identifiable as Pa elements of *Hadrodontina aequabilis.*

Occurrence: Samankassou (1995) and Perri & Farabegoli (2003) reported the species *Hadrodontina aequabilis* from the Mazzin Member, Western Dolomites, Lower Triassic.

Samples MS1, MS2, MS17, MS18, Induan/Olenekian, Nimra Member, Ma'in Formation, Jordan.

Samples TJ88 and TJ90, Induan?, Karatash Group, SE Pamir, Tajikistan.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY *Anchignathodontidae* Clark, 1972

GENUS ***Hindeodus*** Rexroad & Furnish, 1964

Hindeodus excavatus (Behnken, 1975)

(Pl. 11, figs. 5a, b; Pl. 12, figs. 6a, b; 7a, b)

1975 *Ellisonia excavata* Behnken, pl.1, figs. 9-14

1975 *Anchignathodus minutus* (Ellison)- Behnken, p. 297, pl.1, figs. 16- 18

1975 *Anchignathodus minutus* (Ellison)- Kozur, pp. 5-7, pl. 1, fig. 16

1981 *Anchignathodus minutus permicus* Igo, pp. 26- 27, pl.10: figs. 1-4

1977 *Hindeodus?excavatus* (Behnken)- Sweet, pp. 215- 217, pl.1, figs. 7-11

Emended diagnosis: Wardlaw (2000) described this species as characterized by a Pa element with narrow, pointed cusp and with denticles of nearly equal width except for the posteriormost few, these being narrower and decreasing in height posteriorly; 3-4denticles immediately posterior to cusp les fused than more posterior denticles. Small specimens triangular in lateral profile. Sa element with downward-directed processes at about a 40° angle from horizontal; processes nearly straight and bearing thin, fine denticles of variable height, with 2-3 large lateral denticles at or near distal end, and with a small distal denticle only sometimes developed; denticles on processes straight to slightly recurved.

Remarks: specimens from SE Pamir are small and almost all broken (pl. 11, figs. 5a, b; Pl. 12, figs. 6a, b; 7a, b). Basal cavity expanded, in upper and lower view. The blade is formed by denticles that are almost all of the same height except for the posteriormost and anteriormost 3- 4 that appears to be reduced in size.

Occurrence: Kozur & Mostler (1991) reported this species from Higher Lower Permian to Middle Permian, worldwide.

Samples TJ7, TJ9, TJ11, Kungurian, Kubergandy Formation, Kubergandy section, SE Pamir, Tajikistan.

Hindeodus scitulus (Hinde, 1900)

(Pl. 9, figs. 4a, b, c)

Original description: platform elongated and narrow, basal cavity shallow and narrow. Carina is straight with large and fused denticles. Both sides of the basal cavity are symmetrical.

Remarks: specimen from sample RH54 (Rahdar section, Central Iran) is well preserved (pl. 9, figs. 4a, b, c). Carina is formed by high denticles fused only at the bases: unfortunately they are almost all broken in their uppermost part, so in lateral view is impossible to appreciate their variation in size. In lower view both sides of the basal cavity are almost symmetrical.

Occurrence: Hinde (1900) reported this species from the Visean/ Serpukovian limit.

Sweet (1988), reported this species from the Osagean- middle Chesterian in North America.

Sample RH54, Visean/ Serpukovian, Gachal Formation, Rahdar section, Central Iran.

Hindeodus wordensis Wardlaw, 2000

(Pl. 6, figs. 3a, b, c; 4a, b, c; Pl. 20, figs. 1a, b, Pl. 22, figs. 4a, b, c; Pl. 24, 4a, b, c)

1984 *Hindeodus excavatus* (Behnken)- Wardlaw & Collinson, pp., 268- 269, pl. 5, figs. 1,2,4-9

1986 *Hindeodus excavatus* (Behnken)- Wardlaw & Collinson, p. 133, fig. 17.13- 20

1990 *Hindeodus excavatus* (Behnken)- Warldaw& Grant, A6, pl. 2, figs. 1-15, pl. 3 figs. 4,5,9- 11

1992 *Hindeodus excavatus* (Behnken)- Gullo & Kozur, p. 218, fig. 5e.

Holotypus: USNM 404252 (Wardlaw & Collinson, 1986, fig. 17.20)

Original diagnosis (Wardlaw 2000): Pa element with large cusp; denticles increasing in width posteriorly, except for posteriormost, and generally decreasing in height posteriorly, except for posteriormost three, which may be of subequal hight; cusp much higher than denticles; Sa element with short lateral processes; processes slightly upturned laterally and bearing, for at least part of their length, denticles of alternating (small versus larger) sizes.

Remarks: in sample BEV46 (Jamal Group, Central Iran) and in samples TJ30 and TJ31 from Gan Formation (Kubergandy section, SE Pamir) there are few little specimens of *Hindeodus wordensis*. They bear 10- 12 denticles fused at the base. In specimen illustrated in plate 6, figs. 4a, b, c the height of the denticles generally increase anteriorly: the first posterior 4 denticles highly increase in height while the next two looks a bit smaller, the other denticles resume the trend and increase again in height. Tre anteriormost three denticles are reduced.

The smallest specimen, illustrated in plate 6, figs. 5a, b, c, bears denticles that increase continuously in height forming a straight line in lateral view. The anteriormost three denticles are still reduced.

Occurrence: *Hindeodus wordensis* is common in the Word, Altuda and Bell Canyon formations of West Texas (that ranges from Wordian to Capitanian) and in the Gerster Limestone (Guadalupian) and the upper part of the Phosphoria and related rocks in the Great Basin and northern Rocky Mountains (Lower and Middle Permian) (Wardlaw, 2000).

Sample BEV 45, Upper Wordian/ Lower Capitanian (?), Jamal Group, Bagh-e-Vang section, Tabas area, Central Iran.

Samples TJ30 and TJ31, Capitanian, Gan Formation, Kubergandy section, SE Pamir, Tajikstan.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Idiognathodontidae Harris & Hollingsworth, 1933

GENUS ***Idiognathodus*** Gunnell, 1931

1931 *Idiognathodus* Gunnell

1932 *Idiognathodus* Gunnell- Stauffer & Plummer

1933 *Idiognathodus* Gunnell

1933 *Idiognathodus* Gunnell- Harris & Hollingsworth

1941 *Idiognathodus* Gunnell- Ellison

1972 *Idiognathodus* Gunnell- Ellison

1978 *Idiognathodus* Gunnell- Kozitskaya, in Kozitskaya *et al.*

1979 *Idiognathodus* Gunnell- Barskov & Alekseev

1983 *Idiognathodus* Gunnell- Park

1987 *Idiognathodus* Gunnell- Barskov *et al.*

1988 *Idiognathodus* Gunnell- Sweet

Type species: *Idiognathodus claviformis* Gunnell, 1931

Original diagnosis: plate subsymmetrically lanceolate to claviform, and connected posteriorly (Gunnell regarded posterior end as the anterior one) with denticle- bearing bar. Oral surface of plate flat to subconvex bearing nodes or ridges. Aboral surface of plate concave with longitudinal groove separating two subequal areas.

Remarks: in 1972 Ellison gave the following characteristics of the genus: “Straight to arched and slightly curved laceolate platform with anterior blade meeting the platform in a median position and continuing on the platform for a short distance; oral surface of platform convex, flat or slightly concave, and covered with continuous transverse ridges; nodose lateral lobes present or absent on one or both sides at the anterior portion of the platform; sides of platform expanded as a basal apron over the gnathodid escutcheon; apex of escutcheon beneath the median part of the platform.” As well as the other workers Ellison noted the presence of intermediate forms between *Idiognathodus* and *Streptognathodus*. To the main differences between two genera he added the presence of continuous transverse ridges on the greater posterior part of the platform in *Idiognathodus*. Barskov *et al.* (1987) specified the length of carina, limited it up to one-third of the platform length for *Idiognathodus.* Grayson *et al.* (1990) based on data from multielement reconstructions placed the genus *Streptognathodus* in synonymy with *Idiognathodus* as was done before by Baesemann (1973) but focused the attention only on the character of the anterior portion of the platform to distinguish the species. Barrick & Boardman (1989), studying the occurrence of *Idiognathodus*and *Streptognathodus* species in Missourian- Lower Virgilian deposits of Texas, regard *Streptognathodus* as a valid genus with grooved posterior platform, but they consider the species, older than Missourian ones, as separate and unrelated derivations from an *Idiognathodus* ancestor (Nemirovskaya, 1999).

Nemirovskaya (1999) distinguish *Idiognathodus* and *Streptognathodus* as two separate genera and sccept the last diagnosis of Ellison (1972) and the other workers but also take into account the character of the anterior portion of the platform for speciation of *Idiognathodus.* The rostral ridges of the first Bashkirian *Idiognathodus* are mostly parallel to the carina and incorporated within the platform or slightly extend beyond the anterior limit of the platform. In younger Moscovian species they tend to be sxtended downward and curved outward from the platform away from the blade.

We agree with Ellison (1972) and Nemirovskaya (1999) in considering *Idiognathodus* and *Streptognathodus* as two distinct genera, discriminating them mostly on the basis of the absence or presence of the median groove in the upper surface. Unfortunately, most of the specimens are broken in the anterior part, making hard the classification to a specific level.

<u>Occurrence</u>: Upper Carboniferous of Europe and Asia, Pennsylvanian of North America (Nemirovskaya 1999).

Idiognathodus lobatus Gunnell, 1933

(Pl. 7, figs. 5a, b, c; 6a, b, c; 7a, b, c; Pl. 8, figs. 6a, b, c)

1933 *Idiognathodus lobatus* Gunnell- pl. 31, figs.17,18

1989 *Idiognathodus lobatus* Gunnell- Barrick & Boardman, pl. 1, figs. 7,9,24

1999 *Idiognathodus lobatus* Gunnell- Barrick & Walsh, fig. 6.4

1941 *Idiognathodus delicates* Gunnell, 1931- Ellison, pl. 22, fig. 33

1933 *Idiognathodus modulates* Gunnell, pl. 31, fig. 15

Diagnosis: Pa element with a reduced elongate rostral lobe and robust normal caudal lobe.

Remarks: a population composed by several specimens of *Idiognathodus lobatus* is present in sample ANK12, almost all the specimens shows a blade that is broken in the anteriormost part (figs. 5a, b, c and 6a, b, c, plate 7) or totally missing (figs. 7a, b, c and 8a, b, c, plate7).

In upper view platforms shows several parallel, well delineated ridges that appears to be perpendicular to the median axis of the platform or slightly waved (see figs. 7a, b, c, plate 7). Several accessory nodes are present in the junction area between carina and blade. The inner parapet appears to be slightly longer than the outer one. The blade is composed by several laterally compressed denticles fused at the base in the posterior part, the anteriormost part of the blade is always missing.
Specimens illustrated in figs. 8a, b, c (plate 7) shows slightly “V” shaped ridges. Platform is height and slightly curved in lateral view.
In sample ANK26 (Anarak section, Central Iran) only one broken specimens of this species is present.

Occurrence: *Idiognathodus lobatus* first appears in the Huspuckney Shale of the Swope Sequence, eastern Kansas, that is Missourian (Upper Carboniferous) in age (Rosscoe, 2008)

Samples ANK12 and ANK26, Zaladou Formation, Tabas area, Central Iran the age of this samples is uncertain, in fact *I. lobatus* occurs in the same samples with *Streptognathodus longus* that is reported to be Gzhelian- Asselian in age by Chernykh (2005, 2006), Chernykh *et al.* (2009) and Boardman *et al.* (2009). The distribution of *I. lobatus* is reported only for the Swope Sequence, eastern Kansas (Rosscoe, 2008) so further investigation on the distribution of this genus is needed.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY FAMILY Anchignathodontidae Clark, 1972

GENUS ***Iranognathus*** Kozur, Mostler & Rahimi-Yazd, 1975

Type species: *Iranognathus unicostatus*, Kozur, Mostler Rahimi-Yazd, 1975.

Emended diagnosis (from Mei *et al.*, 1998): a seximembrate multielement genus, the recognition of which is based on the carminiscaphate Pa element. This element possesses a fused and a narrow carina with sharp upper margin. Top of carina bears subtle pustulose micro-ornamentation.

Mei *et al.* (1998) consider this genus homeomorphic with *Sweetognathus* Clark, 1972 distinguished them by different configuration of carina: *Sweetognathus* possesses a wide and blunt carina which is usually denticulate and paved with diagnostic secondary pustulose ornamentation while *Iranognathus* possesses a fused and sharp carina and the pustulose ornamentation is subtle.

Beyers & Orchard, 1991 recognized three morphotypes primarily on the basis of carina fusion but Mei *et al.*, 2002 find that it may occur in a single population and we agree with this interpretation.

Mei *et al.*, 2002 reported that denticles are usually fused in the flat anterior carina, but tips of denticles are usually discrete in the declining posterior carina.

Occurrence: uppermost Guadalupian and Lopingian.

Iranognathus movschovitschi Kozur & Pjatakova, 1975

(Pl. 26, figs. 4a, b, c, 5a, b, c)

1975 *Diplognathodus movschovistchi*, Kozur & Pjatakova- pl. 2, figs. 3, 4, p. 39

Holotype:: specimen illustrated in Kozur (1975), plate 2, fig. 4, p. 39; Slgs. – Nr. PK 1-1

Original diagnosis: spathognathodiformes element, kleinwüchsig. Das Blatt weist vorn 5-7 Zähne auf, während die Carina hinten zu einer glatten Leiste verschmolzen ist, die flach nach hinten abfällt. Vorn sind die Zähne am gröβten, ohne daβ ein Hauptzahn ausgebildet ist. Die sehr groβe Basalgrube umfaβt mehr als die halbe Länge des Conodonten. Sie ist sehr stark un etwas asymmetrsch ausgewitet und sehr tief eingesenkt. Unter dem vorderen Teil del Conodonten ist eine sehr schmale Basalfusche vorhanden, die noch deutlich vor dem Vorderende aussetzt.

Remarks: two specimens of *Iranognathus movschovistchi* have been found in SE Pamir (sample TJ67, Gan Formation). Both specimens appears to be broken but the one illustrated in plate 26, figs. 5a, b, c is more preserved, especially in posterior part, while the anterior blade is broken in both specimens. Carina is formed by a single row of small and low denticles that appears to be almost of the same height along all the carina. In lateral view platform appears to be arched.

Occurrence: Probe 10/6a, unteres Dzhulfian (mittleres Artinskian) (Kozur, 1975)

Top of *Clarkina dokouensis* zone (Lowermost Lopingian), Penglaitan section, Laibin, South China (Mei *et al.*, 2002).

Sample TJ67, Capitanian, Gan formation, Kutal 2 section, SE Pamir.

Iranognathus punctatus Wardlaw 2000

(Pl. 26, figs. 6a, b, c)

2000 *Iranognathus punctatus* Wardlaw- pl. 3- 12, fig. 23

Holotype: USNM 482789, plate 3- 12, fig. 23

Original diagnosis: Pa element bearing several lateral nodes or "punctae" on upper surface of flaring basal cavity; single carina covered with nodes posteriorly and forming a ridge anteriorly; lateral and carinal nodes and carinal ridge with pustulose micro-ornamentation; some lateral nodes merging in larger specimens.

Remarks: specimen from SE Pamir (plate 26, figs. 6a, b, c) is well preserved. Is visible the single carina composed by nodes and the accessory nodes on the right side that forma a sort of "second carina" on the anteriormost end of the platform.

Occurrence: *Iranognathus punctatus* is common to the middle part of the Wargal Formation, Salt Range, Pakistan that is Murgabian in age (Wardlaw, 2000; Zia-ul-Rehman M. & Masood K. R. 2008).

Sample TJ 67, Capitanian, Gan Formation, Kutal II section, SE Pamir (Tajikistan).

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Gondolellidae, Lindström 1970

GENUS ***Jinogondolella*** Mei & Wardlaw, 1994

Type species: *Gondolella nankingensis* Ching, 1960.

Diagnosis (Wardlaw & Mei, 1998; Mei & Wardlaw, 1994): a gondolellid genus that is typically serrated on the anterior platform throughout ontogeny, has a low fixed blade, and bears micro-ornament for the entire length of the platform. The ratio of the carina-furrow width to platform maximum width usually ranges from 1/4 to 1/3.

Emended diagnosis (Lambert *et al.*, 2006): a gondolellid genus with a distinctive P1 element that usually bears serrations on the anterior platform (variably developed within the Middle Permian lineage). In addition, among the 15-element apparatus S3 element is distinctive in having a bifurcating anterior process.

Remarks: Lambert *et al.* (2007) reported that all species of *Jinogondolella* bear anterior platform margines that are serrated to some degree, but serrations have been observed also on some gondolellid species that do not belong to this clade.

According to Mei & Henderson (2002) and Lambert *et al.* (2007) the genus *Jinogondolella* is restricted to warm, shallow water in Permian pan tropical belt.

Jinogondolella altudaensis (Kozur, 1992)

(Pl. 19, figs. 8a, b, c)

1992 *Clarkina altudaensis* Kozur, p. 103- 106, figs. 9- 12, 14- 17.

1992 *Clarkina* cf. *C. changxingensis* (Wang & Wang)- Kozur, p. 106.

1992 *Clarkina* cf. *subcarinata* (Sweet)- Kozur, fig. 21.

1998 *Jinogondolella altudaensis* (Kozur)- Wardlaw & Mei, p. 39- 40, pl. 5, figs. 1- 23, pl. 6, figs. 1- 6, 8- 24.

1998 *Jinogondolella crofi* (Kozur & Lucas)- Mei *et al.*, pl. 1, figs. 4, 7, 8.

1999 *Jinogondolella altudaensis* (Kozur)- Wilde *et al.*, pl. 5, figs. 8- 14.

2000 *Mesogondolella altudaensis* (Kozur)- Wardlaw, p. 46, pl. 3- 5, figs. 4, 7, 8.

2002 *Jinogondolella altudaensis* (Kozur)- Lambert *et al.*, p. 350, pl. 1, figs. 4, 16, pl. 2, figs. 14- 16, 20- 31, pl. 4, figs. 1- 5, 9- 10, 13- 15, 18- 21, pl. 5, figs. 3- 4, 7- 10, 12- 16, pl. 6, figs. 1- 5, 9.

2002 *Clarkina postbitteri hongshuiensis* Henderson, Mei & Wardlaw (part), pl. 1, figs. 2, 3, 11.

Holotype: rep- no. N 40 14, geology collection of Museum of Northern Arizona, Flagstaff

Original diagnosis: platform moderately broad, widest at the beginning of its posterior third. Posterior end narrowly rounded, mostly with an indistinct notches. Platform end is often a little, something also strongly, asymmetrical and in the latter case obliquely pointed. Lateral platform margin broad, flat, slightly to moderate upturned and still rather narrow lateral margins, but no more platform serrations of the anterior platform disappeared in all specimens. The terminal main cusp disappeared (still present in transitional forms). The keel became broader, totally flat or even higher in the central part than in the marginal part. The name of this species is from the Altuda Formation (West Texas).

Remarks: specimens from SE Pamir shows a platform slightly bigger in the posterior third and usually asymmetrical, most specimens are juvenile (plate 19; figs. 8a, b, c) and it makes hard to identify them. Particularly specimen illustrated in plate 19 (figs. 8a, b, c) shows a typical asymmetrical posterior end.

Occurrence: Wardlaw (2000) reported this specimens from the Altuda Formation, western Glass Mountains, West Texas.

Lambert *et al.* (2010) report this species from the Uppermost Lamar Limestone Member and Reef Trail Member in the Guadalupe Mountains, and equivalent strata in the Apache and Glass Mountains (that are Capitanian in age).

Sample TJ29, Wordian, Gan Formation, Kubergandy section, SE Pamir, Tajikistan.
Sample TJ34, Capitanian. Gan Formation, Kubergandy section, SE Pamir, Tajikistan.
Samples TJ64 and TJ65, Capitanian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

Jinogondolella aserrata (Clark & Behnken, 1979)
(Pl. 18, figs. 8a, b, c; Pl. 19, figs. 1a, b, c; 2a, b, c, 3a, c; 4a, b; 5a, b, c, 6a, b, c; 7a, b, c; Pl. 20, figs. 2a, b, c; 4a, b, c; Pl. 22, figs. 2a, b, c; 3a, b, c)

1979 *Neogondolella aserrata* (Clark & Behnken)- p. 271- 272, pl. 1, figs. 1- 11.

1989 *Mesogondolella aserrata* (Clark & Behnken)- Kozur, p. 392.

1994 *Mesogondolella aserrata* (Clark & Behnken)- Mei *et al.*, pl. 1, figs. 4- 7, 11- 11.

1994 *Jinogondolella aserrata* (Clark & Behnken)- Mei & Wardlaw, p. 21.

1998 *Jinogondolella aserrata* (Clark & Behnken)- Mei *et al.*, pl. 2, fig. 9.

2000 *Mesogondolella aserrata* (Clark & Behnken)- Wardlaw, p. 45, pl. 3- 3, figs. 1- 16, pl. 3- 5, figs. 1- 7, pl. 3- 10, figs. 11- 17.

2002 *Mesogondolella rustaquensis* Mei & Henderson- p. 353, pl. 6, figs. 1- 3, 5, 9- 10.

2002 *Mesogondolella idahoensis lamberti* Mei & Henderson (part), p. 533- 534, pl. 7, figs. 1- 4, 6- 8.

2003 *Mesogondolella rustaquensis* Mei & Henderson- Henderson & Mei, pl. 3, fig. 9

2003 *Mesogondolella idahoensis lamberti* Mei & Henderson- Henderson & Mei, p. 4, figs. 1- 4, 6- 8.

2008 *Jinogondolella aserrata* (Clark & Behnken)- Yadong *et al.*, p. 459, pl. 1, figs. 1- 19.

<u>Diagnosis</u> (Wardlaw, 2000): platform of moderate width and length, slightly arched and bowed, widest posterior to middle, narrowing gradually to anterior from widest point; platform with a blunty rounded posterior end with a brim in most large specimens. Nearly 50% of specimens with slight to marked inflection along inner lateral margin in posterior one- third of specimen, lateral platform margin serrated to slightly serrated (1 or 2 poorly developed pairs) on anterior one- third of platform. Cusp small to moderate, circular to elongate in cross section; denticles generally of varying size and height on steadily in size anteriorly, except distalmost, which decrease in size; generally denticles in middle section of carina the lowest and most fused; furrows shallow and not well demarcated (micro-ornamentation infringing on furrows), and margins only slightly upturned (reflecting the shallower furrows). Lower side with poorly to well- developed double loop posterior to slit- like basal pit; loop posteriorly terminal on lower attachment surface; lower attachment surface appears as a shallow keel anteriorly and a narrow, slightly elevated groove as an inner keel in anterior one- third of element.

<u>Remarks:</u> Wardlaw (2000) noticed that the poorly defined and shallow furrows that are not completely smooth distinguish this species from its predecessor (*M. nankingensis*)

and successor species (*M. postserrata*), both of which have nicely incised, smooth furrows.

Few specimens have been found from SE Pamir. They are all broken in the anterior part (plate 18, figs. 8a, b, c; plate 22, fig. 2a, b, c; 3a, b, c) and the blade is missing. Platform is short and moderately width. Denticles of the carina are low and discrete or slightly fused at the base. Cusp is of the same height of posterior denticle. Lower side with poorly developed double loop posterior to slit- like basal pit. Specimen illustrated in plate 18 (figs. 8a, b, c) is at a more adult growth stage respect to those illustrated in plate 22 (figs. 2a, b, c; 3a, b, c), shows a narrow posterior brim and, on the lower surface, a more developed double loop.

<u>Occurrence:</u> Wardlaw reported this species from Vidrio Formation, Glass Del Northe Mountains, West Texas.

Yadong *et al.* (2008) reported this species from Uppert Roadian to Lowermost Capitanian at Shangsi section, Northeast Sichuan Province, China.

Samples TJ31 and TJ34, Capitanian, Gan Formation, Kubergandy section, SE Pamir, Tajikistan.
Sample TJ55, Roadian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

Jinogondolella cf. ***nankingensis***

<u>Description:</u> in sample TJ55 (Kutal 2 section, SE Pamir) is present a numerous but not well preserved population of *Jinogondolella* cf. *nankingensis*: platform appears to be more or less parallel sided in the posterior part, tapering anteriorly. The cusp is slightly higher than the posterior denticles.

Platform tapers anteriorly but the anteriormost end of the elment is not preserved and also the blade is broken in all the specimens. No serrations are visible in the anterior part of the platform and this is the reason beacause of I have classified this specimens as *Jinogondolella* cf. *nankingensis*.

Remarks: according to Ching (1960) the typical *Jinogondolella nankingensis* is characterized by a P1 element with a serraterd anterior third: in rare specimens all the platform margin is serrated but in general serrations are limited to the narrowing portion of the platform.

J. nankingensis is the senior synonym of *Jinogondolella serrata* (Clark & Ethington, 1962).

Occurrence: sample TJ55, Roadian, Gan formation, Kutal 2 section, SE Pamir, Tajikistan.

Jinogondolella* cf. *postserrata

(Pl. 24, figs. 1a, b, c, 7a, b, c; 8a, b, c)

Description: specimens from SE Pamir shows a platform of narrow width but moderate length, older specimens (plate 24, figs. 2a, b, c) shows a wider platform. The platforms are not completely preserved and the anterior part of the platform is always missing.
The platform taper in the anteriormost part, more or less abruptly. The posterior end is blunt (plate 24, figs. 1a, b, c) except for the older specimens (plate 24, figs. 2a, b, c) that develop a posterior brim. Cusp slighter bigger than the posterior denticles.
Specimen illustrated in plate 24, figs. 1a, b, c shows some slightly serration on the anteriormost end of the platform.

Remarks: respect to the species *Jinogondolella postserrata,* specimens from SE Pamir shows no or only few serrations and a cusp slightly bigger than the classic *postserrata.*

Occurrence: sample TJ63, Wordian, Gan Formation, Kutal 2 section.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Gondolellidae, Lindström 1970

GENUS ***Mesogondolella*** Kozur, 1989b

Type species*: Gondolella bisselli* Clark & Benkhen, 1971.

Original diagnosis: typical, not modified gondolellid apparatus. Cypriodelliform element generally has a sharp ridge, running from the upward- bending above the basal cavity towards the tip of the main cusp.

Platform elements has an unreduced platform of different shape, mostly running to the anterior end. Therefore, no free blade is present with exception of the highest representatives, where a short free blade may be present. Platform surface either unsculptured or with weak transverse ribs or serrations, especially in the anterior third or anterior half of the platform. Adcarinal furrows smooth or with fine mostly indistinct transversely elongated irregular reticulum. The remaining platform surface has strong microreticulation. Lower surface has a shallow V-shaped keel that ends near the posterior end near the posterior end of the platform. The terminal basal cavity is elongated and distinctly separated into two pits connected by a frurrow. The elevation around the basal cavity is oval and low, in the posterior part moderately high. Carina is generally low, highest anteriorly, especially in the posterior part sometimes totally fused in adult specimens. Cross- sections of the denticles are mostly round, in the anterior part often laterally compressed. Main cusp is terminal and indistinct to prominent. Rarely a narrow brim is developed behind the end of the carina, but mostly the carina reaches the posterior end of the platform.

Remarks: *Mesogondolella* may still represent a polyphyletic group. Early Permian forms (including the genotype) have an apparatus similar to *Jinogondolella* without the bifid S2 element but having three pairs of P elements (see Lambert *et al*., 2007). Serration with the Early Permian forms has not been documented. The apparatus for Middle and Late Permian forms has not been well documented. The apparatus of *M. phosphoriensis* is illustrated as *Xianognathus abstractus* in both Wardlaw & Collinson (1986) and Behnken *et al*. (1986) from the same horizon at the Conda Mine, Idaho. That apparatus appears to show the same apparatus pattern as those from Early Permian *Mesogondolella*. A partial apparatus from *M. bitteri* was illustrated in a thesis (Marcantel, 1975) that indicates three pairs of P elements for that species.

Emended diagnosis (Henderson & Mei, 2007): as above but excluding those Middle Permian forms with weak transverse ribs or serrations. The S3 elements have a simple anterior process lacking bifurcation.

Mesogondolella bisselli (Clark and Behnken, 1971)

(Pl. 3, figs. 7a, b: 8a, b; Pl. 4 figs. 1a, b, c; Pl.5 figs. 1a, b, c; 2a, b)

1971 *Gondolella bisselli* Clark& Behnken, p. 429, pl.1, figs. 12- 14, pl. 2, figs. 4,5: pl.3 figs. 13, 14

1975 *Neogondolella bisselli* (Clark & Behnken)- Behnken, p. 306, pl. 1, figs. 27, 31

1981 *Neogondolella bisselli* (Clark & Behnken)- Wang & Wang, p. 229, pl.2, figs. 16, 17

1981 *Neogondolella bisselli* (Clark & Behnken)- Igo, p. 37, pl. 1, figs. 2-9

1984a *Neogondolella bisselli* (Clark & Behnken)- Orchard, pl. 22. 1, figs. 14, 16, 17.

1084b *Neogondolella bisselli* (Clark & Behnken)- Orchard, p. 213, pl. 23.1, figs. 11, 17, 10?

1986 *Neogondolella bisselli* (Clark & Behnken)- Ritter, p. 154, pl.1, fig. 1

1987 *Neogondolella bisselli* (Clark & Behnken)- Wang & Rui, pl. 1, fig. 13

1988 *Neogondolella bisselli* (Clark & Behnken)- Orchard, p. 12, 12, pl. 3, figs. 1-3, 7-9, 14?

1989 *Neogondolella bisselli* (Clark & Behnken)- Wang & Higgins, p. 283, pl. 7, figs. 1, 3

1991 *Neogondolella bisselli* (Clark & Behnken)- Wang, p. 26, pl. 4, figs. 12, 13

Holotype: specimen illustrated by Clark and Behnken (1971), pl. 2, figs. 4,5: pl.3 figs. 13, 14

Diagnosis (Chernykh, 2006): platform is flat in outline and rounded at the posterior and gradational tapering anterior margins. Carina includes 12-15 small pointed denticles, from which 1-2 denticles can form the anterior platform margin. Cusp slightly larger than denticles adjacent with it. Basal cavity is relatively narrow.

Remarks: all specimens of *M. bisselli* founded in sample BEV 41 (Bagh-e-Vang section, Central Iran) are broken and the anterior part is missing, they shows a platform from flat to slightly arched with several discrete denticles. The cusp is two times bigger than the last denticle.

In sample BEV 42 (Bagh-e-Vang section, Central Iran) a monospecific fauna composed by several specimens of *Mesogondolella bisselli* have been found. These specimens show several well preserved discrete denticles laterally compressed and almost of the same height. The cusp is terminal and slightly bigger than the last posterior denticle. The platform outline shows subparallel margins which taper gently in the anterior third of the platform, the posterior end is rounded. The platform is gently arched in lateral view.
The anterior blade is composed by five laterally compressed denticles fused only at the base and only slightly higher than the posterior ones.
The specimens of *M. bisselli* from sample BEV 15 are well preserved as the ones in BEV 42 and shows the same morphology except for the blade which is composed by three denticles which are completely discrete.

Occurrence: Sakmarian Stage (Sterlitamakian substage); *anceps* Zone; Lower Permian; western slopes of southern Urals (Chernykh, 2006).

Kochusu Formation, SE Pamir, Tajikistan (Kozur *et al.*, 1994).

Samples BEV41, BEV42 and BEV15, Middle Upper Sakmarian, "Bagh-e-Vang Member", Bagh-e-Vang section, Tabas area, Central Iran.

Mesogondolella gujioensis (Igo, 1981)
(Pl. 4, figs. 2a, b, c; 3a, b, c; 4a, b, c)

1981 *Neogondolella gujioensis* (Igo) -p. 37, 38 pl. 3, figs. 1- 19, Pl. 4, Figs. 1- 6

1987 *Neogondolella gujioensis* (Igo)- Wang et Rui, pl. 1, fig. 12

1988 *Neogondolella gujioensis* (Igo) - Orchard, p. 13, pl. 2, figs. 23, 24

1989 *Neogondolella gujioensis* (Igo) - Wang & Higgins, p. 283, pl. 9, figs. 9- 11

1991 *Neogondolella gujioensis* (Igo) - Wang, p. 27, pl. 2, fig. 9

1994 *Mesogondolella gujioensis* (Igo) - Wang Z. p. 222, pl. 2, figs. 14, 15

Holotype: Igo (1981) p. 37, 38 pl. 3, figs. 1- 19, Pl. 4, Figs. 1- 6.

Original diagnosis: in oral view, element is laterally subsymmetrical, lanceolate and highly arched. Carina is composed of anterior four or five discrete, laterally com pressed denticles and a posterior nodose ridge. Posterior cusp exists at the posterior end, but it is not well developed in most adult specimens. Platform extends in full length of unit and its both sides are subparallel in central part. Anterior one-third of platform is subtriangular with rounded point. Margins of platform bow upward. Surface of platform is smooth to granular with shallow and broad lateral furrow. In aboral view, lower surface bears broad keel. Obscure groove is connected to small basal cavity, which is surrounded by loop.

Remarks: ontogenetic changes are not so distinct, but in early growth stage the element bears large posterior cusp extended beyond posterior end. Thin loop appears surrounding basal cavity and narrow basal groove is developed in early growth stage. In mature stage, conspicuous posterior cusp disappears. Obscure basal groove, low and broad obscure keel and small rounded cusp are characteristic in this stage. Lateral furrow in early growth stage is shallower than that of mature stage. This species resembles *M. bisselli*, particularly in early growth stage, but the former is distinguishable from the latter in having relatively short and posteriorly broadened platform and by the features of the lower surface, i. e. *M. gujioensis* has broad keel, but *M. idahoensis* has narrow one. Furthermore, the latter has remarkable basal groove which is lacking or obscure in the former (Igo, 1981).

Several specimens of *M. gujioensis* were founded in sample BEV 43: they shows a medium preservation and all specimens are broken in the anteriormost end or, in some cases, in the anterior third of the platform.

Carina is constituted by several (up to 14) denticles round and discrete but closely spaced. They are almost of the same length while the blade is formed by four fused and laterally compressed denticles which are higher than the carina denticles.

The cusp is terminal and at least two time bigger than the posteriormost denticle.

Platform is thick and slightly arched in lateral view. Platform margins are subparallel or slightly larger in the middle part and then taper anteriorly. The posterior end is squared or rounded. Carinal furrows are slightly visible and a reticular ornamentation is present on the upper surface of the platform. In gerontic specimens an accessory denticles should be present near the cusp and also a posterior brim should be present.

Occurrence: according to Igo (1981) the species ranges from Late Middle Sakamotozawan to Early Akasakan. Gujio Hachiman (Akuda Formation) and Ichinose (unnamed formation), Gifu Prefecture and Mt. Ibuki (Ibukiyama Limestone Group), Shiga Prefecture (Igo, 1981).

Mesogondolella gujioensis- M. intermedia Zone to *M. idahoensis* Zone, Nashui of Luodian and Yangchang of Ziyun, Guizhou, China (Wang, 1994).

Upper Jachtashian (Kungurian) of Japan, Chisian of Japan and Sicily (Kozur & Mostler, 1991).

Sample BEV43, Upper Sakmarian/Artinskian, Bagh-e-Vang Member, Bagh-e-Vang section, Tabas Area, Central Iran.

***Mesogondolella idahoensis idahoensis* (**Youngquist, Hawley & Miller, 1951)
(Pl. 10, figs. 1a, b; 2a, b, c; 3a, b, c; 4a, b, c; 5a, b; 6 a, b; 7a, b; 8a, b; Pl. 11, figs. 1a, b; 2a, b; 8a, b, c)

1951 *Gondolella idahoensis*, Youngquist, Hawley & Miller, pl. 54, figs. 1-3, 14, 15.

1975 *Neogondolella idahoensis* (Youngquist, Hawley & Miller)- Behnken, pl. 1m figs. 28- 30.

1984 *Neogondolella idahoensis* (Youngquist, Hawley & Miller)- Wardlaw & Collinson, pl. 1, figs. 10, 11.

1986 *Neogondolella idahoensis* (Youngquist, Hawley & Miller)- Wardlaw & Collinson, pl. 1, figs. 17.11- 12.

2007 *Neogondolella idahoensis* (Youngquist, Hawley & Miller)- Lambert *et al.*, pl. 3, figs. 4d, e, I, 6j- m.

Holotype: specimen illustrated in Youngquist, Hawley & Miller (1951). Figs. 3H, Q- R)

Emended diagnosis: Ning *et al.* (2010) reported the following key- characters for this species: the Pa element of juvenile and adult specimens has a large cusp that is usually at least three times as large as the posterior denticles, but it may be reduced. It also has an anterior carina with widely separated and largely discrete denticles. The platform is slender with a square termination. Ning *et al.* (2010) identified the high and sharp cusp of this species as the key- character to differentiate it from *M. idahoensis lamberti*.

Remarks: specimens from SE Pamir shows a carina composed by 4- 6 big, rounded, discrete denticles almost of the same height or slightly increasing in height anteriorly. The blade is formed by high and fused denticles. The cusp is terminal, sharp and approximately three times bigger the last denticle. The posterior end of the platform should be more or less squared: both sides of the platform are subparallel in the posteriormost third of the platform and then gently tapers in the anterior part.

Specimens from sample TJ5 (Kubergandy section, SE Pamir) shows a great variability in platform outline, due also to the older stadium of these specimens (see figs. 7a, b; plate 10).

Specimen from sample TJ21 (Kubergandy section, SE Pamir) have been identified as *Mesogondolella* cf. *idahoensis idahoensis* because of it broken platform. The big cusp and the subparallel margins in the posterior half of the platform point to *M. idahoensis* rather than *M. idahoensis lamberti* but the specimen is too bad preserved to univocally identify it as *M. idahoensis*.

Occurrence: Movshovich. (1986) reported this species from the Upper Kubergandian of SE Pamir.

Kozur *et al.*, (1994) reported the species *M. idahoensis* from lower part of Kochusu Formation and indicate it as a guide for the Cathedralian Stage.

Ning *et al.* (2010) reported this species only in the Uppermost Kungurian of South China, in Pingxiang and Dachongling sections, Guangxi region.

Samples TJ1, TJ4, TJ5, TJ6 and TJ8, Kungurian, Kubergandy Formation, Kubergandy section, SE Pamir, Tajikistan.
Sample TJ57, Roadian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

Mesogondolella idahoensis lamberti Mei & Henderson, 2002
(Pl. 12, figs. 4a, b, c; 5a, b, c; Pl. 20, figs. 3a, b, c; 6a, b, c; 7a, b, c; 8a, b, c; Pl. 22, figs. 6a, b, c; Pl. 23, figs. 2a, b, c; 3a, b, c; 4a, b, c; 5a, b, c; 6a, b, c; 7a, b, c, 8a, b, c)

1951 *Neogondolella idahoensis*(Youngquist, Hawley & Miller)

1975 *Neogondolella idahoensis* (Youngquist, Hawley & Miller)- Behnken, pl.1, figs. 28-30

1988 *Neogondolella idahoensis*(Youngquist, Hawley & Miller)- Orchard & Forster, Pl.3, figs.13, 17, 22- 24

1990 *Neogondolella idahoensis*(Youngquist, Hawley & Miller)- Wardlaw & Grant, p.A6, pl. 1, figs.8, 9, 14-16, 19-22; pl. 2, figs. 20-22, 26-28; pl.4, figs. 24, 25

1988 *Neogondolella idahoensis* n. subsp., - Orchard & Forster, pl. 3, figs. 18- 20.

1999 *M.* aff. *J. nankingensis* (King)- Mei *et al.*, p. 23, fig.1, 1999b, p. 15 in Table 1.

2000 *Neogondolella idahoensis*(Youngquist, Hawley & Miller)- Lambert *et al.*, p. 182, pl. 8-4, figs. 19, 22- 29

2000 *Neogondolella idahoensis*(Youngquist, Hawley & Miller)- Wardlaw, figs. 1.8, 1.9, 1.10

2001 *Mesogondolella siciliensis* n. subsp.- Mei & Henderson, p. 249, in Table 1.

<u>Holotype:</u> specimen illustrated in Mei & Henderson, 2002, pl. 2, fig. 8 from the Stratotype Canyon in the Guadalupe Mountains, West Texas, USA.

Original diagnosis: Pa element of young and adult specimens has a small cusp that is only slightly bigger than the posterior denticles, an anterior blade with largely fused denticles, and a platform with the middle and posterior parts usually parallel-sided and anterior part tapering evenly towards anterior and thus straight-sided. The apparatus is as the same ad that constructed by Orchard & Rieber (1999) for *Neogondolella* and has a bifurcate Sc1 element in which one of the bifurcate processes consists of only one denticle. The name is in honor of Dr. Lance Lambert for his contribution in defining the base of the Guadalupian.

Remarks: Ning *et al.* (2010) reported that this species is very similar to *M. siciliensis* in denticulation except that the anterior blade is always slightly higher and more fused in *M. siciliensis*. However, there is a characteristic difference in the platform outline. The platform of *M. siciliensis* is usually widest in the middle part, whereas in *M. idahoensis lamberti* the platform is usually parallel-sided in the middle and posterior parts, and commonly widest in the posterior part, rarely in the middle part.

In SE Pamir the species *M. idahoensis lamberti* have been founded in several samples in the Gan Formation (Kutal 2 section, SE Pamir): these specimens are quite variable in platform outline (see specimens illustrated in plate 9 and plate 23) while the pattern of the denticulation and the cusp are the same in all the specimens. A single, broken specimen, is present in sample TJ92 and another fragment have been found in sample TJ95: also if they are broken is possible to recognize, on these specimens, the characteristic pattern of denticulation that identify them as *M. lamberti.*

Specimen illustrated in plate 21 (figs. 1a, b, c) from sample TJ 49 (Kutal 2 section, SE Pamir) is named *Mesogondolella* cf. *idahoensis lamberti* because of it bad preservation: only the posterior part of the platform is preserved and the cusp is broken. The cusp seems to be bigger than the posterior denticle pointing to the subspecies *M. idahoensis idahoensis* rather than *M. idahoensis lamberti* but it is broken preventing a univocal identification.

Occurrence: Ning *et al.* (2010) report this species form Uppermost Kungurian and Roadian of Pingxiang and Dachongling section, Guangxi region, South China.

Samples TJ42, TJ47, TJ49, TJ50, Kungurian, Kubergandy Formation, Kutal 2 section, SE Pamir, Tajikistan.
Samples TJ52, TJ53, TJ54, TJ56, TJ57, Roadian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.
Samples TJ58, TJ59, TJ60, TJ62, TJ63 Wordian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.
Samples TJ92 and TJ95, Kungurian/Roadian, Kurteke section, SE Pamir, Tajikistan.

Mesogondolella manifesta Chernykh, 2005

(Pl. 1, figs. 1a, b, c; 2a, b, c; 3a, b, c; 4a, b, c; Pl. 2, figs. 1a, b, c; 2a, b, c,; 3a, b, c)

2005 *Mesogondolella manifesta* Chenrykh, pl. XXIII, figs. 9- 13, 16

2006 *Mesogondolella manifesta* Chernykh, plate XXVII, fig. 17

Holotype: Usolka Section, bed 27 (60.6 m above base of section). Lower Permian Sakmarian Stage (Tastubian substage); *merrilli* zone.

Original diagnosis: the platform is narrow, elongated with the parallel margins for 2/3 of the length, rounded in posterior margin and constricted to front end. Carina includes numerous (up to 20) laterally compressed denticles, of which the majority are attached by their bases. The cusp is larger than the penultimate denticle and is located at the rear edge of platform. Adcarinal furrows are narrow and shallow, covered with reticulate microornament. Basal cavity is narrow. The name is from the Latin *manifestus* (easily identified).

Remarks: all specimens of *M. manifesta* founded in sample BEV 40, Bagh-e-Vang section, Tabas area, Central Iran are broken in the anterior third of the platform. The platform is thick and the margins are subparallel and appear to gently tapering in the anterior part (plate 1, figs. 1a, b, c; 2a, b, c, 3a, b, c; 4a, b, c). Carina is formed by several (up to 10) laterally-compressed denticles: some specimens shows totally discrete denticles

in the carina, while others shows denticles fused only at the base. In some specimens the posteriormost two denticles are slightly smaller than the others.
The denticles of the carina are almost all of the same height. The cusp is terminal and bigger than the other denticles. Carinal furrows are shallow and narrow. In lateral view the platform appears to be gently arched.

Specimens form sample BEV 10 (Bagh-e-Vang section, Central Iran) are still broken in the anterior part (plate 2, figs. 1a, b, c; 2 a, b, c; 3a, b, c). They shows several slightly laterally- compressed, fused at the base, denticles. The posteriormost two denticles are smaller than the others (which are almost all of the same height).

Two broken specimens classified as *Mesogondolella* cf. *manifesta* is present in sample SHA12 (Shesht- Angosht section, Central Iran).In the first specimen (plate 9, figs. 6a, b, c) is only the posterior third of the platform and the cusp is broken even if it looks straight and bigger than the last denticles. Denticles appears to be discrete and almost of the same height.
The second specimen (that is not illustrated) is only the anteriormost part of a platform and shows three denticles on the blade which are almost discrete and bigger than the posterior ones.

<u>Occurrence:</u> Tastubian substage of Sakmarian Stage; *merrilli* zone, Lower Permian; western slope of Ural Mountains (Chernykh, 2006).

Samples BEV40 and BEV10, Lower- Middle Sakmarian, “Bagh-e-Vang Member”, Bagh-e-Vang section, Tabas Area, Central Iran,
Sample SHA12, Sakmarian (?), “Bagh-e-Vang Member”, Shesht-Angosht section, Tabas area, Central Iran.

Mesogondolella monstra Chernykh, 2005

(Pl. 2, figs. 4a, b, c; Pl. 28, figs. 3a, b, c; 4a, b, c, 5a, b, c; 6a b, c, 7a, b, c, 8a, b, c; Pl. 29 figs. 1a, b, c, 2a, b, c)

2005 *Mesogondolella monstra* Chernykh, p. 93, pl. 25, figs 1, 4; pl. XXII, figs. 7, 8, 12, 14- 16

2006 *Mesogondolella monstra* Chernykh, pl. XXVII, figs. 15- 16

Holotype: Usolka Section, bed 25 (53 m above base); lower part of the Tastubian substage of Sakmarian Stage; *merrilli* Zone.

Original diagnosis: platform is weakly asymmetric, straight or slightly rounded from behind and tapered narrowly to anterior end. Carinal denticles fused at their bases, of which the front 4-6 teeth are larger than rest (including the cusp) and they are raised above them in the form of a distinct comb. Massive chisel-shaped cusp on rear edge of platform. Basal cavity is narrow. The name is from the Latin *monstratus* (put out itself).

Remarks: all the specimens present in sample BEV10 (Bagh-e-Vang section, Central Iran) are broken in the anterior 1 or 2/3 making their identification very hard. Specimen illustrated in plate 2, figs. 4a, 4b, 4c is broken and encrusted but shows at least three anterior denticles (the anteriormost are missing) higher respect to the other denticles of the carina. The cusp is broken but appears to be higher than the posterior denticles.

Several well preserved specimens of *M. monstra* are present in sample TJ82 (100m below the top of the Tashkazyk Formation, Mudzubulak, SE Pamir, Tajikistan): this samples yield a very numerous and well preserved population of *M. monstra* (plate 28, figs. 3a, b, c; 4a, b, c; 5a, b, c; 6a, b, c, 7a, b, c; 8 a, b, c; plate 29, figs. 1a, b, c; 2a, b, c). From these integer specimens is possible to appreciate, together with the platform outline, the feature of the three- four anteriormost denticles of the blade that are discrete and higher than the others.

Occurrence: Tastubian substage of Sakmarian Stage, *merrilli* to *binodosus* Zones; Lower Permian, western slope of Ural Mountains (Chernykh, 2005).

Sample BEV10, Lower Sakmarian, “Bagh-e-Vang Member”, Bagh-e-Vangh section, Tabas area, Central iran.

Sample TJ82, Sakmarian, 100m below the top of the Tashkazyk Formation, Mudzubulak, SE Pamir, Tajikistan.

Mesogondolella pingxiangensis Zhang, Henderson & Xia, 2010

(Pl. 13, figs. 4a, b; 5a, b; Pl.14, figs. 8a, b, c; Pl. 15, figs. 1a, b, c; 3a, b; Pl. 16, figs. 4a, b; 5a, b; 6a, b, c; 7a, b, c, 8a, b, c; Pl. 17, figs. 3a, b, c, 4a, b, c; 5a, b, c; 6a, b, c; Pl. 18, figs. 5a, b, c; 6a, b, c; 7a, b, ; Pl. 21,figs. 2a, b, c, 3a, b, c; Pl. 22, figs. 7a, b, c; 8a, b, c; Pl. 26, figs. 1a, b, c)

2010 *Mesogondolella pingxiangensis* Zhang, Henderson & Xia sp. nov. *(Figs 4A–I)*. In: Ning *et al.*

Holotype: Pnv 9-22/1130-1-16 (Fig. 4C);sample pnv 9-22 of the Pingxiang section,China; lower Roadian.

Original diagnosis (in Ning *et al.*, 2010): a species of Mesogondolella with smooth anterior platform margins, closely spaced discrete to partially fused denticles on the carina, mostly fused denticles forming a high anterior blade, a moderate-sized cusp slightly higher than the penultimate posterior denticle and a strongly arched platform from posterior to anterior.

The strongly arched aspect of the Pa element as seen in lateral view is the key diagnostic character. In many species during this interval, the posterior platform is straight to gently arched and the anterior is downwardly deflected, but in this species both the anterior and posterior part of the platform show downward deflection in lateral view.

This species has an identical platform shape, including outline and arching, to some specimens of *Jinogondolella nankingensis nankingensis* from South China (e.g. Luodian section; see plate 1, fig. 3 of Mei & Henderson, 2002). It is, therefore, considered to be a smooth gondolellid related to *Jinogondolella nankingensis nankingensis* or at least a geographic variant within a broader concept of late forms of Mesogondolella lamberti. It is deemed to be a likely ancestor of *Jinogondolella nankingensis nankingensis*.

Specimens of *Mesogondolella pingxiangensis* from SE Pamir shows strongly arched platforms: also when the platforms are less arched they are deflected downward in anterior and posterior parts (see plate 13, figs. 4a, b; 5a, b).
Denticles of the carina are low, slightly fused at the base and almost of the same height. Denticles of the carina are high, fused and laterally compressed. Cusp is of the same height of the other denticles.

<u>Occurrence:</u> as an ancestor to serrated *J. nankingensis nankingensis*, this form should be considered late Kungurian, but significant evidence including associated radiolarians suggests that the presence of serration is delayed in many South China sections and that this species defines at least an earlier interval of the Roadian. It was recovered from beds 9–18 to 9–22 of the Pingxiang section (Ning *et al.*, 2010).

Sample TJ12, Roadian, Kubergandy Formation, Kubergandy section, SE Pamir, Tajikistan.
Samples TJ25, TJ26, TJ27 and TJ29, Wordian, Gan Formation, Kubergandy section, SE Pamir, Tajikistan.
Samples TJ30, Capitanian, Gan Formation, Kubergandy section, SE Pamir, Tajikistan.
Sample TJ50, Kungurian, Kubergandy Formation, Kubergandy section, SE Pamir, Tajikistan.
Samples TJ52, TJ53 and TJ54, Roadian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

Mesogondolella siciliensis (Kozur, 1975)

(Pl. 5, figs. 3a, b, c; 7a, b, c; 8a, b, c; Pl. 6, figs. 2a, b, c; 6a, b, c; 8a, b, c; Pl. 9, figs. 7a, b, c; 8a, b, c; Pl. 11, figs. 3a, b; 9a, b, c; Pl. 12, figs. 1a, b, c; 2a, b, c, 3a, b; 8a, b, c, Pl. 13, figs. 1a, b, c; 2a, b; 3a, b; Pl. 14, figs. 3a, b, c; 4a, b, c; 5a, b, c, 6a, b, c, 7a, b, c; Pl. 15, figs. 4a, b; 5a, b, 6a, b, c; Pl. 16 figs. 6a, b, c; Pl. 17, figs. 1a, b, 2a, b, 7a, b, c; Pl. 18, figs. 2a, b; Pl. 21, figs. 8a, b, c; Pl. 22 figs. 1a, b, c; Pl. 23, figs. 1a, b, c, Pl. 24, figs. 2a, b, c)

1975 *Gondolella siciliensis* (Kozur,)- p. 20- 21.

1965 *Gondolella rosenkrantzi* (Bender & Stoppel)- 1965, pl. 14, figs. 4-6

1975 *Gondolella siciliensis* (Kozur)- pp. 20-21.

1989 *Mesogondolella zsuzsanne* (Kozur)- pp. 389- 399.

1989 *Gondolella siciliensis* (Kozur)- Kozur, pl.3, figs. 6,7, pl. 5, figs. 1-7, fig. 1.

1989 *Mesogondolella idahoensis* (Youngquist, Hawley & Miller)- Kozur, pl. 2, figs. 5-6, pl.3, figs. 4-7

1989 *Mesogondolella phosphoriensis* (Youngquist, Hawley & Miller)- Kozur, pl.4, fig. 1.

1989 *Mesogondolella slovenica* (Ramovs)- Kozur, pl. 4, fig. 4.

1989 *Mesogondolella zsuzsanne* (Kozur)- Kozur pl.1, figs. 1-4, pl.2, figs. 1-4.

1993 *Gondolella siciliensis* (Kozur)- Kozur pl. 1, fig. 7.

1994 *Gondolella siciliensis* (Kozur)- Kozur pl.1, figs.4, 11.

1995 *Gondolella phosphoriensis* (Youngquist, Hawley & Miller)- Kozur pl.1, figs. 7-9.

1997 *Mesogondolella phosphoriensis* (Youngquist, Hawley & Miller)- Kozur pl. 1, figs. 4-5.

1997 *Mesogondolella slovenica* (Ramovs)- Kozur pl.1, fig.6.

1997 *Gondolella siciliensis* (Kozur)- Kozur pl. 3, figs. 1-3.

2002 *Mesogondolella siciliensis* (Kozur)- Mei & Henderson, pl. 1, figs. 6, 8, 9, 11-13, pl. 5, figs. 1-11, pl.6, figs. 4, 6-8, 11.

2003 *Mesogondolella siciliensis* (Kozur)- Henderson & Mei, pl. 1, figs. 1-14.

Holotype: *Das bei BENDER & STOPPEL (1965), Taf. 14, Fig. 5 unter G. rosenkrantzi abgebildete Exemplar.*

Original diagnosis*: Großwüchsiger Conodont mit breiter Plattform, deren größte Brreite etwa in der mitte liegt. Von hier wird sie nach hinten zunächst etwas schmäler und verbreitert sich dann nahe dem abgestumpften oder breit gerundeten Hinterende wieder etwas, ohne hier im allgemeinen jedoch die fehlt. Die Carina trägt 13- 19 Zähnchen übergehen. Der letze Zahn ist meist etwas breiter als die übrigen, ohne jedoch einen typischen Hauptzahn zu bilden. Plattformoberfläche grubig. Der "Kiel" ist mäßig breit; diue Basalfurche un ddie Basalgrube sind deutlich.*

Vorkommen*: Mittelperm (Wordian) des tethyalen Bereichs.*

Bexiehungen*: Die engsten Beziehungen bestehen zu G. rosenkrantzi aus dem Capitanian (? Und unterem Abadehian), bei der ebenfalls das freie Blatt noch fehlt, die aber ihre größte Breite stets nahe dem Hinterende aufweist und dadurch in der Aufsicht ihren charakteristichen langgestreckt-drei-eckigen Umriß erhält." Nach dem erstmaligen Nachweis in Mittelperm von Sizilien.*

Emended diagnosis (Mei & Henderson, 2002): a species of *Mesogondolella* in which the Pa element of young and adult specimens has a small cusp that is equal to or only slightly bigger than the posterior denticles, an anterior blade with high and largely fused denticles, and a platform that is usually widest around the middle part. The posterior denticles are more discrete than the anterior ones. The apparatus is the same that constructed by Orchard and Rieber (1999) for *Neogondolella*, but the Sc1 element does not have a bifurcate process.

Remarks: specimens of *Mesogondolella siciliensis* from sample BEV44 and BEV 45 (Bagh-e-Vang section, Central Iran) are well preserved while specimes from SE Pamir (Tajikistan) shows different level of conservation.

Juvenile specimens show 9 discrete denticles : the posteriormost 4-5 are almost of the same height while the anteriormost 3-4 are slightly higer. The cusp is sharp and at least two times bigger than the posteriormost denticle. In upper viewplatform margins tapering gently in the anterior part and tend to be slightly wider in the middle part of the platform. The posterior margin is square to rounded. Specimens show a discrete variability in platform arching.

Adult specimens shows a higher blade formed by several, about 7, fused denticles. Denticles of the blade increase in height anteriorly except for the last one which is slightly lower than the previous one. Carinal denticles are 4-5, rounded and discrete. There is a gap between the posteriormost denticle and the cusp that is terminal, erected and sharp. Some adult and gerontic specimens develop a posterior brim.
Platform outline shows some variability in upper view ranging from wider in the middle part of the platform, gently tapering anteriorly and posteriorly, to almost straight and parallel margins tapering only anteriorly.
Platform arching is quite variable: some specimens are only slightly arched while others shows a well develop arch in lateral view. Specimens from sample SHA15, illustrated in plate 9, figs. 7a, b, c; 8a, b, c are broken but the outline of the platform and the features of the blade identified these specimens as *M. siciliensis.*

Looking at variability in platform outlines I recognized some transitional forms between *Mesogondolella siciliensis* and *Mesogondolella omanensis* both in Central Iran (specimens illustrated in plate5 fig. 4a,b,c and plate 6 fig. 3a, b, c) and in SE Pamir (pl. 18, figs. 2a, b): this specimens have subparallel to parallel margin and a subtriangular outline in upper view.
M. omanensis evolves from *M. siciliensis* in Upper Wordian and transitional forms are very common in this lineage. Transitional forms are characterized by a less widening in the middle part of the platform (that can be more or less indistinct) and both sides of the platform tend to be parallel. Kozur & Wardlaw (2010) assigned the specimens with one side straight and the other convex to the species *M. omanensis.*

Specimen illustrated in plate 6 looks a more advanced transition to *Mesogondolella omanensis*: denticles are more numerous than in *Mesogondolella siciliensis* and cusp is only slightly bigger than the posteriormost denticle of the carina. Carina is composed by 5 discrete and rounded denticles and blade by 10 fused denticles. Denticles increase in height starting from the posteriormost denticle of the carina. The last denticle of the blade is slightly lower than previous one.

<u>Occurrence:</u> Kozur designed this species as a Guadalupian index taxon (Kozur, 1988, 1989b, Kozur *et al.*, 2001).

Henderson & Mei (2003) reported this species from the Upper Kungurian in South China, Texas and Oman.

Ning *et al.* (2010) reported abundant specimens of *M. siciliensis* from Uppermost Kungurian to lowest Roadian in the Pingxiang section, Guangxi region, South China.

Samples BEV 44, BEV 45, BEV 46 and BEV 48, Wordian/Lower Capitanian (?), Jamal Group, Bagh-e-Vang section, Tabas area, Central Iran.

Sample SHA15, Bagh-e-Vang Member, Shesht- Angosht section, Tabas area, Central Iran.

Samples TJ1, TJ6, TJ7, TJ8, TJ9, TJ10, TJ11 and TJ12, Kungurian, Kubergandy Formation, Kubergandy section, SE Pamir, Tajikistan.
Samples TJ22, TJ24, TJ25, TJ26, TJ27, TJ29 and TJ30, Roadian, Gan Formation, Kubergandy section, SE Pamir, Tajikistan.

Samples TJ42, TJ47 and TJ60, Wordian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

Samples TJ92 and TJ94 Roadian, Kurteke formation, Kurteke section, SE Pamir, Tajikistan.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Sweetognathidae Ritter, 1986

GENUS ***Pseudohindeodus*** Gullo & Kozur, 1992

Type species: *Pseudohindeodus ramovsi* Gullo & Kozur, 1992, p. 222, topmost Chihsian (topmost Lower Permian) at Pietra dei Saracini, Sosio Valley area, Italy.

Remarks (Shen *et al.*, 2013): *Pseudohindeodus* was defined by Gullo & Kozur (1992) as having a diagnostic crimp around the fringe of the extremely flared basal cavity, which is absent in *Hindeodus* Rexroad & Furnish, 1964 and *Diplognathodus* Kozur & Merrill in Kozur, 1975. Gullo & Kozur did not describe an S0 element in *Pseudohindeodus*, which can easily differentiate it from *Hindeodus*. However, Wardlaw (2000, pl. 3-1, figs. 5- 24) figured various apparatus elements of *Pseudohindeodus ramovsi* including S0 and S2 to S4 elements, the digyrate S1 element is not shown. The S0 element is alate with a long denticulate posterior process in distinct contrast to the alate S0 of *Hindeodus* with a very short (swelling of cusp) adenticulate posterior process. The S2 to S4 elements are all bipennate and are characteristically bilaterally asymmetrical with longer posterior processes than in comparable elements of *Hindeodus* (Sweet 1970a, b; von Bitter & Merrill, 1985). Thus, *Pseudohindeodus* may not be closely related to *Hindedous* despite the general similarity in their P1 elements.

Pseudohindeodus has a similar apparatus to *Diplognathodus* (Kozur & Merrill in Kozur, 1975), with the only difference being the development of a crimp around the fringe of the flared basal cavity in the P1 element in all growth stages (Wardlae, 2000; Gullo & Kozur, 1992). However, this character may not be significant to differentiate *Pseudohindeodus* from *Diplognathodus*.

Pseudohindeodus ramovsi Gullo & Kozur, 1992

(Pl. 5, figs. 6a, b, c; Pl. 11, figs. 4a, b; 6a, b; 7a, b; Pl. 15, figs. 8a, b, c; Pl. 18, figs. 4a, b, c; Pl. 24, figs. 5a, b)

1992 *Pseudohindeodus ramovsi* Gullo & Kozur, pp. 223- 224, fig. 4A- H

1982 *Anchignathodus minutus* (Ellison)- Ramovš, pp. 425, fig. 4/7

1975 *Anchignathodus typicalis* Sweet- Behnken, pp. 297- 298, pl. 2: fig. 12

1990 *Hindeodus excavatus* (Behnken)- Wardlaw & Grant, A6, pl. 3, figs.3

2000 *Pseudohindeodus ramovsi* Gullo & Kozur- Wardlaw, pp. 64-65, pl. 3-1, figs. 5- 24

Diagnosis (from Wardlaw, 2000): Pa element completely denticulate, denticles compressed and laterally expanded, but posteriormost 3 or 4 less compressed and decreasing in size distally; in upper view, surface above fringing crimp spade-shaped.

Remarks: this species have been found both in Central Iran (Bagh-e-Vang section) and in SE Pamir. Specimens from both areas appears to be small but well preserved showing the classic outline of this species in upper and lower view. Population from sample TJ7 (Kubergandy section, SE Pamir) is particularly well preserved (plate 11, figs. 4a, b; 6a, b and 7a, b).

Occurrence: Wardlaw (2000) reported *P. ramovsi* occurrence throughout the Road Canyon, Word and Altuda formations and also from a sample in the South Wells Limestone Member of the Cherry Canyon Formation (Roadian- Capitanian).

Gullo & Kozur (1992) reported it from Wordian strata of Sicily.

Lai *et al.* (2008) reported *P. ramovsi* ranging up to the *J. shannoni* Zone in West Texas.

Sample BEV44, Wordian, Jamal Group, Bagh-e-Vang section, Tabas area, Central Iran.

Samples TJ7 and TJ11, Kungurian, Kubergandy Formation, Kubergandy section, SE Pamir, Tajikistan.

Sample TJ34, Capitanian, Gan Formation, Kubergandy section, SE Pamir, Tajikistan.
Sample TJ63, Wordian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY *Idiognathodontidae* Harris & Hollingsworth, 1933

GENUS ***Streptognathodus*** Stauffer & Plummer, 1932

1932 *Streptognathodus* Stauffer & Plummer

1933 *Streptognathodus* Gunnell

1933 *Polygnathus* Harris & Hollingsworth

1941 *Streptognathodus* Ellison

1972 *Streptognathodus* Ellison

1978 *Streptognathodus* Kosenko & Kozitskaya, in Kozitskaya *et al.*

1979 *Streptognathodus* Barskov & Alekseev

Type species: *Streptognathodus excelsus* Stauffer & Plummer, 1932

Diagnosis (from Nemirovskaya, 1999): according to the first description of Stauffer & Plummer (1932), the platform is “somewhat lanceolate, subsymmetrical, with a deep axial furrow, toward which the eight to dozen or more lateral ridges marking the upper surface, extend from each side and in which they disappear”. Usually shelf- like processes extend out from each side at the base of the plate and may bear nodes. Blade enters the platform and extends as a carina " into the furrows and usually ends at some point between the base and middle of the plate." Gunnell (1933) noted that the upper surface of the plte has "longitudinal, median groove on each side of which occur nodes or ridges". Later on Ellison (1941, 1972) gives a revised diagnosis of the genus *Streptognathodus* as follows: "Straight to arched and slightly curved lanceolate elongate platform with the anterior blade meeting the platform in a median position and continuing posteriorly onto the platform as a carina for about one- third the length of the platform; an oral trough then continues posteriorly for the remainder of the length of the plate; parapets on both sides may or may not be present at the anterior part of the platform; sides of the platform expanded as a basal apron over the excutcheon; apex of the excutceon beaneath the median trough". Barskov *et al.* (1987) inclue in the genus also the forms with long carina that "can reach the posterior end of the platform". Barrick & Boardman (1989) distinguish *Streptognathodus* from *Idiognathodus* mainly by the same features but they consider the Bashkirian- early Moscovian streptognathodids as "separate and unrelated derivations from an *Idiognathodus* ancestor". Such point of view might be reasonable, taking into account the advanced structure of the first Bashkirian *Streptognathodus* and the considerable difference between them and the early Moscovian streptognathodids.

For this thesis we follow the diagnosis accepted by Nemirovskaya (1999).

Remarks (from Boardman *et al.*, 2009): *Streptognathodus* has a typical compliment of gnathodid ramiform elements in a septimembrate (15-element) apparatus. Because of the abundance of their material, Boardman *et al.* (2009) are able to notice that Pa element occurs as an asymmetric pairs as previously reported by Wardlaw *et al.* (1991). Commonly, both dextral and sinistral elements have been identified specifically. Both dextral and sinistral forms have the same stratigraphic range: the dextral morphotypes looks slightly more robust than the sinistral ones. The posterior carinal termination, the

median furrow, and the style of denticulation are similar in both dextral and sinistral forms. The more robust form generally has a few more accessory denticles or develops them slightly earlier in growth (if size is a good proxy for growth) than the slender form.

In forms that do not commonly develop accessory nodes, one or two may be present on gerontic examples of the robust form. The ramiform elements of the apparatus are very similar between species.

Observing material from the Americus Limestone Member (Foraker Limestone, see also Gunnell, 1933) Boardman *et al.* observed three major lineages of *Streptognathodus* that dominate the latest Carboniferous and earliest Permian. These are a lineage of very closely related robust forms that are characterized by no to few accessory nodes (denticles) exemplifi ed by *S. barskovi*, a lineage of moderate to robust forms that are characterized by common accessory nodes (denticles) and lobes exemplifi ed by *S. wabaunsensis* and *S. farmeri*, and a lineage of elongate forms that are characterized by few accessory nodes (denticles) exemplifi ed by *S. elongatus*. All three lineages appear to derive from *Streptognathodus bellus*.

Nemirovskaya (1999) remarks that, inspite of *Streptognathodus* having intergradational forms with *Idiognathodus,* it differs from the latter by having a median trough and parapets and by the absence of continuous transverse ridges on most of the platform.

<u>Range</u>: Middle Carboniferous- Lower Permian, cosmopolitan (Nemirovskaya, 1999).

Streptognathodus **aff.** ***lanceatus***

(Pl. 1, figs. 5a, b, c; 7a, b, c; 8a, b, c)

<u>Description:</u> our specimens from sample BEV40, Bagh-e-Vang section, Bagh-e-Vang Member, Tabas area, Central Iran unfortunately are few and bad preserved. Particularly the blade is not preserved in our specimens, making difficult to determine the species.

In specimens from sample BEV40 platform gradually tapers proceeding to the posterior end, were the posteriormost part of the platform is preserved it looks pointed. Median axial groove is well defined and cut all the transverse ridges except for the posteriormost

1-2; it is more or less sinuous and in a median position or shifted to one side. Blade is always broken. In lateral view platform is high and only slightly arched.

Remarks: Chernykh (2005) describe the platform as "nearly symmetrical, arrowhead shaped. Front branches of the parapets relatively short, up to 1/3 of the length of the platform. They widely deployed in hand and covered with fully developed transverse ribs, adjacent to the free blade in the last third of its length. The internal parapet somewhat broader the external one. The "tongue" of platform restricted with weakly convex edges and pointed (sharpened) on the back end. It is covered with 10-12 transverse ribs, that are crossed at the axis by V-shaped trough, keeping intact one or two of the last rib". The name of the species is from the Latin "lanceatus" because of the arrow end of the platform.

Chernykh (2005) reported dextral and sinistral elements as almost identical, however the sinistral ones often shows the internal parapet omitted down a bit while this feature was never observed in dextral specimens.

Our specimens from sample BEV40, Bagh-e-Vang section, Bagh-e-Vang Member, Tabas area, Central Iran unfortunately are few and bad preserved. Particularly the blade is not preserved in our specimens, making difficult to determine the species. Platform gradually tapers proceeding to the posterior end, were the posteriormost part of the platform is preserved it looks pointed. Median axial groove is well defined and cut all the transverse ridges except for the posteriormost 1-2; it is more or less sinuous and in a median position or shifted to one side. Blade is always broken. In lateral view platform is high and only slightly arched.

The co- occurrence of *S.* aff. *lanceatus* species with the species *Mesogondolella manifesta*, which is Sakmarian in age, allow us to conclude that this species could range up to Lower- Middle Sakmarian.

Occurrence: *Streptognathodus fusus* zone, Asselian Stage, Cisuralian; western slope of southern Urals (Chernykh, 2005, 2006).

Sample BEV40, Lower Sakmarian, "Bagh-e-Vang Member", Bagh-e-Vang section, Tabas area, Central Iran.

Streptognathodus longus Chernykh, 2005

2005 *Streptognathodus longus* Chernykh, pl. VII, figs. 1- 12; pl. XII, figs. 10- 15

2006 *Streptognathodus longus* Chernykh, pl. III, fig. 7

Holotype: No U-25-16, Usolka section, Asselian Stage, bed 16/ 4, *glenisteri* zone.

Original diagnosis: elongate- lanceolate flat platform with a fully developed transverse ribs, partly interruptible with median furrow.

Remarks: (Chernykh, 2005) on some rare specimens on the lateral internal side of the platform appear 1-2 small nodes.

Several specimens of *S. longus* have been found in samples ANK12 and ANK26 in Anarak 3 section (Central Iran): they are almost well preserved also if the blade is not entirely preserved (plate 7 fig. 8a, b, c; plate 8 figs. 2a, b; 3a, b, c; 4a, b, c; 5a, b, c). Platform appears to be narrow and elongated, the posterior end is quite variable in shape and should be sharp or rounded. A small constriction is present on the outer side of the platform at the junction with the carina. Upper side of the platform shows several transverse ribs more or less continuous: in some specimens almost all the ribs appear to be interrupted by the median groove, while in other specimens the posteriormost ribs are continuous.

This species was found, in both samples, together with a typical carboniferous species: *Idiognathodus lobatus*. In literature *S. longus* is reported to be Asselian in age but the age of the Zaladou Formation (Central Iran) should be Gzhelian according to fusulinids. This open a question on the truly range of this species.

Several species from ANK12 (Anarak 3 section, Central Iran) sample are named as *Streptogathodus* cf. *longus* because of some character like a wide median groove in figs. 1a, b, c, plate 8 or bad preservation like specimens illustrated in plate 8, figs. 6a, b, c and 7 a, b, c.

Occurrence: Chernykh reported this species from the *glenisteri- cristellari* Zone, Asselian Stage, Cisuralian; western slope of Souther Urals.

Chernykh and Chuvashov (2014) reported that the species *S. longus* is present throughout the entire Asselian.

Samples ANK12 and ANK26, Gzhelian?, Zaladou Formation, Anarak 3 section, Tabas area, Central Iran.

Streptognathodus* cf. *plenus

(Pl. 7, figs. 3a, b, c)

Description: sample IR10-11 only contains one well preserved specimens of *Streptognathodus* cf. *plenus.* The specimen appears to be integer: in upper view the platform appears to be crossed by the blade for more than one half. The posteriormost denticle appears to be rounded and separated from the rest of the blade.
Platform is constricted in its middle part and the posterior end is rounded.
Platform ornamentation is formed by "V" shaped ridges separated by a median groove in the posterior half of the platform and from the blade in the anterior part. Parapets are slightly asymmetrical and expanded in the anteriormost part.
The blade is of the same length of the platform.

Occurrence: sample IR10- 11, Sardar Group, Zaladou section, Tabas area, Central Iran.

***Streptognathodus postconstrictus* Chernykh, 2006**

(Pl. 1, figs. 6a, b, c; Pl. 2, figs. 6a, b, c)

2006 *Streptognathodus postconstrictus* Chernykh, pl. XI, figs. 13- 17

Holotypus: No U-34-17, Left form; Usolka section; Asselian Stage, bed 22 / 2, *postfusus* zone.

Original diagnosis (Chernykh, 2006): extended, wide at the front platform with a sharp contraction at the level of the end of carina and severely protruding slightly ribbed internal front branch of the parapet. The name of the species is from the Latin *post* (after) and *constrictus* (name of existed Asselian conodont- index species).

Remarks: Chernykh (2006) described the Pa element with a platform that look more wide in the anterior part because of the strongly protruding internal front branch of the parapet. At the anterior ending of the carina there is a clear platform contraction that is strongly expressed on the inner side of the platform. Front and rear branches of parapets are approximately equal in length and are gently inclined and widely disclosed. They appear to be gently ribbed in the area surrounding the carina. Toward free blade ribs become wavy or smooth. Rear branch of internal parapet issued upwards and onside compared to the external branch. Front branches of parapets form concave V-shaped in cross section elongated tongue that covered with 10-11 transverse ribs, separated by a narrow median trough. This trough lies in the same line with carina. Carina smooth, short, less than 1/3 of the length of the "tongue". Free blade weakly notched is about half the length of platform. Dextral forms differ from the sinistral one by shortened tongue and relatively longer front branches of parapets. Sinistral forms show a definite similarity to S. *constrictus*, but differ from it by strongly protruding internal front branch of the parapet . Another noticeable difference is that on *S. constrictus* median trough situated at an angle relative to carina, while on the described species the median trough oriented the same way as carina.

Specimens of *S. postconstrictus* in samples BEV40 e BEV10, Bagh-e-Vang section, Bagh-e-Vang member, Tabas area, Central Iran appear broken and fractured. The blade is always broken like the outer ends of the basal cavity.

In upper view the platform appears to be wider in the anterior part and gently taper toward the posterior end which ends with a tip. Median groove is in the middle of the carina and completely divided the anteriormost 9- 10 denticles while the posteriormost 6 are more continuous. Specimens illustrated in plate 1, figs. 6a, b, c shows an expansion on the internal branch of the parapet with some accessory nodes.

As for the species *S.* aff. *lanceatus* the co-occurrence of *S. postconstrictus* together with *M. manifesta* point to an Asselian- Lower/Middle Sakmarian for this species.

Occurrence: *Streptognathodus postfusus* Zone*,* Asselian Stage, Cisuralian; western slope of southern Urals (Chernykh, 2006).

Samples BEV40 and BEV10, Lower Sakmarian, "Bagh-e-Vang Member", Bagh-e-Vang section, Tabas area, Central Iran.

Streptognathodus postfusus Chernykh & Reshetkova, 1987

(Pl. 2, figs. 5a, b, c; 7a, b, c)

1987 *Streptognathodus postfusus* Chernykh & Reshetkova, sp. nov. Plate II, fig. 11- 13

2009 *Streptognathodus postfusus* Chernykh & Reshetkova - Boardman *et al.*, p. 152.

Holotype: No. 181; Bashkirian ASSR, Krasnousol'sk Region, right bank of the Usolka River; Lower Permian, Asselian Stage, zone of *S. postfusus.*

Diagnosis (from Boardman *et al.,* 2009): platform high, from above flattened, elongated, constricted at level of end of median carina, with almost symmetrically located axial groove. Axial carina takes up less than one-fourth of length of platform. The name is from the Latin *post* (after) and *fusus*, the name of an index-conodont of the Asselian stage.

Remarks: the specimens from sample BEV10, Bagh-e-Vang Member, Bagh-e-Vang section, Tabas area, Central Iran are fairly preserved but the blade is broken in all the specimens. Platform is wide, more expanded in the middle part and parapets are slightly asymmetric (the inner ones is longer than the outer ones). Median groove divided platform into two more ore least equal parts in upper view. Almost all the transverse ridges are interrupted by the median groove, except for the posteriormost 1-2.

The presence of this species together with Sakmarian species like *M. monstra* and *M. manifesta* point to the fact that *S. postfusus* could range trough the Asselian until the Lower- Middle Sakmarian.

Occurrence: Upper zone of the Asselian Stage of the Lower Permian; western slope of the southern Urals (Chernykh, 2006; Boardman *et al.*, 2009).

Gzhelian- Asselian (Chernykh *et al.*, 2009)

Sample BEV10, "Bagh-e-Vang Member", Bagh-e-Vang section, Tabas area, Central Iran, Lower Sakmarian.

PHYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY Anchignathodontidae Clark, 1972

GENUS ***Sweetognathus*** Clark, 1972

1972 *Sweetognathus* Clark

1978 *Rabeignathus* Kozur

1987 *Homoiranognathus* Ritter

1990 *?Xuzhougnathodus* Ding & Wan

1992 *Parasweetognathus* Reimers

1992 *Protosweetognathus* Reimers

1995a *Wardlawella* Kozur

Type species: *Sweetognathus withei* (Rhodes, 1963)

Emended diagnosis (from Mei *et al.*, 2002): a genus of sweetognathid with a Pa element of tongue-like and flat-topped carina, whether denticulate or fused, paved with well developed pustulose ornamentation on its blunt top, and usually passing into the anterior blade gradually. In some specimens, part of the fused carina or some of the nodes/ridges reduce along the median line of the carina to form a groove that does not extend to the end of the carina. The groove is usually narrow and shallow with a depth less than or equal to the height of nodes/ridges.

Remarks: as reported in Mei *et al*. 2002 the genus *Sweetognathus* is very flexible in morphology, so the single species could be differentiated mainly by looking at the general configuration of pustulose nodes and the blade-carina transition within the population and during ontogeny. Accessory nodes and an adenticulate carina may not be diagnostic for differentiate this genera because they appear to parallel stratigraphic cycles and aren't stable.

According to this considerations Mei *et al.*, 2002 consider the genus *Rabeignathus* Kozur, 1978; *Homeoiranognathus* Ritter, 1987; *Xuzhougnathus* Ding & Wan, 1990; *Parasweetognathus* Reimers, 1992; *Protosweetognathus*, Reimers, 1992 and *Wardlawella* Kozur, 1995a as a junior synonyms for *Sweetognathus* Clark, 1972.

Mei *et al.*, 2002 recognized three morphotypes for the Pa element in a typical *Sweetognathus* population: the first possesses a carina with oval nodes (narrow morphotypes), the second has a carina with transversely oval to transversely elongated ridges with the anterior ridges variously reduced on one side and making the anterior carina asymmetrical (asymmetrical wide morphotype), and the third has a symmetrical carina with transversely elongated ridges (symmetric wide morphotype). These three morphotype shows complete intergradation.

Following Mei *et al.*, 1998a *Sweetognathus* is differentiated from I*ranognathus* in which the carina is sharply narrow at top, fused and with rudimentary denticles usually confined to the posterior part, and poorly developed pustules.

A sample collected in the upper part of the Cisuralian Tashkazyk Formation of the Bazar Dara Group yielded a well preserved conodont fauna (Angiolini et al., in press). This conodont association comprises *Mesogondolella monstra*, *Streptognathodus* sp., *Sweetognathus* cf. *merrilli*, *Swwtognathus* cf. *bucaramangus, Sweetognathus* cf. *behnkeni*, and *Sweetognathus whitei*. According to Chernykh (2005), *Mesogondolella monstra* is typical of the Tastubian (early Sakmarian) and *Sw. merrilli* has been correlated with the early Sakmarian (Chernykh and Chuvashov, 2014) in its type region.
enderson (2014) in particular distinguished two "*Sw. whitei*" species: a *Sw. whitei* from the Florence limestone, midwest USA, and correlated as Asselian-Sakmarian in age (Boardman *et al.*, 1998) and *Sw.* aff. *whitei* from the Dalny Tulkas section in southern Urals, Russia as Artinskian in age (Chernykh and Chuvashov, 2014). The two forms are very similar, but differ in terms of transverse ridges and pustulose micro-ornamentation: in fact *Sw. whitei* Rhodes bears bell-shaped transverse ridges that are somewhat irregular in shape, with a pustulose micro-ornamentation irregularly distributed on top and on the slope of the ridges, while the younger *Sw.* aff. *whitei* shows more regular transverse ridges and more regular pustulose micro-ornamentation, which is confined to the upper surface of the ridges (Henderson, 2014). Given the plasticity typical of *Sweetognathus* species it would be prudent to investigate other regions to determine how well this differentiation holds up. In such studies, it will be important to look at sample populations and to consider the entire assemblage.

Henderson (2014) reported that *Sw. whitei* Rhodes appears in association with abundant *Streptognathodus* specimens, while *Sw.* aff. *whitei* is associated with *Mesogondolella* specimens and no *Streptognathodus* because of the extinction of the latter taxon in the early to mid-Sakmarian. The co-occurrence of *Sw. whitei*, *Streptognathodus* sp. and *Mesogondolella monstra* in the upper part of the Tashkazyk Fm. supports an early Sakmarian age for the species *Sw.whitei* in SE Pamir.

Sweetognathus **aff.** ***anceps***

(Pl. 3, figs. 3a, b, c; 4a, b, c; 5a, b, c; 6a, b, c; Pl. 4, figs. 5a, b, c, 6a, b, c)

Description: specimens of *S.* aff. *anceps* are present in samples BEV41 and BEV15 of the Bagh-e-Vang Member of the Jamal Formation, Tabas area, Central Iran. Some specimens, like the ones illustrated in plate 3, figs. 3a, 3b, 3c are fairly preserved while others are seriously broken like the ones illustrated in plate 3, figs. 5a, 5c, 6a, 6c.
Carina is constituted by usually 8 from oval to dump- belled shaped nodes almost all of the same size except for the posteriormost one (when preserved) which is reduced in size. First three posteriormost nodes are more spaced than the others.
There is a pustulose ornamentation on the nodes but no continuous ridge, the blade is slightly asymmetrical respect to the platform.
Platform is low and plate and the posterior part of the blade carried low and equal denticles. The anterior part of the blade is always missing.

Remarks: because of the bad preservation of this specimens is impossible to univocly identify them as *Sweetognathus anceps* (Chernykh, 2005).

Occurrence: upper part of Sterliatamak Horizon, Sakmarian Stage; Burstevian Horizon, Artinskian Stage of the Cisuralian, Urals Mountains (Chernykh, 2005, 2006).

Samples BEV41and BEV15 from Bagh-e-Vang Member, Jamal Formation, Tabas area, Central Iran, Middle- Upper Sakmarian.

Sweetognathus **cf.** ***behnkeni***

(plate 27, figs. 1a, b, c; 8a, b, c)

Description: two specimens of *Sw.* cf. *behnkeni* have been found from sample TJ82 in the Tashkazyk Formation (SE Pamir). The specimen illustrated in figs. 1a, b, c (plate 27) is well preserved, while for the other specimens only the anterior part was founded (figs. 8a, b, c).

In upper view the carina appears to be composed by several, wide, rectangular nodes with a pustulose ornamentation and a pustulose ridge on the middle. The nodes of the carina are very closely spaced.

They are wider in middle and anterior part and taper in the posterior part of the carina until a blunt end.

The anteriormost denticles appears to be cuneiform, with the pointed end oriented toward the median line of the carina. A single, asymmetrical node is present at the junction between carina and blade. Blade is composed, at least in the posteriormost part, by pustulose nodes that are almost of the same width but rapidly increase in height.

In lateral view platform appears to be flat with the carina denticles almost all of the same height except for the posteriormost that rapidly decrease in size.

Remarks: respect to *Sweetognathus behnkeni* (Kozur, 1975) nodes of the carina appears to be more regular in size, arrive until the posterior end of the platform and are more closely spaced.

Occurrence: this specimens of *Sw.* cf. *behnkeni* are from the Sakmarian of SE Pamir, Tajikistan (Tashkazyk Formation) and were found in association with the typical Sakmarian species *M. monstra.*

Sweetognathus cf. ***bicarinum***

(Pl. 13, fig. 6a; Pl. 15, figs. 2a, C)

Description: few broken specimens of *Sweetognathus* cf. *bicarinum* have been found in SE Pamir. These specimens distinctly shows a carina composed by two distinct rows of nodes, unfortunately the blade and the posteriormost part of the specimens are broken (plate 13, fig. 6a).

Remarks: the junction area between blade and carina, that is diagnostic for this species, is not preserved.

<u>Occurrence:</u> samples TJ12 and TJ25, Upper Kungurian/Roadian, Kubergandy Formation, Kubergandy section, SE Pamir, Tajikistan.

Sweetognathus binodosus Reimers, 1999

1963 *Spatognathodus withei*- Rhodes, pl. 47, fig. 26?

1978 *Sweetognathus* n. sp. B aff. *S. bogoslovskajae*- Kozur, pl. 3, figs. 3, 4

1979 *Sweetognathus withei* (Rhodes)- Clark *et al.*, pl. 1, fig. 15

1981 *Swetognathus whitei* (Rhodes)- Igo, pl. 6, figs. 19, 22; pl. 7, figs. 1, 8

1984 *Sweetognathus* aff. *S. withei* (Rhodes)- Orchard, p. 213, pl. 23, fig. 1

1988 *Sweetognathus inornatus* (Ritter)- Henderson, pl. 13, figs. 7, 11, 19

1994 *Sweetognathus inornatus* (Ritter)- Beauchamp & Henderson, fig. 20- 4

<u>Holotype:</u> U- 32a- 6; Usolka section, Cisuralian, Sakmarina Stage, bed 26/3, *merrilli* Zone.

<u>Diagnosis</u> (Chernykh, 2006): Pa element with carinae consisting of a single row of low cross- oval or dump- belled pustulating nodes (knots); in the area of joining with a free blade the carinae presented short postulated strips of longintudinally elongated postulated nodes.

<u>Remarks:</u> specimens from sample BEV 41 (Bagh-e-Vang section, Central Iran) are all broken but specimen illustrated in plate 3, figs. 3a, b, c is quite well preserved, particularly the junction between the platform and the blade. Carina is constituted by eight dumbbell- shaped, discrete denticles. Denticles are almost of the same dimensions except for the posteriormost one which is reduced in shape.
The first three posteriormost nodes are more spaced than the others. All the nodes have a pustulose ornamentation but no continuous pustulose ridge is present between the nodes.

The joint between the carina and the blade is slightly asymmetrical. The anteriormost part of the blade, unfortunately, is broken.
The basal cavity is expanded but the platform appears to be broken in both sides.
Samples illustrated in plate 3, figs. 4a, b, c is broken and the blade is totally missing but the carina appears to be the same of specimen previously described. The junction between the platform and the blade is preserved and appears to be slightly asymmetrical like in the previous specimens. No pustulose ridge is present connecting the nodes of the carina.
The other two specimens of *Sweetognathus* aff. *binodosus* present in sample BEV41 are illustrated in plate 3, figs. 5a, c and 6a, c: they are both broken, the carina is not entirely preserved and the junction between carina and blade is not clearly visible.
Specimens from sample BEV15 (Bagh-e-Vang section, Central Iran) appears to be well preserved respect to those from sample BEV41 and are almost complete, only the external part of both sides of the basal cavity is broken and the anteriormost part of the blade is missing in one specimens.
Carina is formed by 5- 6 nodes more oval than dumbbell- shaped almost of the same dimension also if the anteriormost one is reduced. The last denticle of the posterior end of the carina is more spaced from the others, round and positioned along the median axis of the carina.
Denticles of the blade increase in height except for the anteriormost one or two that are reduced and appears to be lower than the previous ones.

A single specimens is present in sample TJ3 from the base of Kubergandy Formation in the Kubergandy section (SE Pamir). The specimens is not illustrated because of it bad preservation.

A transitional forms between *Sweetognathus binodosus* and *Sweetognathus anceps* is present in sample BEV43 (Central Iran).

Specimens illustrated in plate 3, figs. 5a, b, c; 6a, b, c are named as *Sweetognathus* aff. *binodosus* because of the bad preservation, especially for the lack of the platform- carina junction area in figs. 6a, b, c and the bad preservation of the same area in figs. 5a, b, c.

S. binodosus appears in the Urals in Late Tastubian time. The presence in the studied collection of the most primitive and more advanced forms of the species suggests that is the FAD of the species.

Occurrence: Upper Tastudian Horizon of Sakmarina Stage- Irginian Horizon of Artinskian Stage in the Urals; Schroyer Limestone of Wreford Formation- basal part of the Asselian- Sakmarian Florence Limestone of Barneston formations of Chase Group in Kansas, North America (Boardman *et al.*, 2009); *Pseudosweetognathus costatus* zone, section in Ziyun County, Guizhou Province, China (in Chernykh, 2006).

Sample BEV41, Middle/ Upper Sakmarian, "Bagh-e-Vang Member", Bagh-e- Vang Section, Tabas Area, Central Iran.

Sample TJ3, Kungurian, Kubergandy Formation, Kubergandy Section, SE Pamir, Tajikistan.

Sweetognathus* cf. *bucaramangus

(plate 27, figs. 4a, b, c)

Description: this specimens looks very similar to *Sweetognathus* cf. *merrilli* (described further in the text). In upper view is clearly visible a carina formed by several closely spaced nodes with pustulose ornamentation and a poor developed pustulose ridge, more visible in the anterior part of the carina and almost absent in the posterior.

Platform ornamentation is formed by several big nodes on both sides.

Carina is formed by a single row of narrow but high nodes more spaced than the ones in the carina.

In lateral view platform appears to be slightly arched and is possible to appreciate that almost all the nodes are of the same height except for the blade nodes that abruptly increase in height.

Remarks: respect of *Sw.* cf. *merrilli* nodes appears to be more numerous and more closely spaced.

Occurrence: this specimen of *Sw.* cf. *bucaramangus* is from the Sakmarian of SE Pamir, Tajikistan (Tashkazyk Formation) and were found in association with the typical Sakmarian species *M. monstra.*

Sweetognathus fengshanensis Mei & Wardlaw, 1998
(Pl. 18, figs. 1a, b, c; 3a, b, c)

1998 *Sweetognathus fengshanensis* Mei & Wardlaw in Mei *et al*.- pl.2, fig.6, pl.3, 5-9

1998 *Iranognathus* sp. nov., Wang et al.- pl. II, fig. 2

2000 *Iranognathus* aff. *I. punctatus* Wardlaw- pl. 3-2 figs. 36, 37

Holotype: specimen figured by Plate 3, fig. 5, from LFB-144, the Fengshan Section, Liucheng Country of Guangxi.

Derivatio nominis: after the name of Fengshan Town, Liucheng Country of Guangxi.

Diagnosis: a species of *Sweetognathus*, the Pa element of which possesses a carina with fused and smooth anterior part and denticulate posterior part bearing 4-5 circular nodules. Inner cup surface bearing 3-4 nodules tending to line up as an arc. Outer cups surface bearing 4-6 nodules tending to form more or less straight ridge.

Remarks: *Sweetognathus fengshanensis* is the youngest known species of *Sweetognathus*. It is differentiated from its predecessor, *Sweetognathus iranicus hanzongensis*, by possessing accessory nodes.

Occurrence: upper part of the Maokou Formation, Fengshan Section, Liucheng Country of Guangxi. Late Guadalupian in Texas and South China (Mei *et al.*, 2002).

Sample TJ 29, Gan Formation, Kubergandy Section, SE Pamir (Tajikistan).

Sweetognathus iranicus hanzongensis (Wang, 1978)

(Pl. 30, figs. 2a, b, c; 3a, b, c; 4a, b; 5a, b, c; 6a, b; 7a, b, c; 8a)

1978 *Gnathodus hanzongensis* Wang- pl.1 33- 35, 40, 41

1987 *Iranognathus* sp. nov., Kang *et al.*, pl. IV, figs. 15- 16

1991 *Sweetognathus hanzongensis* (Wang)- Wang & Dong, pl. III, figs. 6-8

1994 *Sweetognathus hanzongensis* (Wang)- Wang & Shen, pl. 48, figs. 1- 2

1998 *Sweetognathus iranicus* Kozur, Mostler & Rahimi- Yazd- Wang *et al.,* pl. II, fig. 3

Emended diagnosis(from Mei *et al.*, 2002): a subspecies of *Sweetognathus* with Pa element that is almost exclusively dominated by the narrow morphotype which possesses a smooth and anteriorly tapering anterior carina.

Remarks: in samples from Halq- Jemel and Tebaga Sensu Strictu sections (Tunisia) some well preserved specimens of *Sweetognathus iranicus hanzongensis* have been found (see plate 30). Particularly in sample HJ32 (Unit V, Halq- Jemel section) a good population was present: specimens shows the characteristic carina of this species that is composed by oval to rounded nodes in the posterior part and shows a median groove in the anterior part.

Occurrence: Mei *et al.* (2002) reported this species from the Guadalupian of South China.

Sample HJ32, Wordian, Unit V, Halq- Jemel section, Tebaga de Medenine, Tunisia.
Sample TSS11, Wordian, Unit II, Tebaga Sensu Strictu, Tebaga de Medenine, Tunisia.
Sample TJ63, Safetdara Formation, Bolorian Stratotype section, Darvaz area, N Pamir.

Sweetognathus cf. ***merrilli***

(plate 27, figs. 2a, b, c; 3a, b, c; 5a, b, c)

Description: these species have been found in sample TJ82 (Tashkazyk Formation) of SE Pamir (Tajikistan). Specimens are well preserved: in upper view they shows a carina composed by several oval nodes with pustulose ornamentation. The pustules forms a non-continuous slightly visible ridge between the bigger nodes of the carina, usually in the middle part. A nodose ornamentation, more developed in more mature specimens (see pl. 27, figs. 5a, b, c) is clearly visible on both sides of the platform, in upper view.
Nodes appears to be almost of the same size, slightly reducing in width on the anteriormost end.
Blade appears to be short respect to the carina (but is also broken in all specimens) and formed by pustulose nodes more spaced and smaller than the ones of the carina.
In lateral view the Pa element appears to be flat or slightly arched. Blade appears to be formed by laterally- compressed high nodes.

Remarks: respect to classic *Sweetognathus merrilli* (Kozur, 1975) this specimens shows a major regularity in carinal nodes.

Occurrence: *Sw. merrilli* is reported from the Florence Limestone Member of the Barneston Limestone that is Late Asselian/ Sakmarian in age (Boardman *et al.*, 1998).

This specimens of *Sw.* cf. *merrilli* are from the Sakmarian of SE Pamir, Tajikistan (Tashkazyk Formation) and were found in association with the typical Sakmarian species *M. monstra.*

Sweetognathus modulatus Chernykh, 2006

2006 *Sweetognathus modulatus*- Chernykh pl. 19, figs. 8- 10

Holotype: ZH41-38, Kazakhstan, Aktyubinsk region; Zhil-Tau Section, Zhaksy-Kargala River; Aleksandrov Formation, Bed 3; Saranin Horizon, Kungurian Stage, Cisuralian.

<u>Original diagnosis:</u> Pa element with a carinae consisting of transversely elongated, steady located and not pitched in the midway equal teeth. In the front of carinae three twice smaller nodes that are connected with each other by median edge are located.

<u>Remarks:</u> specimens fro SE Pamir shows a carina high and parallel to the lateral margin. It is formed by 6- 7 denticles of the same height and symmetrically disposed and a pustulose ornamentation. Blade is missing and only some nodes is preserved on the anteriormost end of the platform. There is no pustulose ridge connecting denticles of the carina.
Basal cavity is symmetric also if part of the inner margini s lacking.

<u>Occurrence:</u> Chernykh (2006) reported this species from Zhil-Tau Section, Zhaksy-Kargala River; Aleksandrov Formation, Bed 3; Saranin Horizon, Kungurian Stage, Cisuralian.

Sample TJ163, Safetdara Formation, Bolorian Stratotype section, N Pamir, Tajikistan.

Sweetognathus subsymmetricus Wang, Ritter and Clark, 1987
(Pl. 6, figs. 7a, b, c, Pl. 7, figs. 1a, b, c; Pl. 30, figs. 1a, b, c)

1987 *Sweetognathus subsymmetricus* Wang *et al*.- figs. 6.1–6.7.

1987 *Sweetognathus paraguizhouensis* Wang *et al*.- figs. 6.14, 6.15.

1991 *Sweetognathus* sp.- Beyers & Orchard, pl. 2- figs.1, 2, 7.

1991 *Sweetognathus iranicus* Kozur, Mostler & Rahimi- Yazd- Wang & Dong, pl. I, fig. 3.

1991 *Sweetognathus whitei* (Rhodes)- Wang and Dong, pl. I, fig. 17.

1992 *Sweetognathus subsymmetricus* Wang, Ritter and Clark- Gullo and Kozur, fig. 6, H, I.

1994 *Sweetognathus subsymmetricus* Wang, Ritter and Clark- Wang & Shen, pl. 47, figs. 1–6, 8.

1994 *Sweetognathus behnkeni* Kozur- Wang & Shen, pl. 47, fig. 7.

1994 *Sweetognathus sweeti* Kozur, Mostler and Rahimi-Yazd- Wang & Shen, pl. 47, figs. 9.

1994 *Sweetognathus paraguizhouensis* Wang, Ritter and Clark- Wang & Shen, pl. 48, figs. 5, 6.

1994 *Sweetognathus inornatus* Ritter- Wang & Shen, pl. 48, figs. 3, 4, 8.

2002 *Sweetognathus subsymmetricus* Wang, Ritter and Clark- Mei *et al.*, p. 86, figs. 10.23, 10.24.

<u>Original diagnosis:</u> A type II *Sweetognathus* pectiniform element with an asymmetric blade-platform junction an asymmetric development of the anteriormost 1 or 2 tranverse ridges.

<u>Emended diagnosis</u> (Mei *et al.*, 2002): a species of Sweetognathus with a Pa element possessing a discrete carina on which the anterior ridges reduce in width anteriorly, but distinctly more on one side than the other in the asymmetrical morphotype. In the wide morphotype the anterior one to three ridges are the widest and the following ridges reduce gradually in width posteriorly.

<u>Remarks</u>: this species is readily distinguished from other Type III sweetognathids on the basis of asymmetry in the anteriormost transverse ridges and blade-platform junction on the pectiniform element. This distinctive morphology is developed in both juvenile and mature specimens (Wang *et al.*, 1987).

Sweetognathus subsymmetricus can be differentiated from *S. guizhouensis* by the latter normally having the second anteriormost ridge as widest in the asymmetrical morphotype (Mei *et al.*, 2002).

Sample BEV48 (Bagh-e-Vang section, Central Iran) yield two specimen of *Sweetognathus subsymmetricus* while BEV49, from the same section, provided only one specimen.

The specimens from both samples looks fairly well preserved, particularly specimen from sample BEV49 is complete with all the blade preserved.

The specimens bear 6-7 oval elongated nodes with a pustulose ornamentation which is more visible in specimens from sample BEV48 (see plate 6, figs. 7a, b, c).

At the junction between carina and blade there is a single asymmetrical node. Blade is formed by several (5- 6) denticles laterally compressed and fused at the base. Denticles gradually increase in height anteriorly. The basal cavity is expanded.

The same species was found in sample TJ92 from Kurteke Formation (Kurteke section, SE Pamir): is a single specimens with a medium preservation but the characteristic junction between blade and carina is clearly visible (plate 30, figs. 1a, b).

Several transitional forms *Sweetognathus guyouensis*/ *S. subsymmetricus* are present in samples TJ50 and TJ60 from the Gan Formation (Kutal 2 section, SE Pamir): in these specimens is noticeable the junction between the platform and the blade in which the anteriormost nodes of the carina appears to be reduced on one side but are still present, while in true *S. subsymmetricus* specimens nodes are present only on one side of the carina at the junction with the blade.

<u>Occurrence:</u> Wang (1994) report this species from *Neostreptognathodus pequopensis* Zone , Nashui of Loudian, Guizhou, China.

Mei *et al.* (2002) reported this species from the Upper Kungurian to the Lower Guadalupian in the Equatorial Warm Water Province.

Samples BEV48 and BEV49, Kungurian, Jamal Group, Bagh-e-Vang section, Tabas area, Central Iran.

Sample TJ92, Roadian, Kurteke Formation, Kurteke section, SE Pamir, Tajikistan.

Sweetognathus withei (Rhodes, 1963)

(plate 27, figs. 6a, b, c; 7a, b, c)

2014 *Sweetognathus withei*- Henderson, p. 15, figs. 1- 4

The author of the species did not provide the diagnosis of the species.

Description: (Rhodes, 1963) axis blade straight or slightly curved with a maximum flexure in the front. At his side form the upper edge of nearly straight, but slightly bent downwards and otognutaya regularly in the back half. Front-lower angle of about 90 or slightly less. List massive, but thinner front than the rear half. Oral edge bearing 13 to 15 denticles. In the anterior portion of the blade these denticles may be up to seven in number; they are conspicuously laterally compressed, and fused for the greater part of their length; only their blunted apices are discrete, and these have laterally compressed anterior and posterior edges. The denticles of the posterior portion of the bar number about 8, and are quite different in form from those of the anterior portion, being nodelike, rather than bladelike in form. They are discrete, being separated from each other by an interval about equal to their anterior posterior length. They are joined only by a low median bladelike ridge that it is conspicuous in oral but not in lateral view. These posterior denticles correspond in position to the flaring navel extension, and vary somewhat in shape. But their main feature is their lateral expansion, which is such that their width is two or three times greater than their length. They vary from subcrescentic to suboval to dumbbell shaped in oral outline. The "navel" is much more like that of Streptognathodits or Idiognathodes than that of the “typical" spathognathodids. The whole posterior half or two thirds of the unit is excavated by an elongated, widely flaring cavity with aprons that have a lachryform outline. The width may approach two thirds of the length of the posterior flared portion.

Specimens from SE Pamir (sample TJ82, Tashkazyk Formation) are almost well preserved (see pl. 27, figs. 6a, b, c; 7a, b, c). In oral view carina appears to be constituted by several spaced oval nodes with a pustulose ornamentation. Nodes appears to be more

regular in the smallest specimens illustrated in figs. 6a, b, c (pl. 27) while in the bigger one are more irregular, especially in the posterior part of the platform.
The pustulose ornamentation connect all the nodes of the carina along the median axis.
Blade is formed by a single row of narrow nodes.

<u>Remarks:</u> the species has been found *Sw. whitei* in SE Pamir together with a typical Sakmarian association. *Sw. withei sensu* Rhodes bears bell-shaped transverse ridges that are somewhat irregular in shape, with a pustulose micro-ornamentation irregularly distributed on top and on the slope of the ridges, while, according to Henderson (2014) the younger *Sw.* aff. *whitei*, proposed by Chernykh as a marker for the Artinskian (Chernykh & Chuvashov, 2014), shows more regular transverse ridges and more regular pustulose micro-ornamentation, which is confined to the upper surface of the ridges.

<u>Occurrence:</u> for the stratigraphic distribution I have decided to follow Henderson (2014), distinguishing the *Sweetognathus withei* lineage in *Sw. withei* and *Sw.* aff. *withei* reporting the distribution for *Sw. withei* (to further discussion see cap. 8).

Uppermost part of Jiazhai Formation, Baoshan Block, western Yunnan (Wang *et al.*, 1999; Ueno *et al.*, 2002).

Florence limestone, midwest USA, Asselian-Sakmarian (Boardman *et al.*, 1998).

Sample TJ82, Sakmarian, 100m below the top of the Tashkazyk Formation, Mudzubulak, SE Pamir, Tajikistan.

HYLUM Conodonta Pander, 1856

ORDER Conodontophorida Eichenberger, 1930

FAMILY unnamed

GENUS ***Vjalovognathus*** (Kozur, 1977)

Typer species: *Vjalovites shindyensis* Kozur, 1976

Description: Pa element deeply excavated, with a thin- walled crown structure easily broken. The identification of *Vjalovognathus* is based mainly on the Pa element, especially the characters of the denticles, in which the cross- section of the denticles is most important.

Remarks: Kozur (in Kozur & Mostler, 1976) established the conodont genus *Vjalovites* with the type species *V. shindyensis* from the Lower Permian (Leonardian). The genus is a younger homonym of the tentaculite genus *Vjalovites* Ljashenko, 1969, therefore the new name *Vjalovognathus* is proposed by Kozur (1977).

Occurrence: Kozur (in Kozur & Mostler, 1966) reported this species from Leonardian of Pamir.

In southern latitudes it occurs from Artinskian through Lopingian (Nicoll & Metclafe, 1990; Mei & Henderson, 2001).

Zheng *et al.* (2007) reported this genus as limited to the north margin of eastern Gondwana, ranging throughout Permian, mainly Early and Middle Permian.

***Vjalovognathus* sp.**

Description: a broken Pa element of a *Vjalovognathus* sp. The specimens appears to be broken and the anterior part is missing. Denticles appears to be elongated, oval with squared edges. Denticles from the middle and lower part of the carina appears to be higher. The anteriormost three denticles decrease in size and are more spaced.

Remarks: Mei *et al.* (2002) regarded at the genus *Vjalovognathus* like a diagnostic genus for the peri-Gondwana Cool Water Province (GCWP). Its presence in the same section with typical warm water specimens like *Sweetognathus fengshanensis* and *Sweetognathus subsymmetricus* in typical for a mixed fauna zone like SE Pamir.

Occurrence: sample TJ52, Capitanian, Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

Chapter 8
Results

For this thesis I have studied several samples from Central Iran (Bagh-e-Vang, Shesht-Angosht, Zaladou, Anarak 3 and Rahdar), Tunisia (Halq- Jemel, Merbah-el-Oussif and Tebaga *sensu strictu* sections), N Pamir (Gundara and Bolorian Stratotype section) and SE Pamir (Kubergandy, Kutal 2, Kurteke and Kurystyk sections) in order to determine the age of these sections, correlate conodonts and fusulinids, make paleoenvironmental considerations and detect paleobioprovinces. The main results for each areas have been exposed here under.

8.1 Central Iran

Five stratigraphic sections have been studied with the following results.

Bagh-e-Vang section

Bagh-e-Vang section (Tabas area, Central Iran) was the most rich in conodonts among the Central Iran sections.

Studying conodont samples collected from Bagh-e-Vang section the following main events have been detected, from earliest to latest:

Streptognathodus postconstrictus Wardlaw, Boardman & Nestell, 2009, *Streptognathodus* aff. *lanceatus* and *Mesogondolella manifesta* Chernykh, 2005, present in sample BEV40, indicate a Lower Sakmarian age. According to Boardman *et al.* (2009) *S. postconstrictus* and *S.* aff. *lanceatus* occur into Tastubian substage of Sakmarian stage in Kansas. In the western slope of southern Urals. *M. manifesta* occur, as reported in Chernykh (2006) and Boardman *et al.* (2009), into *merrilli* Zone of the Sakmarian stage.

In sample BEV 10 the co-occurrence of *Streptognathodus postconstricuts* Wardlaw, Boardman & Nestell, 2009, whose range is from Upper Asselian to Sakmarian (Chernykh, 2006; Boardman *et al.* 2009), *Mesogondolella monstra* Chernykh, 2005 and *Mesogondolella manifesta* Chernykh, 2005 (Tastubian substage of Sakmarian Stage; *merrilli* Zone; Lower Permian; western slope of Ural Mountains) indicate a Lower Sakmarian age for the association (see Chernykh & Reshetkova, 1987; Chernykh 2005, 2006; Boardman *et al.,* 2009).

In sample BEV 41and 15 *Sweetognathus binodosus* Reimers, 1999 and *Mesogondolella bisselli* (Clark & Behnken, 1987) point to a Middle/Upper Sakmarian age.

Sw. binodosus was found by Chernykh (2005, 2006) from upper Tastubian Horizon of Sakmarian Stage to the Irginian Horizon of Artinskian Stage in the Urals.

It is also reported from the Schroyer Limestone, Wreford Formation to the basal part of Florence Limestone of Barneston formations of Chase Group in Kansas, North America (Asselian- Sakmarian, according to Henderson, 2014); and from *Pseudosweetognathus costatus* zone, Kungurian, section in Ziyun County, Guizhou Province, China (see Chernykh, 2006).

Sample BEV 42 has a monospecifc fauna charachterized by *Mesogondolella bisselli* (Clark & Behnken, 1987) which indicate a Middle-Upper Sakmarian age (Chernykh 2006, 2014; Boardman *et al.*, 2009). Chernykh (2006) found *M. bisselli* into *anceps* Zone, Sakmarian age, in the Urals.

In sample BEV 43 the presence of transitional forms *Sweetognathus binodosus/ Sweetognathus anceps* and *Mesogondolella gujioensis* (Igo, 1981) suggest an Upper Sakmarian/Lower Artinskian age (Igo, 1981; Chernykh, 2014).

Condont assemblage in sample BEV 44 and BEV 45 is represented by *Mesogondolella siciliensis* (Kozur, 1975). *M. siciliensis*, according to Kozur and Wardlaw (2010), ranges from the middle Roadian to the Wordian-Capitanian boundary interval. The holotype of *M. siciliensis* is from the Rupe del Passo di Burgio block in the Sosio Valley, Sicily which is Wordian in age (Kozur, 1975; Kozur & Wardlaw, 2010).

In sample BEV 45 some transitional forms *Mesogondolella siciliensis*/ *Mesogondolella omanensis* are present, pointing to a Wordian age.

In sample BEV 46 *Hindeodus wordensis* Wardlaw, 2010 and *M. siciliensis* point to a Wordian age. *Hindeodus wordensis* was reported by Wardlaw (2000) from the Word, Altuda and Bell Canyon formations of west Texas and in the Gerster Limestone and the upper part of the Phosphoria (Wordian- Capitanian) and related rocks in the Great Basin and northern Rocky Mountains. The FAD of *Hindeodus wordensis* is Mid-Rodian in age (Wardlaw, 2000).

The co- occurrence of *M. siciliensis* and *Sweetognathus subsymmetricus* Wang, Ritter & Clark, 1987 in sample BEV 48 point to a Kungurian age.

In sample BEV 49 *S. subsymmetricus* point to a Kungurian age according to Wang *et al*. (1987). Both BEV48 and BEV49 samples are from the upper part of the Bag-e-Vang section, that is interested by faults.

On this considerations, the age of the studied Bagh-e-Vang samples from lower and middle part of the section, ranges from Sakmarian to Wordian.

This section was previously studied by Leven *et al.* (2007) that reported a Yaktashan to Murgabian age based primary on fusulinids and then on conodonts.

Such a difference in age can be attributed to lack of perfect correspondence between Leven *et al.* and our samples: in fact is impossible to precisely correlate the stratigraphic column of Leven *et al.* (2007) with the one of Balini *et al.* (2010). Furthermore few broken conodonts specimens were illustrated by Leven *et al.* (2007) and most of them were identified only to a generic level.
To solve the correlation between conodonts and fusulinids in this area is crucial to obtain fusulinids data from samples collected in the same level of conodonts ones.

The presence of species *M. monstra* and *S. subsymmetricus* point to a warm Boreal Realm affinity (Urals, Russian Platform, Yukon Territory and Carnic Alps) for this area during Lower and Middle Permian: the species *M. siciliensis* indicate the presence of deep water and is coherent with the deepening trend detected throughout the Bagh-e- Vang section.

Shesht- Angosth section

Shesht- Angosht section was sampled in order to obtain new data from a section that will be not affected by faults like Bagh-e-Vang. Few samples were collected during a field trip in 2012 by Balini *et al.* and they revealed to be very poor in conodonts.

Still, correlation between sample SHA12, which is 12 m above the base of the section (unit B of “Bagh-e-Vang Member”), and sample BEV10 (lower part of “Bagh-e-Vang Member” in Bagh-e-Vang section) is quite interesting. Sample SHA12 is stratigraphically closed to sample BEV10 and contains two fragments of *Mesogondolella* cf. *manifesta*, a typical Sakmarian species: unfortunately the specimens are too broken to be certainly identified.

Species *M. manifesta* is present in sample BEV10 together with another typical Sakmarian species: *M. monstra.* Those species are typical of *merrilli* Zone (Chernykh, 2006).

Sample SHA15 (see fig. 15) was sampled (64 m above the base of the Shesht-Angosht section) on top of the “Bagh-e-Vang Member” where cherty limestones begins, and contains only *M. siciliensis*. *M. siciliensis* is a wide-range species that spans from the Upper Kungurian to Lower Capitanian (Kozur, 1988, 1989b; Kozur *et al*., 2001).

Also if few conodonts have been recovered from Shesht- Angosht section its correlation with Bag-e-Vang section appears to be feasible not only on the basis of lihological affinity but also thanks to the conodonts recovered from this section.

Zaladou section

Correlation among Zaladou, Anarak 3 and Rahdar sections based only on conodonts is actually impossible because of the scarcity of specimens. However the presence of fusulinids help us in correlating at least partially these sections.

Conodont *Idiognathodus* sp. from sample ZAL3 of the Zaladou Formation (Zaladou section) is coherent with a Carboniferous age of this section even if it does not added new constrains in order to define the age of this section. Conodont *Streptognathodus* cf. *plenus*, that is reported to be Asselian in age from literature, should be problematic for the correlation of Zaladou section: but the distribution of *Streptognathodus* genus is quite wide and the Asselian age of *Streptognathodus plenus* Chernykh, 2005 is reported from the Urals and no data are available from other region in order to exclude that this species could range also in the Upper Carboniferous. The supposed Gzhelian age of the upper part of the Zaladou Formation seems to be confirmed by the appearance of Asselian fusulinids at the base of the Tighe- Maadanaou Formation. However a single specimens from a single sample is not enough to determine the age of the upper part of Zaladou Formation and further sampling and studying is needed on this area.

Anarak 3 section

In samples ANK12 and ANK26 I have found together the species *Streptognathodus longus* Chernykh, 2005 and *Idiognathodus lobatus* Gunnel, 1933: these species are both Carboniferous in age but the ranges of *I. lobatus* is not well defined in literature (Gunnell, 1933), the only recent data (Rosscoe, 2008) reported this species only from the Swope Basin sequence that is Missourian (Upper Carboniferous) in age. The lower distribution of *S. longus* is Ghzelian in age according to Chernykh *et al.* (2009) and the age of the Upper part of Zaladou Formation is Gzhelian accordin to fusulinids (Balini *et al.*, 2011): further investigation on *I. lobatus* distribution and further sampling in order to obtain more conodonts from the Zaladou Formation is crucial to solve this question.

8.2 Tunisia

Three stratigraphic sections have been studied for this area, but unfortunately Merbah-el-Oussif was completely barren for conodonts, while for Halq Jemel and Tebaga *sensu strictu* only one samples for each section yielded significant conodonts.

In Halq Jemel section the conodont *Sweetognathus iranicus hanzongensis* (Wang, 1978) was found together with typical Midian fusulinids fauna: *Chusenella rabatei* Skinner and Wilde, 1967 and *Dunbarula* ex gr. *nana* Kochansky-Devidé and Ramovs, 1955.

Sw. iranicus hanzongensis is quite long ranging conodont species spanning the Roadian to middle Capitanian (Guadalupian), whereas the FAD of the fusulinid *Dunbarula* ex gr. *nana* is Early Midian. This finding may support the correlation of the lower Midian Stage of the Tethyan scale to the upper Wordian of the Global scale of the Permian (Davydov 1994, Kozur and Davydov 1996, Stevens *et al.* 1997, Kobayashi *et al.* 2007).

Nine meters above this assemblage, in sample HJ103 (see fig. 58) the advanced *Dunbarula mathieui* Ciry, 1948 has been found. The genus *Dunbarula* shows a development from Late Wordian through Wuchiapingian and the species *D. mathieui* elsewhere co-occurs with *Yabeina* sp. and *Lepidolina* sp. of Capitanian age (Chedia *et al.,* 1986). *D. mathieui* indicates a Capitanian age of the succession starting from bed THJ3 through bed THJ9 in the Halq Jemel section.

The finding of fusulinids and conodonts in the same bed in the Halq Jemel section is of great interest as it provides a tool of correlation between the International (Global) and the Tethyan regional scale that still remains unresolved, particularly for the Guadalupian part.

The same conodont species, *Sw. iranicus hanzongensis*, have been founded in Tebaga *sensu strictu* section, in sample TSS11 (see fig. 59). The Wordian age of this samples was detected using fusulinids because of the long range of *Sw. iranicus hanzongensis*.

Sw. iranicus hanzongensis is typical of shallow and warm water and is coherent with the belonging of Tunisia to a Warm Water Equatorial paleoprovince during Permian. This species is typical of S China and was recovered also in N Pamir, allowing a correlation among these areas.

8.3 N Pamir

Two stratigraphic sections have been studied but unfortunately only the Bolorian Stratotype section yielded conodonts in its basal part.

Conodonts *Sw. iranicus hanzongensis* (Wang, 1978) and *Sweetognathus modulatus* (Chernykh, 2006) have been found from the base of Safetdara Formation (Bolorian Stratotype section).
The presence of *Sw. modulatus* point to a Bolorian age for the base of Bolorian Stratotype section while the presence of *Sw. iranicus hanzongensis* give some paleoenvironmental information pointing to a shallow and warm water paleoenvironment, detecting a warm water paleoprovince affinity for this area, at least in Lower Permian.

8.4 SE Pamir

Four stratigraphic sections have been studied in SE Pamir with the following results.

Kubergandy type section

This section is composed by the Kubergandy Formation and the Gan Formation.

Conodonts date the base of Kubergandy Formation as Kungurian according to the presence of *Mesogondolella idahoensis idahoensis* (Youngquist, Hawley & Miller, 1951). The Upper part of this formation is Radian in age, according to the presence of *Mesogondolella pingxiangensis* (Zhang, Henderson & Xia, 2010).

Two fusulinids biozones have been detected in the lower part of this formation (the Bolorian *Misellina parvicostata* zone and the *Misellina ovalis* zone, see fig. 43). In the Upper part of the Kubergandy type Formation was found the species *Cancellina* sp. that marks the beginning of Kubergandian. From the same level the presence of *M. pingxiangensis* marks the beginning of Roadian.

The top of the Kubergandy Formation seems to be younger in the Kubergandy section than in the Kutal 2 section where it still lies in the Kungurian, suggesting local diachroneity as would be expected for a formation boundary. Thus, based on conodonts, most of the Kubergandy Formation was deposited in the Kungurian, reaching the early Roadian only in its upper part in the Kubergandy type section.

The base of the Gan Formation is Roadian in age, according to conodont *M. pingxiangensis*, in its lower part, Wordian in its middle part and Capitanian in its upper part because of the presence of and *Jinogondolella altudaensis* (Kozur, 1992) and *Jinogondolella aserrata* (Clark & Behnken, 1979) that is considered a marker for the Wordian (Shen *et al.*, 2003).

Regarding fusulinids the *Cancellina cutalensis* zones is present in the lower part of Gan Formation, then the Lowe Murgabian *N. simplex* zone was detected and at the Roadian/ Wordian limit the Middle Murgabian *N. craticulifera- N. schuberti* zone begins. At the Wordian/ Capitanian boundary was found the Upper Murgabian *N. margaritae* zone was detected and about 10 meters above the midian *Yabeina opima* zone was found.

Kutal 2section

Kutal 2 section is formed by Shindy Formation at its very base, Kubergandy and Gan formations.

No conodonts are present in the Shindy Formation and in the lowermost part of the Kubergandy Formation, but the Bolorian fusulinids *Misellina claudiae* Deprat, 1912, *Misellina aliciae* (Deprat, 1912) and *Misellina termieri* Deprat, 1915 are present.

Conodonts from middle part of Kubergandy Formation point to a Kungurian age, according to the presence of *Mesogondolella idahoensis lamberti* Mei & Henderson 2002. From the middle part of Kubergandy formation was detected the *M. ovalis- Armenina* zone that is Kubergandian in age.

The Upper part of Kubergandy Formation in still Kungurian in age according to conodonts (transitional forms *Sweetognathus guizhouensis/ Sw. subsymmetricus*) and the Kubergandian *C. cutalensis* zone was detected. About 15 meters above this zone the Lower Murgabian *N. simplex* zone was detected.

The lower part of Gan Formation is Roadian in age according to the presence of *M. pingxiangensis.*

The middle part of Gan Formation is Wordian in age according to the presence of *Jinogondolella aserrata* (Clark & Behnken, 1979) and the Middle Murgabian *N. schuberti* zone was detected.

The upper part of Gan Formation in Capitanian according to the conodont *J. altudaensis* and the Midian *N. margaritae* zone have been detected for fusulinids.

The Wuchapingian age of the Uppermost Gan and Takhtabulak formations is based only on fusulinids because no conodonts were recovered from these parts of the section.

Kurteke section

This section is formed only by Kurteke Formation.

The base of the Kurteke Section (and Kurteke Formation) is Roadian in age according to the presence of conodont *M. idahoensis lamberti* and the upper part of Kubergandian *C. cutalensis* and the Murgabian *N. simplex* zone have been identified in the lower part of the section.

In this case conodonts and fusulinids ages cannot be correlated perfectly, also due to the relative poorness of the conodont fauna: cconsequently, this section is very interesting for discussing the chronostratigraphic correlations between the Tehyan regional stages Bolorian, Kubergandian and Murgabian and the standard stages Kungurian, Roadian and Wordian.

Bazar Dara Group- Tashkazyk Formation

A sample collected in the upper part of Tashkazyk Formation of the Bazar Dara Group (sample TJ82) yielded a well preserved conodont fauna comprising: *M. monstra*, *Streptognathodus* sp., *Sweetognathus* cf. *bucaramangus, Sweetognathus* cf. *merrilli*, *Sw*eetognathus cf. *behnkeni*, and *Sweetognathus whitei* (Rhodes, 1963). According to Chernykh (2005), *M. monstra* is typical of the Tastubian (early Sakmarian) and *Sw. merrilli* has been correlated with the early Sakmarian (Chernykh & Chuvashov, 2014) in its type region.
Sw. bucaramangus, Sw. cf. *behnkeni* are still Sakrmarian in age according to Chernykh (2006).

Because of the presence of a Sakmarian fauna the presence of *Sw. withei* in this sample seems to confirm the hypothesis of Lucas (2014) and Henderson (2014) that consider the species *Sw. withei* (sensu Rhodes) as a Sakmarian species.

The Sakmarian age of this sample is confirmed by the associated late Sakmarian brachiopods, at the top of the Tashkazyk Formation (Grunt and Dmitriev, 1973; Angiolini *et al*., in press).

In addition to these data, such older forms of *Sw. whitei* reported from Nevada (Ritter, 1987) and Bolivia (Suarez Riglos et al., 1987) are now confirmed to be of late Asselian and early Sakmarian age, based on strontium isotopes and high-precision U-Pb data (Henderson, 2014). To be noted that, as reported by Henderson (2014), the Bolivian conodont fauna contains, besides *Sw. whitei,* abundant *Streptognathodus* specimens, like *S. fusus* and *S. postfusus* which are typical of the Upper Asselian (Chernykh, 2006).

The main results in correlating International and Tethyan timescales are represented in fig.

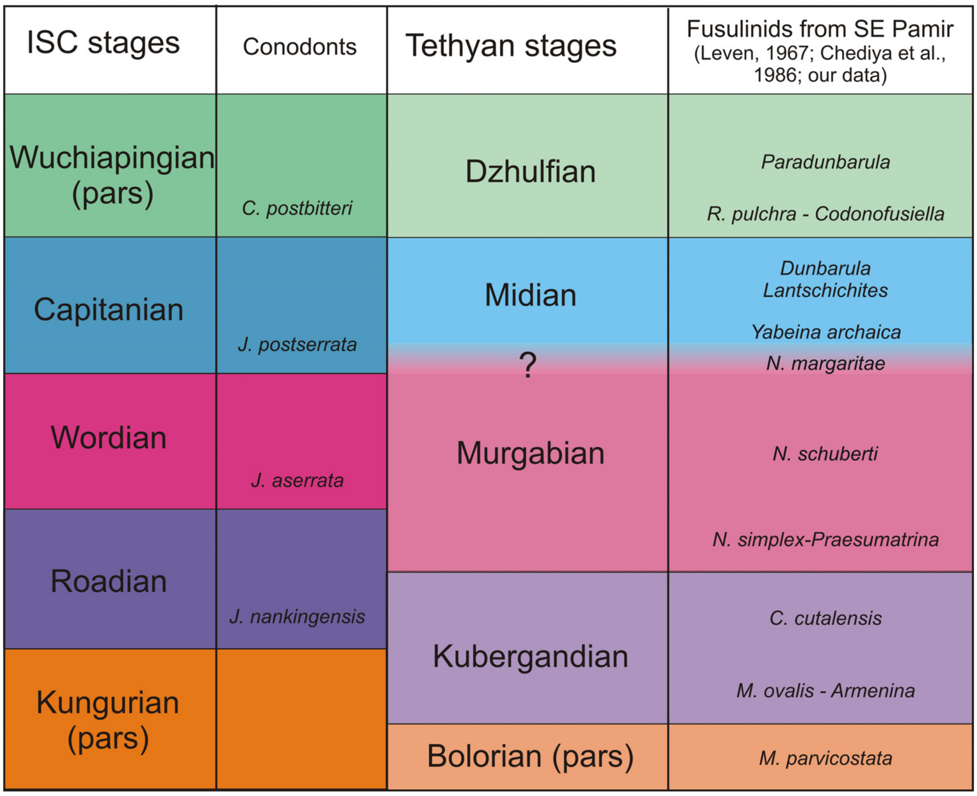

Fig. 61. Correlation between International and Tehtyan stages (from Angiolini *et al.*, in press).

Provincialism and biostratigraphical implications

Specimens from SE Pamir can be correlated with Oman, S. China, Texas, Sicily and Central Iran for the presence of *M. siciliensis* and transitional form to *Mesogondolella omanensis;* to South China, for the presence of *M. pingxiangensis*; to the Altuda and Word Formations (U.S.A.) for the presence of *J. altudaensis*, *Hindeodus wordensis* (Wardlaw, 2000) and *Hindeodus excavatus* (Behnken, 1975) and to Urals for the presence of *Sw. withei* and *M. monstra*.
The presence of such a differentiated fauna suggest that SE Pamir was located in a mixed fauna zone during Permian.

Mei & Henderson (2001) observed how Permian provincialism reflects on conodont morphology: they observed that warm water gondolellids have small cusps relative to posterior denticle height and high and fused anterior denticles, whereas cool- water taxa have larger cusps and lower, discrete, anterior denticles.

Permian conodonts contains both serrated and non- serrated forms and the base of Roadian and Guadalupian have been defined by the Subscommission on Permian Stratigraphy on the base of the First Appearance Datum (FAD) of the serrated species *Jinogondolella nankingensis* (Ching, 1960) (Glenister *et al.*, 1992, 1999; Jin *et al.*, 1997; Lambert *et al.*, 2000) but the Permian profound provincialism and the recognition of geographic clines throughout conodonts (Henderson & Mei, 2000a, b; Mei & Henderson, 2002) open many question on conodont taxonomy. Particularly Henderson & Mei (2003) reported that serrated forms from Roadian are confined in cool- water provinces (like Phosphoria and Svedrup Basin).

Almost all the specimens of *Jinogondolella* present in the studied fauna of SE Pamir, that shows a mixed assemblage of cool and warm water taxa, does not shows serrations and few specimens shows some trace of this character. This is a very interesting data that support the hypothesis that serration are under ecological control (Henderson & Mei, 2002, 2003).

Chapter 9

Conclusions

This study added new important data in order to correlate International and Tethyan timescales, to reconstruct paleoenvironmental conditions and paleobioprovinces subdivisions in Tethyan gulf during Upper Carboniferous and Permian and to clarify taxonomy of Permian conodont.

9.1 Correlation between conodonts and fusulinids

Correlation between conodonts and fusulinids have been possible only in Central Iran and SE Pamir, where both groups were abundant.

- In Bagh-e-Vang section (Central Iran) conodonts from our samples have been correlated with fusulinids from literature (e. g. Leven *et al.*, 2007), showing problems in correlation. In order to solve these problems fusulinids samples have been collected by Balini *et al.* (2010) from the same section and levels of conodont ones, but these are still under study and data are not available yet.

- In SE Pamir correlation between conodonts and fusulinids collected from the same levels fit quite well except for Kurteke section that need more sampling. According to data collected from this area, the Bolorian stage of Tethyan scale correlates with the Lower/ Middle Kungurian of the International timescale, the Kubergandian correlates with Middle/Upper Kungurian and Lower Roadian and Murgabian correlates with Upper Roadian and Wordian: the upper limit of Murgabian and the lower limit of Midian stages of Tethyan timescales are still uncertain, but the Midian correlate at least with Middle and Upper Capitanian and Dzhulfian with Wuchiapingian (see fig. 61).

9.2 Correlation among different Cimmerian Blocks and the global scale

- According to conodont fauna recovered (e. g. *Mesogondolella monstra* Chernykh, 2005 and *Mesogondolella manifesta* Chernykh, 2005) Lower and Middle Permian of Central Iran can be correlated with Lower and Middle Permian of SE Pamir, Urals, Russian Platform, Yukon Territory and Carnic Alps.

- Permian from Tunisia can be correlated with N Pamir and S. China.

- Middle Permian from SE Pamir can be correlated with S. China, Texas, Sicily and Central Iran according to the founded conodont fauna (e. g. *Mesogondolella siciliensis* (Kozur, 1975) and *Mesogondolella* cf. *nankingensis*).

- Lower Triassic of SE Pamir can be correlated with Western Dolomites and Jordan because of the presence of *Hadrodontina aequabilis* Staesche, 1964.

9.3 Individuation of paleobioprovinces and paleoenvironmental considerations

- According to conodonts Central Iran shows a Warm Water Boreal affinity and in Bagh-e-Vang section is possible to recognize a deepening trend because of the increase of specimens of deep-water genera (*Mesogondolella*) respect to the shallow water ones (*Sweetognathus*).

- Tunisia was part of the Equatorial Warm Water Province and the presence of the conodont *Sweetognathus iranicus hanzongensis* (Wang, 1978) in Halq Jemel and Tebaga *sensu strictu* sections point to a shallow and warm water environment, as expected because of the location of this area in the Tethyan Gulf during Permian.

- N Pamir shows an Equatorial Warm Water Province affinity at least during Lower Permian and conodonts from Bolorian Stratotype section (*Sweetognathus iranicus hanzongensis* Wang, 1978 and *Sweetognathus modulatus* Chernykh, 2006) point to a shallow and warm water environment.

- SE Pamir is principally characterized by warm water species (e.g. *Mesogondolella pingxiangensis* Zhang, Henderson & Xia, 2010, *Jinogondolella* cf. *nankingensis*) but some cold specimens such as the genus *Vjalovognathus* indicate that a mixed warm and cold fauna is present.

9.4 Taxonomical revision of Carboniferous and Permian conodonts

- From Upper Carboniferous strata of Zaladou section (Central Iran) was found the species *Streptognathodus* cf. *plenus*. The species *Streptognathodus plenus* Chernyk, 2005 is reported only from the Asselian stage in the Urals (Chernykh, 2005, Boardman *et al.*, 2009) but there are no indication about the range and distribution of this species out of this area. So, the finding of *S.* cf. *plenus* in Upper Carboniferous strata from Central Iran indicate that further studies are needed in order to better define the extension of the range of the species *S. plenus.*

- Species *Streptognathodus longus* Chernykh, 2005 and *Idiognathodus lobatus* Gunnell, 1933 have been found in the same Upper Carboniferous samples from Anarak 3 section (Central Iran): information about these species distribution are rare, especially for *I. lobatus* that have been reported only from the Missourian of Swope Sequence, eastern Kansas (Gunnell, 1933, Rosscoe, 2008). Coexisting of these two species in the same samples and lack of literature data of their distribution demonstrate that more study is needed in order to better comprehend their distribution and range extension.

- Several non- serrated or slightly serrated forms have been founded in Middle Permian samples from SE Pamir: the presence of non- serrated *Jinogondolella* cf. *nankingensis*, *Jinogondolella altudaensis* (Kozur, 1992), *Jinogondolella aserrata* (Clark & Behnken, 1979) and slightly-serrated specimens of *Jinogondolella* cf. *postserrata* validate the hypothesis that this characters is under ecological control and is related to warm water environment.

- In SE Pamir the species *Sweetognathus withei* (Rhodes, 1963) was founded together with a typical Sakmarian fauna (e.g. *Mesogondolella monstra* Chernykh, 2005, *Sweetognathus* cf. *merrilli*) and some *Streptognathodus* sp. specimens. *Streptognathodus* genus became extinct in Middle Sakmarian (e. g. Nemirovskaya, 1999; Henderson, 2004) so the species *Sw. withei*, that has a very discussed range, is Sakmarian in age and not Artinskian as proposed by Chernykh & Chuvashov, 2014.

In conclusion this study is very important in order to better understand the evolution of Cimmerian Terranes during Upper Carboniferous and Permian and their paleobiogeographical affinities. Conodonts are very powerful biostratigraphic tools and have a great potential for correlation between Cimmerian Terranes: furthermore great progress have been made in correlation between International and Tethyan timescales.

Permian provincialism is a great obstacle in biostratigraphic correlations, but these results demonstrate that, with long and accurate study, it can be solved allowing a better comprehension of the Earth in this ancient period.

Some questions, however, remains open making crucial to prosecute studies in these areas with further samplings and analyses on the conodont faunas.

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Plates

PLATE 1

Fig. 1a, b, c: ***Mesogondolella manifesta****,* upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 2a, b, c: ***Mesogondolella manifesta***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Mesogondolella manifesta***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 4a, b, c: ***Mesogondolella manifesta***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Streptognathodus*** **aff.** ***lanceatus***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Streptognathodus postconstrictus***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Streptognathodus*** **aff.** ***lanceatus***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 8a, b, c: ***Streptognathodus*** **aff.** ***lanceatus***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

PLATE 2

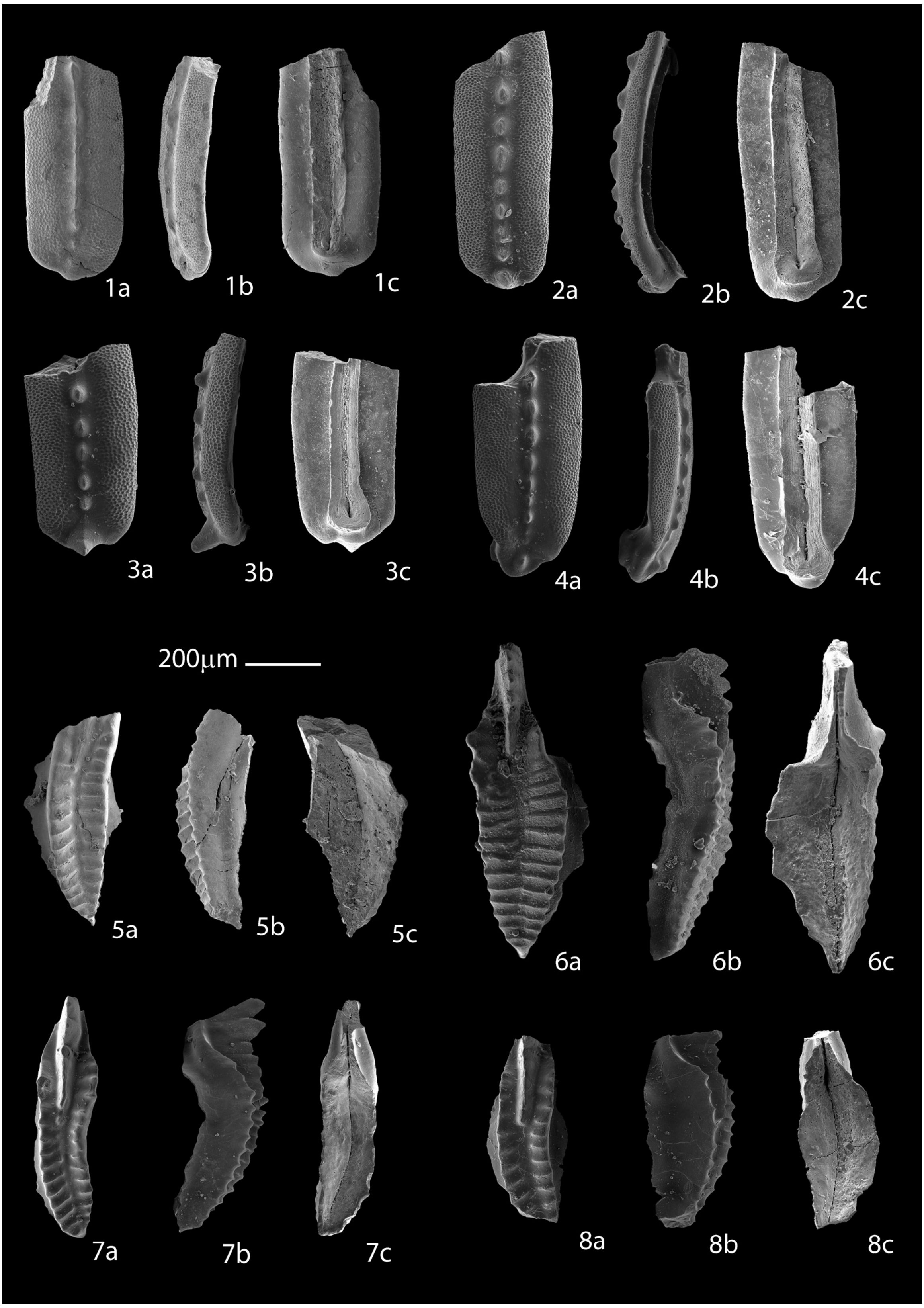


Plate1.

Fig. 1a, b, c: ***Mesogondolella manifesta,*** upper, lateral and lower view, sample BEV10, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 2a, b, c: ***Mesogondolella manifesta***, upper, lateral and lower view, sample BEV10, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Mesogondolella manifesta***, upper, lateral and lower view, sample BEV10, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 4a, b, c: ***Mesogondolella monstra***, upper, lateral and lower view, sample BEV10, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Streptognathodus postfusus***, upper, lateral and lower view, sample BEV10, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Streptognathodus postconstrictus*,** upper, lateral and lower view, sample BEV10, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Streptognathodus postfusus***, upper, lateral and lower view, sample BEV10, Bagh-e-Vang section, Tabas area, Central Iran.

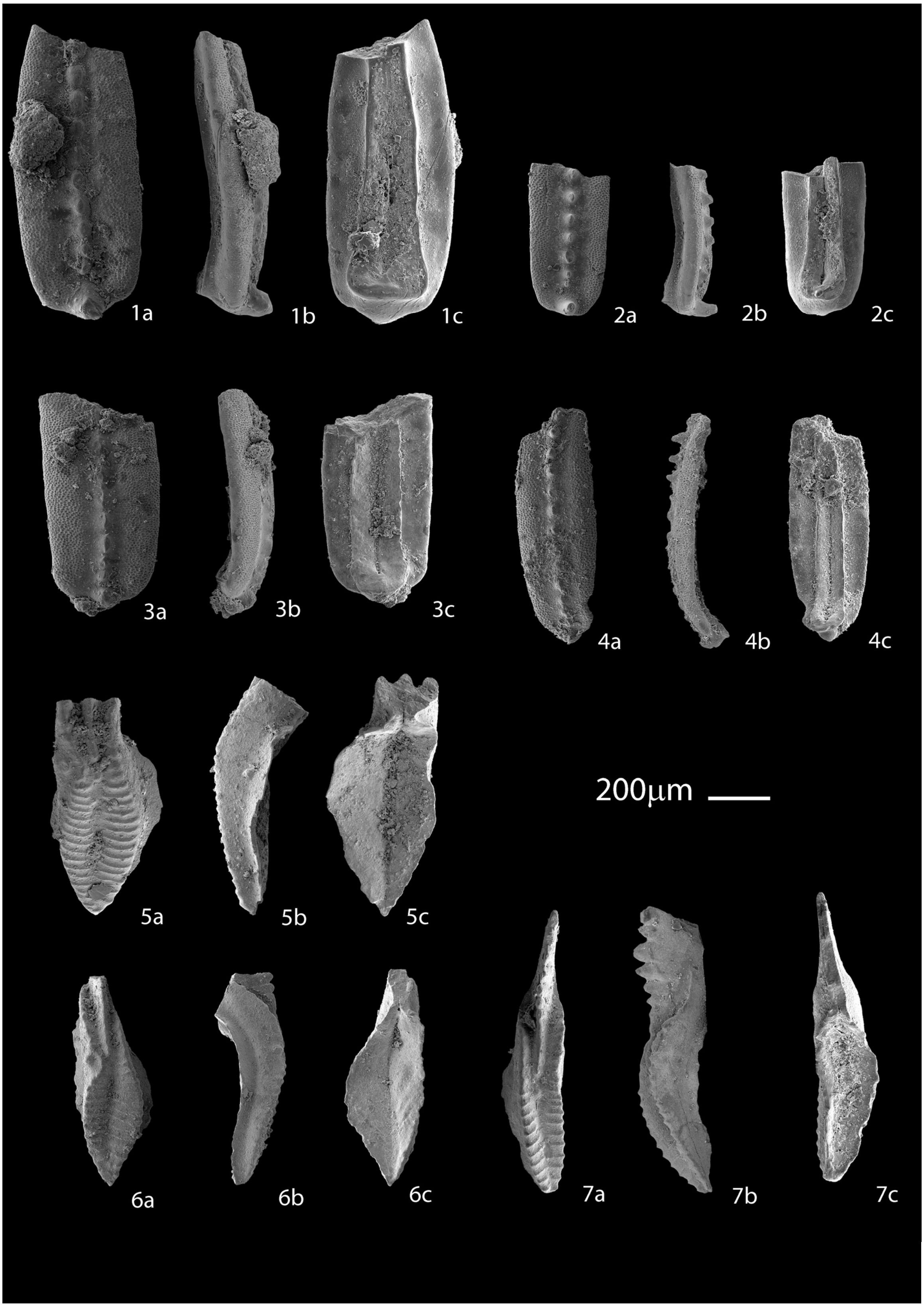


Plate 2.

PLATE 3

Fig. 1a, b, c: ***Mesogondolella bisselli,*** upper, lateral and lower view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 2a, b, c: ***Mesogondolella bisselli***, upper, lateral and lower view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Sweetognathus* aff. *anceps***, upper, lateral and lower view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 4a, b, c: ***Sweetognathus* aff. *anceps***, upper, lateral and lower view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Sweetognathus* aff. *anceps***, upper, and lower view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Streptognathodus* aff. *anceps***, upper, and lower view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 7a, b: ***Mesogondolella bisselli***, upper and lateral view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 8a, b: ***Mesogondolella bisselli***, upper and lateral view, sample BEV41, Bagh-e-Vang section, Tabas area, Central Iran.

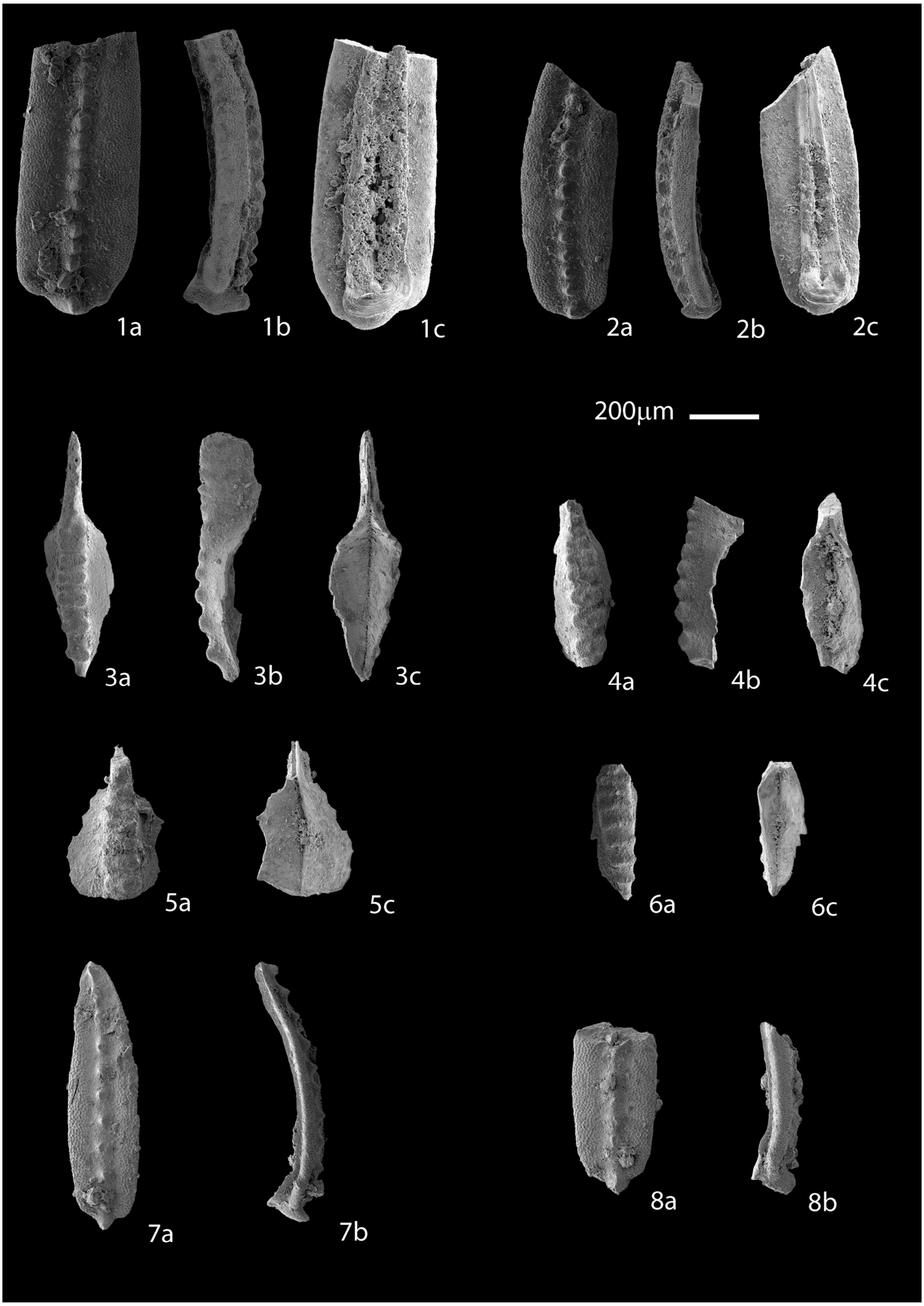


Plate 3.

PLATE 4

Fig. 1a, b, c: ***Mesogondolella bisselli,*** upper, lateral and lower view, sample BEV42, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 2a, b, c: ***Mesogondolella guyouensis***, upper, lateral and lower view, sample BEV43, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Mesogondolella guyouensis***, upper, lateral and lower view, sample BEV43, Bagh-e-Vang section, Tabas area, Central Iran.

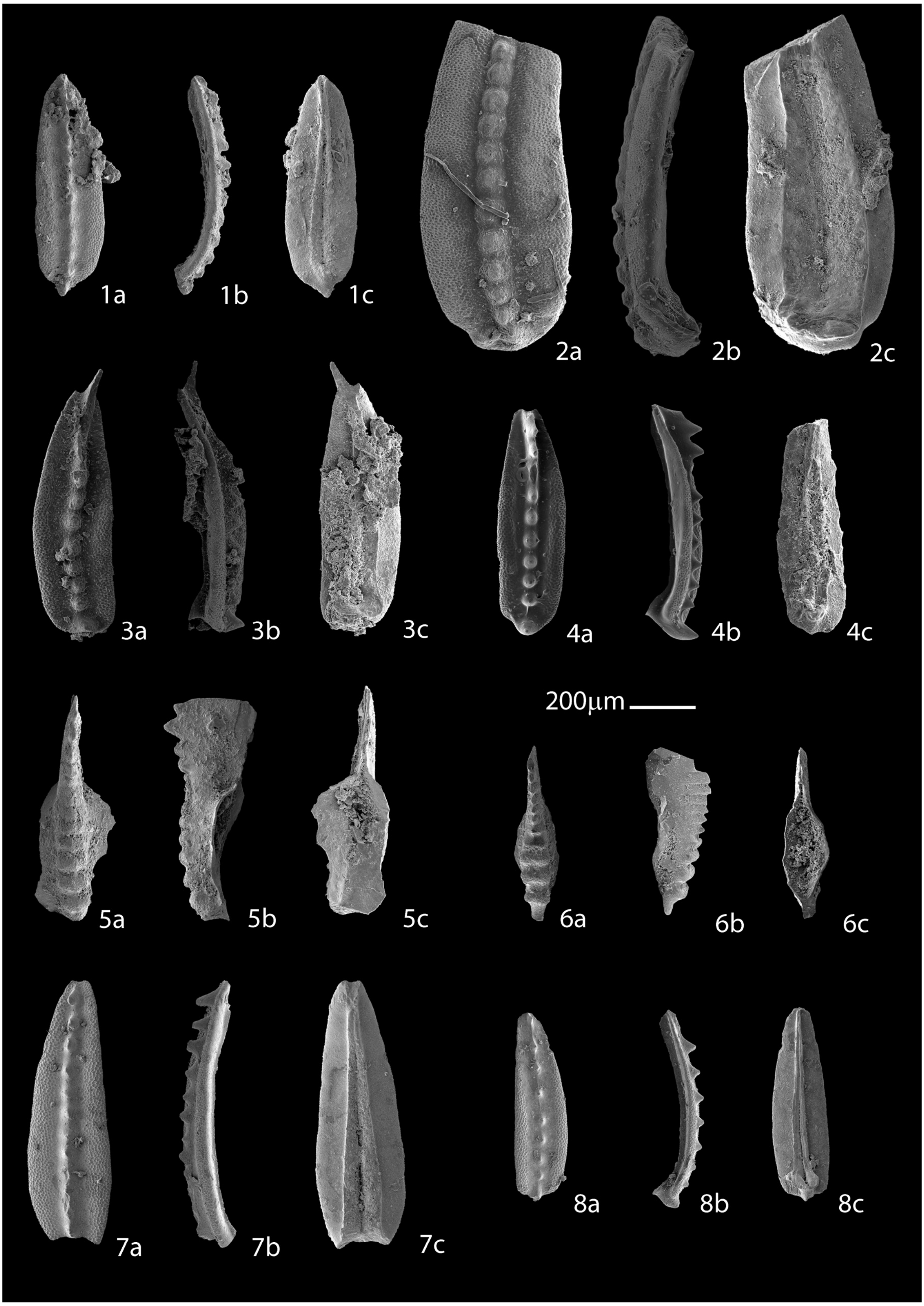
Fig. 4a, b, c: ***Mesogondolella guyouensis***, upper, lateral and lower view, sample BEV43, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Sweetognathus* aff. *anceps***, upper, lateral and lower view, sample BEV15, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Sweetognathus* aff. *anceps***, upper, lateral and lower view, sample BEV15, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Mesogondolella bisselli***, upper, lateral and lower view, sample BEV15, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 8a, b, c: ***Mesogondolella bisselli***, upper, lateral and lower view, sample BEV15, Bagh-e-Vang section, Tabas area, Central Iran.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200μm
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6a
6b
6c
7a
7b
7c
8a
8b
8c

Plate 4.

PLATE 5

Fig. 1a, b, c: ***Mesogondolella bisselli,*** upper, lateral and lower view, sample BEV15, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 2a, b: ***Mesogondolella bisselli***, upper and lateral view, sample BEV15, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Mesogondolella siciliensis***, upper, lateral and lower view, sample BEV44, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 4a, b, c: **trans. *Mesogondolella siciliensis/M. omanensis***, upper, lateral and lower view, sample BEV44, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 5a, b, c: **trans. *Mesogondolella siciliensis/M. omanensis***, upper, lateral and lower view, sample BEV44, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Pseudohindeodus ramovsi***, upper, lateral and lower view, sample BEV44, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Mesogondolella siciliensis***, upper, lateral and lower view, sample BEV44, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 8a, b, c: ***Mesogondolella siciliensis***, upper, lateral and lower view, sample BEV40, Bagh-e-Vang section, Tabas area, Central Iran.

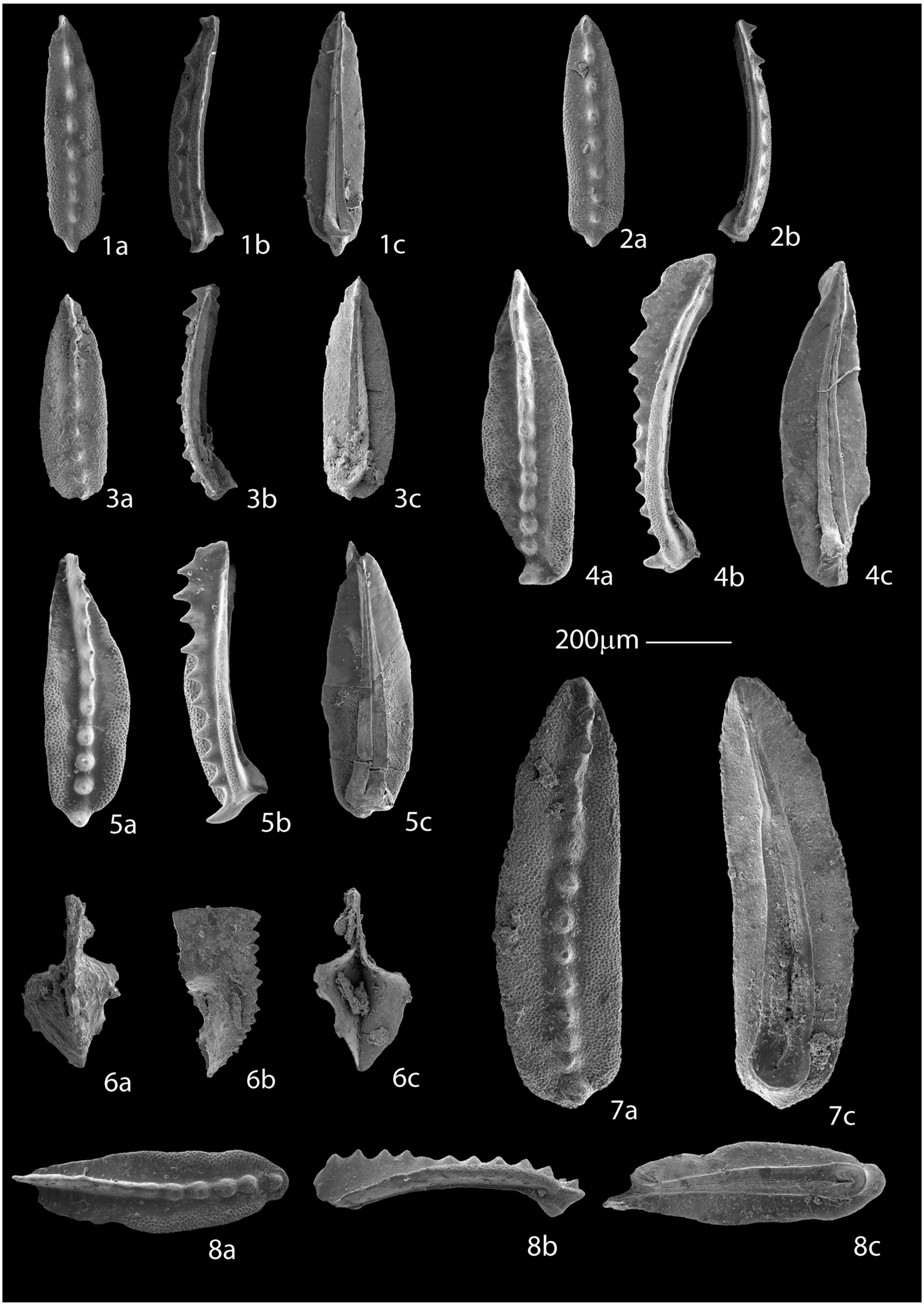


Plate 5.

PLATE 6

Fig. 1a, b, c: **trans. *Mesogondolella siciliensis/M. omanensis*,** upper, lateral and lower view, sample BEV45, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 2a, b, c: ***Mesogondolella siciliensis***, upper, lateral and lower view, sample BEV45, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 3a, b, c: **trans. *Mesogondolella siciliensis/M. omanensis***, upper, lateral and lower view, sample BEV45, Bagh-e-Vang section, Tabas area, Central Iran.

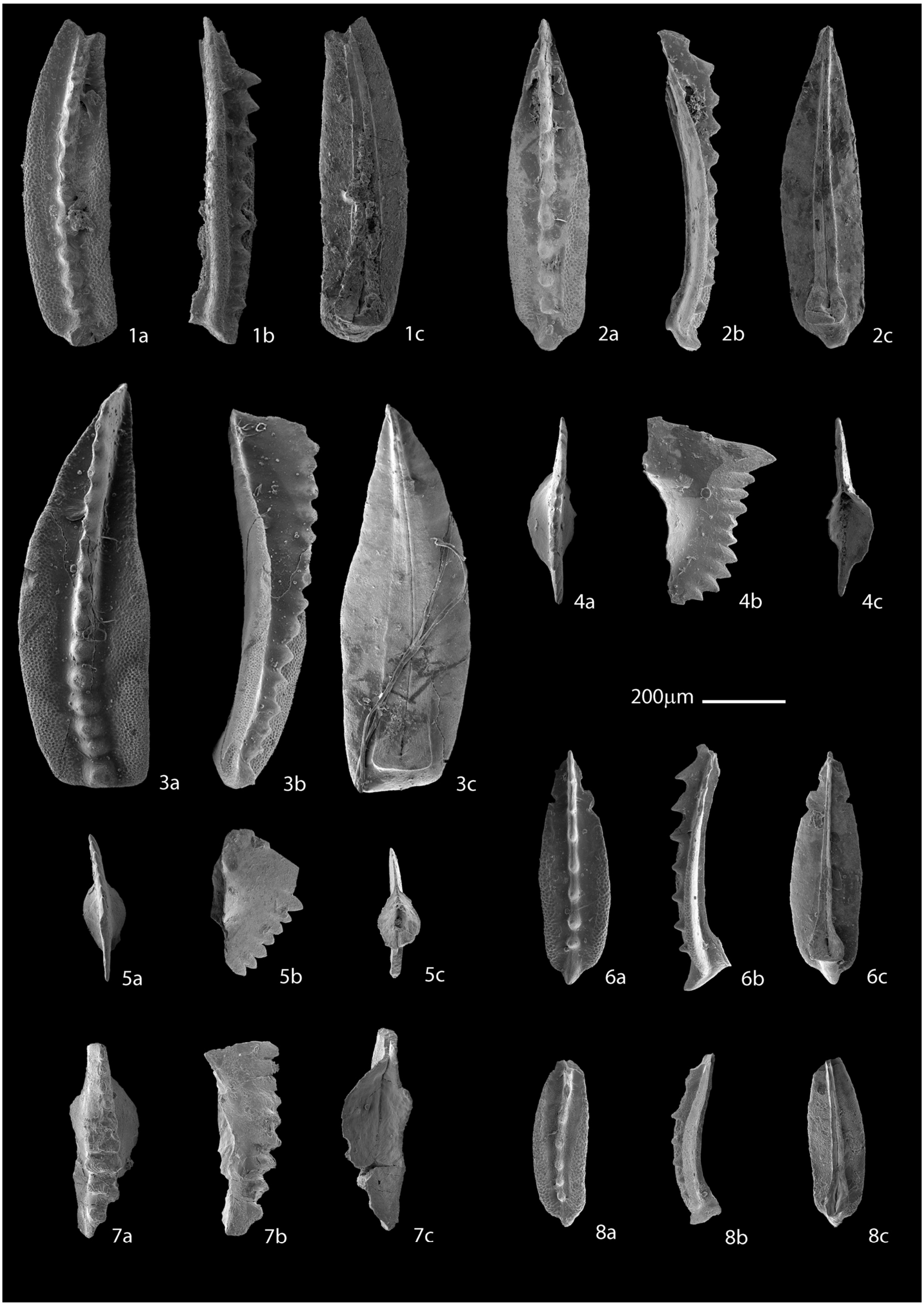
Fig. 4a, b, c: ***Hindeodus wordensis***, upper, lateral and lower view, sample BEV46, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Hindeodus wordensis***, upper, lateral and lower view, sample BEV46, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Mesogondolella siciliensis***, upper, lateral and lower view, sample BEV46, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Sweetognathus subsymmetricus***, upper, lateral and lower view, sample BEV48, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 8a, b, c: ***Mesogondolella siciliensis***, upper, lateral and lower view, sample BEV48, Bagh-e-Vang section, Tabas area, Central Iran.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6a
6b
6c
7a
7b
7c
8a
8b
8c

Plate 6.

PLATE 7

Fig. 1a, b, c: ***Sweetognathus subsymmetricus,*** upper, lateral and lower view, sample BEV49, Bagh-e-Vang section, Tabas area, Central Iran.

Fig. 2a, b, c: ***Idiognathodus* sp.**, upper, lateral and lower view, sample ZAL3, Zaladou section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Streptognathodus* cf. *plenus***, upper, lateral and lower view, sample IR10-11, Zaladou section, Tabas area, Central Iran.

Fig. 4a, b, c: ***Diplognathodus* sp.**, upper, lateral and lower view, sample ANK7, Anarak 3 section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Idiognathodus lobatus***, upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Idiognathodus lobatus***, upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Idiognathodus lobatus***, upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 8a, b, c: ***Streptognathodus longus***, upper, lateral and lower view, sample ANK 12, Anarak 3 section, Tabas area, Central Iran.


1a
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2a
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200µm
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4c
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5b
5c
6a
6b
6c
7a
7b
7c
8a
8b
8c

Plate 7.

PLATE 8

Fig. 1a, b, c: ***Streptognathodus* cf. *longus*,** upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 2a, b: ***Streptognathodus longus***, upper and lateral view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Streptognathodus longus***, upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 4a, b, c: ***Streptognathodus longus***, upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Streptognathodus longus***, upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Idiognathodus lobatus***, upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Streptognathodus* cf. *longus*,** upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

Fig. 8a, b, c: ***Streptognathodus* cf. *longus*,** upper, lateral and lower view, sample ANK12, Anarak 3 section, Tabas area, Central Iran.

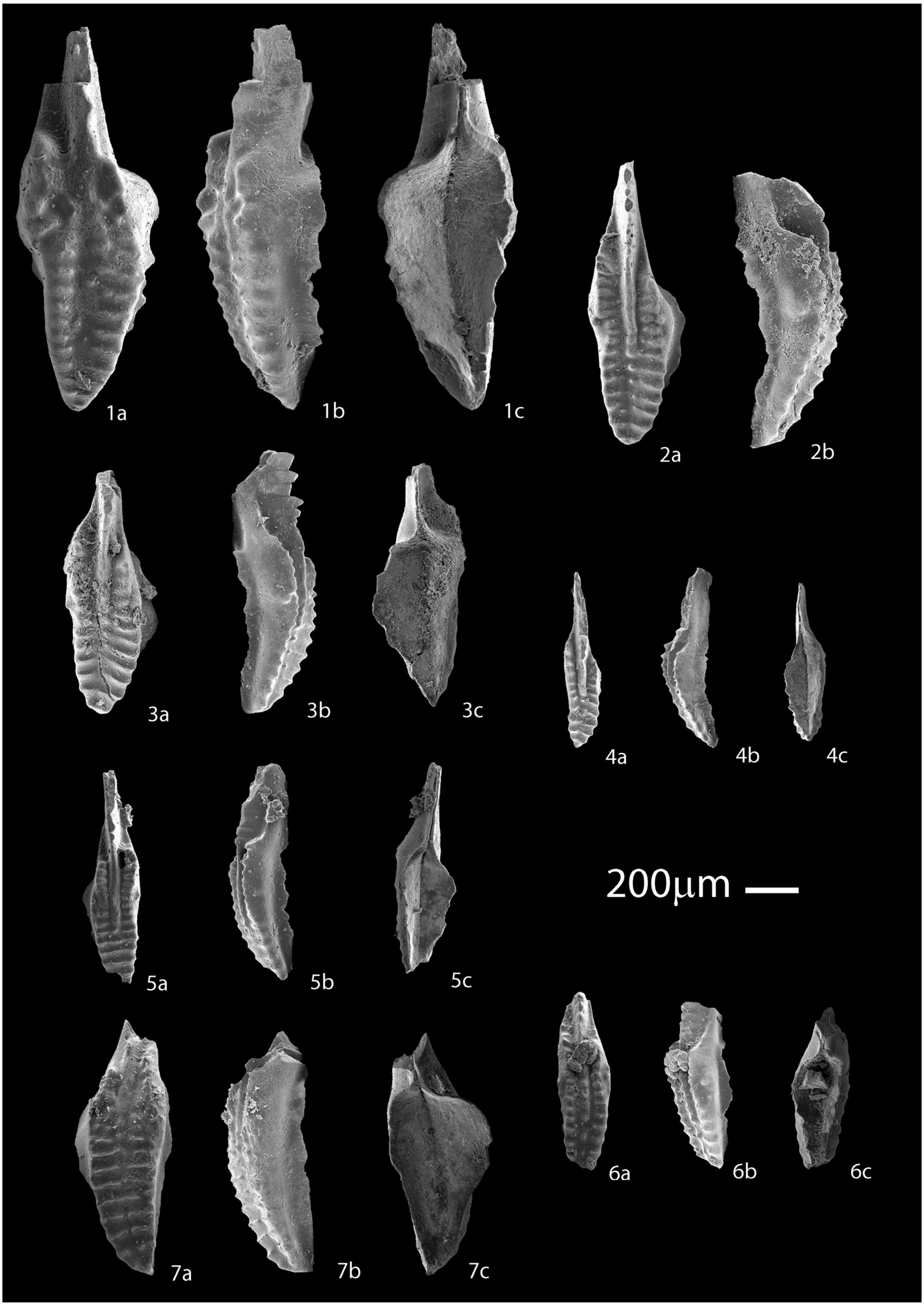


Plate 8.

PLATE 9

Fig. 1a, b, c: ***Gnathodus girtyi girtyi****,* upper, lateral and lower view, sample RH51, Rahdar section, Tabas area, Central Iran.

Fig. 2a, b, c: ***Gnathodus girtyi girtyi****,* upper, lateral and lower view, sample RH51, Rahdar section, Tabas area, Central Iran.

Fig. 3a, b, c: ***Hindeodus* sp.**, upper, lateral and lateral view, sample RH54, Rahdar section, Tabas area, Central Iran.

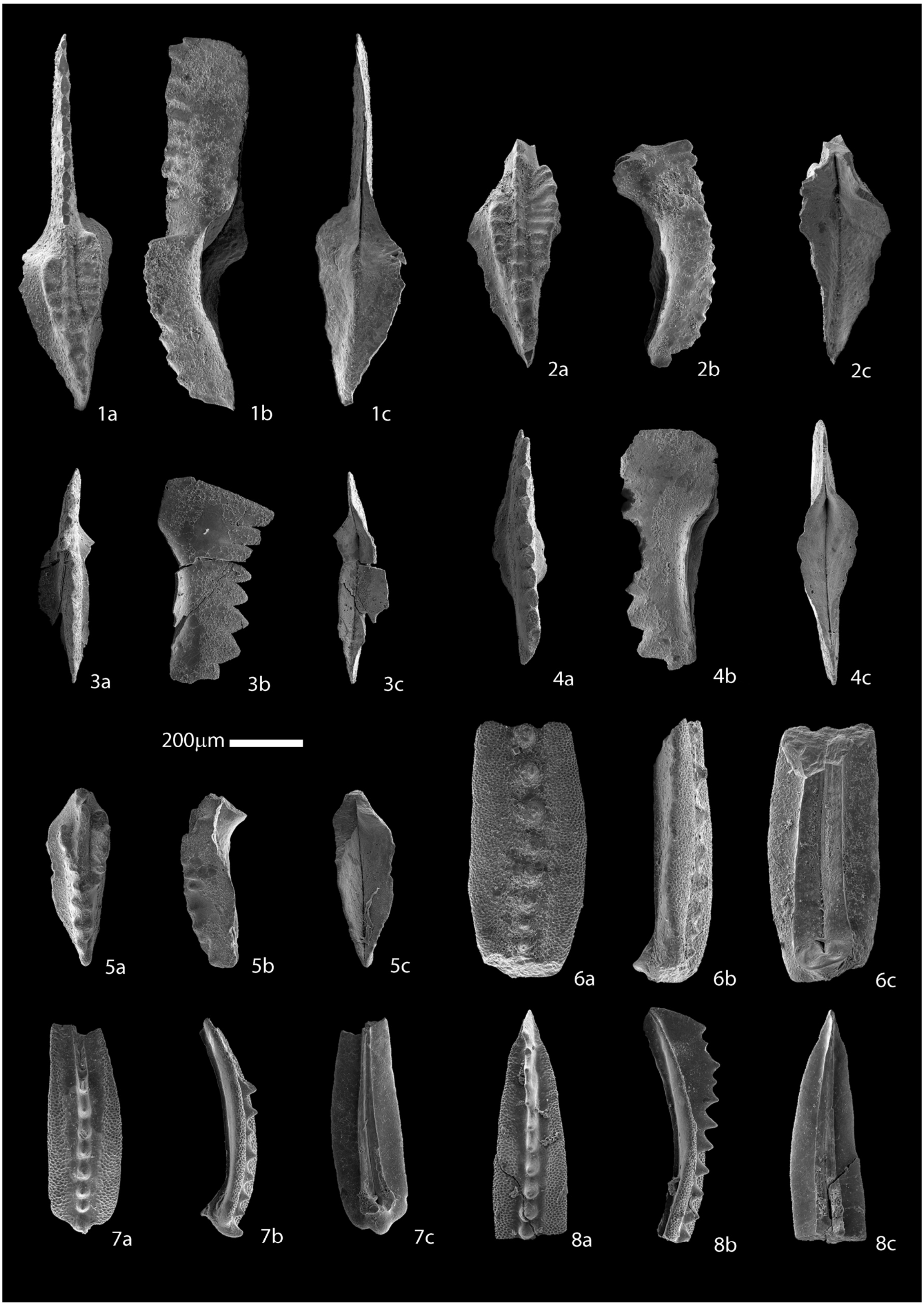
Fig. 4a, b, c: ***Hindeodus scitulus***, upper, lateral and lower view, sample RH54, Rahdar section, Tabas area, Central Iran.

Fig. 5a, b, c: ***Gnathodus girtyi simplex***, upper, lateral and lower view, sample RH54, Rahdar section, Tabas area, Central Iran.

Fig. 6a, b, c: ***Mesogondolella* cf. *manifesta***, upper, lateral and lower view, sample SHA12, Shesht- Angosht section, Tabas area, Central Iran.

Fig. 7a, b, c: ***Mesogondolella siciliensis****,* upper, lateral and lower view, sample SHA15, Shesht- Angosht section, Tabas area, Central Iran.

Fig. 8a, b, c: ***Mesogondolella siciliensis****,* upper, lateral and lower view, sample SHA15, Shesht- Angosht section, Tabas area, Central Iran.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5a
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6a
6b
6c
7a
7b
7c
8a
8b
8c

Plate 9.

PLATE 10

Fig. 1a, b,: ***Mesogondolella idahoensis****,* upper and lateral view, sample TJ1, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Mesogondolella idahoensis****,* upper, lateral and lower view, sample TJ1, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella idahoensis****,* upper, lateral and lower view, sample TJ1, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Mesogondolella idahoensis****,* upper, lateral and lower view, sample TJ4, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b: ***Mesogondolella idahoensis****,* upper and lateral view, sample TJ4, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b: ***Mesogondolella idahoensis****,* upper and lateral view, sample TJ4, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b: ***Mesogondolella idahoensis****,* upper and lateral view, sample TJ5, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b: ***Mesogondolella idahoensis****,* upper and lateral view, sample TJ5, Kubergandy section, SE Pamir, Tajikistan.

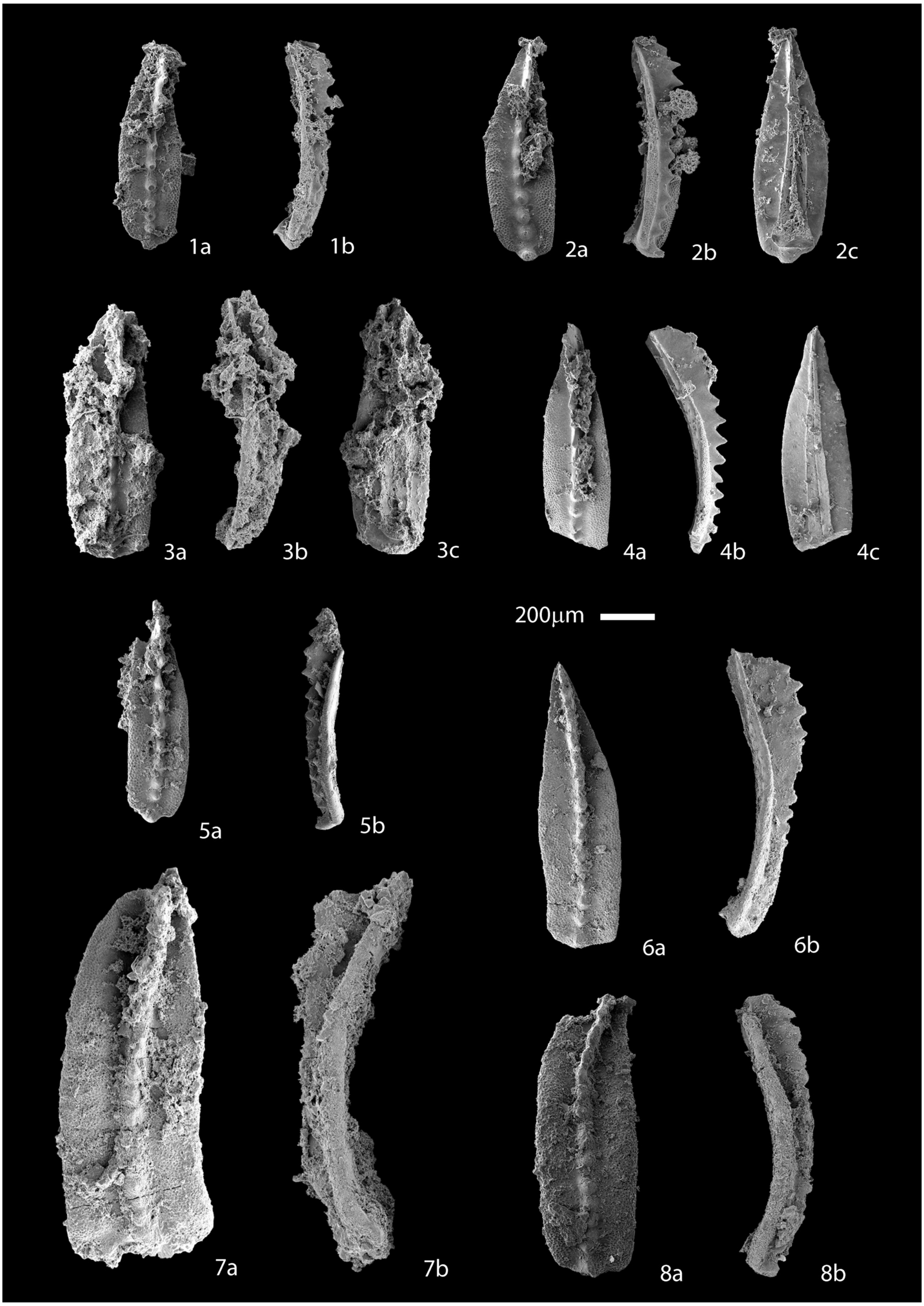

Plate 10.

PLATE 11

Fig. 1a, b,: ***Mesogondolella idahoensis,*** upper and lateral view, sample TJ6, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b: ***Mesogondolella idahoensis,*** upper, lateral and lower view, sample TJ6, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b: ***Mesogondolella siciliensis,*** upper and lateral view, sample TJ7, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b: ***Pseudohindeodus ramovsi,*** upper and lateral view, sample TJ7, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b: ***Hindeodus excavatus,*** upper and lateral view, sample TJ7, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b: ***Pseudohindeodus ramovsi,*** upper and lateral view, sample TJ7, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b: ***Pseudohindeodus ramovsi,*** upper and lateral view, sample TJ7, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella idahoensis,*** upper, lateral and lower view, sample TJ8, Kubergandy section, SE Pamir, Tajikistan.

Fig. 9a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ8, Kubergandy section, SE Pamir, Tajikistan.

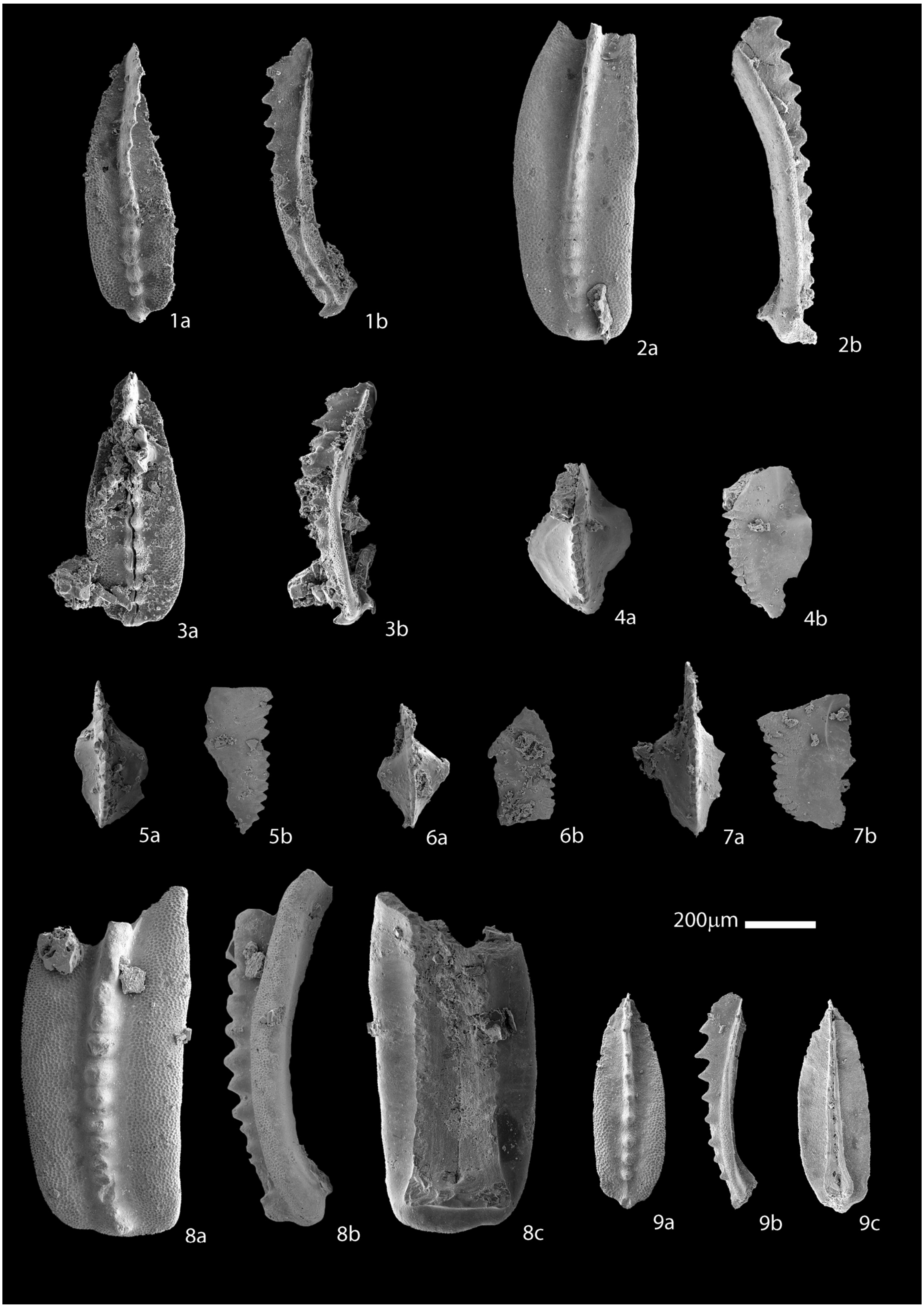

Plate 11.

PLATE 12

Fig. 1a, b,: ***Mesogondolella siciliensis,*** upper and lateral view, sample TJ8, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ9, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b: ***Mesogondolella siciliensis,*** upper and lateral view, sample TJ9, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Mesogondolella idahoensis lamberti,*** upper, lateral and lower view, sample TJ9, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Mesogondolella idahoensis lamberti,*** upper, lateral and lower view, sample TJ9, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b: ***Hindeodus excavatus,*** upper and lateral view, sample TJ9, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b,: ***Hindeodus excavatus,*** upper and lateral view, sample TJ11, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ11, Kubergandy section, SE Pamir, Tajikistan.

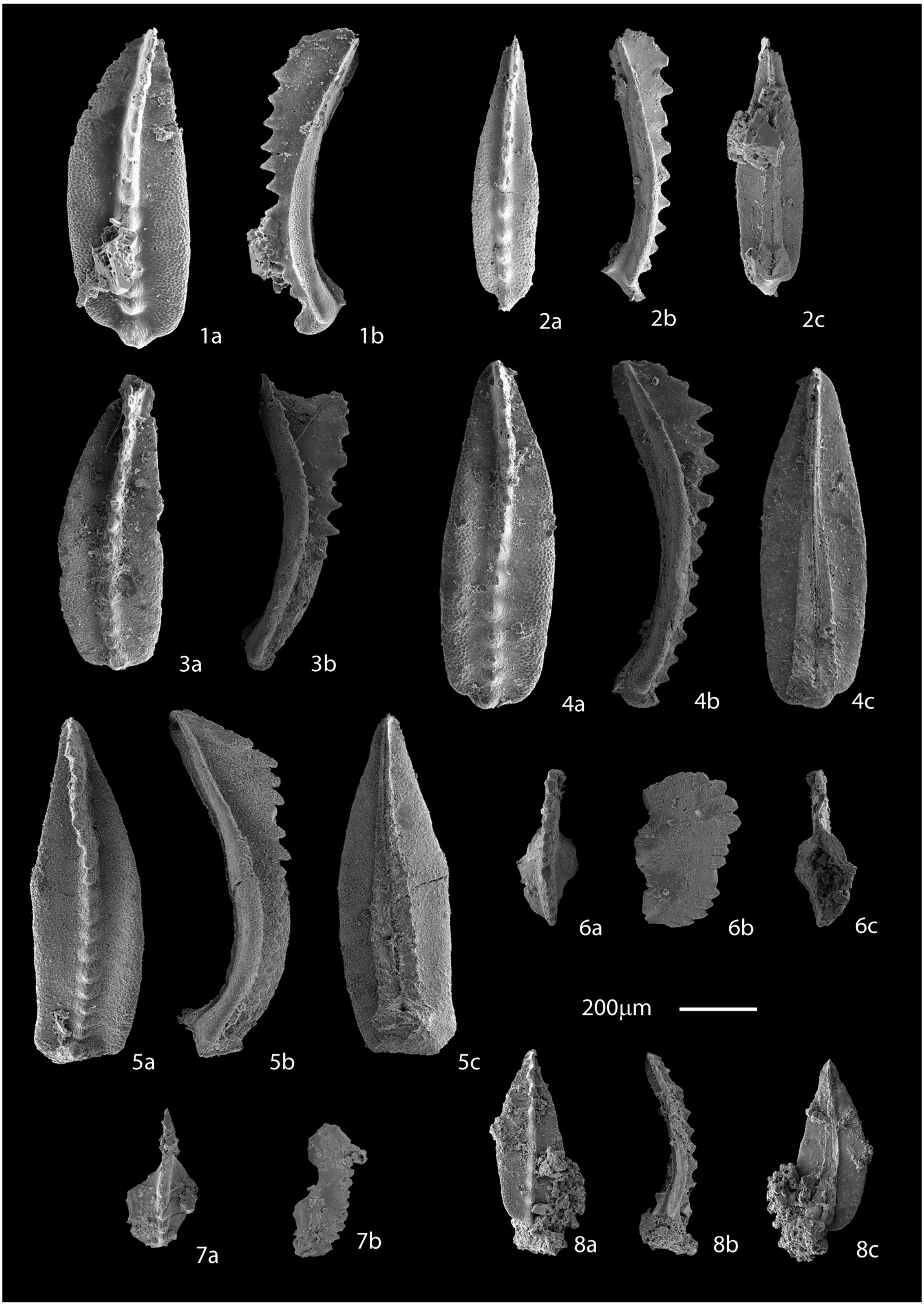

Plate 12.

PLATE 13

Fig. 1a, b, c: ***Mesogondolella siciliensis,*** upper and lateral view, sample TJ11, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b: ***Mesogondolella siciliensis,*** upper and lateral view, sample TJ12, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b: ***Mesogondolella siciliensis,*** upper and lateral view, sample TJ12, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b: ***Mesogondolella pingxiangensis,*** upper and lateral view, sample TJ12, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b: ***Mesogondolella pingxiangensis,*** upper and lateral view, sample TJ12, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a: ***Sweetognathus*** **cf.** ***bicarinum,*** upper view, sample TJ12, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella sp.,*** upper, lateral and lower view, sample TJ21, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella sp.,*** upper, lateral and lower view, sample TJ21, Kubergandy section, SE Pamir, Tajikistan.

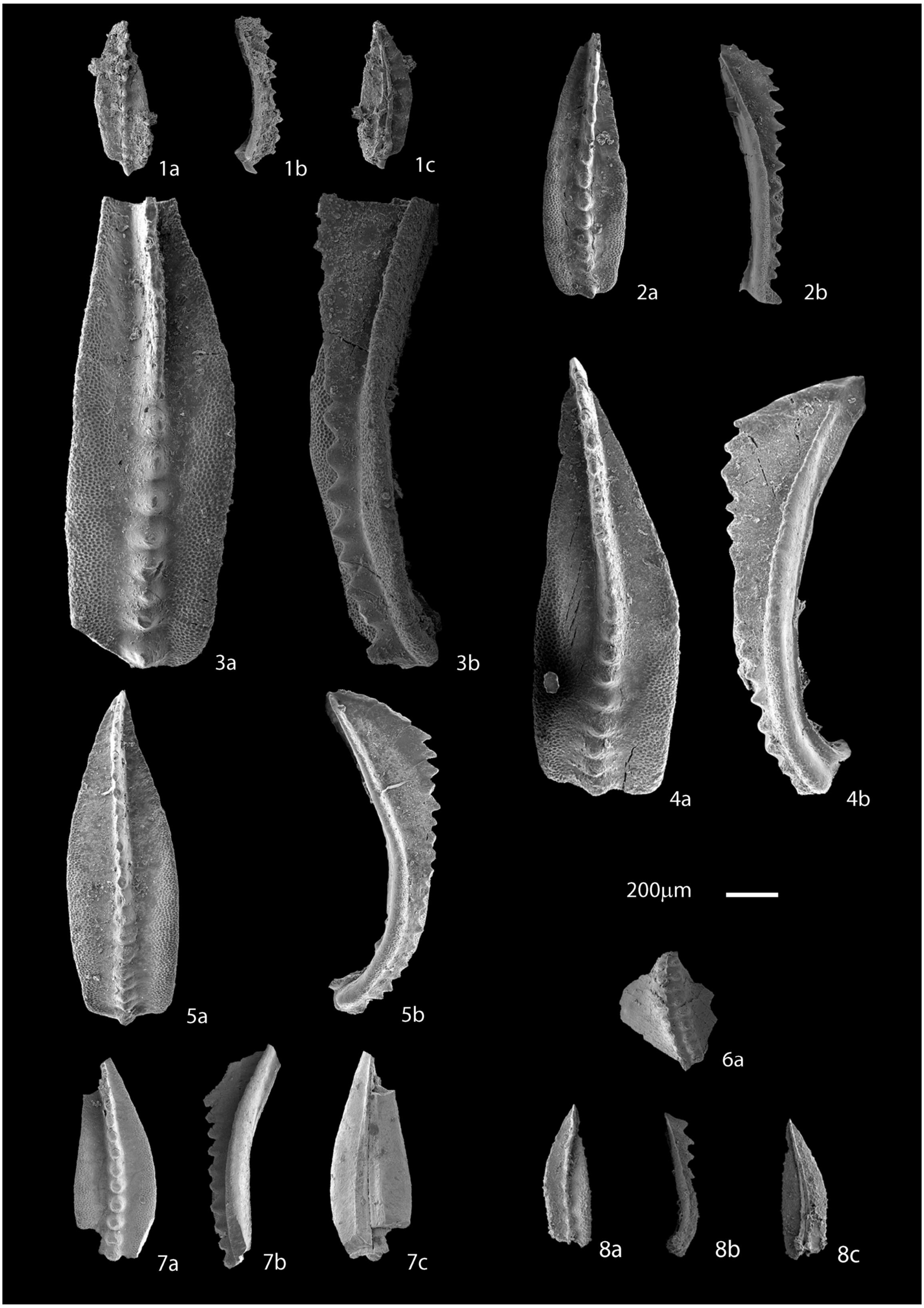

Plate 13.

PLATE 14

Fig. 1a, b, c: ***Mesogondolella* cf. *idahoensis,*** upper and lateral view, sample TJ21, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b, c: **trans. *Sweetognathus guyouensis/S. subsymmetricus,*** upper, lateral and lower view, sample TJ22, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ24, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ24, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ24, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella pingxiangensis,*** upper, lateral and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

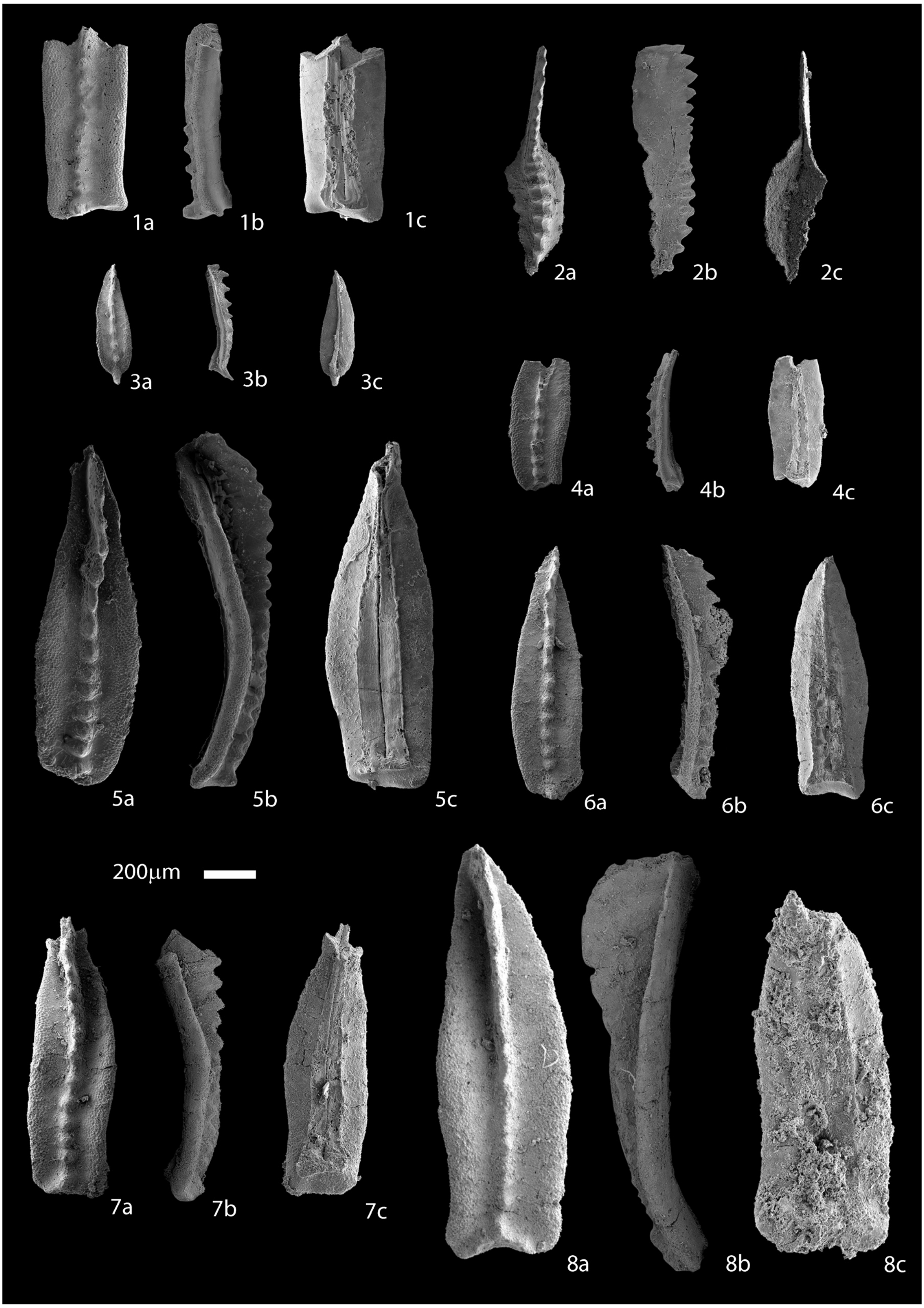
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Plate 14.

PLATE 15

Fig. 1a, b, c: ***Mesogondolella pingxiangensis**,* upper, lateral and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, c: ***Sweetognathus* cf. *bicarinum**,* upper and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b: ***Mesogondolella pingxiangensis**,* upper and lateral view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b: ***Mesogondolella siciliensis**,* upper and lateral view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b: ***Mesogondolella siciliensis**,* upper and lateral view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella siciliensis**,* upper, lateral and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b: **trans. *Sweetognathus guyouensis/S. subsymmetricus**,* upper, lateral and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Pseudohindeodus ramovsi**,* upper, lateral and lower view, sample TJ25, Kubergandy section, SE Pamir, Tajikistan.

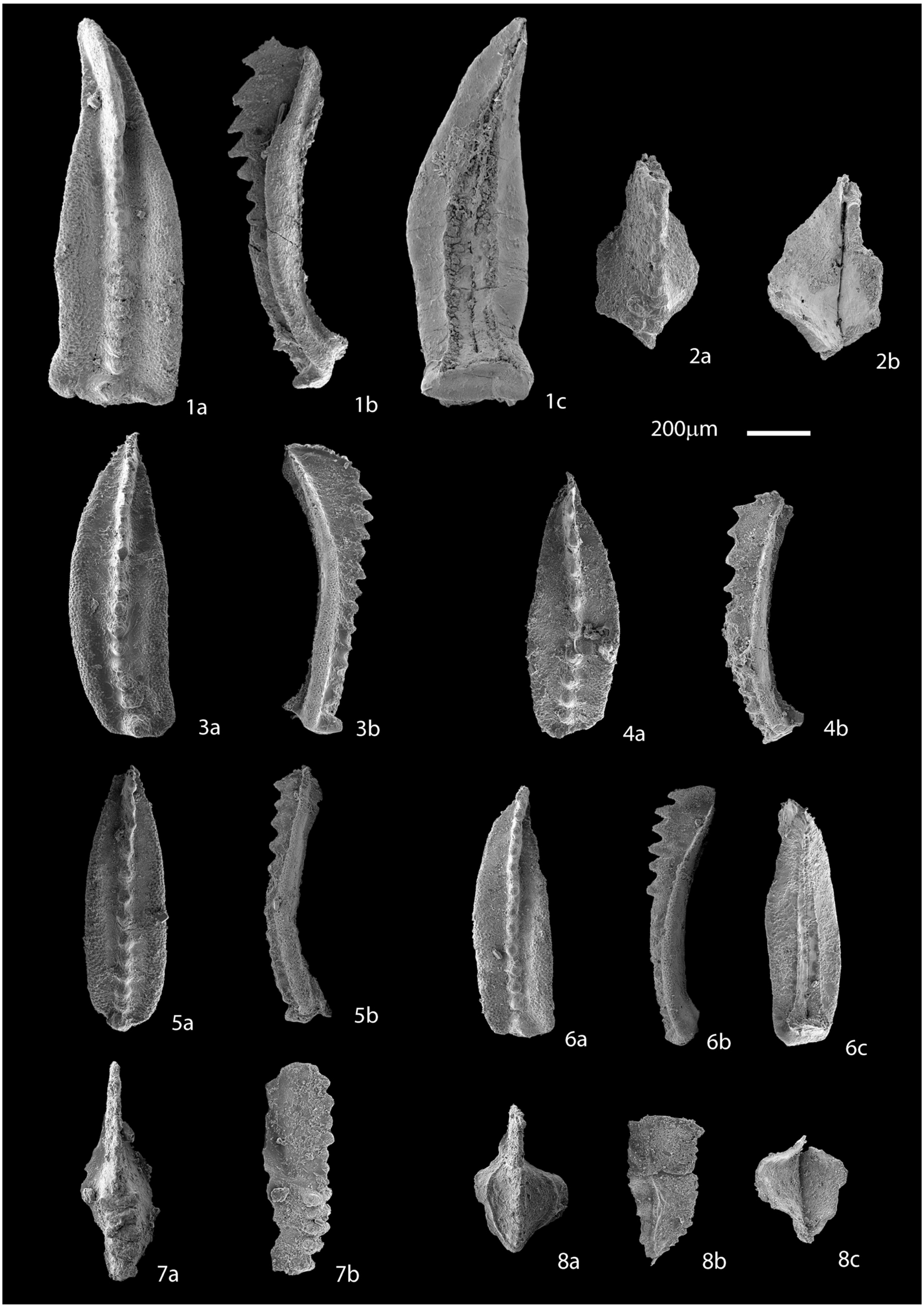

Plate 15.

PLATE 16

Fig. 1a, b, c: **trans.** ***Sweetognathus guyouensis/S. subsymmetricus,*** upper, lateral and lower view, sample TJ26, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b, c: **trans.** ***Sweetognathus guyouensis/S. subsymmetricus,*** upper, lateral and lower view, sample TJ26, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b: **trans.** ***Sweetognathus guyouensis/S. subsymmetricus,*** upper, lateral and lower view, sample TJ26, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b: ***Mesogondolella pingxiangensis,*** upper and lateral view, sample TJ26, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b: ***Mesogondolella pingxiangensis,*** upper and lateral view, sample TJ26, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella siciliensis,*** upper, lateral and lower view, sample TJ27, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella pingxiangensis,*** upper, lateral and lower view, sample TJ27, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella pingxiangensis,*** upper, lateral and lower view, sample TJ27, Kubergandy section, SE Pamir, Tajikistan.

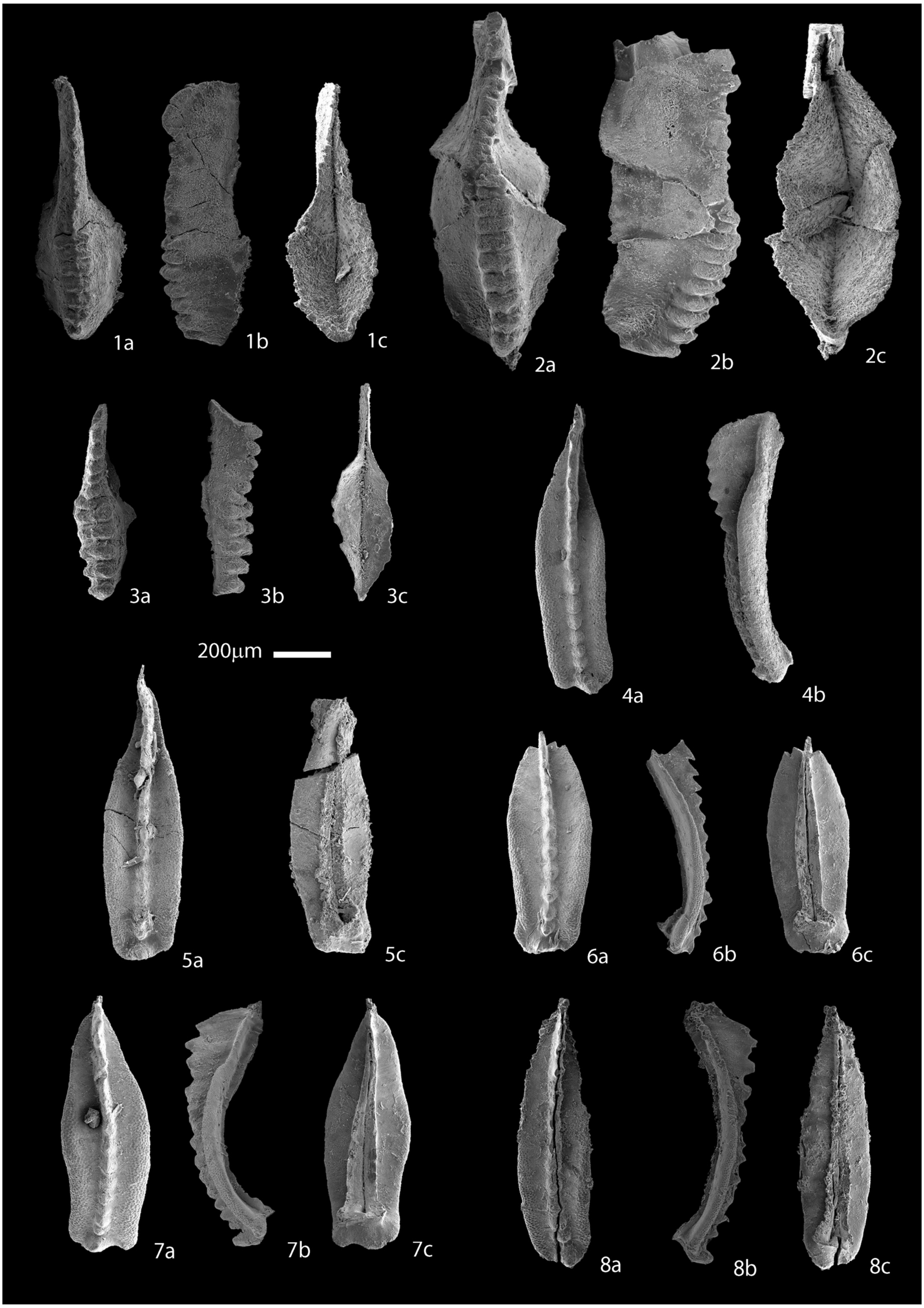

Plate 16.

PLATE 17

Fig. 1a, b: ***Mesogondolella siciliensis****,* upper and lateral view, sample TJ27, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b: ***Mesogondolella siciliensis****,* upper and lateral view, sample TJ27, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella pingxiangensis****,* upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Mesogondolella pingxiangensis****,* upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Mesogondolella pingxiangensis****,* upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella pingxiangensis****,* upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella siciliensis****,* upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella* sp.**, upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

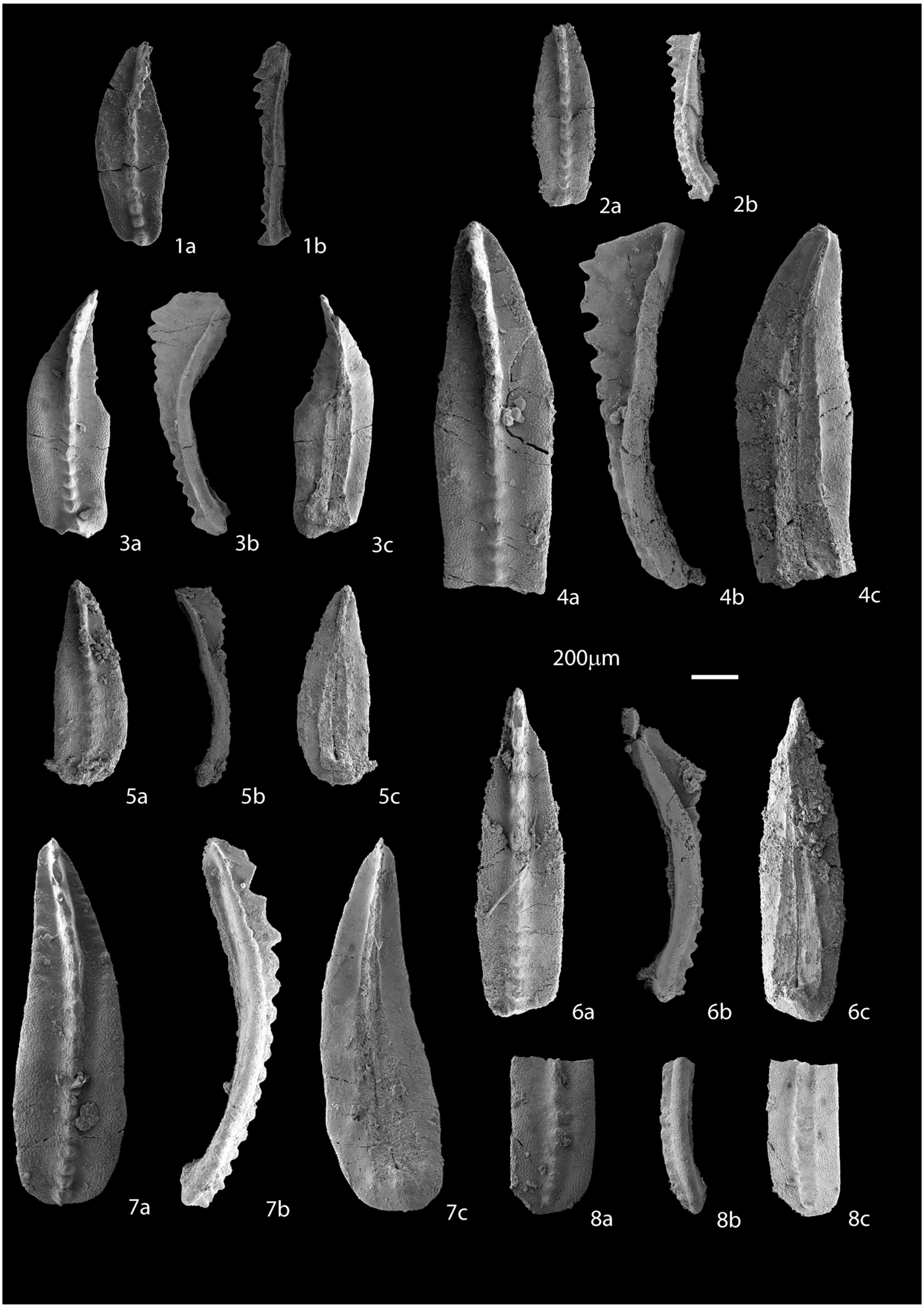

Plate 17.

PLATE 18

Fig. 1a, b, c: ***Sweetognathus fengshanensis,*** upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b: **Trans. *Mesogondolella siciliensis/ M. omanensis,*** upper and lateral view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Sweetognathus fengshanensis,*** upper, lateral and lower view, sample TJ29, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Pseudohindeodus ramovsi,*** upper, lateral and lower view, sample TJ30, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Mesogondolella pingxiangensis,*** upper, lateral and lower view, sample TJ30, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella pingxiangensis,*** upper, lateral and lower view, sample TJ30, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella pingxiangensis,*** upper, lateral and lower view, sample TJ30, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Jinogondolella aserrata,*** upper, lateral and lower view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

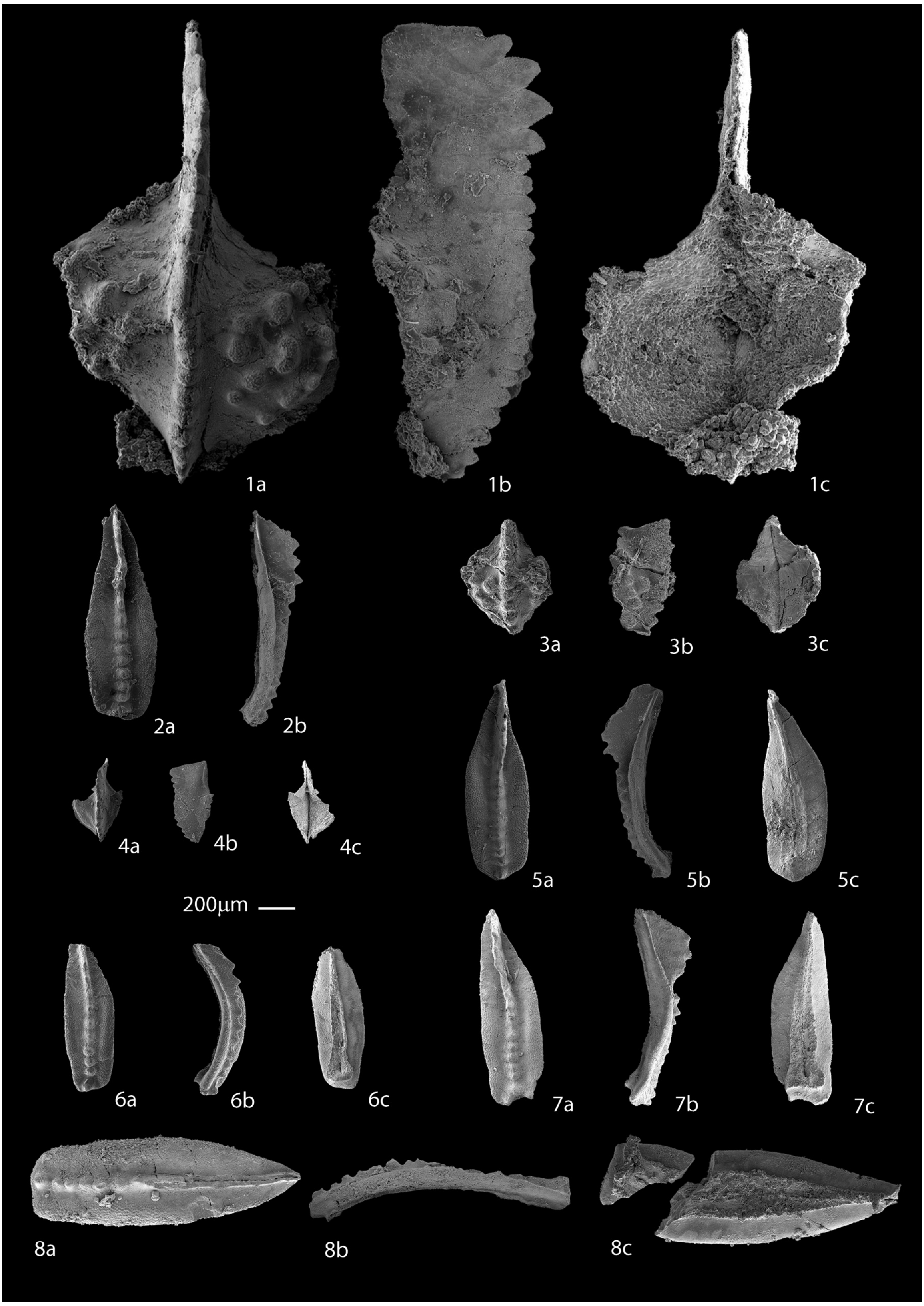
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Plate 18.

PLATE 19

Fig. 1a, b, c: ***Jinogondolella aserrata**,* upper, lateral and lower view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, c: ***Jinogondolella aserrata**,* upper and lateral view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

Fig. 3a, b: ***Jinogondolella aserrata**,* upper and lateral view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Jinogondolella aserrata**,* upper, lateral and lower view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Jinogondolella aserrata**,* upper, lateral and lower view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Jinogondolella aserrata**,* upper, lateral and lower view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Jinogondolella aserrata**,* upper, lateral and lower view, sample TJ31, Kubergandy section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Jinogondolella altudaensis**,* upper, lateral and lower view, sample TJ34, Kubergandy section, SE Pamir, Tajikistan.

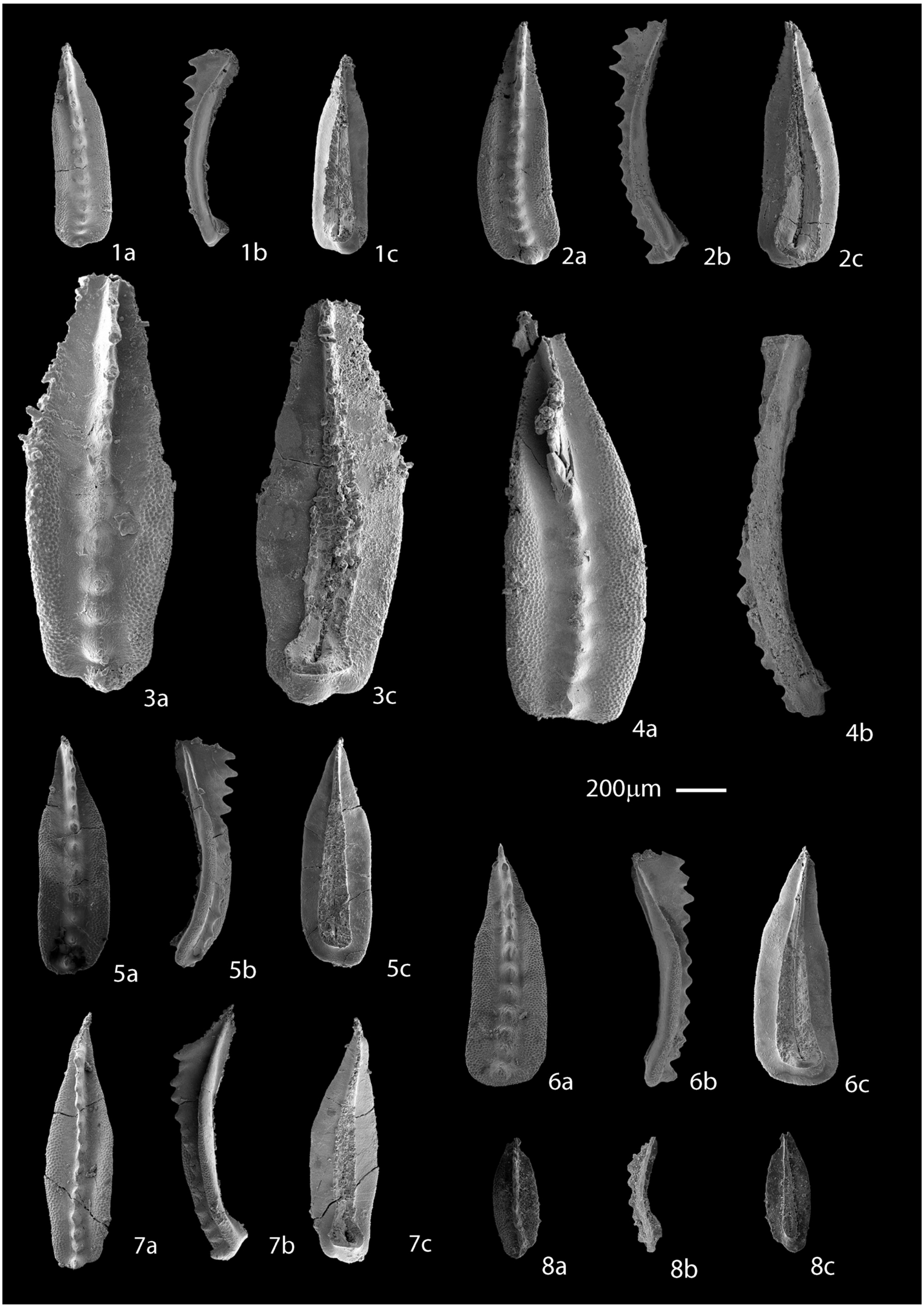

Plate 19.

PLATE 20

Fig. 1a, b: ***Hindeodus wordensis,*** upper and lateral view, sample TJ34, Kubergandy section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Jinogondolella aserrata,*** upper, lateral and lower view, sample TJ36, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella idahoensis lamberti,*** upper, lateral and lower view, sample TJ42, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Jinogondolella aserrata,*** upper, lateral and lower view, sample TJ46, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Jinogondolella* sp.**, upper, lateral and lower view, sample TJ47, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella idahoensis lamberti,*** upper, lateral and lower view, sample TJ47, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella idahoensis lamberti,*** upper, lateral and lower view, sample TJ47, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella idahoensis lamberti,*** upper, lateral and lower view, sample TJ49, Kubergandy section, SE Pamir, Tajikistan.

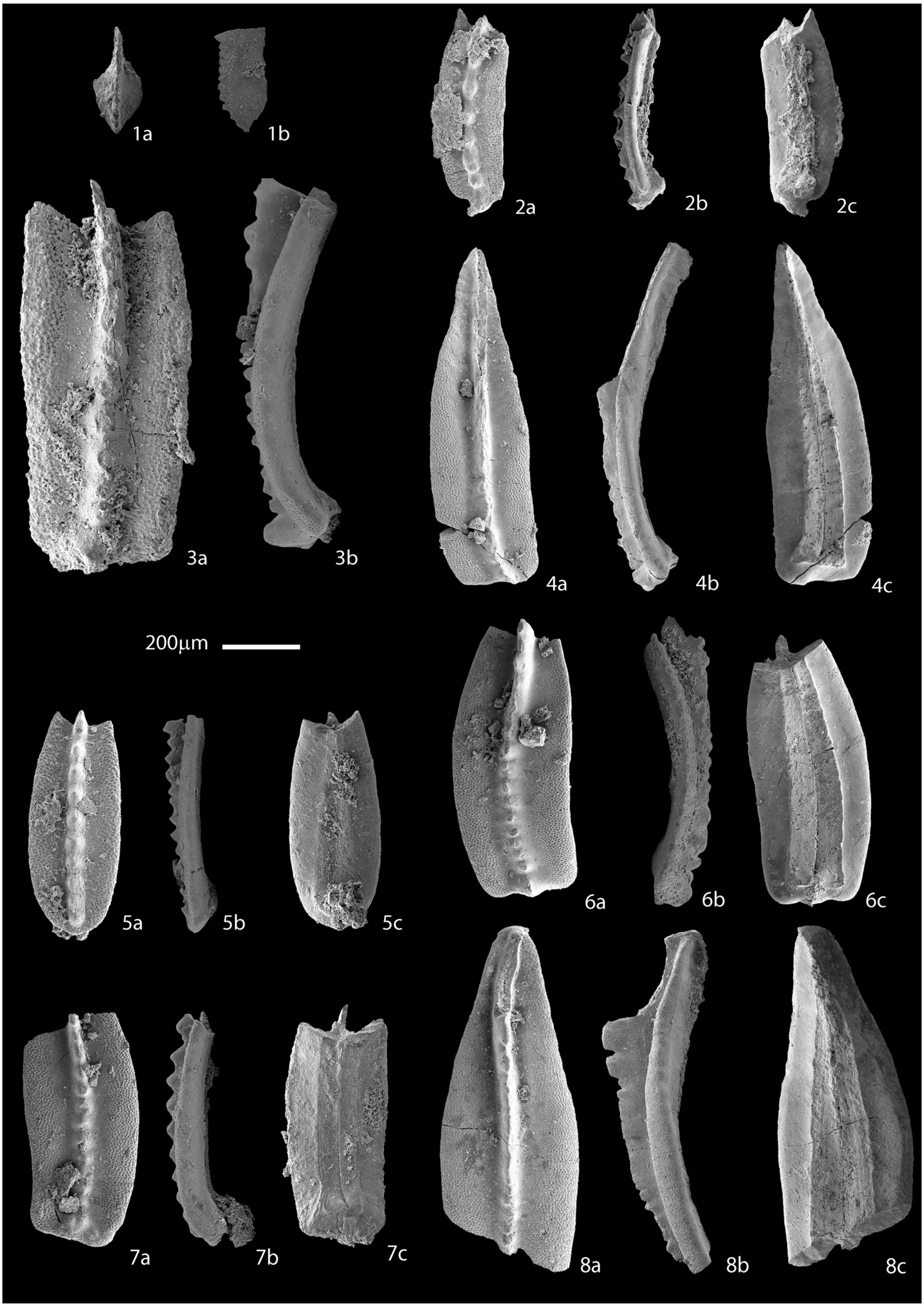

Plate 20.

PLATE 21

Fig. 1a, b, c: ***Mesogondolella* cf. *idahoensis lamberti*,** upper, lateral and lower view, sample TJ49, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Mesogondolella pingxiangensis*,** upper, lateral and lower view, sample TJ50, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella pingxiangensis*,** upper, lateral and lower view, sample TJ50, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Mesogondolella pingxiangensis*,** upper, lateral and lower view, sample TJ50, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 5a, b, c: **trans. *Sweetognathus guyouensis/S. subsymmetricus*,** upper, lateral and lower view, sample TJ50, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 6a, b, c: **trans. *Sweetognathus guyouensis/S. subsymmetricus*,** upper, lateral and lower view, sample TJ50, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 7a, b, c: **trans. *Sweetognathus guyouensis/S. subsymmetricus*,** upper, lateral and lower view, sample TJ50, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella* cf. *siciliensis*,** upper, lateral and lower view, sample TJ51, Kubergandy section, SE Pamir, Tajikistan.

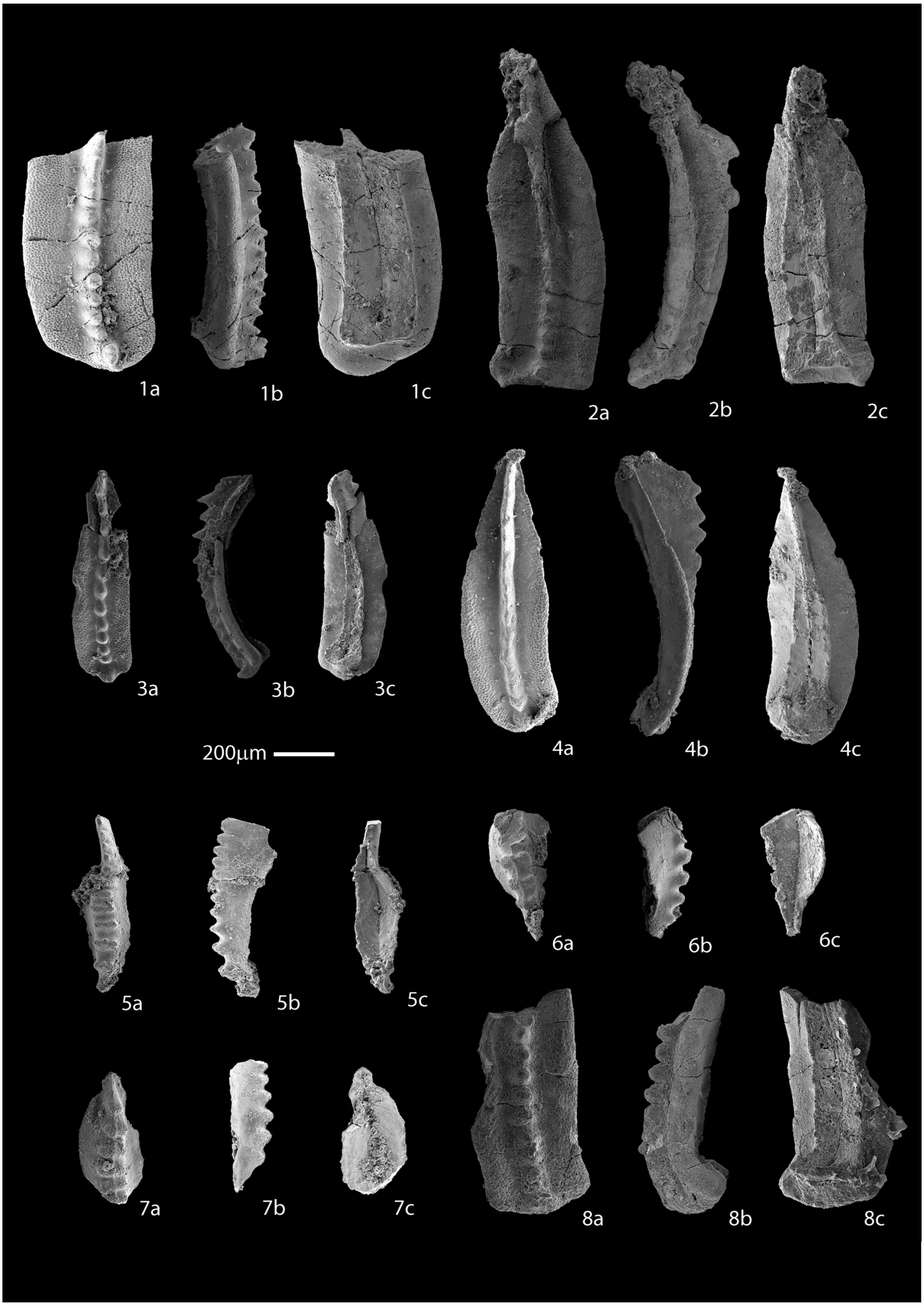
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Plate 21.

PLATE 22

Fig. 1a, b, c: ***Mesogondolella* cf. *siciliensis*,** upper, lateral and lower view, sample TJ51, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Jinogondolella aserrata*,** upper, lateral and lower view, sample TJ51, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Jinogondolella aserrata*,** upper, lateral and lower view, sample TJ51, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Hindeodus wordensis*,** upper, lateral and lower view, sample TJ51, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Vjalovognathus* sp.,** upper, lateral and lower view, sample TJ52, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella idahoensis lamberti*,** upper, lateral and lower view, sample TJ53, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella pingxiangensis*,** upper, lateral and lower view, sample TJ53, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella pingxiangensis*,** upper, lateral and lower view, sample TJ53, Kutal 2 section, SE Pamir, Tajikistan.

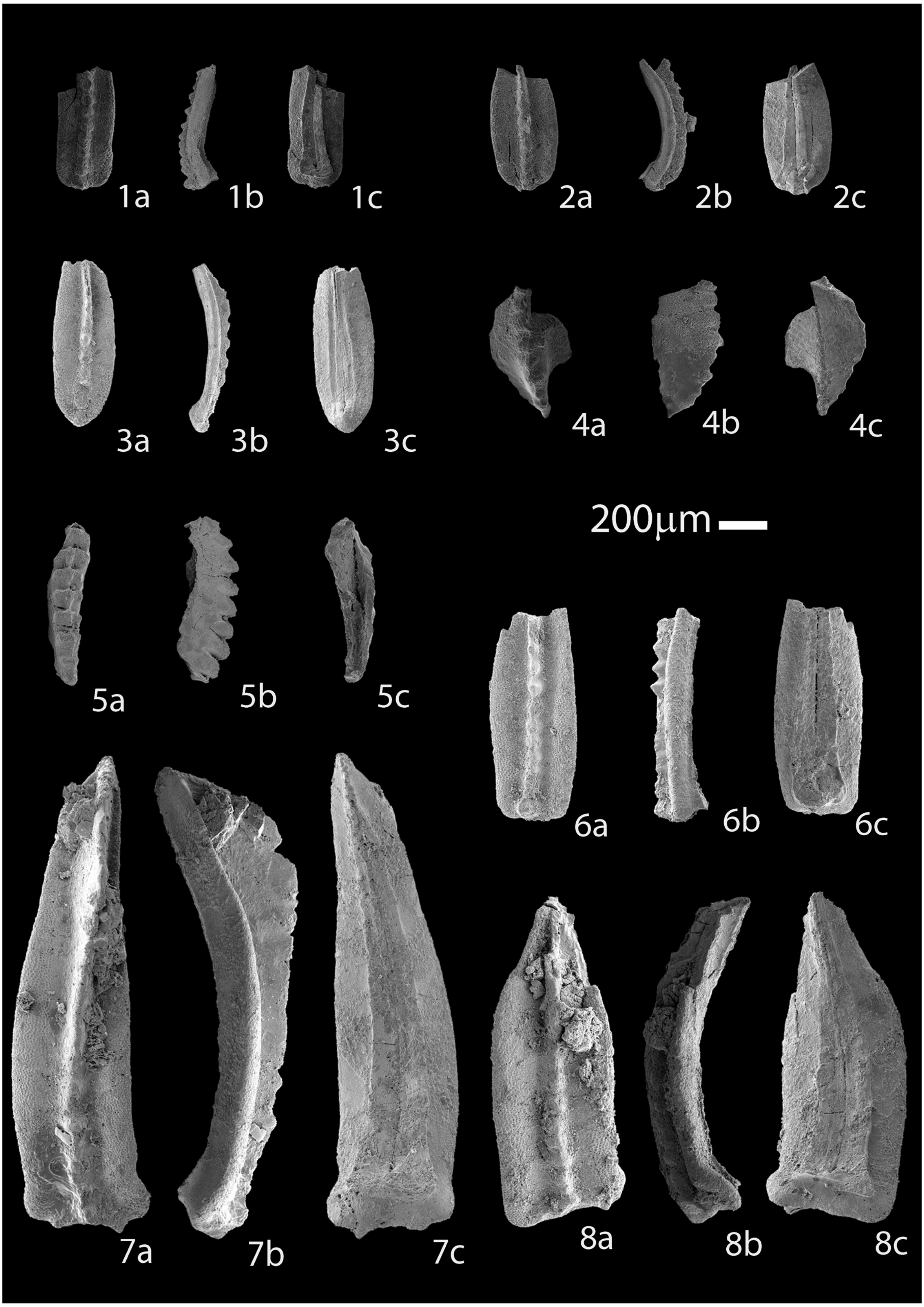
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Plate 22.

PLATE 23

Fig. 1a, b, c: ***Mesogondolella siciliensis****,* upper, lateral and lower view, sample TJ54, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Mesogondolella idahoensis lamberti****,* upper, lateral and lower view, sample TJ54, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella idahoensis lamberti****,* upper, lateral and lower view, sample TJ54, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Mesogondolella idahoensis lamberti****,* upper, lateral and lower view, sample TJ56, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Mesogondolella idahoensis lamberti****,* upper, lateral and lower view, sample TJ56, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella idahoensis lamberti****,* upper, lateral and lower view, sample TJ57, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella idahoensis lamberti****,* upper, lateral and lower view, sample TJ58, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella idahoensis lamberti****,* upper, lateral and lower view, sample TJ59, Kutal 2 section, SE Pamir, Tajikistan.

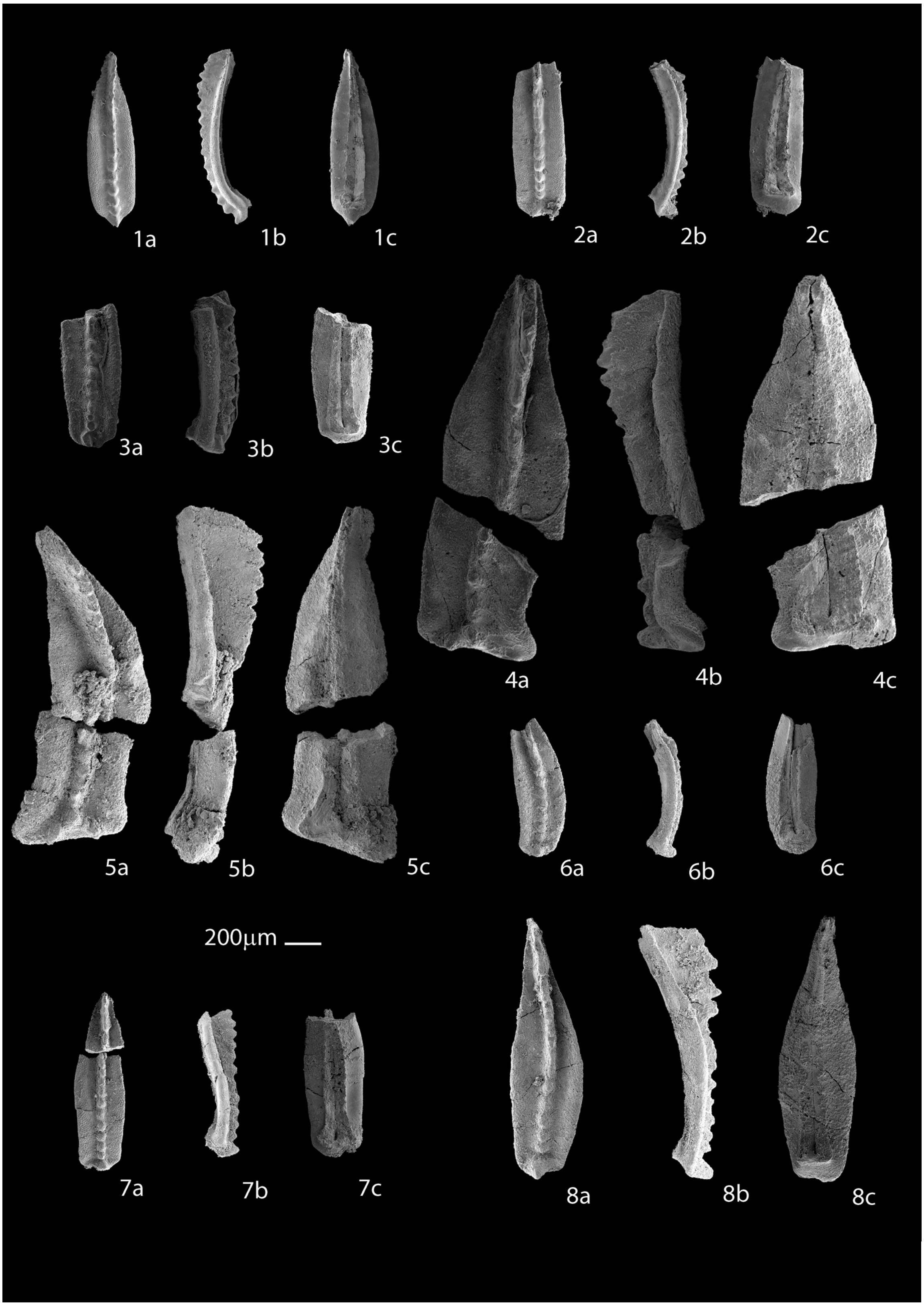
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Plate 23.

PLATE 24

Fig. 1a, b, c: ***Jinogondolella* cf. *postserrata*,** upper, lateral and lower view, sample TJ60, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Mesogondolella siciliensis*,** upper, lateral and lower view, sample TJ60, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 3a, b, c: **trans. *Sweetognathus guyouensis/S. subsymmetricus*,** upper, lateral and lower view, sample TJ60, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Hindeodus wordensis*,** upper, lateral and lower view, sample TJ60, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 5a, b: ***Pseudohindeodus ramovsi*** , upper and lateral view, sample TJ62, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Jinogondolella* sp.**, upper, lateral and lower view, sample TJ63, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Jinogondolella* cf. *postserrata*,** upper, lateral and lower view, sample TJ63, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Jinogondolella* cf. *postserrata*,** upper, lateral and lower view, sample TJ63, Kutal 2 section, SE Pamir, Tajikistan.

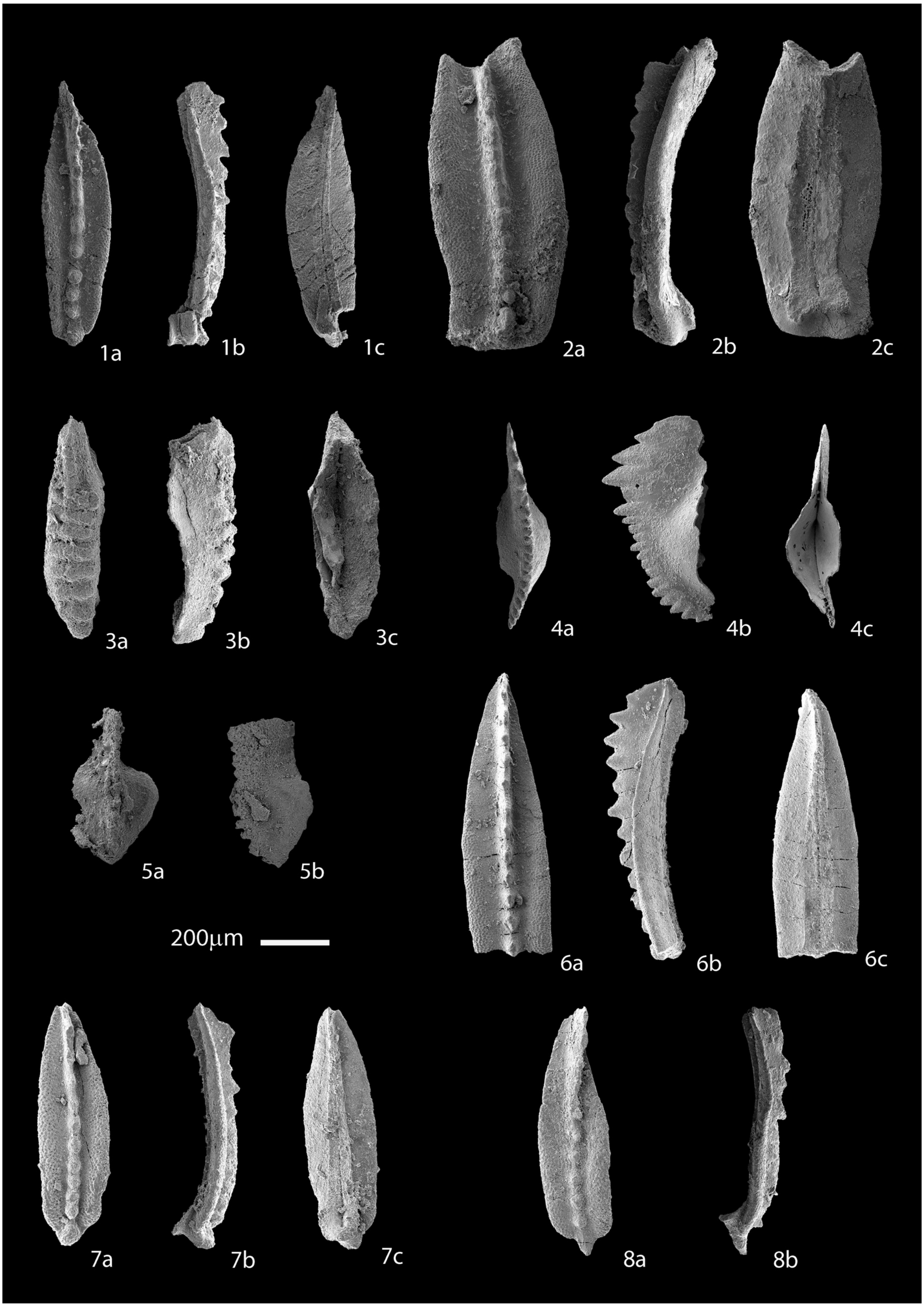

Plate 24.

PLATE 25

Fig. 1a, b, c: ***Jinogondolella* sp.**, upper, lateral and lower view, sample TJ65, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Jinogondolella* cf. *altudaensis*,** upper, lateral and lower view, sample TJ66, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Jinogondolella* cf. *altudaensis*,** upper, lateral and lower view, sample TJ66, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Jinogondolella* cf. *altudaensis*,** upper, lateral and lower view, sample TJ66, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Jinogondolella* cf. *altudaensis*,** upper, lateral and lower view, sample TJ66, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Sweetognathus* sp.**, upper, lateral and lower view, sample TJ66, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Clarkina* sp.**, upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Clarkina* sp.**, upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

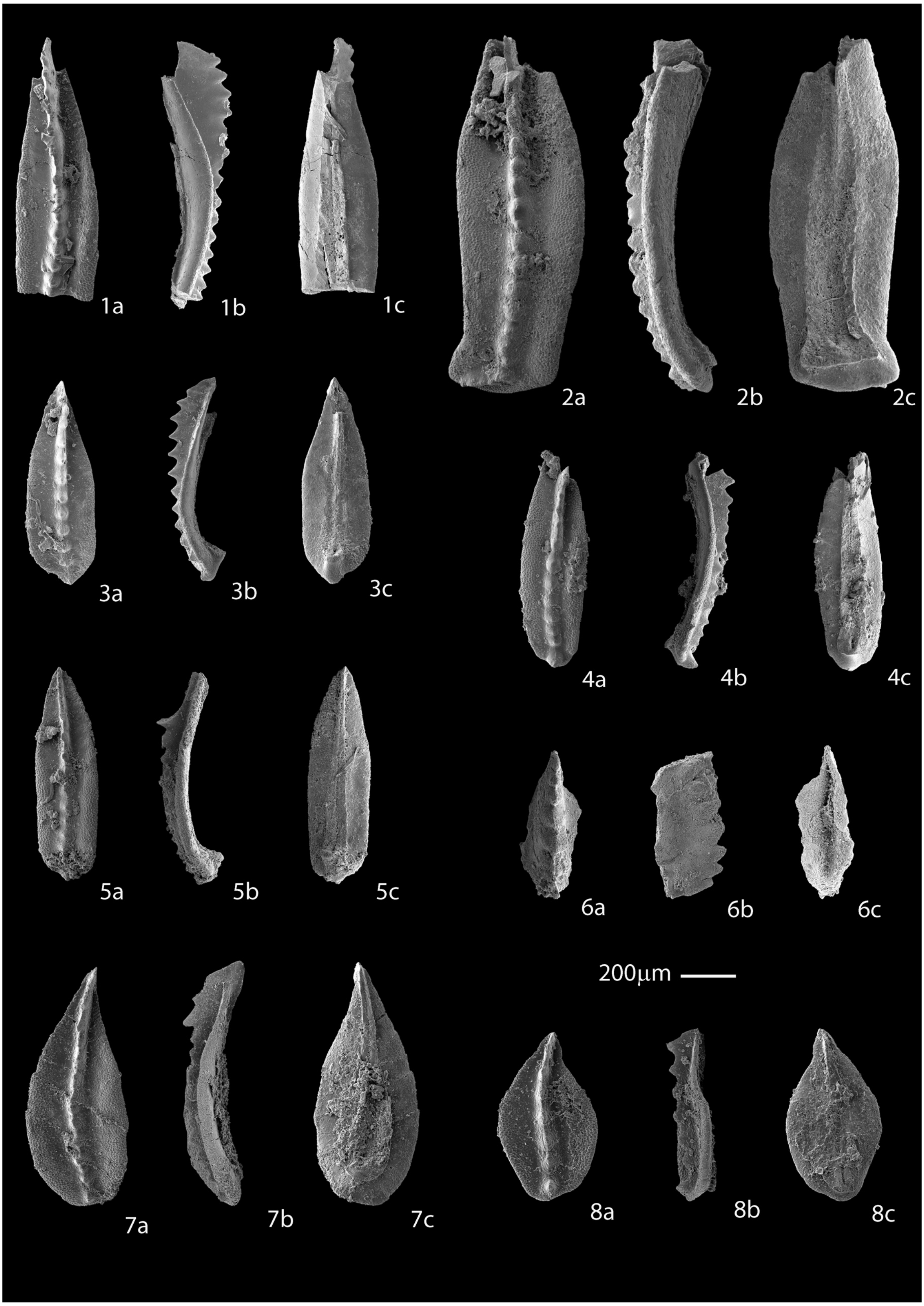
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Plate 25.

PLATE 26

Fig. 1a, b, c: ***Mesogondolella pingxiangensis,*** upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Mesogondolella* cf. *altudaensis,*** upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella* cf. *altudaensis,*** upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

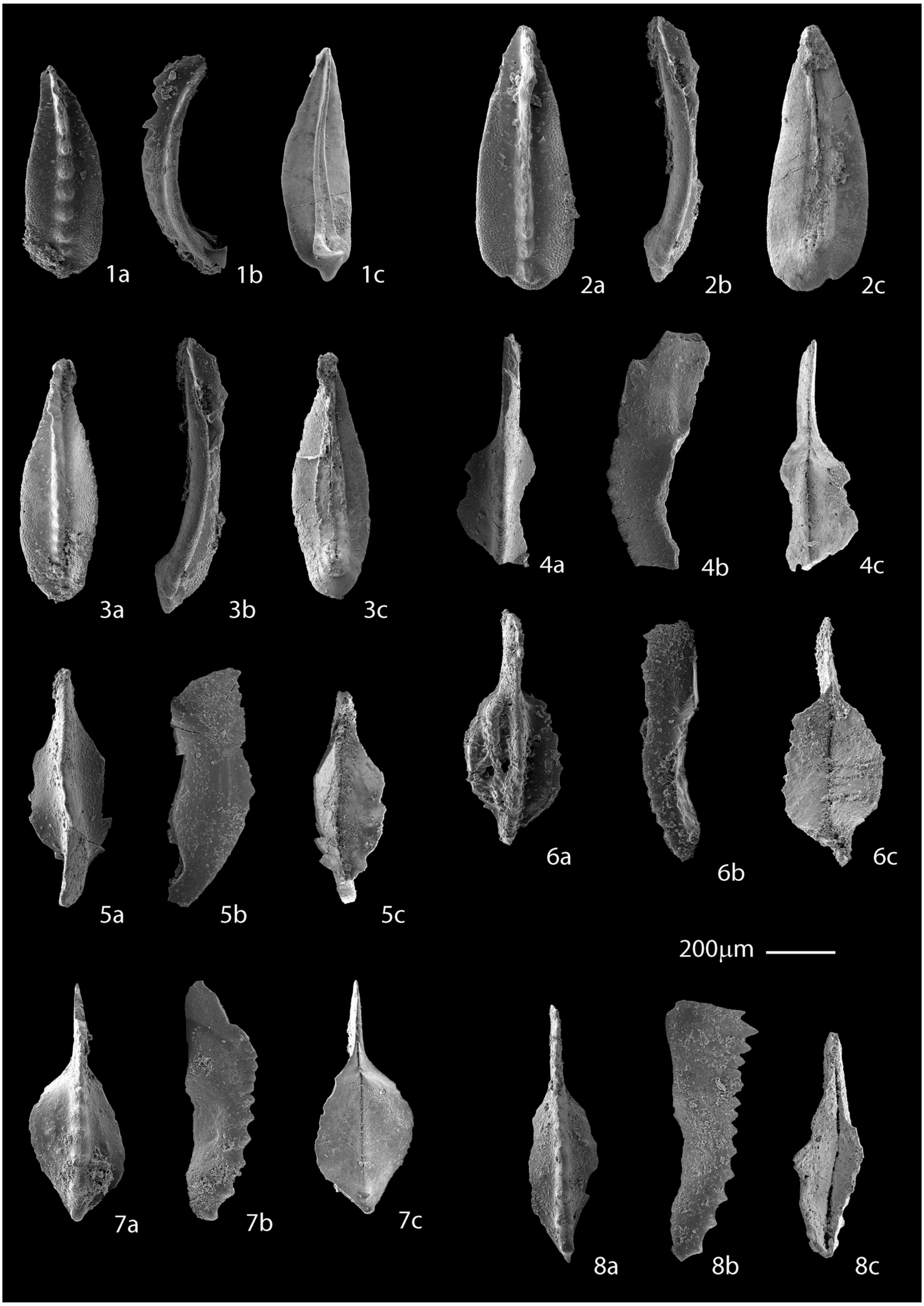
Fig. 4a, b, c: ***Iranognathus movschovistchi,*** upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Iranognathus movschovistchi,*** upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Iranognathus punctatus,*** upper, lateral and lower view, sample TJ67, Kutal 2 section, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Sweetognathus* cf. *merrilli,*** upper, lateral and lower view, sample TJ82, Kurystyk section, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Sweetognathus* cf. *merrilli,*** upper, lateral and lower view, sample TJ82, Kurystyk section, SE Pamir, Tajikistan.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8a
8b
8c

Plate 26.

PLATE 27

Fig. 1a, b, c: ***Sweetognathus* cf. *behnkeni*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Sweetognathus* cf. *merrilli*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Sweetognathus* cf. *merrilli*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

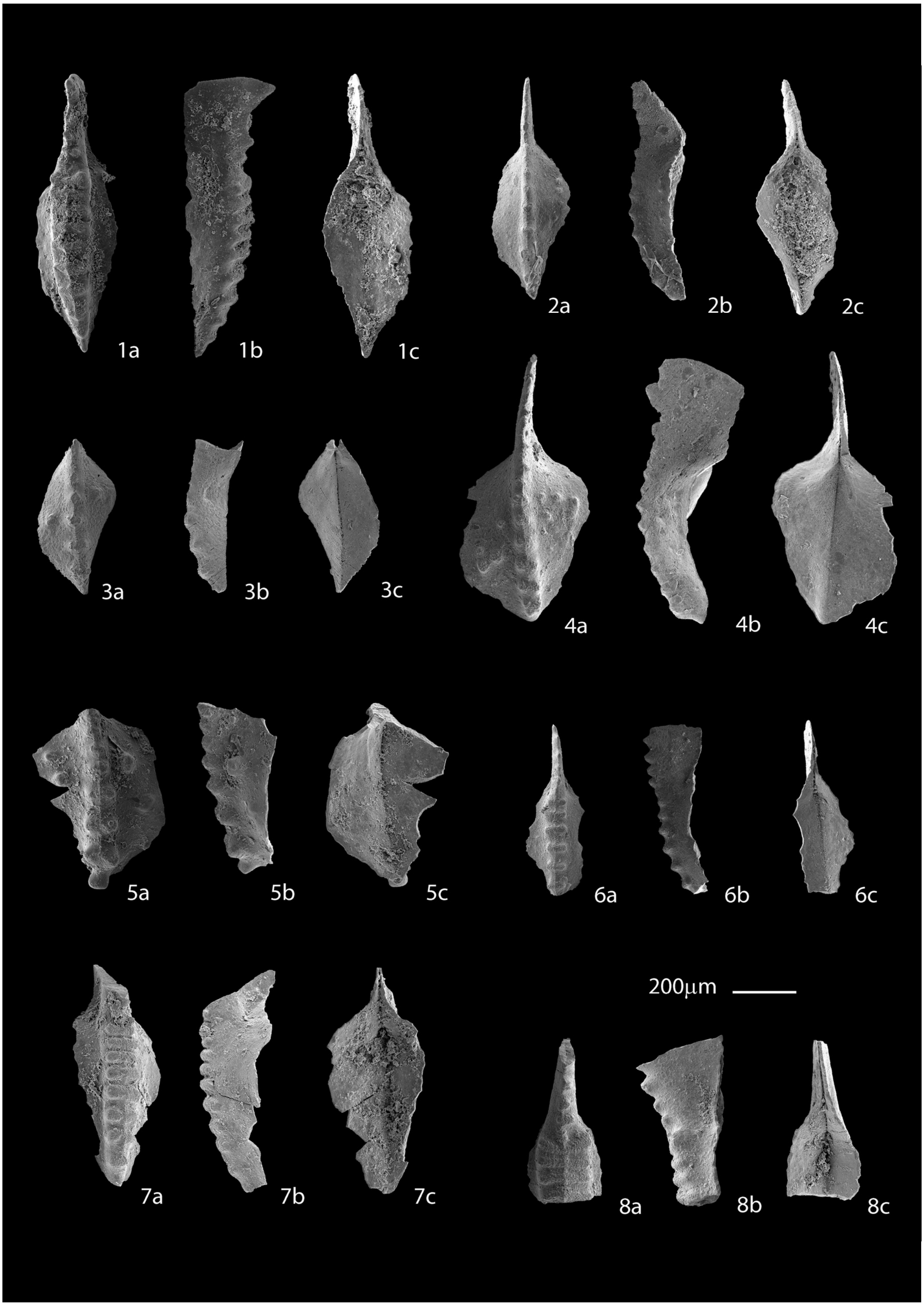
Fig. 4a, b, c: ***Sweetognathus* cf. *bucaramangus*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Sweetognathus* cf. *merrilli*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Sweetognathus whitei*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Sweetognathus whitei*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Sweetognathus* cf. *behnkeni*,** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.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200μm
7a
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7c
8a
8b
8c

Plate 27.

PLATE 28

Fig. 1a, b, c: ***Idiognathodus* sp.**, upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Idiognathodus* sp.**, upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

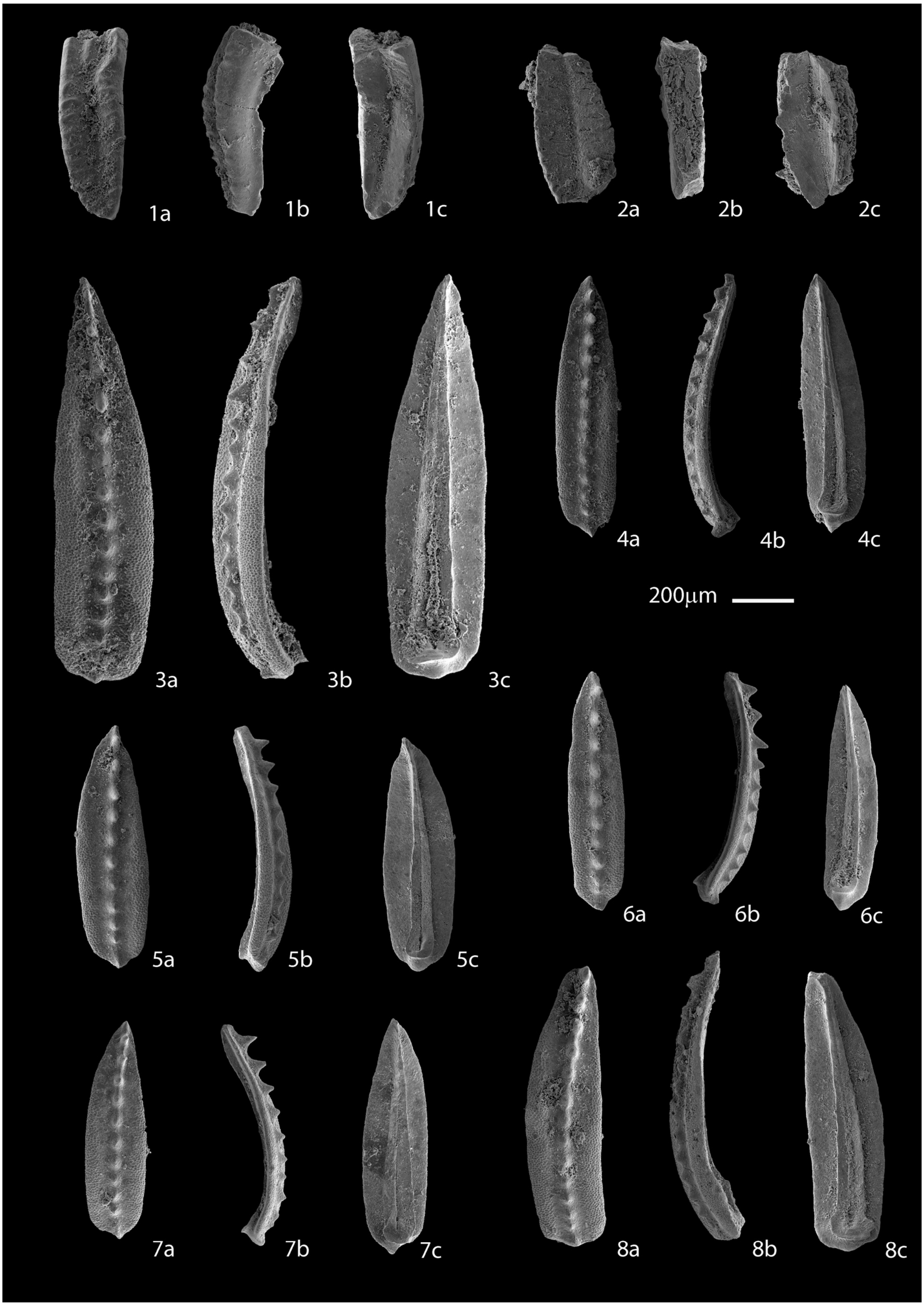
Fig. 4a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 6a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 7a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 8a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.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5b
5c
6a
6b
6c
7a
7b
7c
8a
8b
8c

Plate 28.

PLATE 29

Fig. 1a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Mesogondolella monstra,*** upper, lateral and lower view, sample TJ82, Tashkazyk Formation, SE Pamir, Tajikistan.

Fig. 3a, b, c: ***Hadrodontina aequabilis,*** upper, lateral and lower view, sample TJ88, Kurteke section, SE Pamir, Tajikistan.

Fig. 4a, b, c: ***Hadrodontina aequabilis,*** upper, lateral and lower view, sample TJ88, Kurteke section, SE Pamir, Tajikistan.

Fig. 5a, b, c: ***Hadrodontina aequabilis,*** upper and lower view, sample TJ88, Kurteke section, SE Pamir, Tajikistan.

Fig. 6a, b: ***Hadrodontina aequabilis,*** upper and lower view, sample TJ90, Kurteke section, SE Pamir, Tajikistan.

Fig. 7a ***Clarkina*** **sp.,** upper and lower view, sample TJ90, Kurteke section, SE Pamir, Tajikistan.

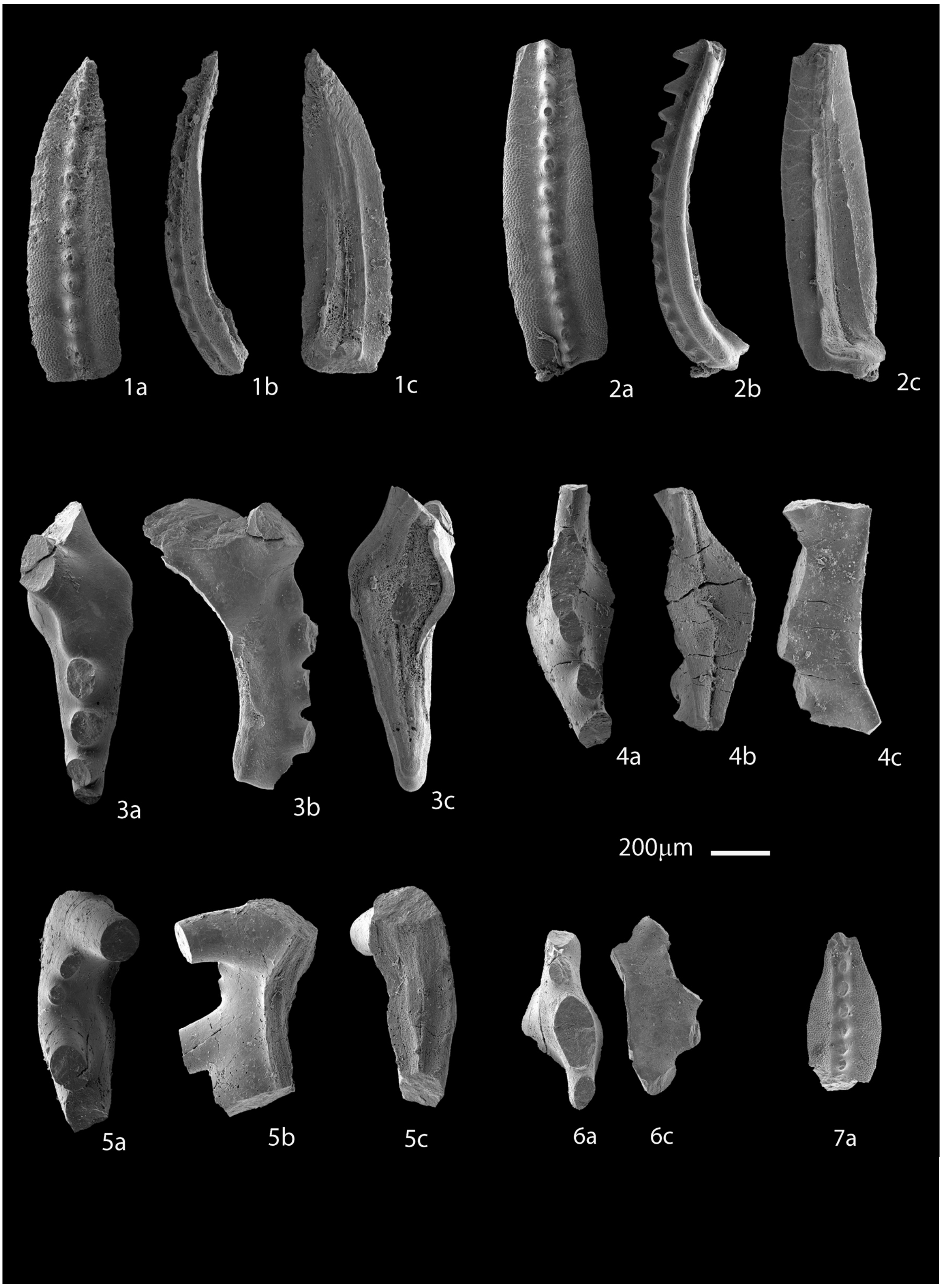

Plate 29.

PLATE 30

Fig. 1a, b, c: ***Sweetognathus subsymmetricus,*** upper, lateral and lower view, sample TJ92, Kurteke section, SE Pamir, Tajikistan.

Fig. 2a, b, c: ***Sweetognathus iranicus hanzongensis,*** upper, lateral and lower view, sample HJ32, Halq Jemel section, Tunisia.

Fig. 3a, b, c: ***Sweetognathus iranicus hanzongensis,*** upper, lateral and lower view, sample HJ32, Halq Jemel section, Tunisia.

Fig. 4a, b: ***Sweetognathus iranicus hanzongensis,*** upper and lateral view, sample HJ32, Halq Jemel section, Tunisia.

Fig. 5a, b, c: ***Sweetognathus iranicus hanzongensis,*** upper, lateral and lower view, sample HJ32, Halq Jemel section, Tunisia.

Fig. 6a, b: ***Sweetognathus iranicus hanzongensis,*** upper and lower view, sample HJ32, Halq Jemel section, Tunisia.

Fig. 7a, b, c: ***Sweetognathus iranicus hanzongensis,*** upper, lateral and lower view, sample HJ32, Halq Jemel section, Tunisia.

Fig. 8a: ***Sweetognathus iranicus hanzongensis,*** upper view, sample TSS11, Tebaga *sensu strictu* section, Tunisia.

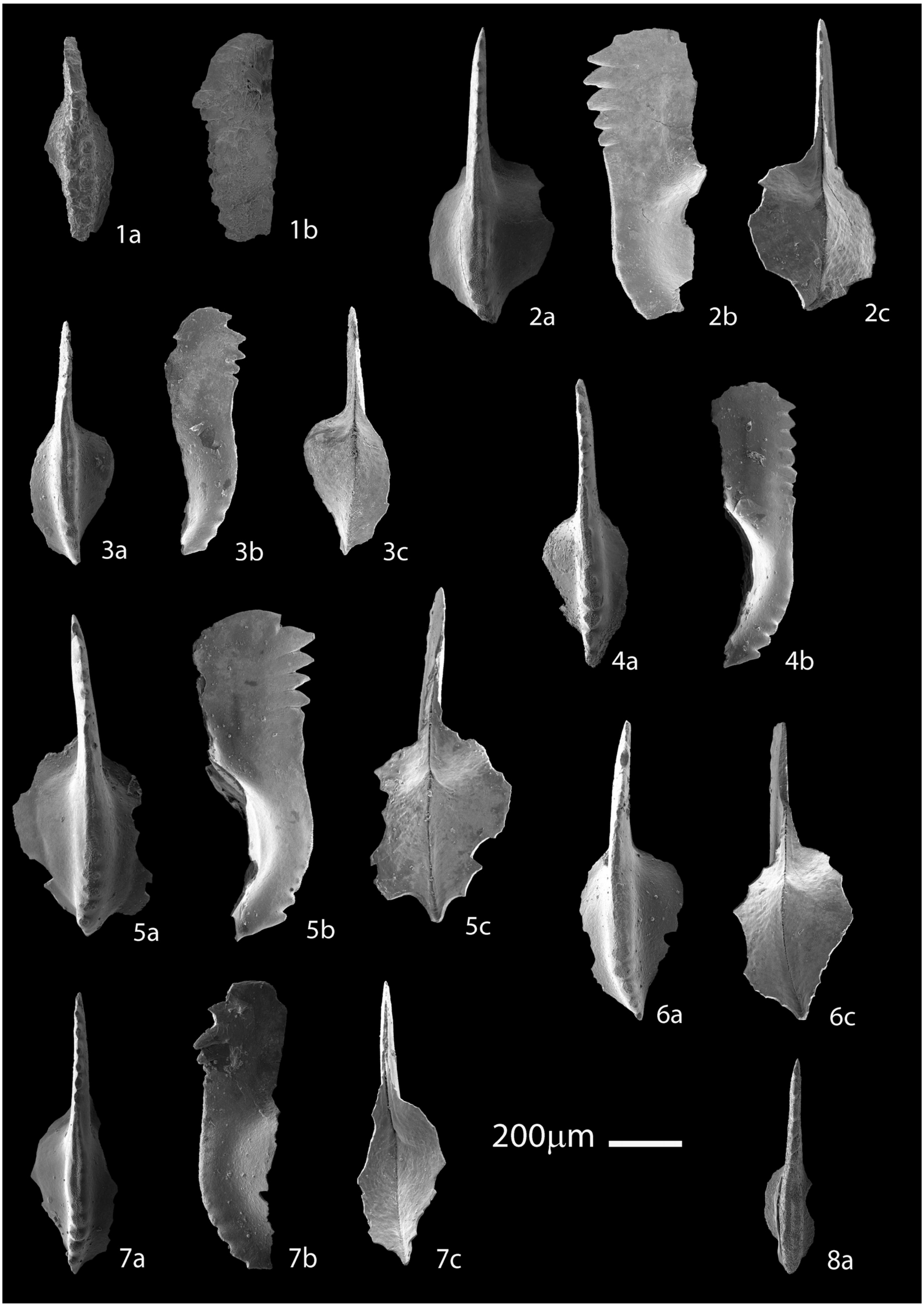

Plate 30.

Appendix I

Formations	Samples	Age	*Streptognathodus postconstrictus*	*Streptognathodus* aff. *lanceatus*	*Streptognathodus postfusus*	*Sweetognathus binodosus*	*Sweetognathus* aff. *binodosus*	*Sweetognathus* aff. *anceps*	Trans. *Sweetognathus binodosus/anceps*	*Sweetognathus subsymmetricus*	*Hindeodus wordensis*	*Mesogondolella monstra*	*Mesogondollella manifesta*	*Mesogondolella gujioensis*	*Mesogondolella bisselli*	*MKesogondolella siciliensis*	Trans.*Mesogondolella ciliensis/omanensis*	Ramiforms	Fragments
JAMAL GROUP	BEV 37																		1
	BEV 49	Kungurian								1									
	BEV 48	Kungurian								1						7		1	9
	BEV 47																		1
	BEV 46	Wordian									1					3	6	5	6
	BEV 45	Wordian									1						22	55	11
	BEV 44	Rodian/ Wordian														14	13	43	58
"BAGH-E-VANG MEMBER"	BEV 15	Middle/Upper Sakmarian						2							6			7	4
	BEV 43	Upper Sakmarian/ Lower Asseliam												53				11	39
	BEV 42	Middle/Upper Sakmarian													13			5	15
	BEV 41	Middle/Upper Sakmarian				7	9								13			25	10
	BEV 10	Lower Sakmarian	3		5		1					3	9					1	21
	BEV 40	Lower Sakmarian	3	9									10						24

Table 1. Conodont fauna from Bagh-e-Vang Section, Tabas, Central Iran.

Formation	Samples	Age	*Mesogondolella siciliensis*	*Mesogondolella* cf. *manifesta*	Ramiforms	Fragments
"BAGH-E-VANG Mb."	SHA16					
	SHA15	Roadian/ Woridan	2			4
	SHA12	Kungurian(?)		1		1
	SHA8					
	SHA4					
	SHA1					1

Table 2. Conodont fauna from Shesht-Angosht section, Tabas, Central Iran.

Formations	Samples	Age	*Streptognathodus* cf. *plenus*	*Streptognathodus* sp.	*Idiognathodus* sp.	Ramiforms	Fragments
ZALADOU Fm.	ZAL15						
	ZAL14						
	ZAL13						
	ZAL12						1
	ZAL9						
	IR10-14						
	IR10-13						
	IR10-12					1	
	IR10-11	Asselian?	1	1			1
	ZAL3	Upper Carboniferous			1		
SARDAR Fm.	IR10-10						

Table 3. Conodont fauna from Zaladou Section, Tabas, Central Iran.

Formations	Samples	Age	*Streptognathodus* sp.	*Streptognathodus longus*	Declinognathodus sp.	*Idiognathodus lobatus*	fragments	ramiforms
ZALADOU FORMAàTION	ANK53						1	
	ANK49							
	ANK43							
	ANK42							
	ANK38							
	ANK35							
	ANK26	**Gzhelian(?)**		1		1	1	
	ANK22							
	ANK21							
	ANK20							
	ANK16							
	ANK12	**Gzhelian(?)**		16		42	20	
	ANK11							
	ANK8							
	ANK7				1			
	ANK6		1					

Table 4. Conodont fauna from Anarak 3section, Tabas Area, Central Iran

Formations	Samples	Age	*Streptognathodus*	*Hindeodus* sp.	*Hindeodus scitulus*	*Gnathodus girtyi girtyi*	*Gnathodus girtyi simplex*	Fragments
KHAN FORMATION	RH63							
	RH33							
	RH36							
	RH34							
GACHAL FORMATION	RH54	Visean/ Serpukovian		1	1		1	1
	RH15							
	RH51	Serpukovian/ Lower Bashkirian				2		1
	RH4		1					

Table 5. Conodont fauna from Rahdar Section, Tabas, Area, Central Iran

Formation	Samples	Age	*Mesogondolella siciliensis*	*Mesogondolella idahoensis idahoensis*	*Mesogondolella pingxiangensis*	*Mesogondolella sp.*	*Sweetognathus subsymmetricus*	*Sweetognathus binodosus*	*Sweetpgnathus* cf. *bicarinum*	*Pseudohindeodus ramovsi*	*Hindeodus excavatus*	Ramorms	Fragments
KUBERGANDY FORMATION	TJ18												
	TJ17		2										
	TJ16		1										
	TJ15		4										
	TJ14												
	TJ13												
	TJ12	Roadian	28		12				1			22	151
	TJ11	Kungurian	39							1	1	91	13
	TJ10	Kungurian	4									3	1
	TJ9	Kungurian	33	14							1	52	62
	TJ8	Kungurian	2	12								17	53
	TJ7		36				1			8	11	2	8
	TJ6	Kungurian	7	26				1				36	116
	TJ5	Kungurian		27								9	136
	TJ4	Kungurian		1									5
	TJ3					1							
	TJ2												
	TJ1	Kungurian	6	4								6	12

Table 6. Conodont fauna from the Kubergandy Formation, Kubergandy type section, SE Pamir, Tajikistan.

Formation	Samples	Age	*Mesogondolella siciliensis*	*Mesogondolella pingxiangensis*	*Sweetognathus* sp.	*Sweetpgnathus* cf. *bicarinum*	*Sweetognathus fengshanensis*	Trans. *Sw. gujioensis/Sw. subsymmetricus*	*Pseudohindeodus ramovsi*	*Jinogondolella altudaensis*	*Jinogondolella aserrata*	*Hindeodus wordensis*	Ramorms	Fragments
GAN FORMATION	TJ34								1	8			7	
	TJ33													
	TJ32													1
	TJ31										149	3	97	>300
	TJ30	Wordian	71	12	1							1	31	165
	TJ29	Wordian	58	9			2						48	>300
	TJ28													
	TJ27		3	1									5	17
	TJ26	Roadian	108	14				6					15	109
	TJ25	Roadian	97	2				6					66	128
	TJ24		3										8	17
	TJ23													
	TJ22		6					1					6	24
	TJ21		1											16
	TJ20		5											
	TJ19		1											

Table 7. Conodont fauna from Gan Formation, Kubergandy type section, SE Pamir, Tajikstan.

Formations	Samples	Age	*Mesogondolella idahoensis lamberti*	*Mesogondolella siciliensis*	*Mesogondolella pingxiangensis*	Trans. *Sweetognathus guizhouensis/Sw subsymmetricus*	Ramiforms	Fragments
	TJ50	Kungurian	5		32	7	76	>300
	TJ49	Kungurian	5					14
	TJ48							
	TJ47	Kungurian	19	2			15	44
	TJ46							4
	TJ45							
	TJ44							
	TJ43							
	TJ42							
	TJ42	Kungurian	5				5	39
	TJ41							
	TJ40							
	TJ39						1	5
	TJ38							1
	TJ37							
	TJ36							
SHINDY Fm.	TJ35							
	TJ76							

Table 8. Conodont fauna from Shindy and Kubergandy formations, Kutal 2 section, SE Pamir, Tajikistan.

Formation	Samples	Age	*Mesogondolella idahoensis lamberti*	*Mesogondolella siciliensis*	*Mesogondolella pingxiangensis*	*Mesogondolella* sp.	*Jinogondolella aserrata*	*Jinogondolella altudaensis*	*Jinogondolella* cf. *postserrata*	Trans. *Sw. gujioensis/ Sw. subsymmetricus*	*Vjalovognathus* sp.	*Sweetognathus* sp.	*Hindeodus excavatus*	*Hindeodus wordensis*	*Hindeodus* sp.	*Pseudohindeodus ramovsi*	Ramiforms	Fragments
TAKHTABULAK Fm.	TJ74																	
	TJ73																	
	TJ72																	
	TJ71																	
	TJ70																	
	TJ69																	
GAN FORMATION	TJ67																	
	TJ66	Capitanian						139				1			1		14	193
	TJ65					2											4	18
	TJ64	Capitanian						2										35
	TJ63	Wordian							8					2		3	36	39
	TJ62													1				
	TJ61																	
	TJ60	Wordian		56						1				1			13	49
	TJ59	Upper Roadian	2														4	95
	TJ58	Upper Roadian	19												1		43	115
	TJ57	Upper Roadian	6										2				4	71
	TJ56	Upper Roadian	52														3	
	TJ55	Upper Roadian					64										11	
	TJ54	Roadian	10		7												5	41
	TJ53	Roadian	16		27												9	>300
	TJ52	Roadian	5		2						1						23	>300
	TJ51																	

Table 9. Conodonts from Gan Formation, Kutal 2 section, SE Pamir, Tajikistan.

Formation	Samples	Age	*Hadrodontina aequabilis*	*Clarkina* sp.	Ramiforms	Fragments
KARATASH Group	TJ91					6
	TJ90	Induan	2	1		8
	TJ89					
	TJ88	Induan	3			
TASHKAZYK Fm.	TJ84					
	TJ87					
	TJ86					3

Table10. Conodont fauna from Kurystyk section, SE Pamir, Tajikistan.

Formation	Samples	Age	*Mesoondolella monstra*	*Streptognathodus* sp.	*Sweetognathus* cf. *bucaramangus*	*Sweetognathus* cf. *merrilli*	*Sweetognathus* cf. *behnkeni*	*Sweetognathus wihei*	Ramiforms	Fragments
TASHKAZYK Fm.	TJ82	Sakmarian	69	2	2	3	4	5	46	240
	TJ80									1

Table 11. Conodont fauna from Tashkazyk Formation, Bazar Dara Group.

Formation	Samples	Age	*Mesoondolella idahoensis lamberti*	*Sweetognathus subsymmetricus*	Ramiforms	Fragments
KURTEKE Fm.	TJ99					
	TJ98					
	TJ97					
	TJ96					
	TJ95					5
	TJ94					4
	TJ93				23	11
	TJ92	Kungurian /Roadian	1	1	8	18

Table 12. Conodont fauna from Kurteke section, SE Pamir, Tajikistan.

Formation	Samples	Age	*Sweetognathus iranicus hanzongensis*	*Sweetognathus modulatus*	Ramiforms	Fragment
GAN Fm.	TJ187					
	TJ185					
SAFETDARA Fm.	TJ184					
	TJ183					
	TJ182					
	TJ188					
	TJ179					
	TJ178					
	TJ175					
	TJ174					
	TJ173					
	TJ170					
	TJ169				1	
	TJ164					
	TJ163	Bolorian	1	2		
	TTJ162					
TCHELAMCHI Fm.	TJ166					
	TJ165					

Table 13. Conodont fauna from Bolorian Stratotype section, N Pamir, Tajikistan.

Unit	Samples	Age	*Sweetognathus iranicus hanzongensis*	*Sweetognathus* sp.	Fragments	Ramiforms
UNIT V	HJ36					
	HJ33			1		
	HJ32	Wordian	6			6
	HJ30					

Table 14. Conodont fauna from Halq-Jemel section, Tebaga de Medenine, Tunisia.

Unit	Samples	Age	*Sweetognathus iranicus hanzongensis*	Fragments	Ramiforms
UNIT I	TSS11	Wordian	1		
	TSS10				
	TSS9			1	
	TSS7				
	TSS6				
	TSS3				
	TSS2				
	TSS1				

Table 15. Conodonts fauna Tebaga *sensu strictu* section, Tebaga de Medenine, Tunisia.

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