Rivista Italiana di Palaeontologia e Stratigrafia
(*Research in Palaeontology and Stratigraphy*)
vol. 125(1): 283-315. **March 2019**

OLENEKIAN TO EARLY LADINIAN STRATIGRAPHY OF THE WESTERN PART OF THE AGHDARBAND WINDOW (KOPEH-DAG, NE IRAN)

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To cite this article: Balini M., Nicora A., Zanchetta S., Zanchi A., Marchesi R., Vuolo I., Hosseiniyoon M., Norouzi M. & Soleimani S. (2019) - Olenekian to early Ladinian stratigraphy of the western part of the Aghdarband window (Kopeh-Dag, NE Iran) . *Riv. It. Palaeontol. Strat.*, 125(1): 283-315.

Keywords: Cimmerian orogeny; Early Triassic; Olenekian; Iran; Kopeh-Dag; Ammonoids; Conodonts; Stratigraphy; Peri-Caspian; Palaeobiogeography.
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Abstract. The structural setting and the stratigraphy of the Lower to Middle Triassic sedimentary succession exposed in the western part of the Aghdarband window (Kopeh-Dag, NE Iran) is described. Six stratigraphic sections in the Sefid-Kuh Limestone, Nazar-Kardeh Formation and Sina Formation have been studied in the tectonic units 1a and 2. The lithostratigraphy is revised, with bio-chronostratigraphic constrains provided by conodonts and ammonoids. The new Olenekian ammonoid genus *Megatirolites* is erected. It is based on species thus far known only from Mangyshlak (West Kazakhstan) but it is occurs also in the Sefid-Kuh Limestone.

The evolution of the Lower Triassic carbonate ramp of the Sefid-Kuh Limestone, persisted in the Middle Anisian, with a three-stage development (Sefid-Kuh 1, 2 and 3 members) separated by drowning and onset of siliciclastics. The last stage is in part coeval with the Middle Anisian basinal Nazarkardeh Formation.The unconformity-bounded, three-stage development of the carbonate ramp documents that in the Aghdarband Basin the tectonic control over sedimentation started already in the Olenekian, since the onset of the marine transgression. The transgression of the Ladinian Sina Formation sealed a complex morphology resulting from the tilting and erosion of the Middle Anisian units.

A new palaeogeographic position along the southern Laurasia margin is proposed for the Triassic Aghdarband Basin. Based on the palaeobiogeographic affinity of the Olenekian ammonoid occurences, we suggest that the Aghdarband Basin was located in a back-arc position in close connection with Mangyshlak (West Kazakhstan) and Tuarkyr (Turkmenistan), passing northwestward to a large epicontinental basin extending to the Donbass area. At least during the Olenekian the Aghdarband Basin had no direct connection with the Nakhlak Basin, which was proably located in a different intra-arc or more probably fore-arc region with respect to the Palaeotethys subduction-related Triassic arc.

Received: January 13, 2019; accepted: March 20, 2019

Introduction

Aghdarband in the Kopeh-Dag (northeastern Iran) is a small area of great interest for the understanding of the Triassic evolution of the southern margin of the Laurasia plate during the final stage of closure of the Palaeotethys. A thick Triassic succession resting on late Palaeozoic units, is exposed SW of the village of Aghdarband, in a small 15x25 km erosional window surrounded by the more than 6 km-thick post-Cimmerian Middle Jurassic to Miocene sedimentary succession forming the Kopeh-Dag fold-and-thrust belt (Afshar-Harb 1979; Robert et al. 2014). This succession exposed in the Aghdarband area provides the only opportunity to study on surface Triassic sediments pertaining to the southern margin of the Laurasia plate. The only three other sites exposing coeval successions are in fact located far north, within the interior of the Laurasia plate, being Tuarkyr (Garzanti & Gaetani 2002), Mangyshlak (Gaetani et al. 1998) and Mount Bogdo (e.g., Shevyrev 1968), respectively 700, 1100 and 1700 km NW from Aghdarband.

Besides being of crucial importance for the understanding of the evolution of Laurasia, the Triassic of Aghdarband is also a reference for the reconstruction of the late drift history of the Cimmerian blocks, namely of the Iran plate, just before its early Late Triassic collision with Laurasia.

The Triassic of Aghdarband has been compared by several authors (e.g., Seyed-Emami 1971; Davoudzadeh & Seyed-Emami 1972; Davoudzadeh & Schmidt 1982; Vaziri 2001; Seyed-Emami 2003) to the one of Nakhlak (Alavi et al. 1997; Bagheri & Stampfli 2008; Balini et al. 2009; Zanchi et al. 2009b), an enigmatic, arc-related succession which is now located within the internal part of Central Iran (Fig. 1). Moreover, Aghdarband has been commonly included in discussions on the palaeogeographic setting of Iran (e.g., Davoudzadeh & Weber-Diefenbach 1987; Wendt et al. 2005; Balini et al. 2009) and in the reconstructions of geodynamic and structural evolution of the Laurasia margin (Garzanti & Gaetani 2002; Bagheri & Stampfli 2008; Zanchi et al. 2009a; Zanchetta et al. 2013; Zanchi et al. 2016; Berra et al. 2017).

Despite of its great geological significance, the Triassic of Aghdarband is not very well known. The area is remote and very few geologists visited the region in the past decades. Anton Ruttner, Aymon Baud and Rainer Brandner conducted field works in the area in the 1970s. Afterwards Aghdarband was visited by M. Alavi in the 1990s, and in the 2000s by Wendt et al. (2005), who sampled the Devonian and Carboniferous, and more recently by Ghasemi-Nejad et al. (2008).

The most significant papers on the Triassic of Aghdarband were published in 1991, in a thematic volume dedicated to the geology of Aghdarband. This volume included a general description of the geology of the area (Ruttner 1991), supported by a geological map and a structural analysis of the very complex deformation patterns of the sedimentary successions, as well as some specific contributions on selected stratigraphic intervals (e.g., Baud et al. 1991a,b). These papers were complemented by descriptions of macrofossils (Krystyn & Taztreiter 1991; Siblik 1991; Kristan-Tollmann 1991a), microfossils (Kristan-Tollmann 1991b; Oberhauser 1991; Donofrio 1991) and megafossil plants (Boersma & van Konijnenburg-van Cittert 1991), all written by very experienced palaeontologists who actually did not visit the area, but worked on samples/specimens collected by Ruttner, Baud and Brandner.

Weak point of this surge of data is in the accuracy of stratigraphy. Only some of the new formations proposed by Ruttner (1991) and Baud et al. (1991a,b) were described based on stratigraphic sections. Very few palaeontologic samples were taken on stratigraphic or geologic sections, and several macrofossils samples were even taken from debris. The awareness of the importance of high-resolution data for stratigraphic and geologic investigation of complex geological problems, such as the reconstruction of the history of the Cimmerian blocks, is the reason of our decision, made in 2004, to study the Aghdarband area. A team of structural geologists, stratigraphers and palaeontologists from the universities of Milano and Milano Bicocca, and from the Geological Survey of Iran, conducted multidisciplinary field works in the area in 2005, 2007, 2008, 2009 and 2016, in the framework of the PRIN 2004, MEBE and DARIUS PROGRAMMES.

These extensive field works led to a paper by Zanchi et al. (2016) focused on the structural evolution of the area. In this study, a new model on the Cimmerian left-lateral transpression recorded in the area has been proposed.

In this contribution, we present new data on the geology and stratigraphy of the western part of

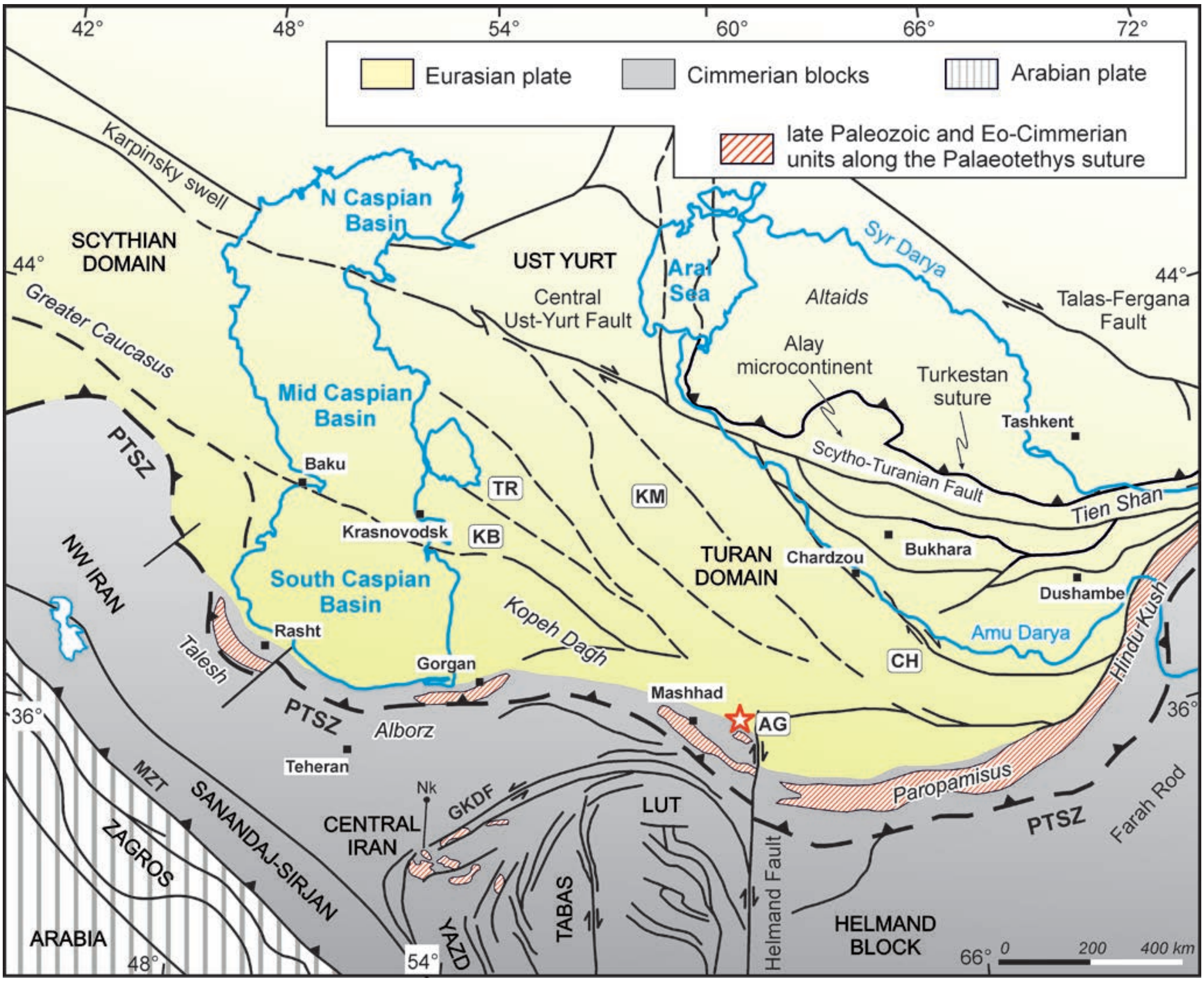

Fig. 1 - Tectonic scheme of the area east of the Caspian Basin (modified after Natal'in & Sengör 2005, and Zanchetta et al. 2013). Tectonic unit in colours are those related to the accretion and shaping of the Southern Eurasia margin during Late Permian-Early Triassic times. AG: Aghdarband basin (white & red star in the map); CH: Chardzou arc; KB: Karabogaz; KM: Karakum–Mangyshlak microblock; TR: Tuarkyr; PTSZ: Palaeotethys Suture Zone; Nk: Nakhlak; MZT: Main Zagros Thrust; GKDF: Great Kavir - Doruneh Fault system. For a complete description of the tectonic units refer to Natal'in & Sengör (2005).

the Aghdarband window, which was never studied in detail. We outline the major tectonic structures of the area, and then we revise the stratigraphy of the shallow water Sefid-Kuh Limestone, the deep water Nazar-Kardeh Formation and overlying basal part of the Sina Formation. We base our stratigraphic revision on the detailed study of bed-by-bed sampled sections, with bio-chronostratigraphy based on conodonts and ammonoids, with the support of some brachiopod and bivalve data.

The Triassic of Aghdarband

Geological setting

The Aghdarband window is structurally divided into three parts (Ruttner 1991; Zanchi et al. 2016; Fig. 2a). The Northern unit, consisting of late Palaeozoic rocks, and the Southern unit, consisting of siliciclastic successions lacking of fossils, which bound an intermediate part, consisting of thick but deformed, mostly marine and often fossiliferous Triassic successions. This portion, documenting the Aghdarband Basin, is furthermore subdivided in three main tectonic units named unit 1, 2 and 3 from N to S (Ruttner 1991; Zanchi et al. 2016). The sedimentary successions are deeply deformed in all the tectonic units. In unit 1 the deformation consists of folding and faulting related to transpression, while thrusting characterizes units 2 and 3, suggesting a strong partitioning of the finite deformation.

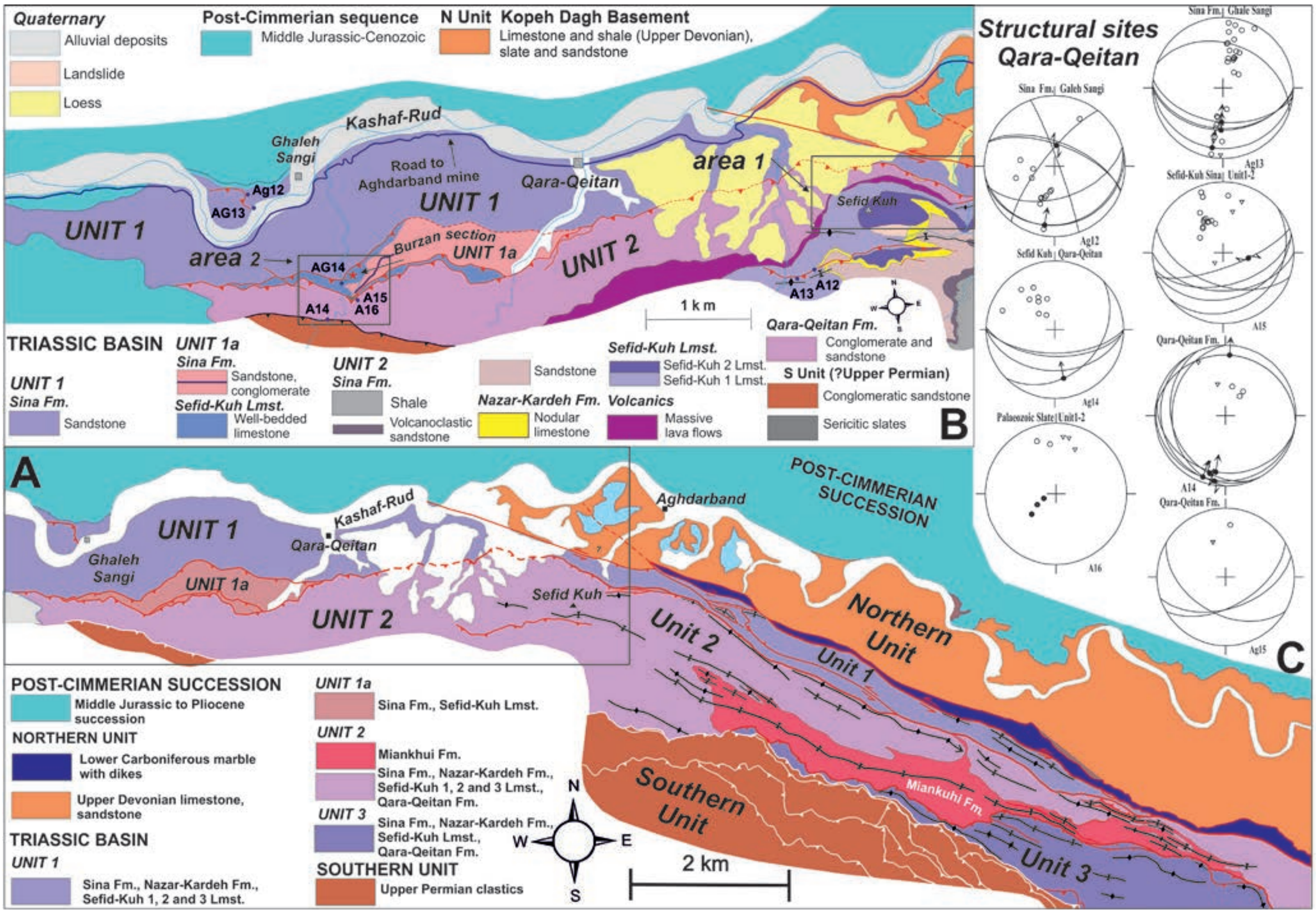

Fig. 2 - Geology of the Aghdarband area. A) Tectonic scheme modified from Zanchi et al. (2016). B) Geological map of the western part of the Aghdarband erosional window, from our original data. Modified from Zanchi et al. (2016). C) Significant stereographic projections from the western part of the study area; location in Fig. 2A. Cyclographic projections are faults with black dots as striations with relative sense of motion, empty circles are poles to bedding (S_0), triangles are poles to axial plane cleavage (S_1) and black dots are fold axes; Schmidt's projection, lower hemisphere. Modified from Zanchi et al. (2016).

The central and eastern part of the Aghdarband basin (units 1-3) and of the northern frame were studied in detail by Ruttner, who provided a detailed geological map at 1:12,500 scale (Ruttner 1991: pl.1). This map was centred on the Aghdarband coal mine as Ruttner was invited to study the geology of the area by the mining company. Two broader structural maps of the area are available. The first is at about 1:45,500 scale (Ruttner 1991: fig. 2) and the second is at about 1:92,5000 (Eftekharnezhad & Behroozi 1991: fig. 1). Our study area is located west of the geological map by Ruttner (1991) and overlaps with this map. In this area, only tectonic units 1 and 2 are documented (Fig. 2B).

Stratigraphic setting

Figure 3 summarizes the updated Triassic stratigraphy of the tectonic units 1, 2 and 3, that is revised with respect to the original, more simplified, reconstruction given by Ruttner (1991: fig. 4). This new stratigraphy was anticipated in Zanchi et al. (2016: fig. 4), as support for the geologic study of the Aghdarband window. However, the data and the litho- and biochronostratigraphic revision of the Lower Triassic to Anisian formations of the units 1a and 2 are presented here.

The Lower Triassic is documented in all the tectonic units by the Sefid-Kuh Limestone (Baud et al. 1991a), which overlain the mostly conglomeratic Qara-Qeitan Formation. The conglomerates include Carboniferous granitoids (U–Pb zircon age of 313.3 ± 4.3 Ma; Zanchetta et al. 2013) and possibly Permian acidic to intermediate volcanic rocks. Due to the lack of fossils, the age of the Qara-Qeitan Formation is, however, debated. This formation has been referred to the early Early Triassic by Ruttner (1991), to the Late Permian-?Early Triassic by Baud et al. (1991a), to the Late Permian by Alavi et al. (1997), to Early Triassic by Balini et al. (2009)

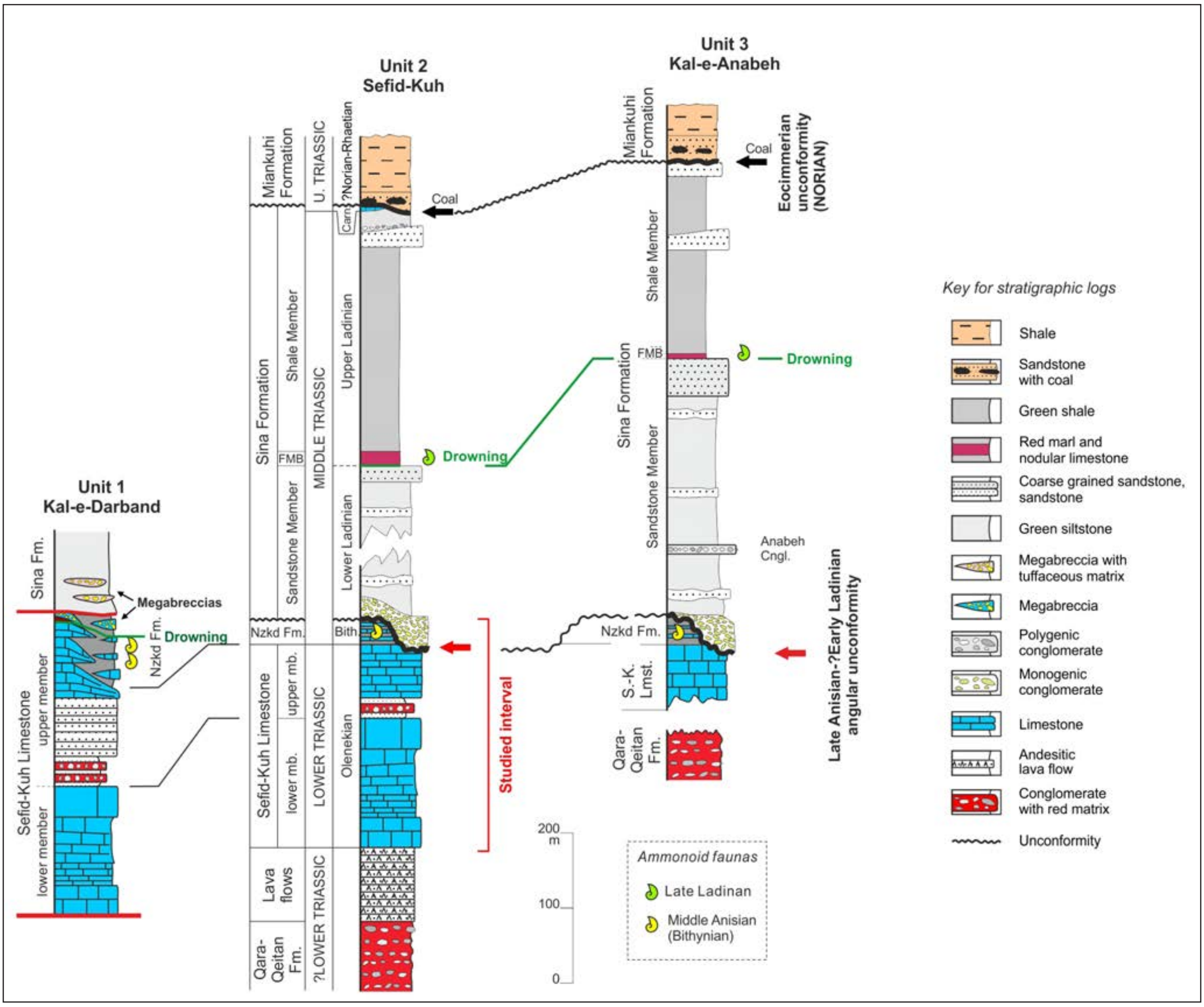

Fig. 3 - The Triassic lithostratigraphy of Aghdarband, tectonic units 1, 2 and 3 (modified from Zanchi et al. 2016, fig. 4). Abbreviations: S.-K. Lmst.: Sefid-Kuh Limestone; Nzkd Fm.: Nazar-Kardeh Formation; FMB: Faqir Marl Bed; Bith: Bithynian; Carn.: Carnian;

or doubtfully to the Early Triassic by Zanchi et al. (2016).

The type section of Sefid-Kuh Limestone is in tectonic unit 2, on the W slope of Sefid Kuh (Fig. 2), just out (West) of the 1:12,500 geological map by Ruttner (1991). The formation consists of a variety of calcareous facies documenting a carbonate ramp (Baud et al. 1991a). The "late Scythian (Spathian)" age of the carbonate ramp was documented (Baud et al. 1991a) by the occurrence of the conodonts recovered from samples at the base and in the middle part of the Sefid-Kuh Limestone. The overlaying Nazar-Kardeh Formation was introduced without any stratigraphic section by Ruttner (1991: p. 29), following Krystyn (in Krystyn & Tatzreiter 1991) for a "carbonatic and tuffaceous" unit, locally represented by cherty limestones, usually rich in ammonoids. The ammonoid record allowed the assignment of the unit to the Bithynian (Krystyn & Tatzreiter 1991). The base of the unit was referred to the Aegean/Bithynian by Ruttner (1991) and to the Late Aegean by Baud et al (1991a) on the basis of a single conodont sample Agh 75/9/b.

The Sina Formation was instead described based on stratigraphic sections (Baud et al. 1991b) from the eastern part of tectonic unit 3. The formation is divided into two members (Ruttner 1991; Baud et al. 1991b): the Sandstone Member consisting of conglomerates overlain by tuffaceous sandstones including a second conglomerate interval (Anabeh Conglomerate), and the overlying Shale Member, consisting of red ammonoid-bearing marls (Faqir Marl Bed) overlain by tuffaceous shales. The formation was assigned to the Ladinian-earliest Carnian (Ruttner 1991; Krystyn & Tatzreiter 1991; Donofrio 1991).

Baud et al (1991b: figs 3 and 6), however, did not accept the Nazar-Kardeh Formation as a valid unit and included this facies within the Sina Formation. They also provided a different reconstruction of the stratigraphic relationships between the conglomerates of the lowermost Sina Formation *sensu* Ruttner (1991) and the Middle Anisian ammonoid-bearing interval (Nazar-Kardeh Formation *sensu* Ruttner 1991 and Krystyn & Tatzreiter 1991). They did not recognize any unconformity between the two units but, on the contrary, they regarded the two facies as heteropic, then coeval (Baud et al. 1991a: fig 6). As it results, according to Baud et al. 1991b, the age of the Sina Formation spans from the Middle Anisian to the Early Carnian.

The uppermost unit of the Triassic of Aghdarband is the Miankuhi Formation, unconformably overlying the Sina Formation. The type area of this unit is within the Miankuhi syncline of Ruttner (1991), in the tectonic unit 2, and lithology consists of a "monotonous sequence of brown-coloured shales, with some interbedded siltstone and/or fine-grained sandstone". Only the lower boundary was described on the basis of a stratigraphic section (e.g., Ruttner 1991, fig. 29). A second section was described by Ghasemi-Nejad et al. (2008). Unfortunately this section is located in a deeply folded part of tectonic unit 2 (see Ruttner 1991, pl. 2, sections 4 and 5, pl. 3, sections G-G', H-H' and I-I'; and Zanchi et al. 2016, fig. 2, 6, 10 and section B-B' in fig. 12), therefore it is surely affected by repetitions by the intensive folding.

Material and methods

Two areas in the western part of the Aghdarband window were selected for our study. The first area is Sefid Kuh (White Mountain), the type area of the Sefid-Kuh Limestone. The second area is located 4.9 km W of Sefid Kuh and is described here for the first time. This new locality does not have a specific topographic name, but it is here referred to as "Burzan", because to access this site it is necessary to take a side road of the main road along the Kashaf-Rud Valley that is going to "Burzan", according to the indication painted on the rock at the road divide.

The field work carried out by structural geologists and stratigraphers was aimed at identifying the best, tectonically undisturbed, well exposed sedimentary succession or to unravel the complex tectonic setting of sites where these successions are cropping out. The stratigraphic study has been focused on 1) the reconstruction of the stratigraphic succession by verifying in the field the superposition of the sedimentary units, and 2) description and sampling of stratigraphic sections for lithology, macrofossils and condonts, following a strict bed-by-bed approach.

Quite often the lithostratigraphic boundaries have been followed along strike for over 1 km in order to verify the superposition of the lithostratigraphic units.

Lithostratigraphic nomenclature is modified from Ruttner (1991) and Baud et al. (1991a), and follows the transliteration from Farsi formalized by Aghanabati (2009): Sefid-Kuh Limestone for Sefid Kuh Limestone; Nazar-Kardeh Formation for Nazarkardeh Formation; Qara-Qeitan Formation for Qara Gheitan/Qara Geithan Formation. Biochronostratigraphy follows an integrated ammonoid-conodont approach which is the best for the Triassic system (e.g., Balini et al. 2010; Orchard 2010).

The classification and nomenclature of conodonts has been improved notably since Ruttner (1991) and Baud et al. (1991a,b), especially for the Lower Triassic. The classification used in this paper is based on the most advanced studies on this group (Orchard 1995, 2007; Kozur et al. 1998; Chen et al. 2015 and Kolar-Jurkovšek et al. 2015, 2017).

Preparation of macrofossils and conodonts has been done in the laboratories of the Dipartimento di Scienze della Terra "Ardito Desio", University of Milano. The studied fossils are deposited in the Museo di Palaeontologia of the Dipartimento.

The western part of the Aghdarband window

Geological setting

The western part of the Aghdarband erosional window is dominated by E-W trending N-verging Cimmerian fold-and-thrust structures (Zanchi et al. 2016). These tectonic structures are sealed by the Middle Jurassic Kashaf-Rud Formation (Fig. 2B), which unconformably rests on Triassic and upper Palaeozoic deformed successions.

Following the structural scheme proposed by Ruttner (1991) and extended by us (Zanchi et al. 2016) to this portion of the Aghdarband area, we mapped four major structural units, the Southern unit, tectonic units 1 and 2, and the Northern unit. Unit 3 is not exposed in this area (Fig. 2B). The Southern unit here consists of upper Palaeozoic (?Permian) volcanoclastic conglomerates stacked on the Qara-Qeitan Formation, which is the stratigraphically oldest part of unit 2. The Qara-Qeitan Formation is covered in turn by massive lava flows of intermediate composition about 100 meters thick, passing to the carbonates of the Sefid-Kuh Limestone. Unit 1 shows a larger extent with respect to the central-eastern side of the window; here, it mainly consists of the sandstones belonging to the lower portion of the Sina Formation. The Northern unit is poorly exposed just to the north of the Kashaf-Rud River,

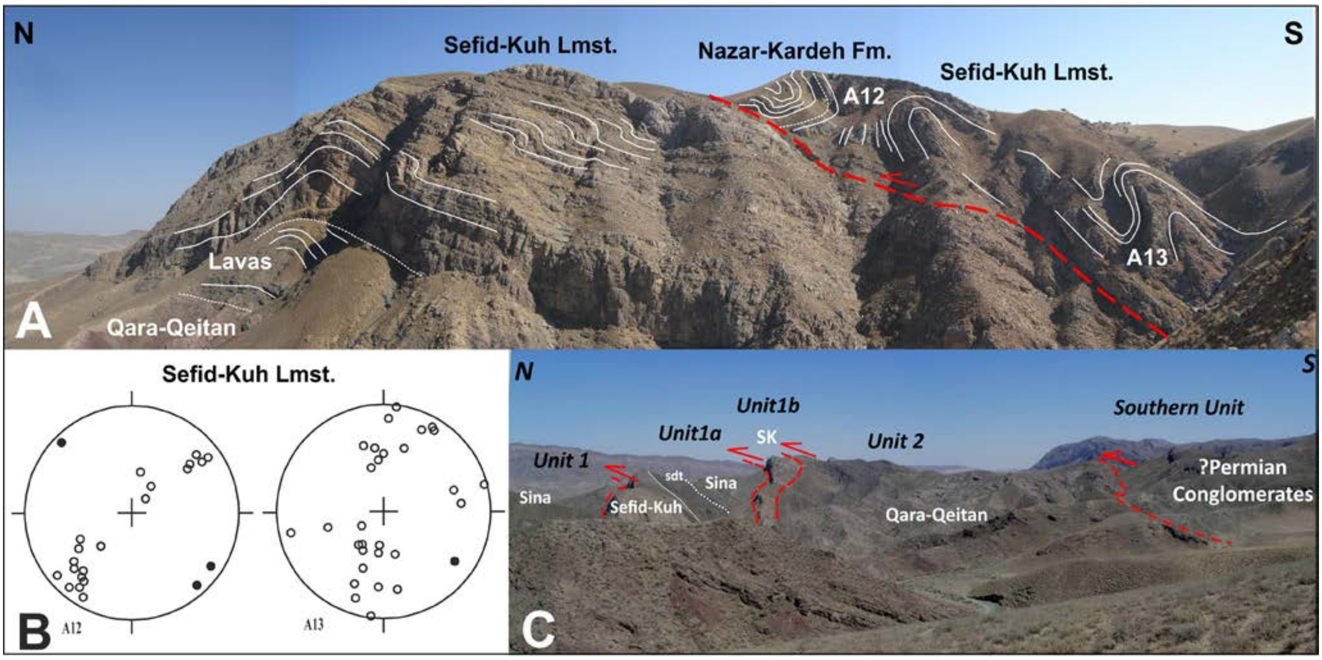

Fig. 4 - Field photos of the Aghdarband area. A) Thrust and folds structures across the Sefid Kuh mountain seen from the West. B) Stereoplots of sites A12 and A13; symbols as in Fig. 2. C) The thrust stack exposed along the "Burzan" valley; SK is for Sefid-Kuh Limestone, sdt for the sandstone layer interbedded within the Sina Formation.

where it is tectonically elided by the ENE-WSW trending Cimmerian left-lateral Northern Fault (Ruttner 1991; Zanchi et al. 2016); the unit includes deformed limestone and sandstones of Devonian age (Ruttner 1991).

A secondary thrust is also exposed southwest of the top of the Sefid Kuh within unit 2 (Fig. 4A). Fault propagation folds formed in the hanging wall trend between E-W and ESE-WNW (Fig. 4B) and deform both the Sefid-Kuh Limestone and the Nazar-Kardeh Formation. Open folds with the same trend also occur in the footwall crossing the top of the Sefid Kuh, deforming the studied stratigraphic succession (Fig. 4A).

A large thrust duplex formed between unit 1 and unit 2 (Figs 2B, 4C and 5A) including two horses, the lower one consisting of the Sefid-Kuh Limestone unconformably followed up-section by sandstones of the Sina Formation. The upper horse only includes the Sefid-Kuh Limestone (Fig. 5A). The lower horse contains the studied stratigraphic section along the Burzan gorge (Figs 2B, 5A); it is about 100 m thick and extends laterally for about four kilometers. The Triassic succession is overthrust at the top of the gorge by the conglomerates of the Qara Qeitan Formation forming the base of Unit 2 (Figs 5B, 5C and 5D).

Mesoscopic faults measured along the Burzan Gorge (Fig. 2C) and around the abandoned village of Galeh Sangi show a N-verging tectonic transport related to an average NNE-SSW shortening direction, consistent with observed axial plane cleavage and folds patterns.

Stratigraphy of the study area 1, Sefid Kuh

The Sefid Kuh (Figs 4A, 6A) in the tectonic unit 2, is the type locality of the Sefid-Kuh Limestone (Baud et al. 1991a), one of the very few lithostratigraphic units of the Triassic of Aghdarband that was described based on stratigraphic sections. The type section (Baud et al. 1991a: figs 1-2; Fig. 7) is located on the W-NW slope of Sefid Kuh, but well exposed outcrops on the N and NE slope of the mountain (Fig. 6B) allow for the study of the succession from the Sefid-Kuh Limestone to the Sina Formation. We sampled for conodonts the same section studied by Baud et al. (1991a: fig. 3) at the base of the Sefid-Kuh Limestone, but most of our work was done on three new sections, SKU E, SKU B and SKU D on the N and NE slopes of the mountain (Fig. 6B).

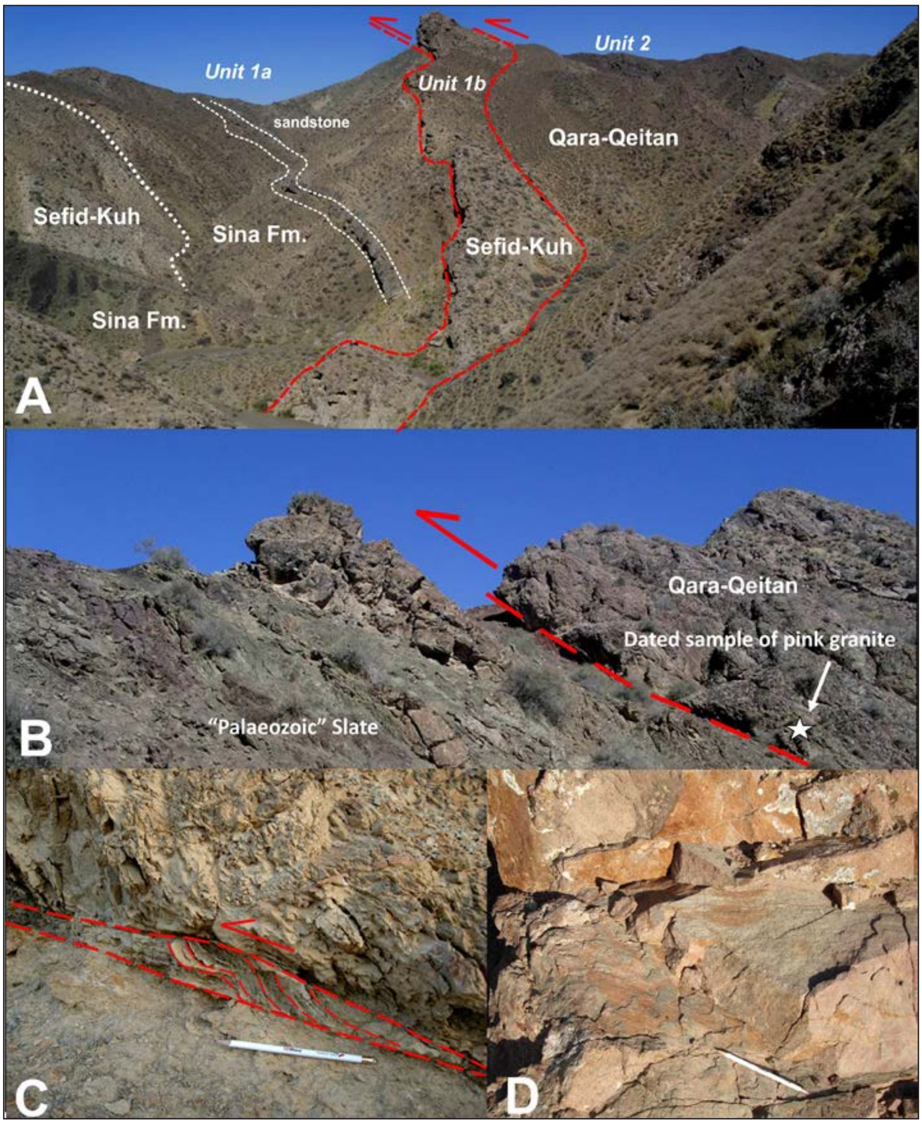

Fig. 5 - Geology along the Burzan gorge, field photos. A) General view of the area where we measured the Burzan section. Note a horse consisting of the Sefid-Kuh Limestone separating the Qara-Qeitan Formation from the lower unit, which includes the Sefid-Kuh Limestone and the Sina Formation. B) The thrust plane stacking the Qara-Qeitan Fm., on top of undated, probably upper Palaeozoic slates. A granitic pebble from the conglomerate has given a zircon U-Pb radiometric age of 314.5 ± 4.2 Ma (Zanchetta et al. 2013), see the star for its location. C) SC structures along the thrust plane of figure 5B. D) Kinematic indicators (steps and growth fibbers) along the fault zone of figure 5B, suggesting dip-slip reverse motion.

Here we summarize the results, following the stratigraphic succession of the lithostratigraphic units.

Sefid-Kuh Limestone

The stratigraphy of the Sefid-Kuh Limestone is much more complex than reported in the literature by Ruttner (1991) and Baud et al. (1991a) (see Zanchi et al. 2016: fig. 4; Fig. 3). Here we provide the description of some key-sections in the tectonic unit 2. In tectonic unit 1, East of the study area, the stratigraphy of the Sefid-Kuh Limestone is even more complex.

Baud et al. (1991a: figs 1-2, p. 115) studied only part of the succession exposed on the W slope of Sefid Kuh (Fig. 6A), where they described one section encompassing the lithologic subunits A to D (Fig. 7A). They assumed a direct superposition of the Nazar-Kardeh Formation on subunit D of Sefid-Kuh Limestone, on top of the Sefid Kuh (figs 1-2; Fig. 7A). The study of the top of this mountain and of its N and NE slopes (section SKU E; Figs 6A-B) reveals that between subunit D and the Nazar-Kardeh Formation (Fig. 7B) there is an intermediate 100-m thick lithologic unit consisting of conglomerates and sandstones in the lower part, and by grainstones in the middle and upper part.

This unit is overlain by the Nazar-Kardeh Formation, which is in turn unconformably overlain by the conglomerates of the lowermost Sina Formation (section SKU B). East from SKU B, at section SKU D, most of the Nazar-Kardeh Formation is laterally replaced by shallow carbonates, unconformably overlain by the conglomerates of the lowermost Sina Formation.

Stratigraphic section SKU

This section is located at the base of the main

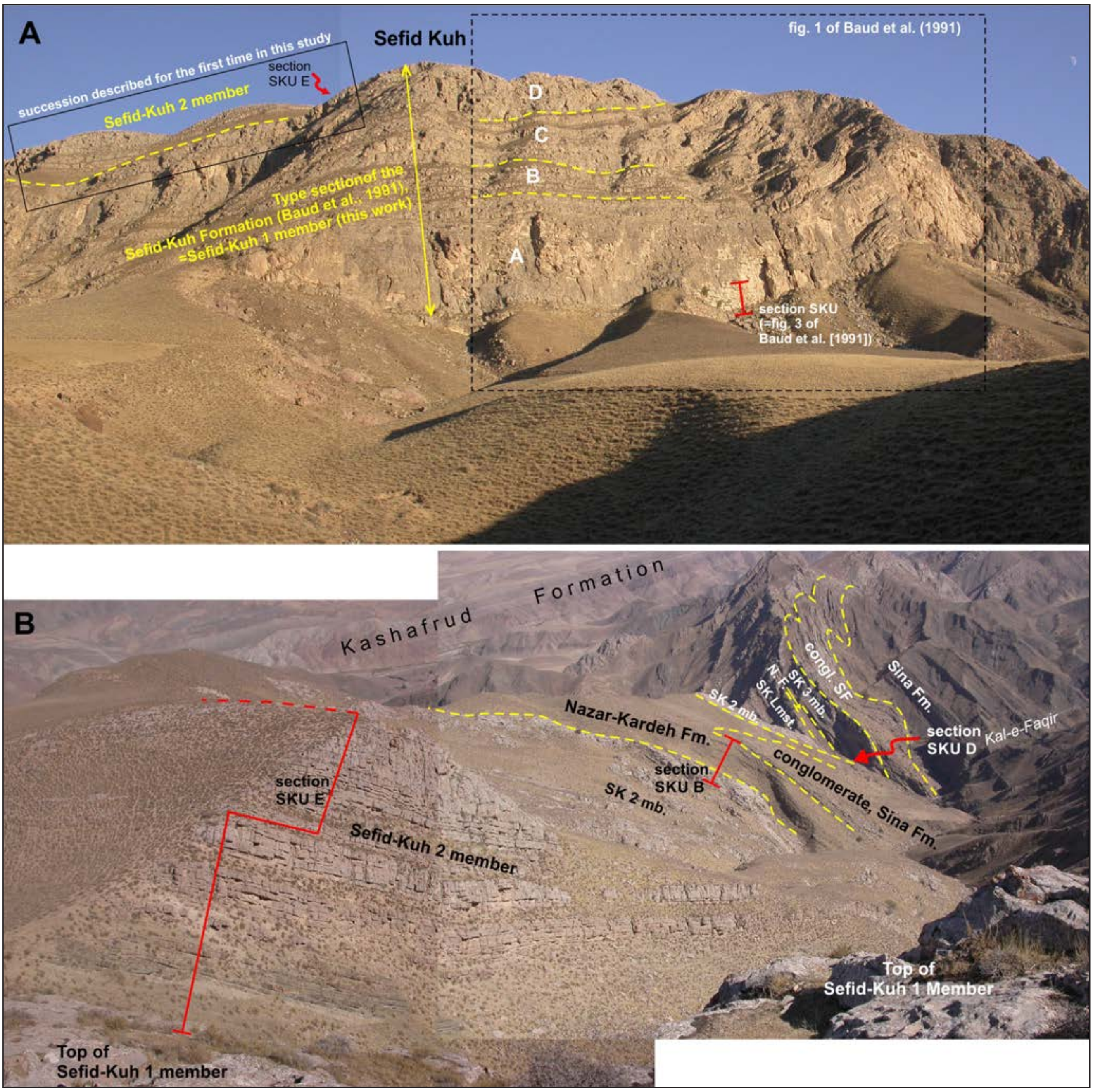

Fig. 6 - Views of the slopes of Sefid Kuh. A) The W-NW slope; letters A to D refer to the subunits described by Baud et al. (1991a). B) The N-NE and E slopes, with the position of the sections SKU E and SKU B. The upper part of the section SKU E (dashed line) is poorly exposed on the gentle slopes in the main outcrop. The section SKU D is located on the eastern side of the Kal-e-Faqir gorge.

wall of the Sefid Kuh (Figs 6A, 8; WGS84 coordinates: 36°00'38.1" N, 60°47'20.3"E), exactly in the same site where Baud et al. (1991a, fig. 3) described their section.

Lithofacies and lithostratigraphy. The section (Fig. 8) covers the uppermost 8 m of andesite lava flows overlain by volcaniclastic sandstones, and the very lower part (16 m) of the limestones of Baud's et al. (1991a) subunit A.

The two-fold subdivision of 1) the andesitic lava overlain by 2) volcaniclastic sandstones is reported here, but it was not recognized by Baud et al (1991a).

Lithology, sedimentary structures and sequence organization of the carbonatic beds are exactly as reported by Baud et al. (1991a, fig 3). Two sequences are recognized. Lithology mostly consist of bioclastic grainstones with thin interbeds of silty marls, and rare occurrence of dolomitized limestones in the lower part of the second sequence. Cross lamination and cross bedding are the most common sedimentary structures.

Bio-chronostratigraphy. The section has been sampled for conodonts. Two out of five samples provided conodonts (Fig. 8; Tab. 1; Pl. 1, figs 8, 9). *Triassospathodus triangularis* (Bender, 1970), occurs in both samples SK2 and SK1. In the latter sample, this species co-occur with *T. homeri* (Bender, 1970) and *T. symmetricus* (Orchard, 1995). The age of the fauna is middle-late Spathian (late Olenekian). Both faunal composition and age are consistent with the occurrence of *Triassospathodus triangularis*, *Ellisonia torta* Sweet, 1970 and *E.* cf. *delicatula*, reported Baud et al. (1991a) in sample Agh 76/93/1, from the same position of the section.

Discussion. The andesitic lava flows and volcanic litharenites were included in the lower part of the Sefid-Kuh Limestone by Baud et al. (1991a and b). They traced the lower boundary of the formation between the underlying conglomerates of the Qara-Qeitan Formation and these lava flows. We do not think this is the most important lithologic change in the succession, and we would prefer to draw the lower boundary of the carbonate platform of the Sefid-Kuh Limestone at the first limestone bed. The andesitic lava flows and overlying volcaniclastic sandstones should be formally separated from both the Qara-Qeitan Formation and Sefid-Kuh Limestone, as distinct lithostratigraphic interval, especially taking into account that westwards the thickness of this lithofacies increases notably to about 100 m, as reported by Alavi et al. (1997: fig. 4).

Stratigraphic section SKU E

The section SKU E (Fig. 9; WGS84 coordinates: 36°00'1.6N, 60°47'32.5"E) has been measured on the eastern side of the N-S crest of the Sefid Kuh, few hundreds of meters North of the top of the mountain. This section is perfectly exposed in its lower part (Fig. 7B), about 50 m thick, while the exposure of the upper part of the limestone interval is not very good. Its upper boundary can be easily followed downslope to section SKU B (Fig. 6B).

Lithofacies and lithostratigraphy. The top of the Sefid-Kuh 1 member consists of grainstones and does not show any evidence of emersion. The overlying succession (Fig. 9) can be divided into two parts. The lower 28 m consist of bedded limestones, breccias, and alternation of green tuffaceous

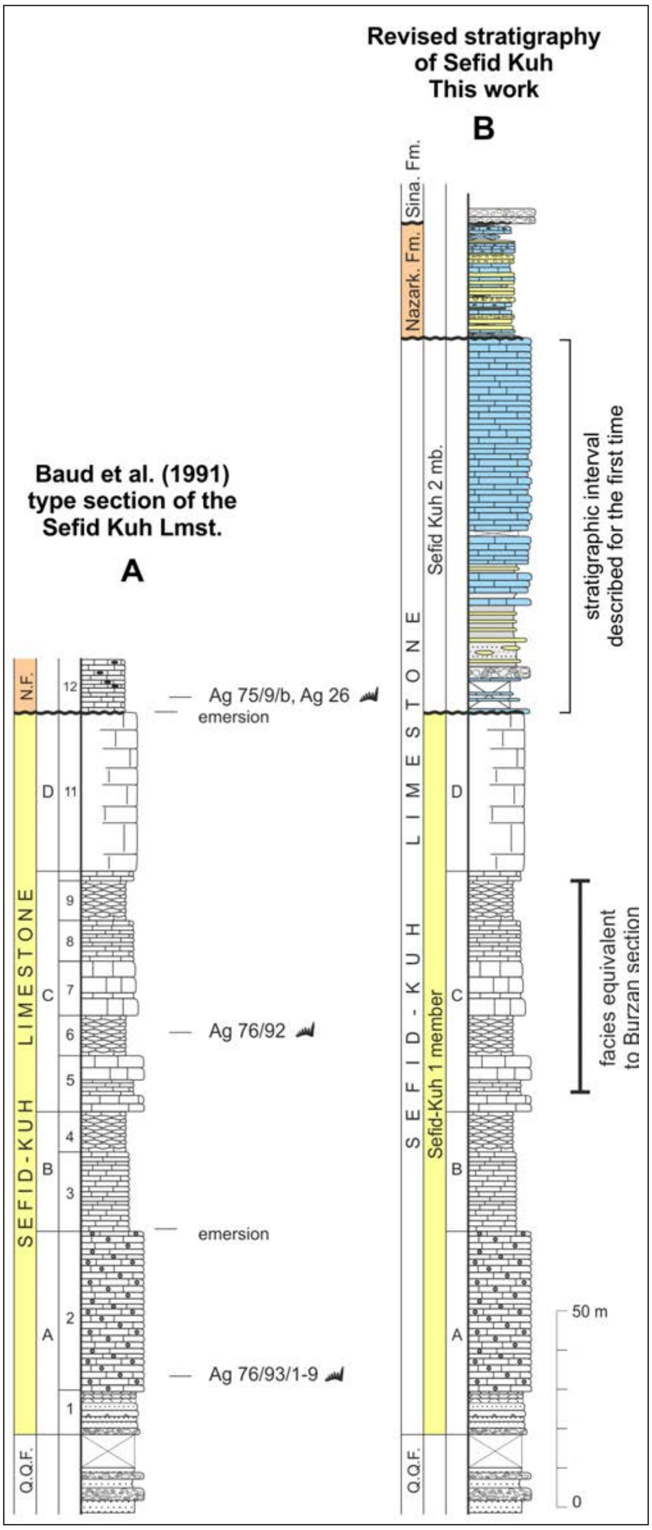

Fig. 7 - The lithostratigraphy of the Sefid Kuh. A) The type section of the Sefid-Kuh Limestone as shown by Baud et al. (1991a: fig. 2). The age of the unit was defined on the basis of three condont samples, here shown. B) Lithostratigraphy revised in this work. The subunits A to D are from Fig. 7A. The overlying succession (color) is described for the first time in this work (Fig. 6B). Q.Q.F.: Qara-Qeitan Formation; N.F.: Nazar-Kardeh Formation. The key for the log A and lower part of B is from Baud et al. (1991a). For the key of the upper part of log B, see Fig. 9.

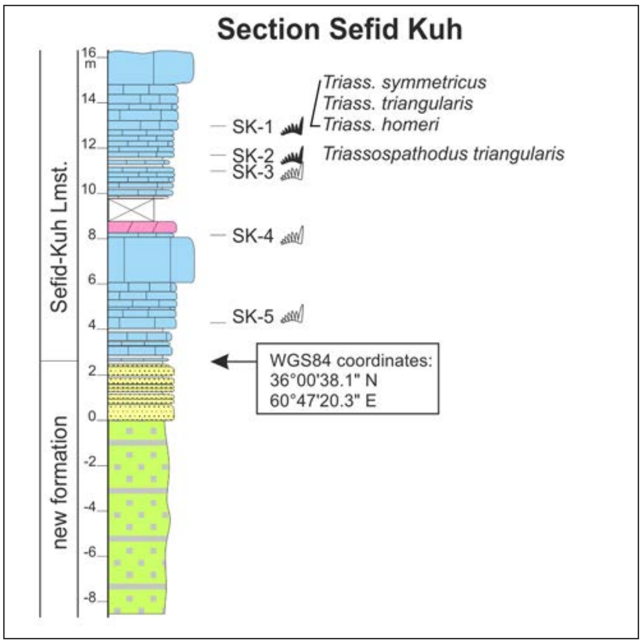

Fig. 8 - The lower boundary of the Sefid-Kuh Limestone. This section has been measured at the same place where Baud et al. sampled their section (1991a: fig. 3). For the key of the log see Fig. 9.

Sample	*Triassospathodus triangularis*	*Triassospathodus homeri*	*Triassospathodus symmetricus*
SK1	2	1	2
SK2	2		

Tab. 1 - Conodonts recovered at section SK, in the basal part of the Sefid-Kuh Limestone.

sandstones and greenish siltstones. The upper 68 m consist of grainstones, bioclastic grainstones, with more rare oncolytic limestones, organized in shallowing upward sequences, at least in the lower part that is best exposed. Fenestrae are common at the very base of this limestone-dominated interval, just above sample SkuE5.

Bio-chronostratigraphy. Unfortunately no one of the 10 conodont samples processed yielded conodonts. Some conodonts have been recovered from the top of Sefid-Kuh 2 at section SKU B (see below). Based on the stratigraphic relationships with the underlying units and the conodonts recovered from the top, we may suggest an age for this unit that is comprised between the middle-late Spathian and the early Middle Anisian (Osmani Zone).

Discussion. The succession exposed at section SKU E is assigned to a new informal member (Sefid-Kuh 2) of the Sefid-Kuh Limestone. This member unconformably overlies the Sefid-Kuh 1 member that is equivalent to the Sefid-Kuh Formation *sensu* Baud et al. (1991a). The decision to enlarge the scope of the Sefid-Kuh Limestone at the type locality, and to keep it as formation is made because the Sefid-Kuh 2 is dominated by limestones that are not significantly different from the wide variety of limestones of the Sefid-Kuh 1 (see Baud et al. 1991a). The separation of the Sefid-Kuh 2 as new formation is not reasonable, because sometimes in the Aghdarband Basin (e.g., tectonic unit 3 and most deformed portions of tectonic unit 1) the separation between Sefid-Kuh 1 and Sefid-Kuh 2 cannot be made. In such a case, the undifferentiated calcareous unit interbedded between the Qara-Qeitan and the Nazar-Kardeh formations is simply referred to an undifferentiated Sefid-Kuh Limestone.

Stratigraphic section SKU D

The section SKU D is located on the eastern side of the the Kal-e-Faqir gorge (Fig. 6B; WGS84 coordinates: 36°00'27.3"N, 60°48'16.1"E). On this side of the gorge the succession is not as deformed as on the western side, where the 3.4 m-thick sandstones in the lower part of the section are not actually exposed. The section (Fig. 9) consists of 16 m of a mostly calcareous unit, with some tuffaceous sandstones in its lower part, that is comprised between thick-bedded limestones assigned to the Sefid-Kuh Limestones and the conglomerates of the Sina Formation. This 16 m-thick interval is described here.

Lithofacies and lithostratigraphy. The lowermost 3.4 m of the section consists of tuffaceous sandstones that are attributed to the Nazar-Kardeh Formation. These sandstones unconformably overlay thick bedded limestones of undifferentiated Sefid-Kuh Limestone. The boundary is sharp, the surface of the last bed of Sefid-Kuh Lmst. is characterized by epirelief of *Planolites*-like *Repichnia* trace fossils, filled by coarse grained volcaniclastic sandstones (Figs 11B-C). The last bed of the Sefid-

Kuh Limestone is also cut by sedimentary dykes (Figs 11B, D-E), filled by two types of calcareous pebbles-small cobbles, embedded in a coarse grained greenish sandstone matrix (Figs 11D-E). The first type consists of well rounded, non-spherical, limestone grains, while the second is represented by angular, non-spherical calcareous grains. On the exposed surface of the top of the Sefid-Kuh Lmst. no cross-cutting relationships of sedimentary dykes on trace fossils are documented. The trace fossils, however, are visible on a side area with respect to the area where the sedimentary dykes are exposed.

The 12.6 m-thick calcareous succession overlying the tuffaceous sandstones might be divided into four intervals. About 3.6 m of nodular/ subnodular, brachiopod limestones, in turn overlain by 5.5 m of thick bedded, locally cherty, recrystallized limestones. The uppermost part of the succession consist of 2 m of grainstones, packestones and about 1.5 m of oncolithic limestones.

The last lithologic interval of the section consists of conglomerates of the Sina Formation, that will be described in the next chapter.

Bio-chronostratigraphy. Three samples out of five yielded conodonts, with conodont color alteration index (CAI) of 1.5 – 2 (Epstein et al. 1977).

The conodont fauna (Fig. 9; Tab. 2; Pl. 1) consists of *Neogondolella regale* Mosher, 1970, *Neogondolella* sp. (? n. sp.), *Paragondolella bulgarica* (Budurov & Stefanov, 1975), *Ellisonia triassica*, Muller, 1956 and indetermined fragments, which document the Bithynian, Osmani Zone (Mosher 1970; Budurov & Stefanov 1972, 1973, 1975; Gedik 1975; Nicora 1977; Kovàcs & Kozur 1980; Germani 2000).

Discussion. The lowest 3.4 m of the section are attributed to the Nazar-Kardeh Formation because of its siliciclastic lithology. The overlying 12.6 m-thick calcareous succession is here assigned to a new third member of the Sefid-Kuh Limestone, the Sefid-Kuh 3. This separation is supported by the age documented by the conodont faunas, that is early Bithynian (Osmani Zone), coeval with the age of the Nazar-Kardeh Formation at section SKU B (see below) and younger than the possible age of the Sefid-Kuh 2 member. The lithostratigraphic assignment of the limestones underlying the Nazar-Kardeh Formation is open, at least as regards the member. The boundary Sefid-Kuh Lmst./Nazar-Kardeh Fm. at SKU D shows strong evidence (Fig. 11) of a significant sedimentary gap between the

Sample	Indeterminated fragment	*Paragondolella bulgarica*	*Neogondolella regale*	*Neogondolella* sp. (? n. sp.)	*Ellisonia triassica*
SkuD7		4	3	3	1
SkuD5c		1	2	1	3
SkuD4	1				

Tab. 2 - Range chart of the conodont taxa identified at section SKU D.

two units, that is not documented at sections SKU E and SKU B. The burrows testify colonization of a softground and the sedimentary dykes document fracturing of a lithified substrate. The fragile deformation of the lithified substrate and the volcaniclastic infilling of the burrows and dykes is here explained as driven by tectonic instability.

Nazar-Kardeh Formation

Ruttner (1991) and Krystyn & Tatzreiter (1991) introduced this formation without any stratigraphic section. Over the years, we have studied with bed-by-bed approach the Nazar-Kardeh Formation in all the tectonic units. The formation shows variations in thickness, fossil content and in part in lithology from tectonic unit 1 to 3. The best exposures are in tectonic unit 1, close to the Ruttner's locality Agh 75/25, and in tectonic unit 3 close to locality Agh 75/37. In this work, we describe one stratigraphic section in the Sefid Kuh area, from tectonic unit 2, that is not suitable as type section of the formation. This section, however, is crucial to clarify the stratigraphic relationships with the underlying and overlying units.

Stratigraphic section SKU B

The section SKU B (WGS84 coordinates: 36°00'35.6"N, 60°47'59.1"E) is located on the NE slope of the Sefid Kuh, approximately in the same position where Ruttner collected the ammonoid sample Agh 75/23b (e.g., Krystyn & Tatzreiter 1991, fig. 1). At this place, the succession comprised between the uppermost part of the Sefid-Kuh 2 and the lowermost conglomerates of the Sina Formation are well exposed. The thickness of the Nazar-Kardeh Formation is about 29 m.

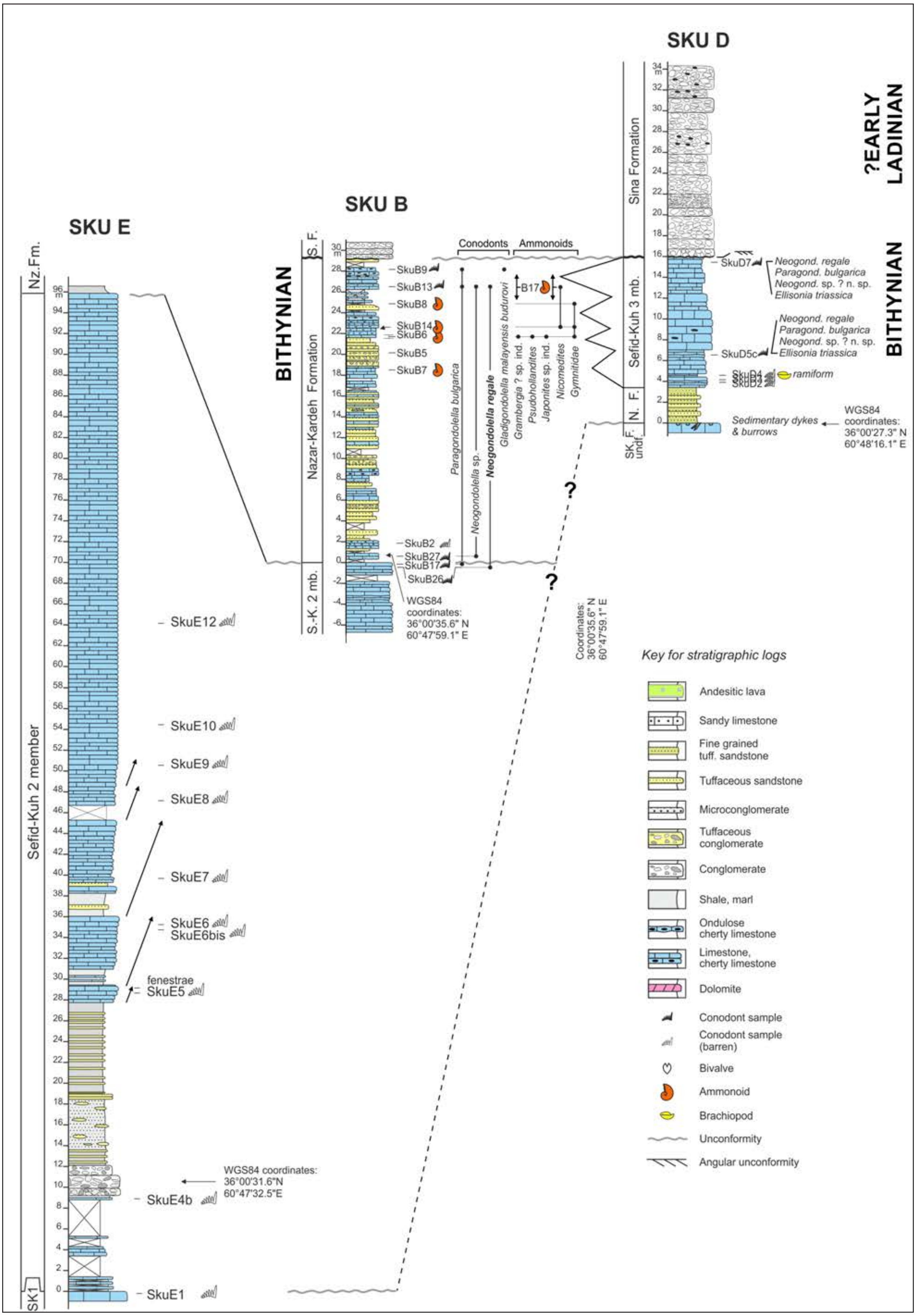

Fig. 9 - Stratigraphic sections studied at Sefid Kuh. The key for stratigraphic logs is as for Figs 7B, 8 and 14.

Fig. 10 - Field pictures of significant facies of the Sefid-Kuh Limestone and Nazar-Kardeh Formation at section SKU B. A) Uppermost oncolithic limestone beds of Sefid-Kuh 2 member. B) Cherty limestone of the Nazar-Kardeh Formation. C) Alternation of limestones and greenish tuffaceous arenites, Nazar-Kardeh Formation. D) Sandy marls of the Nazar-Kardeh Formation, conformably overlain by congolomerates of the lowermost Sina Formation. The scale is 60 cm in Fig. A to C, and 40 cm in Fig. D.

Lithofacies. The Nazar-Kardeh Formation (Fig. 10) consists of limestones, ondulose cherty limestones and tuffaceous sandstones, with a ratio that is nearly 1:1. In this section, macrofossils occur only at some stratigraphic levels, especially in the upper part of the section.

Sample	Indeterminated fragment	*Pargondolella bulgarica*	*Neogondolella sp. ? n. sp.*	*Neogondolella regale*	*Gladigondolella malayensis budurovi*
SkuB9	71	1			2
SkuB13	9	2	6	7	
SkuB27	1		3	2	
SkuB17		3		1	
SkuB26	2			4	

Tab. 3 - Range chart of the conodont taxa identified at section SKU B.

Bio-chronostratigraphy. Ammonoids typical of the Osmani Zone (early Bithynian) are not very abundant and well preserved, but they occur from levels SkuB7 to SkuB8 (Figs 9 and 12; SkuB17 is from float). They include *Grambergia* ? sp. ind., *Nicomedites* sp. ind., *Pseudohollandites*, *Japonites* and *Gymnites*. The description of this fauna is included in a more general review of the Middle Anisian ammonoid faunas from Aghdarband, that is in progress (Balini et al. in progress).

Conodont faunas have been recovered from a thicker interval of the section, spanning from the uppermost part of the Sefid-Kuh 2 member, to the uppermost part of the Nazar-Kardeh Formation. Five samples out of six yielded conodonts, showing a conodont color alteration index (CAI) of 1.5 - 2 (Epstein et al. 1977). These samples are located in the lower ad upper part of the section.

The conodont fauna (Tab. 3; Pl. 1) is characterized by the association *Neogondolella regale* Mosher, 1970, *Paragondolella bulgarica* (Budurov & Stefanov, 1975), *Neogondolella* sp.? n. sp. and ramiforms. In sample SKUB 9 two specimens of *Gladigondolella*

Fig 11 - Section SKU D on the eastern side of Kal-e-Faqir gorge (see Fig. 8). A) General view of the lower part of the section, the dotted box emphasizes the top surface of the Sefid-Kuh Limestone, whose details are shown in Figs B-E. B) The top surface of the last bed of the Sefid-Kuh Limestone, with several trace fossils in the middle part, and many sedimentary dykes (sd) on the right part of the picture. C) Detail of trails (*Repichnia*) filled with coarse grained sandstone. D) View of the complex network of sedimentary dykes filled by relatively large sized and angular limestone blocks (b) and by small and rounded (not spherical) limestone pebbles (p), all embedded in coarse grained sandstones. E) Detail of a sedimentary dyke showing infilling by rounded limestone pebbles and coarse grained sandstones.

malayensis budurovi Kovacs & Kozur, 1980 have been also found.

The conodont assemblage is representative of the Bithynian, Osmani Zone (Mosher 1970; Budurov & Stefanov 1972, 1973, 1975; Gedik 1975; Nicora 1977; Kovàcs & Kozur 1980; Germani 2000).

Discussion on the age of the Nazar-Kardeh Fm. The Nazar-Kardeh Formation was dated Bithynian by Krystyn & Tatzreiter (1991) based on the occurrence of ammonoid faunas of the two zones of this substage. However, Ruttner (1991) and Baud et al. (1991a) reported a slightly different age for the base of the formation: Ruttner (p. 29) referred the base of the unit to the Aegean/Bithynian, while Baud et al (1991a, p. 117) assigned the base of the Nazar-Kardeh Fm. to the Late Aegean. These age attributions were based on the conodont sample Agh 75/9/b whose position was described by Ruttner (p. 29) as "on top of the thick-bedded limestone of subunit D a thin bedded cherty limestone which yielded - besides of foraminifers, spicules, microgastropods, ….. and fish-remains - the conodont *Gondolella bulgarica* (Budurov & Stefanov, 1975) which points to an Early Anisian (Aegean/Bithynian) age of this limestone bed". Unfortunately, the position of this sample was not reported in any of the maps

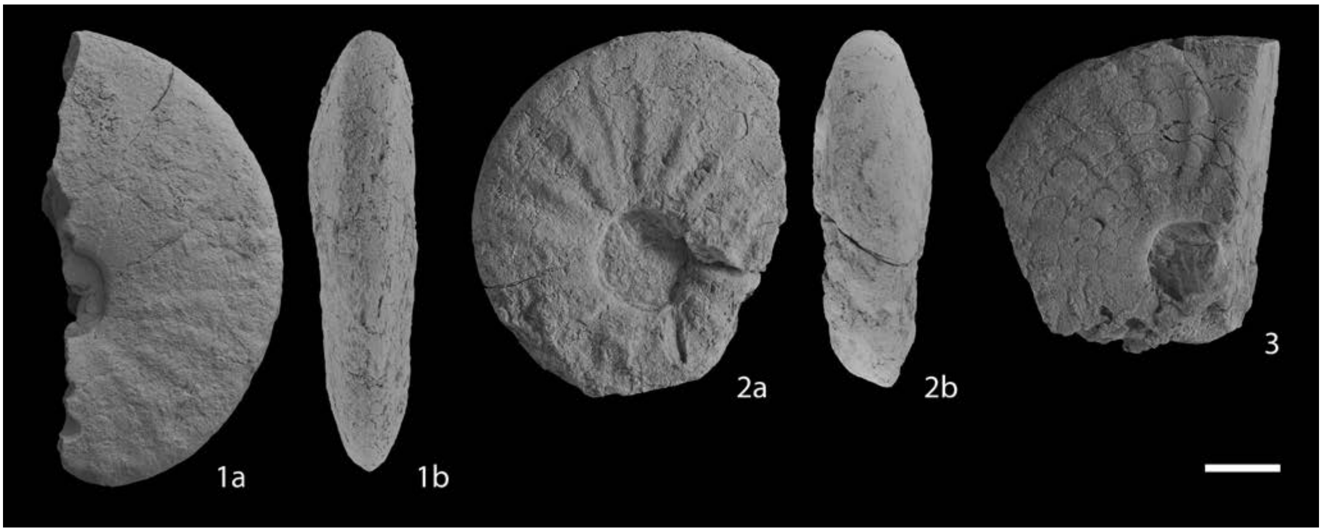

Fig. 12 - Middle Anisian (Bithynian) ammonoids from Nazar-Kardeh Formation, section SKU B. 1) *Nicomedites* sp. ind., specimen MPUM 11837 (SkuB17-3). 2) *Nicomedites* aff. *osmani* Toula, 1896, specimen MPUM 11838 (SkuB14-3). 3) *Nicomedites* aff. *osmani* Toula, 1896, specimen MPUM 11839 (SkuB17-2). Bar scale is 10 mm. All specimens coated with ammonium chloride.

included in the Aghdarband volume, therefore we could not verify the stratigraphic position of this sample and collect additional samples.

On the basis of our field investigations and conodont study we cannot exclude that somewhere in the Aghdarband window the base of the Nakar-Kardeh Formation is of Early Anisian (=Aegean) age, but for sure this is not true for the Sefid Kuh area. Our conclusions are based on the following considerations:

− The specimen from Agh 75/9/b figured on Pl. 2, fig. 1 is included within the variability of *Paragondolella bulgarica* Budurov & Stefanov, 1975.

− The range of this species is Bithynian-Pelsonian (Budurov & Stefanov 1975; Nicora 1977; Kovàcs & Kozur 1980; Balini & Nicora 1998; Farabegoli & Perri 1998a,b; Germani 2000), then this species does not occur in Aegean.

− In the Sefid Kuh area the Nazar-Kardeh Formation never rests on the subunit D, but this subunit is overlain by the Sefid-Kuh 2.

− As the position of sample Agh 75/9/b was not given by the authors, we could not verify whether this sample might be referred to the lower part of the Sefid Kuh 2, that unconformably overlies the subunit D in the Sefid Kuh area.

Sina Formation

The Sina Formation unconformably overlies the Sefid-Kuh Limestone or the Nazar-Kardeh Formation (e.g., Ruttner 1991; Zanchi et al. 2016). The unconformity is often angular and is emphasized by a few decameter-thick conglomerate, as on the NE slope of Sefid Kuh and in Kal-e-Faqir (tectonic unit 2) and in Kal-e-Anabeh (tectonic unit 3). This conglomerate differs in the composition of the pebbles from the Anabeh Conglomerate (Ruttner 1991), that is interbedded within the Sandstone Member of the Sina Formation in tectonic unit 3 (e.g., Ruttner 1991; Baud et al. 1991b; Fig. 4).

Stratigraphic sections SKU B and SKU D

The lowermost conglomerates of the Sina Formation are documented at both section SKU B and SKU D. At SKU B the Sina Formation dip with the slope, then only the very base of the conglomerates is preserved. The thickness is much greater at section SKU D, but a precise measurement is hampered by some repetitions of the succession by faulting. For sure the thickness is greater than the 18 m measured at section SKU D.

Lithofacies. The lower part of the Sina Formation consists of poorly sorted, grain-supported monogenic conglomerates with subangular to angular, usually non spherical medium pebbles to small-large cobbles. Laterally, within the same bed, the conglomerate may grade to breccia. The matrix consists of coarse grained greenish sandstone. Thickness of the beds is usually from 50 to 200 cm. The composition of the cobble/pebble is calcareous, with microfacies consistent with those from the Sefid-Kuh Limestone. The occurrence of chert pebbles/cobbles is rare.

Tab. 4 - Range chart of the conodont taxa identified at section Burzan.

sample	*Triassospathodus brocus*	*Ellisonia delicatula* S1	*Triassospathodus abruptus*	*Ellisonia triassica* M	*Ellisonia triassica* S1	*Ellisonia triassica* (framm)	*Gladigondolella* sp.	*Ellisonia gradata*	*Triassospathodus triangularis*	*Triassospathodus homeri*	*Triassospathodus symmetricus*
BZ23						23			6	18	12
BZ21										1	1
BZ18						2			3	3	
BZ17						2	1	5			
BZ8bis			9	1	2						
BZ4	1	1									

sample	*Triassospathodus homeri*	*Triassospathodus curtatus*
BZB1	2	2

These grains may derive from the erosion of cherty limestones of the Nazar-Kardeh Formation.

Discussion. As already reported in the chapter about the stratigraphic setting, the conglomerates at the base of the Sina Formation were regarded by Baud et al. (1991b: fig. 5) as coeval with the Nazar-Kardeh Formation while this heteropy was rejected by Ruttner (1991: p. 31). We confirm the stratigraphic superposition of the two units. Our lithological description of the conglomerates of the lowermost Sina Formation fits quite well with the one given by Ruttner (1991: p. 31) except for the occurrence of the angular grains and the local fading of conglomerates into breccias.

The conglomerates were deposited in a proximal environment with respect to a source area where the Sefid-Kuh Limestone and the Nazar-Kardeh Formation were eroded.

Stratigraphy of the study area 2, Burzan

The second study area is located at about 11 km WSW from the Aghdarband coal mine, out of the geological map by Ruttner (1991: pl. 1). The locality was selected for study because of the very unusual occurrence of ammonoids, first detected by the structural geology team, in the shallow water facies of the Sefid-Kuh Limestone. At this site, the angular unconformity at the base of the Sina Formation is also well preserved and perfectly exposed.

The locality can be reached from the old road to Aghdarband, on the right side of the Kashaf-Rud river. At about 13 km West of Aghdarband, there is a junction with a side road going South to Burzan, as reported by an indication painted on the rock. After about 2 km to the South, there is a secondary road to East, which joins, after 1.5 km, another trail going to South. At this last junction, it is necessary to turn North-North East, and to continue along the dry riverbed.

The section Burzan (Fig. 14; WGS 84 coordinates of the base of the section: 36°00'27.3"N, 60°48'16.1"E) is exposed on the right side of a small valley, that incises the Sefid-Kuh Limestone and the Sina Formation. Here the Sefid-Kuh Limestone consists of few tens of meters of thick-bedded limestones exposed on a vertical, unaccessible wall, overlain by about 39 m of medium to thin bedded limestones. Only this upper part of the formation and the lowermost part of the Sina Formation have been studied.

The second section studied at this site, Burzan 2, is located about 400 m NE of Burzan. At this site we have studied only the angular unconformity Sefid-Kuh Lmst./Sina Formation.

Sefid-Kuh Limestone

Lithofacies and lithostratigraphy. The Burzan section (Fig. 14) has been measured from the very upper part of the thick bedded limestones, consisting of grainstones (sample BZ1).

The overlying beds are made of bioclastic wackestones/mudstones, sometimes highly burrowed and vermicular.

The ammonoids are preserved on top of thin and bed of bioclastic mudstone (BZ8), within a 70 cm-thick marl-dominated interval. This interval is comprised between two limestone intervals of 50 and 80 cm. These two limestone intervals can be followed along strike for about 400 m to the Burzan B section (Fig. 14). The thickness of the upper limestone interval increases gradually along strike, from 80 to about 200 cm at Burzan 2. At this second section, the Sina Formation is resting directly on the second limestone interval thus documenting the missing of about 30 m of Sefid-Kuh Limestone due to erosion.

Conodonts. Six samples out of 17 collected at Burzan yielded conodonts. The only sample taken at Burzan 2 also provided few specimens. The conodont Color Alteration Index (CAI) is 1.5 - 2 (Epstein et al. 1977).

The conodonts are not particularly abundant but the fauna is well diversified and consists of *Triassospathodus brocus* (Orchard, 1995), *Triassospathodus abruptus* (Orchard, 1995), *T. homeri* (Bender, 1970), *T. triangularis* (Bender, 1970), *T. symmetricus* (Orchard, 1995), *Gladigondolella* sp. and elements of the apparatuses of *Ellisonia triassica* Muller, 1956, *E. gradata* Sweet, 1970 and *E. delicatula* Sweet, 1970 (Fig. 14, Tab. 4; Pl. 2). In section Burzan 2, sample BZ B1 yielded *Triassospathodus curtatus* (Orchard, 1995) and *T. homeri* (Bender, 1970).

The recovered species are very useful and favourable for correlations. Taking into account the standard conodont biozonation by Sweet et al. (1971) correlated with ammonoid zones of Silberling & Tozer (1968) and considering Sweet (1970) and Orchard (1995) the following remarks can be done:

The conodont fauna from the lower portion of the Burzan section characterized by *Triassospathodus brocus* (Orchard, 1995), *T. abruptus* (Orchard, 1995) and *T. homeri* (Bender, 1970) (samples BZ4-BZ8bis) is referable to the uppermost portion of the conodont fauna 2 of Orchard (1995) and/or to the lowermost portion of his fauna 3, that correlates with the uppermost *Procolumbites* beds or lowermost *Prohungarites/Subcolumbites* beds. Following Sweet (1970), the fauna, on the presence of elements of the apparatuses of *Ellisonia delicatula* Sweet, 1970, may be refered to the lower portion of his Zone 8 (*Neogondolella jubata*).

From sample BZ18, on the occurrence of *Triassospathodus triangularis* (Bender, 1970) associated with *T. homeri*, *T. abruptus* and higher up (BZ21) with *T. symmetricus* (Orchard, 1995), and BZB1 with *T. homeri* and *T. curtatus*, the conodont fauna may be correlated with conodont fauna 3 (*Prohungarites/Subcolumbites* beds) of Orchard (1995), with the upper part of Zone 8 of Sweet (1970) and with Zones 11 and/or 12 of Sweet et al. (1971).

Conodont fauna 2 and 3 by Orchard (1995) are referred to a mid Spathian age and are correlable with coeval beds from Oman, Greece, China, Japan, Pakistan, western North America, southern Italy.

Zone 8 of Sweet (1970) may be assigned to the upper Spathian of Salt Range and Trans-Indus Ranges, West Pakistan.

Zones 11/12 of Sweet et al. (1971) are considered mid- upper Spathian of Salt Range and Trans-Indus Ranges, West Pakistan, Greece and western North America.

On the basis of more recent papers concerning conodont zoning by Chen et al. (2015) and Kolar-Jurkovšek et al. (2015, 2017) the conodont fauna from Burzan section can be also correlated to the mid Spathian of South China and Slovenia.

Ammonoids. Four ammonoids have been collected from the top of the bed BZ8. The specimens are partly embedded in the mudstone matrix and range in size from about 15 to more than 150 mm in diameter. Two specimens are too small and too poorly preserved to be classified, while the two other specimens are suitable for classification (Pl. 3, figs 1-2). The largest one is a tirolitid and belongs to the group of *Tirolites rossicus* Kiparisova, 1947 and *T. armatus* Shevyrev, 1968, typical component of the Lower Triassic of Mangyshlak (west Kazakhstan: Shevyrev 1968; Gavrilova 1980, 1989, 2007; Balini et al. 2000; Zakharov & Popov 2007, 2014; Zakharov et al. 2008). The second specimen is a kashmiritid very close to the kashmiritids from Mangyshlak (e.g., Shevyrev 1968).

The occurrence of ammonoids in carbonate platform facies is uncommon. This occurrence is also a great significance for palaeobiogeographic reconstruction of the southern Laurasia, therefore we provide here the full taxonomic description of these specimens. Comparison of the large sized *Tirolites* with topotypic material of *T. armatus* and *T. rossicus* (e.g., Shevyrev 1968; Balini et al. 2000) leads to the separation of this group of large- sized, strongly-ornamented, double-noded tirolitids as the new genus *Megatirolites* (see the Systematic description chapter). The *Megatirolites* from Sefid-Kuh Limestone is left in open specific attribution because its inner whorls, crucial for the classification of the species, are covered by extremely hard limestone matrix (see the

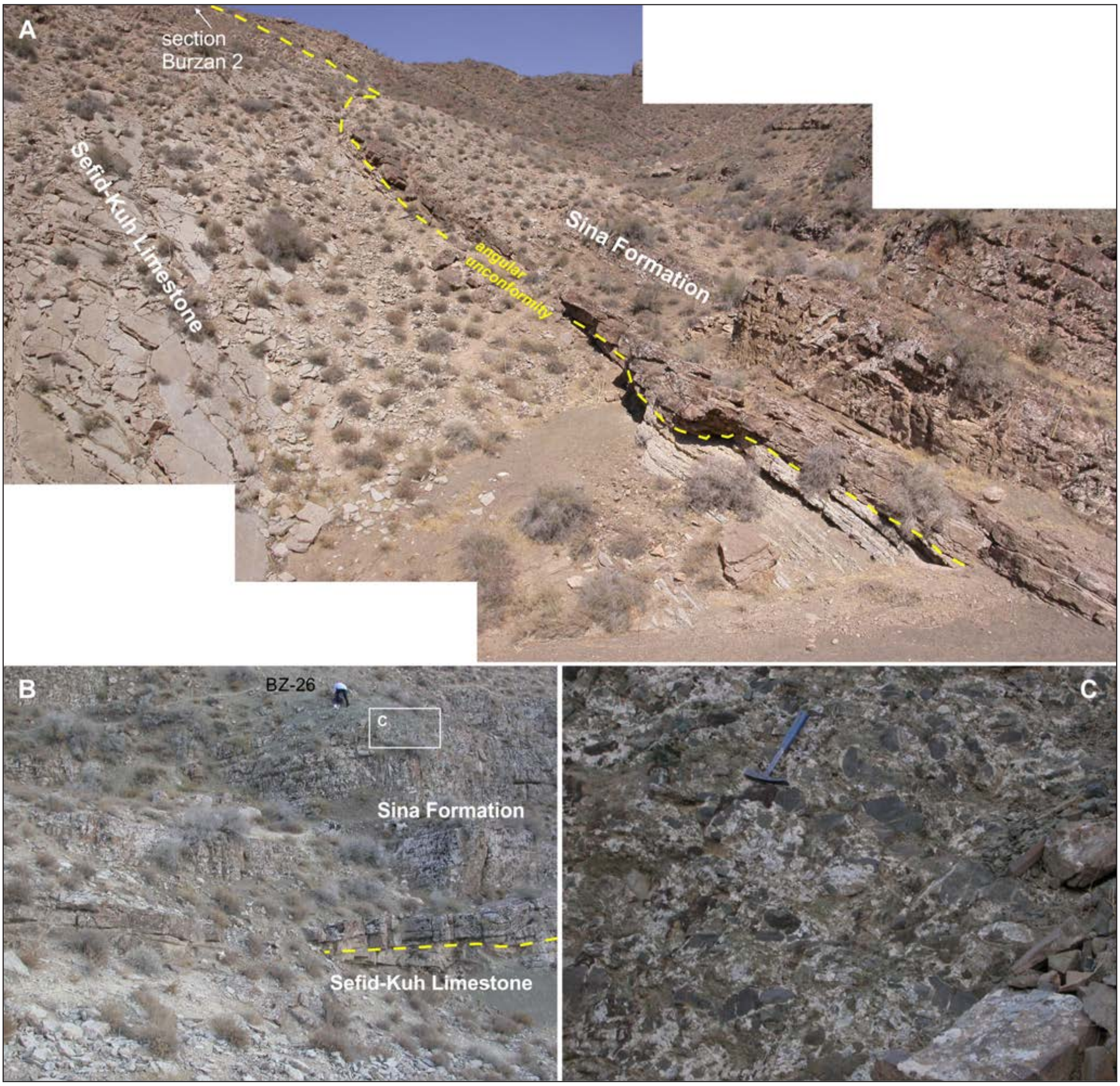

Fig. 13 - The upper part of Sefid-Kuh Limestone and the lower part of the Sina formation at Burzan. A)View of the angular unconformity, with the Burzan 2 section in the backround. B) The lower sandy part of the Sina Formation at Burzan section, with the position of the conglomerate lens (white box) and of the sample BZ26 yielding *Daonella* cf. *lommeli* (Wissmann, 1841). C) Detail of the conglomerate lens.

Systematic description).

The kashmiritid is here classified as *Kashmirites* ? cf. *popowi* Shevyrev, 1968. The reasons for the open nomenclature at both generic and specific level are given in the Systematic description.

Sina Formation

Lithofacies. At Burzan and Burzan 2 sections the lithofacies of the lower part of the Sina Formation is totally different from the one that is documented at Sefid Kuh. In the Sefid Kuh area, the lowermost part of the formation consists of conglomerates, while at Burzan sections the lowermost part of Sina Formation consists of 50-100 cm thick beds of green sandstones and sandy limestones, occasionally bioclastic and fossiliferous. Only one conglomerate lens occurs about 7 m above the base of the unit at Burzan section (Figs 13B-C, 14). The pebbles of this lens, however, are made of green sandstones to siltstones (Fig. 13C), therefore this lens is interpreted as intraformational conglomerate resulting from the erosion of the Sina Formation.

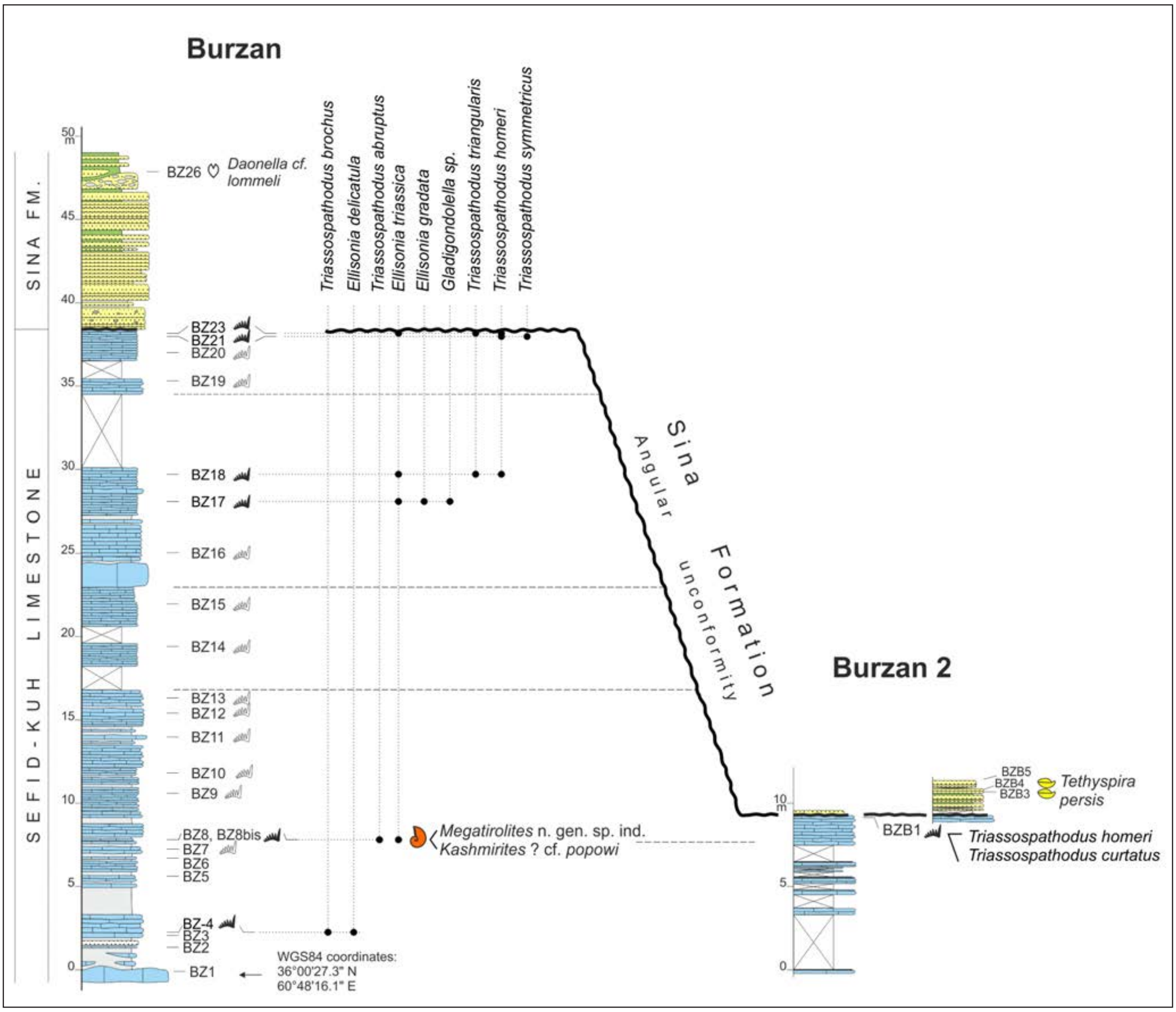

Fig. 14 - Burzan sections, with distribution of conodonts, ammonoids, brachiopods and bivalves. Burzan 2 is located about 400 m NE from Burzan, the main section. For the key of the logs see Fig. 9.

Fossils. The lowermost beds of the Sina Formation at section Burzan 2 are quite rich in fossils. Most of them consist of brachiopods and bivalves, flattened or as negative imprints, preserved on the top surface of the beds. Three-dimensional specimens can be found within these beds. The most common brachiopod is *Tethyspira persis* Siblik, 1991, usually documented by disarticulated valves (Pl. 3, fig. 3). Some fragments of strongly ribbed Spiriferida have also been collected. The bivalve *Daonella* cf. *lommeli* (Wissmann, 1841) (Pl. 3, fig. 4) has been collected at Burzan section, about 8 m above the base of the Sina Formation (Figs 13B, 14). This specimen is poorly preserved, but shows the secondary subdivision of the wide and flat ribs, that is typical of *Daonella lommeli* (Wissmann, 1841), a tethyan daonellid usually regarded as marker for the Late Ladinian. *D. lommeli* was already reported from Aghdarband by Ruttner (1991) and Krystyn & Tatzreiter (1991) from the "Daonella beds", an interval including the upper third of the Sandstone Member, the Faqir Marl bed, and the base of the Shale Member of the Sina Formatrion (Krystyn & Tatzreiter 1991, p. 143).

Systematic descriptions of the Lower Triassic ammonoids from Sefid-Kuh Limestone (MB)

The family-group taxonomy of the Olenekian ammonoids has not yet been revised. The taxonomic setting of Xenoceltitidae is taken from Tozer

(1994). Tirolitidae have been regarded as family by Guex et al. (2010), Jenks et al. (2013), Shigeta et al. (2014) and Ji et al. (2015).

Repository of specimens: Museo di Palaeontologia, Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, Via Mangiagalli 34, 20133 Milano, Italy.

Numbering of the specimens: the specimens are identified by their museum number (acronym MPUM), with the sample number in brackets.

Order **Ceratitida** Hyatt, 1884
Superfamily Xenodiscoidea Frech, 1902
Family Xenoceltitidae Spath, 1930
Genus *Kashmirites* Diener, 1913
Type species: *Celtites armatus* Waagen, 1895

Kashmirites ? cf. ***popowi*** Shevyrev, 1968
Pl. 3, Fig. 2a-b

Material: one specimen MPUM 11368 (BZ8-2).

Description. The slightly deformed specimen, retaining the test, is preserved as half whorl. Its coiling is slightly involute and the whorl section is compressed and subrectangular.

Ornamentation consists of rather dense primary rectiradiate ribs, nearly straight until the outer part of the flank, where they bend forward.

The ventral side is slightly worn, but some ribs and inter-rib furrows seem to continue on this side.

Suture line not visible.

Discussion. The specimen is similar to *Kashmirites popowi* Shevyrev, 1968 in the dense ribbing on the flank. The ribs seem to cross the venter, even if they are wider, as in *K. popowi*. However, the only specimen of *K. popowi* thus far described exhibits a slightly depressed whorl section, then the specimen from Burzan section is attributed to *K. popowi* by *confronta*.

At generic level, the kashmiritids from Mangyshlak, which include also *K. popowi*, would require a revision. However, such a revision is beyond the purpose of this paper, then I prefer to use the original generic assignment originally proposed by Shevyrev.

After Shevryrev, the kashmiritids from Mangyshlak have been referred by Gavrilova (1980), Zakharov et al. (2008) and Zakharov & Popov (2014) to *Eukashmirites* Kummel, 1969. This genus was erected by Kummel (1969) in order to accommodate some species from Timor and Kashmir (*K. acutangulatus* Welter, 1922 and *K. blaschkei* Diener, 1913), but Kummel included also taxa from Mansgyshlak (*E. subdimorphus* [Kiparisova, 1947] and *E. contortus* [Astachova, 1960]). The taxonomy of the group is complex, with similarities or even full synonymy with *Pseudoceltites* Hyatt, 1900 (e.g., Tozer 1981). Brayard et al. (2009) refer the genus to the Smithian, perhaps following Tozer (1981), while in other papers the genus *Eukashmirites* is referred to the upper Olenekian or equivalent beds (e.g., Ehiro et al. 2006; Zakharov et al. 2008; Zakharov & Popov 2014).

Occurrence. The specimen was found in the same level of Burzan section that yielded *Megatirolites* n. gen. sp. ind. This co-occurrence suggests an age equivalent to that of the *Procolumbites* beds *sensu* Balini et al. (2000) and Gavrilova & Snigirevskaya (2018) (=*Columbites* beds of Shevyrev 1968) of Mangyshlak.

Superfamily Dinaritatoidea Mojsisovics, 1882
Family Tirolitidae Mojsisovics, 1882
Subfamily Tirolitinae Mojsisovics, 1882
Genus *Megatirolites* n. gen.
Type species: *Tirolites rossicus* Kiparisova, 1947

Etymology: From the prefix *Mega* (from Greek μέγας: large) and *Tirolites*. The name emphasizes the large size of the mature specimens of the new genus.

Diagnosis: Very large-sized (diameter up to 200 mm) Tirolitinae with subquadrate whorl section and relatively large umbilicus. The coiling is slightly involute (H/U usually from 1.01 to 1.39; rarely <1: *fide* Shevyrev 1968: p. 160, 162) with H/W between 0.9 to 1.08 (ibid). The whorls may overlap or be tangent, depending on the species. Ornamentation consisting of radial, widely-spaced primary ribs, each one ending at the shoulder with a with ventrolateral hollow spine. Outer whorl characterized by large sized rounded umbilical tubercles, each one at the beginning of a rib.

The pointed and long ventrolateral hollow spines are recognizable only on specimens with test. The spines are hollow, then they are not visible on the internal mold which exhibits instead large rounded tubercles.

Very simple ceratitic suture line with two broad saddles on the flank. Extremely weak indentations of the lobes.

Composition of the genus: *Tirolites rossicus* Kiparisova, 1947, *T. armatus* Shevyrev, 1968, and *Megatirolites* sp. ind. (this work).

Comparisons. *Megatirolites* n. gen. is distinguished by all the other known Tirolitinae for the combination of very large size, thick whorl section and the strong ornamentation, with two rows of nodes at least on the outer whorl. Most of the Tirolitinae do not reach the diameter of 10 cm, and in all of them there is only one row of nodes/spines in ventrolateral position. *Tirolites* Mojsisovics 1879, type of the subfamily, is also notably compressed as reported in the old literature (e.g., Hauer 1866; Mojsisovics 1882; Kittl 1903) and confirmed by Kummel (1969) and Posenato (1992).

Remarks on the composition of the genus. The reference paper for the taxonomy of *T. rossicus* Kiparisova, 1947 and *T. armatus* Shevyrev, 1968, is Shevyrev (1968), who studied a large collection of 316 specimens from Mangyshlak, the type area of *T. rossicus*. The descriptions by Shevryrev are unfortunately focused on reconstruction of the ontogeny, starting from the first chamber, and do not provide information on population variability. This variability cannot be understood from the figured specimens because only two specimens for each species have been included in the plates. Shevyrev (1968, p. 163) reports three differences between his new species *T. armatus* and *T. rossicus* Kiparisova: the overlapping whorls, the angular ventral margin and the rough ornamentation. The whorls overlapping for about ¼ of H (see Shevyrev 1968: fig. 49c and 51) look to be the best diagnostic feature for *T. armatus*. The angular shoulder does not seem to be so different in the two species (op. cit.), and the significance of the rough ornamentation is questioned by the population variability of bed-by-bed collected topotypes, whose preliminary report was given by Balini et al. (2000). Large sized *T. rossicus* with non overlapping whorls may show an ornamentation as rough as that of the illustrated types of *T. armatus*.

Occurrence. *Megatirolites rossicus* (Kiparisova, 1947) and *M. armatus* (Shevyrev, 1968) are known from the Lower Triassic Tartaly Formation of Mangyshlak, west Kazakhstan (Kiparisova 1947; Shevyrev 1968; Balini et al. 2000). *Megatirolites* occurs also in Lower Triassic Sefid-Kuh Limestone of Aghdarband, Kopeh-Dag, northeastern Iran (this work).

Age. Early Triassic, Olenekian (middle Spathian) *Procolumbites* beds sensu Balini et al. (2000) and Gavrilova & Snigirevskaya (2018). The age of *Megatirolites* is also calibrated by conodonts. In Mangyshlak Balini et al. (2000) reported from the *Procolumbites* beds the conodonts *Neogondolella dolnapae*, *Neospathodus homeri*, *N. abruptus* and *N. symmetricus*.

Megatirolites n. gen. sp. ind.

Pl. 3, Fig. 1a-b

Material: One specimen MPUM 11371 (BZ8-1).

Description. The specimen is included in hard limestone. One side and most of the venter have been exposed by preparation. The specimen consists of the final part of the phragmocone and 90° of the body chamber. The inner whorls are not exposed. The test is preserved, but it has been removed during the preparation of the specimen.

The ornamentation consists of primary ribs, connecting umbilical tubercles with ventrolateral hollow spines. At least one of the ribs seem to show a sort of very weak loop at ventrolateral spine. This feature is not visible on the very few *Megatirolites,* from Mangyshlak illustrated in literature, but it is visible only on the internal mold of the specimen from Burzan.

The suture line is ceratitic, with two very broad saddles on the flank and very weakly indentations of the 1st lateral lobe.

Remarks. The specimen is attributed to *Megatirolites* n. gen. on account of its large size, thick whorl, ornamentation with umbilical nodes and ventrolateral spines, and suture line. It is left in open nomenclature because the inner whorls are not visible and overlap of the outer whorl on the inner one, the most significant diagnostic feature allowing for the separation of *M. rossicus* from *M. armatus*, is not visible (for discussion see the Remarks on the composition of the genus).

Occurrence. Aghdarband, NE Iran, Sefid-Kuh Limestone, Burzan section, level BZ8. The specimen co-occur with *Kashmirites* cf. *popowi* Shevyrev, 1968.

Discussion

Our research based on high resolution field works and quite large data collection allows for a significant improvement of the local stratigraphy of the Aghdarband Basin, provides additional constraints to the evolution of the basin and at a wider palaeogeographic scale, it suggests a new reconstruction of the palaeobiogeography of the southern Laurasia margin during the end of the evolution of the Palaeotethys.

The Olenekian to Early Ladinian evolution of the Aghdarband Basin

The general evolution of the Aghdarband Basin has been outlined by Zanchi et al. (2016), who located this basin North of the Permian Fariman Basin (Zanchetta et al. 2013), both in a back arc setting and in the frame of an extensional-transtensional tectonic regime (Zanchi et al. 2016: fig. 19 and 20).

Our new data add some further constraints to this reconstruction. The Olenekian to Middle Anisian evolution of the basin, documented in the tectonic unit 2, shows a three-stage development of the Sefid-Kuh carbonate platform, from the Olenekian to the Middle Anisian, not only two stages as reported by Zanchi et al. (2016: fig. 4). These three stages (Sefid-Kuh 1, Sefid-Kuh 2 and Sefid-Kuh 3 members) are separated by two drowning events, each one marked by onset of siliciclastic sedimentation. The comparison with the evolution of tectonic unit 1 described by Zanchi et al. (2016) suggests an higher subsidence for tectonic unit 1, based on the greater thickness of the Sefid-Kuh 1 and 2, and of the siliciclastics of the lower part of Sefid-Kuh 2 member. It also suggests a provenance of the siliciclastics from the present day North. We also confirm that the drowning events were tectonically controlled, because of the lack of transitional facies such as nodular limestones, between the uppermost Sefid-Kuh 1 and the lowermost Sefid-Kuh 2 members (e.g., section SKU E) and the uppermost Sefid-Kuh 2 member-lowermost Nazar-Kardeh Formation (e.g., section SKU B). After the drowning event 2, the sedimentation persisted in a moderately deep basin setting with the deposition of the Nazar-Kardeh Formation, but locally after relatively short time (e.g., section SKU D) the carbonate platform deposition was re-established, with the sedimentation of the limestones of the Sefid-Kuh 3 member.

The Sefid-Kuh Limestone documented in the study area 2, at Burzan, is undifferentiated, therefore its correlation with the succession of the study area 1 is open. Mudstones and wackestones quite common in the 39 m of the Sefid-Kuh Limestone at Burzan section, have not been so far reported from the Sefid-Kuh 2 member, while they have been reported by Baud et al. (1991a) from the succession now assigned to the Sefid-Kuh 1 member. This lithological similarity, however, does not necessarily implies a time-correlation, being the shallow water environments of carbonate platforms well known to be subject to quick changes of facies in both space and time.

The transgression of the Sina Formation on the Nazar-Kardeh Formation or on the Sefid-Kuh Limestone is documented by quite different facies in the study area 1 and 2. These facies, however, are consistent with the sealing of a complex morphology resulting from tilting and erosion of the Nazar-Kardeh Formation and Sefid-Kuh Limestone. The conglomerates (e.g., SKU B and SKU D sections) were deposited in the depressions, while the sandstones/sandy limestones (Burzan/Burzan 2 sections) were deposited on the side or even higher part of the substrate. The occurrence of *Daonella* cf. *lommeli* (Wissmann, 1841) few meters above the basal unconformity of the Sina Formation at Burzan is the best evidence of a rather young age of the Sina Fm. in this locality.

These geometrical relationships are strikingly preserved also out of the study area, in the surroundings of the locality Agh37 of Ruttner (1991) in the Kal-e-Anabeh, tectonic unit 3 (eastern part of the Aghdarband window).

Palaeogeographic significance of the ammonoids and conodonts from the Sefid-Kuh Limestone

The discovery of Olenekian ammonoids from a condont-bearing, well-dated section at Burzan, provides the opportunity to discuss the palaeogeographic affinity of both ammonoids and conodonts.

Ammonoids

The ammonoids from sample BZ8 belong to taxa thus far known only from Mangyshlak. The occurrence in the Aghdarband Basin of the group of *Tirolites rossicus* (Kiparisova, 1947) and *T. armatus* Shevyrev, 1968, here assigned to the new genus *Megatirolites*, is of great significance, for both the palaeobiogeography of tirolitids and the palaeobiogeography of the southern Laurasia margin.

Tirolites Mojsisovics, 1879 is a Spathian (late Olenekian) genus with a mid palaeolatitude worldwide distribution and complex intra- and interspecific variations, resulting in high number of species whose classification is sometimes quite subjective. This genus is surely documented in North America (northwestern US) and the Tethys Realm. Within the Tethys, the genus is known from several tens of fossiliferous localities pertaining to the Western Tethys (e.g., Southern Alps, Dinarids, Carpathians, Greece), the southern Laurasia/ Palaeotethys (e.g., northern South China block, Mongolia, North Vietnam, South Prymorie in the NE Russia, Japan), and perhaps some Cimmerian blocks, even if the palaeogeographic attribution of some sites (e.g., Nakhlak, Central Iran) is a matter of debate (e.g., Bagheri & Stampfli 2008; Zanchi et al. 2016). On the contrary, only few specimens, often poorly preserved and incomplete, have been reported from the northern Gondwana margin (e.g., Salt Range: Guex 1978); therefore the occurrence of *Tirolites* in the Neotethys has still to be confirmed.

In this general framework, the palaeogeographic distribution of *Megatirolites* is intriguing, because it is limited to the peri-caspian basin, an epicontinental basin extending into the Russian platform at least up to the Mount Bogdo and Donbass regions, which was connected to the Palaeotethys ocean to the West (Fig. 15, see also the Early Olenekian map in Dercourt et al. 2000 and Blakey 2008; Barrier et al., 2018). On the other hand, the occurrence of *Megatirolites* and *Kashmirites* ? cf. *popowi* also demonstrates that the peri-Caspian basin was connected to the East with the Aghdarband Basin

Conodonts

The Burzan section yielded quite rich mid Spathian conodont faunas, mostly consisting of representatives of the Gondolellidae (*Triassospathodus*) and Ellisoniidae (*Ellisonia* and *Gladigondolella*) (Pl. 2, Tab. 4).

The comparison of these faunas with faunas from Mangyshlak and West Kazakhstan (Balini et al. 2000) documented in the same beds yielding *Megatirolites*, and Nakhlak, Central Iran (Balini et al. 2009) allows the following considerations:

− in Mangyshlak, Dolnapa section, conodont fauna 2 and 3, related to *Procolumbites* beds, are characterized by the same *Triassospathodus* species found in the Burzan sections and by a very rich neogondolellid fauna (*Neogondolella dolnapae* Balini, Gavrilova & Nicora, 2000; *N. jubata* Sweet, 1970; *Neogondolella* sp. A; *N.* sp. B; *N.* sp. C) that is totally absent in the Burzan sections. The lack of neogondolellids at Burzan is not related to a different palaeobiogeographic setting, but it might be explained as due to a different depositional environment. *Neogondolella* is a typical component of relatively deep environments; therefore, the absence of this group of conodonts at Burzan, in the shallow water carbonates of the Sefid-Kuh Limestones is consistent with the palaeoecology of this group.

− At Nakhlak, section 2, the conodonts found (Balini et al. 2009) are quite poor and represented only by few fragments of *Neospathodus* (= *Triassospathodus*) sp. thus no significant discussion on palaeobiogeographic/palaeoecologic affinity is possible.

Palaeobiogeographic correlation with Nakhlak

The discovery of Olenekian ammonoid within the Sefid-Kuh Limestone at Burzan, provides the additional opportunity to compare the Lower Triassic of the Aghradband Basin with the one of Nakhlak, which is presently located within Central Iran, and with Mangyshlak. This comparision confirms the faunal analysis of Balini et al. (2009: p. 297).

The Alam Formation at Nakhlak is quite rich in Lower Triassic ammonoids (Davoudzadeh & Seyed-Emami 1972; Tozer 1972; Balini et al. 2009). The fauna is dominated by *Albanites*, over much rarer *Columbites*, *Subcolumbites*, *Tirolites*, *Stacheites* and *Procolombites*. The *Albanites* from Nakhlak, however, are not conspecific with those from Maghyshlak described by Shevyrev (1968), while they are conspecific with those from tethyan localities such as Kçira in Albania (Arthaber 1908, 1911; Germani 1997) and Chios (Renz & Renz 1948; Mertmann & Jacobshagen 2003). A similar taxonomical affinity is shown by *Columbites* and *Subcolumbites*, while the species of *Procolumbites* and *Stacheites* are the same in the Tethys and Mangyshlak. The *Tirolites* from Naklhak are documented by small to medium size specimens, that do not show features of *Megatirolites*, by far the most common genus of the Magyshlak faunas (e.g., Shevyrev 1968).

Thus far no ammonoids peculiar of the Mangyshlak fauna have been found at Nakhlak, while they occur (*Megatirolites* n. gen.) at Aghdarband. Such a faunal difference is not consistent with a location of Nakhlak close to Aghdarband, at least during the Olenekian, as postulated recently by Azizi et al. (2018).

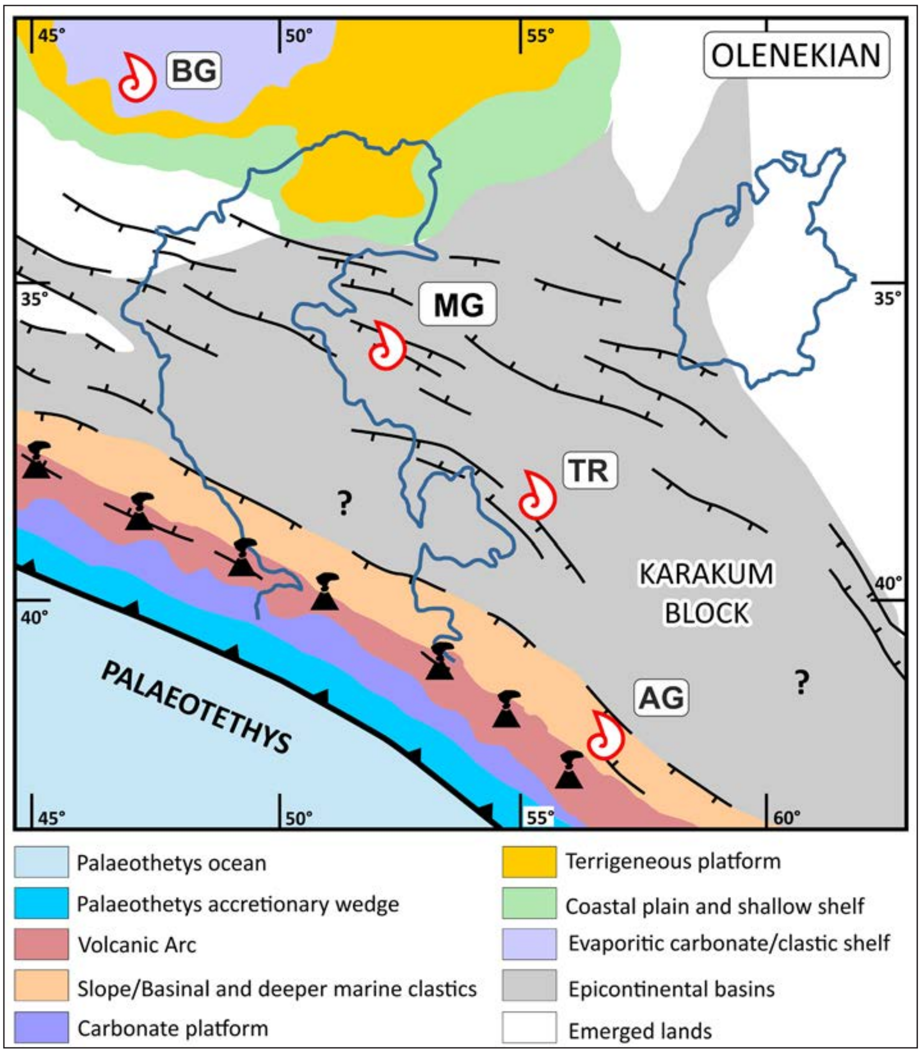

Fig. 15 - Temptative reconstruction of the palaeogeography of the Southern Eurasia margin during the Olenekian, when subduction of the Palaeotethys ocean was still active. The white-red ammonoids indicate the occurrence of ammonoid faunas crucial for correlation. The *Dorikranites* fauna, marker of the *Dorikranites* beds *sensu* Balini et al. (2000) is documented at Mount Bogdo (BG), Mangyshlak (MG) and Tuarkyr (TR). The younger fauna with *Megatirolites*, marker of the *Procolumbites* beds *sensu* Balini et al. (2000) is documented at Mangyshlak (MG) and Aghdarband (AG). Palaeogeography slightly modified from Garzanti & Gaetani (2002) and Barrier et al. (2018).

Conclusions

The revision of the Olenekian to Ladinian stratigraphy of the western part of the Aghdarband window, based on the collection of high resolution field data, and the study of several macro- and microfossils samples collected bed-by-bed, lead to a number of results, here summarized:

– The lithostratigraphy is revised, the age of some units is constrained with conodonts and ammonoids. A new intra-Olenekian unconformity has been identified and the basal unconformity of the Sina Formation is described at three sites (SKU B, SKU D and Burzan).

– The evolution of the Olenekian carbonate ramp of the Sefid-Kuh Limestone is more complex than reported in literature. This development is not limited to a single stage, as reported by Baud et al. (1991a), but shows three stages (Sefid-Kuh 1, 2 and 3 members) separated by drowning and onset of siliciclastic sediments. The third stage (Sefid-Kuh 3 member) is Middle Anisian in age and is in part coeval with the basinal Nazarkardeh Formation.

– The unconformity-bounded, three-stage development of the carbonate ramp documents that in the Aghdarband Basin the tectonic control over sedimentation started already in the Olenekian, since the onset of the marine transgression.

– The transgression of the Ladinian Sina Formation sealed a complex morphology resulting from the tilting and erosion of the Middle Anisian units. The conglomerate facies were deposited in the depressions, while the sandstones/sandy limestone sealed the elevations.

– The most important results from our study concern the reconstruction of the palaeogeographic position of the Triassic Aghdarband basin. Based on the palaeobiogeographic distribution of the new Olenekian ammonoid genus *Megatirolites*, here described, we confirm Zanchi et al. (2016) that the Aghdarband basin was located in a back-arc position in a tectonically active setting dominated by an extensional to transtensional regime. The basin was closely related with the Tuarkyr (Turkmenistan) and Mangyshlak (West Kazakhstan) regions, which were also characterized by marine sedimentation in an extensional setting (Barrier et al. 2018). All these basins were in connection with a large epicontinental sea which extended at least up to the margin of the Donbass area (Fig. 15).

– The different faunal associations found in the Olenekian at Aghdarband suggest that the basin had no direct connection with the Nakhlak basin, which was proably located in a different intra-arc or more probably fore-arc region with respect to the Palaeotethys subduction-related Triassic arc.

Acknowledgements: Field works were carried out in 2005, 2007, 2008, 2009 and 2016 always in cooperation with the Geological Survey of Iran. M. Ghassemi, at that time head of Geology Department of GSI, and J. Taheri, head of the Mashhad branch of GSI, are here warmly thanked for their encouragement and very friendly support during field activities. N. Naimi (GSI, Mashad) helped with the collection of macrofossils. We are indebted with the company Maaden Khavar for providing hospitality at the Aghdarband Coal mine during our field works. We warmly thanks in particular the head of the mine during the 2000s, Arash Tahmasebi, and Mr. Mahmudi for the very friendly assistance. The manuscript has been improved by the accurate review and suggestions provided by Marie-Françoise Brunet (Paris) and Piero Gianolla (Ferrara). Warm thanks to the Editor F. Berra and the technical editor C. Lombardo for the fast and careful support. Financial support for field works was provided by PRIN 2004 grant to A. Zanchi (Milano-Bicocca University) and by a DARIUS Programme grant (2010) to M Balini.

Plate 1

Olenekian to Middle Anisian conodonts from Sefid Kuh area.
Fig. 1 a,b,c - *Gladigondolella malayensis budurovi* Kovacs & Kozur,1980; sample SKUB 9.
Fig. 2 a,b,c - *Neogondolella regale* Mosher, 1970; sample SKUB 13.
Fig. 3 a,b,c - *Neogondolella regale* Mosher,1970; sample SKUB 13.
Fig. 4 a,b,c - *Neogondolella regale* Mosher,1970; sample SKUB 13.
Fig. 5 b,c - *Paragondolella bulgarica* Budurov & Stefanov, 1975; sample SKUD 5.
Fig. 6 a,b,c - transition *N. regale/ P. bulgarica*; sample SKUD 7.
Fig. 7 b,c - *Paragondolella bulgarica* Budurov & Stefanov, 1975; sample SKUD 7.
Fig. 8 a,b,c - *Triassospathodus symmetricus* Orchard, 1995; sample SK 1.
Fig. 9 a,b,c - *Triassospathodus triangularis* (Bender,1970); sample SK 2.
a = upper view; b = lateral view; c = lower view.
Scale bar = 200 µm.

Plate 2

Olenekian conodonts from Burzan section.
Fig. 1 b,c - *Triassospathodus abruptus* Orchard,1995: juvenile onthogenetic stage; sample BZ8bis.
Fig. 2 b,c - *Triassospathodus abruptus* Orchard,1995: sample BZ8bis.
Fig. 3 b,c - *Triassospathodus brocus* Orchard,1995: sample BZ4.
Fig. 4 b,c - *Triassospathodus triangularis* Bender,1970: sample BZ18.
Fig. 5 b,c - *Triassospathodus triangularis* Bender,1970: sample BZ18.
Fig. 6 a,b,c - *Triassospathodus triangularis* Bender,1970: sample BZ23.
Fig. 7 b,c - *Triassospathodus homeri* Bender,1970: sample BZ21.
Fig. 8 b,c - *Triassospathodus homeri* Bender,1970: sample BZ23.
Fig. 9 a,b,c - *Triassospathodus symmetricus* Orchard,1995: medium onthogenethic stage; sample BZ23.
Fig. 10 b,c - *Triassospathodus symmetricus* Orchard,1995: medium onthogenethic stage; sample BZ23.
a = upper view; b = lateral view; c = lower view.
Scale bar = 200 µm.

Plate 3

Fossil invertebrates from Burzan sections.
Fig. 1 - *Megatirolites* n. gen. sp. indet. specimen MPUM 11371 (BZ8-1), Olenekian, Sefid-Kuh Limestone, Burzan section: a) lateral view, b) ventral view.
Fig. 2 - *Kashmirites* ? cf. *popovi* Shevyrev, 1968, specimen MPUM 11368 (BZ8-2), Olenekian, Sefid-Kuh Limestone, Burzan section: a) lateral view, b) ventral view.
Fig. 3 - *Tethyspira persis* Siblik, 1991, two disarticulated ventral valves rotated of 180° and the deposited with opposite convexity: one convex up and one convex down MPUM 11840 (BZB3-1), Ladinian, Sina Formation, Burzan 2 section: a) view from a direction orthogonal from the commissure, b) umbonal view of the lower valve (x) of fig. 3a.
Fig. 4 - *Daonella* cf. *lommeli* (Wissmann, 1841), specimen MPUM 11843 (BZ26), Late Ladinian, Sina Formation, Burzan 2 section: a) internal mold, b) imprint.
All specimens withened with ammonium chloride. Asterisk marks the last suture line of phragmocone.
Scale bar = 10 mm.


1a
1b
1c
2a
2b
2c
3a
3b
3c
4a
4b
4c
5b
5c
6a
6b
6c
7b
7c
8a
8b
8c
9a
9b
9c

PLATE 1

Plate 2

PLATE 3

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