New Discoveries in the Neoproterozoic of Iran

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Introduction During late 2015 new discoveries of Neoproterozoic metazoans were made in the Bafq Region of Central Iran by a joint Iranian-Australian expedition, hosted by the Iranian Geological Survey and the International Geological Program Project IGCP587. Previous to the newly discovered material supposed Vendian/Ediacaran metazoans including *Permoria*, *Beltanella*, and forms similar to *Dickinsonia, Spriggina* and *Medusites* (Stocklin, 1968), a supposed medusiod - *Persimedusites chahgazensis* (Hahn & Pflug 1980) along with *Charnia* (Glaessner, 1984) had been reported, but not well documented (Fedonkin et al., 2007). The new material both questions the identity of the previously described material and adds new taxa to the list of late Precambrian metazoans previously reported, increasing the biodiversity for this region.

Pervious discoveries of Precambrian metazoans in Iran The first report of possible Neoproterozoic (Infracambrian) metazoan fossils from Iran was Stocklin (1968, 1972). He noted in 1968 that "the Infracambrian of North Iran has yielded stromatolites and other problematic fossils. In the lower part of the sequence, a distinct shale marker traceable from the Central Alborz to Azerbaijan contains abundant small dislike features which closely resemble *Permoria* sp. of the Precambrian-Cambrian Vindhyan "System" of India (Pascoe, 1959, p. 498, Pl. w) or *Beltanella gilesi* Sprigg (?) of the Upper Valdai series of the Russian platform, which is just below the Lower Cambrian Baltic Series…." Socklin continues "Another interesting fauna – containing forms closely resembling *Dickinsonia, Spriggina,* and *Medusites asteroides* of the upper Precambrian of Australia – recently was discovered by geologist of the Rio Tinto Company (personal comm.) in the "Rizu series"east of Yazd." [The identification of these Rio Tinto fossil finds was doubted later by Hamdi et al. (1989)] Stocklin (1968) also noted that there was a lead isotope age derived from a synsedimentary ore deposit in the "Rizu series" that contained these fossils with an age range of 595-760+/- 120 million years (Huckriede et al., 1962). The sequence in which these fossils were found, the Rizu Series, consists of cherty dolomites and acidic volcanic, and it is from this very sequence the new materials have been recovered recently.

Later Hahn and Pflug (1980) reported a new form which they named *Persimedusites chahgazensis*, assigning it to the Scyphozoa – the medusoids. This material was recovered from the late Precambrian Esfordi Formation that crops out at Chahgaz near Koushk. They allied it most closely to the gtenus Eulithota from the Late Jurassic of Germany. They noted importantly that another Ediacaran-aged form, also at that time thought to be a medusoid, *Rugoconites*, was distinct from *Persimedusites* in that the grooves (which appear as ridges on *Persimedusites*, which according to them was due to mirror-image preservation) had branched grooves rather than unbranched. We would further note the difference in these structures based on the new material that we have discovered demonstrates that such features in *Persimedusites* are incredibly regular, apparently strictly genetically controlled. It should also be pointed out that now, many of the fossils once interpreted to be medusoids from the Ediacaran, were indeed holdfasts for frond-like organisms and thus understanding of these circular structures has changed since the 1980's.

In the north of Iran, Hamdi et al.,(1989) reported the presence in the Lower Dolomite Member of the Soltanieh Formation a series of phosphatic tubes of Hyolithellus and other forms resembling Rugatotheca, fragments of a protoconodont *Protohertzina*, and possible primitive ?monoplacophorans. This unit in some places lies directly on the Kahar Formation, which has been assigned to the late Neoproterozoic by contained acritarchs (see F. E. Seger, unpublished PhD. Thesis, ETH, Zurich, 1977 – which needs to be re-evaluted and published!). Upsection, the Middle Dolomite Member in this sequence hosts well preserved small shelly fossils [at Dalir] and also contains tubes of *Hyolithellus, Cambrotubulus* and protoconodonts, typical of the Tommotian Stage. Hamdi et al. (1989) further note a similar bistratigraphic and lithological setting of the Soltanieh Formation to similar ones in China, India, Pakistan and Kazakhstan – noting the presences of phosphorites, which are characterized by strong negative carbon isotope anomalies – again suggestive of a Tommotian age for part of the sequence.

Geological setting of Central Iran The geology and especially the tectonic style of Iran is highly influenced by the development and history of the Tethyan region (Fig. 1). The tectonic events, which occurred around the Iranian Plate margins, are related to rifting processes of Gondwana and subsequent collision with the Arabian plate from the WSW. These important processes affected the Iranian Plate and the adjacent plates, such as the African, Indian, Arabian, and Eurasian Plates, during Mesozoic to Tertiary times (Alavi, 2004).

Located as a triangle in the middle of Iran, Central Iran is an important and complicated structural zones in this region. Rocks of all ages, from Precambrian to Quaternary, and several episodes of orogeny, metamorphism, and magmatism can be recognized. There is not yet a general consensus regarding the boundaries of Central Iran. According to Stocklin (1968), Central Iran is bordered in the north by the Elborz Mountains, the Lut Block in the east, and Sanandaj–Sirjan in the south-southwest, whereas Nabavi (1976) considers the northern part of the Lut block as part of Central Iran. Nogol-e-Sadat (1993) extends the frontiers to the northeast as well as Eastern Iran and presents new subzones in his classification. Based on tectono-sedimentary features, Aghanabati (2004) suggested that Central Iran and Sanandaj–Sirjan are all part of the central domain.

Precambrian in Central Iran

According to Hamdi (1985), the oldest rocks in Iran belong to the Koushk Series that crop out in the Bafq region consisting of clastics, acidic volcanics, tuffs and carbonates (mainly dolomite). Other formations of Late Precambrian–Early Cambrian age include the volcano-sedimentary Rizu Formation, and the Dezu and Tashk formations, the Aghda Limestone, the Kalmard Series, the Shorm Beds and the Anarak metamorphics (Ghorbani, M., 2013). Our study concentrated on the Koushk Series to the east of Bafq, specifically targetting the Koushk Mine and Chahmir, areas well detailed geologically by Rajabi et al., 2012. And these areas had produced relatively the best preserved fossil material in the past.

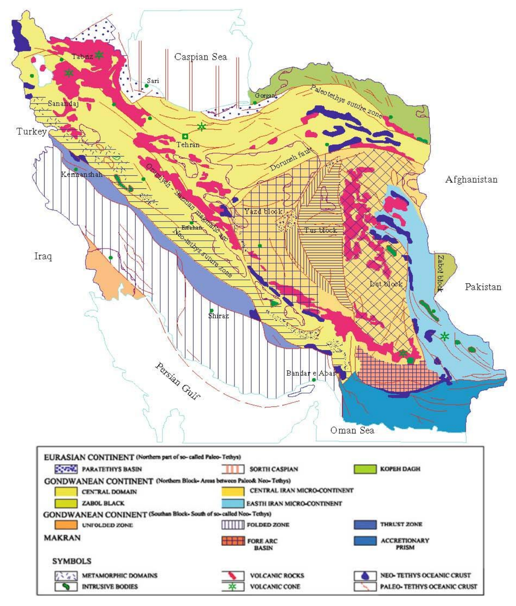


Fig.1 -Important tectono-sedimentary areas of Iran (Aghanabati, 2004)

Study area

The areas investigated in 2015 lie 48 km the Esfordi 1:100,000 map and Chahmir on Behabad 1:100,000 (Soheili and Mahdavi, 1991; Mahdavi, 1996).

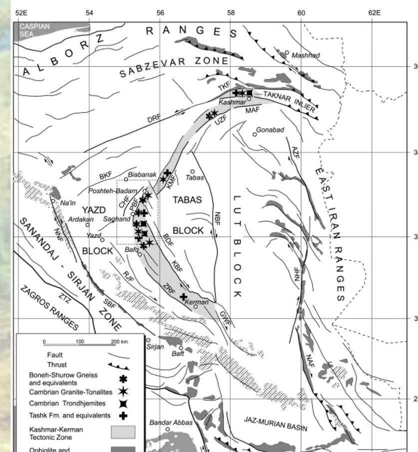


Fig. 2: Location of the study area (from Ramezani-Tucker, 2003)

Geological setting

The Bafq district lies in the central part of the Kashmar– Kerman structural zone (Ramezani and Tucker 2003), also known as the Posht-e-Badam Block (Alavi 1991), in the Central Iranian icrocontinent.
The opening of the Zarigan– Chahmir basin in the Posht-e-Badam Block took place when the Central Iranian Microcontinent broke up in the Late Neoproterozoic−Lower Cambrian, due to the back-arc rifting of the continental margin, which occurred coeval with the convergence of the Proto-Tethys along the continental margin.

The Zarigan–Chahmir basin is bounded by the Kuhbanan Fault to the east and the Posht-e-Badam Fault to the west (Figures 2). The basin is characterized by thick, fine-grained siliciclastic sediments and volcanics of the Lower Cambrian volcano-sedimentary sequence (LCVSS) and the rocks that are equivalent to the Rizu series or Esfordi Formation in the central part of the Zarigan–Chahmir lithotectonic domain (Figure 2). In the Zarigan–Chahmir basin, Precambrian rocks of the Tashk Formation disconformably overlie the late Neoproterozoic metamorphic rocks of the Boneh-Shurow basement complex (Foerster and Jafarzadeh 1994). The Tashk Formation is a 2000 m-thick, well-stratified sequence of weakly metamorphosed to unmetamorphosed, sedimentary, and volcanic/volcaniclastic rocks.

The overlying 1500−2000 m-thick the Lower Cambrian volcano-sedimentary sequence (LCVSS) consists of unmetamorphosed, interlayered, intermediate to felsic, volcanic rocks and sedimentary rocks, including micro-conglomerates, sandstones, volcaniclastics, pyritic black siltstones, shales, dolomitic limestones, and dolomites (Haghipour 1974; Rajabi 2008). Although the LCVSS and their stratigraphic equivalents throughout the Central Iranian Microcontinent have been traditionally assigned to the Precambrian (Huckriede et al. 1962), recent geochronological findings show that the volcanic rocks of the area date from the Lower Cambrian (528.2 + 0.8 Ma) (Ramezani and Tucker 2003). The LCVSS is unconformably overlain by Lower Cambrian red sandstones and conglomerates (Lalun/Dahu Fm.) in the Zarigan and Chahmir areas, as well as in the Bafq region (Foerster and Jafarzadeh 1994; Rajabi 2008).

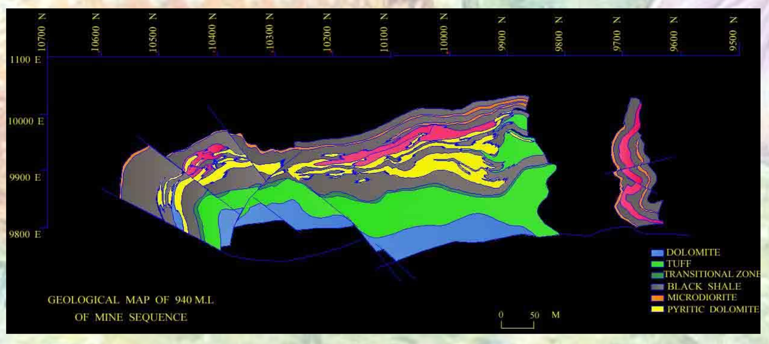
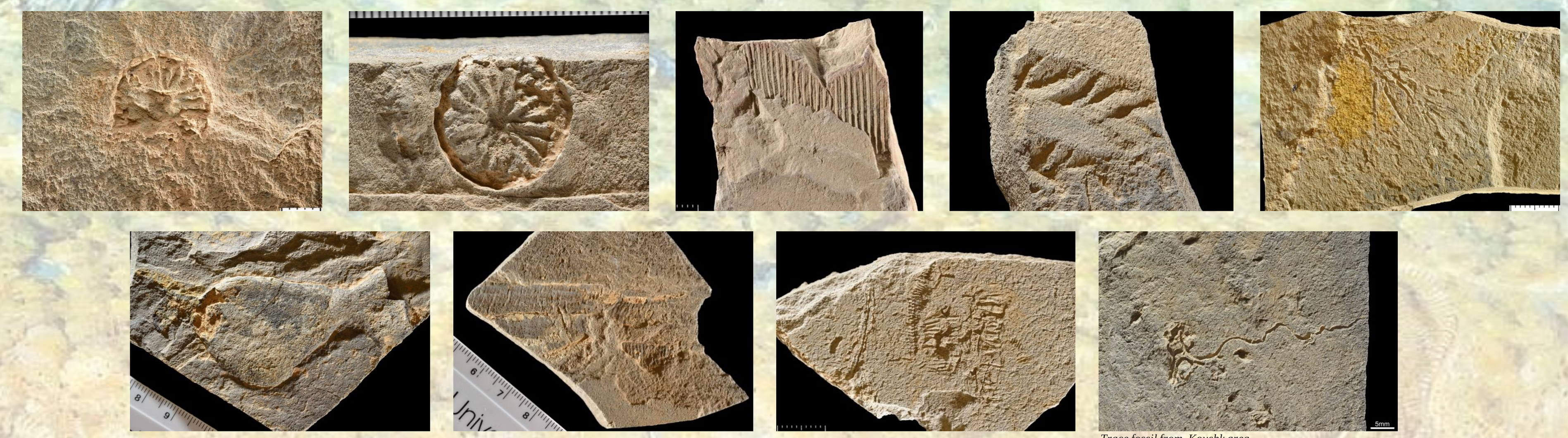


Fig. 7. Koushk Mine Sequence (prepared by Zand, 2015).

Fossils from the Koushk Mine Under Study – their affinities are still being considered.



Trace fossil from Koushk area.

Discussion

Stratigraphy and Paleontology in the study areas

I. Koushk area

The lithology of the study area consists of rhyodacites, rhyolites, dolomites, green tuffs, dark shales and acidic volcanic rocks (Fig. 3& 4).

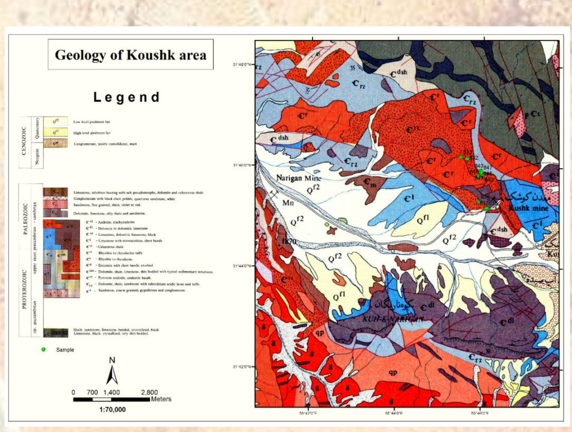


Fig. 3: Geological Map of Koushk area (after Geological Map of ESFORDI 1:100000 by Soheili and Mahdavi, 1991)

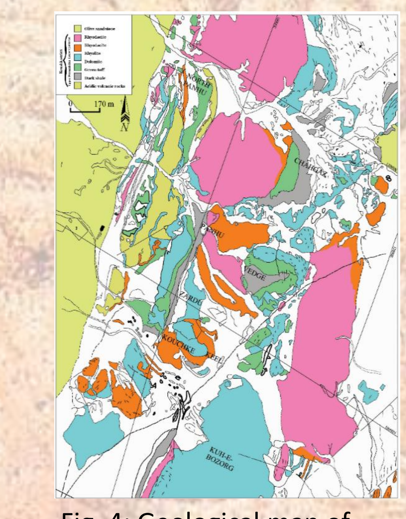


Fig. 4: Geological map of Koushk area (after Koushk mine documents)

The Wedge

Fig. 9. Field team at Koushk Mine and Chahmir area: Left, left to right – T. Rich, F.Farjandi, P. Vickers-Rich, S. Soleimani. Right, left to right, M. Zand, P. Vickers-Rich, T. Rich.

a. Dargazin Section

The thickness of the Dargazin section is about 31 meters. It hosts fossiliferous grey shales, altered green to yellow shales, black-grey shales with some massive sulfide minerals with pyritic intercalations, green to brown tuffs and overlain by dolomites (Fig. 5).

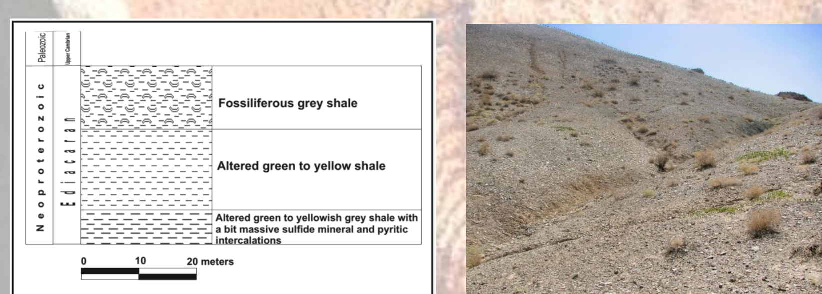


Fig. 5: Dargazin Section. (a) Stratigraphy and (b) outcrop which produced the newly discovered fossils.

b. Wedge Section

The Wedge section is about 146 meters thick and consists of of black-grey shales, fossil-bearing tuffaceous shales, dolomitic tuffs overlain by dolomites (Fig. 6).

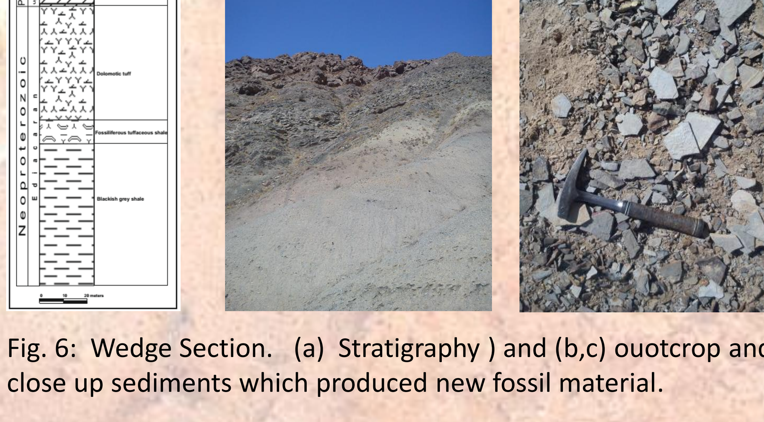


Fig. 6: Wedge Section. (a) Stratigraphy) and (b,c) ouotcrop and close up sediments which produced new fossil material.

II. Chahmir area

In the Chahmir study area, the sequence consists a fossiliferous yellow, tuffaceous shales and strong crushed carbonaceous shale, a highly tectonized sequence. There is little in the way of layering, makng it difficult to map any definite horizons in this sequence (Rajabi et al., 2008). Fossils designated as *Persimedusites* were also found here similar to those from the Koushk Mine – the Wedge.

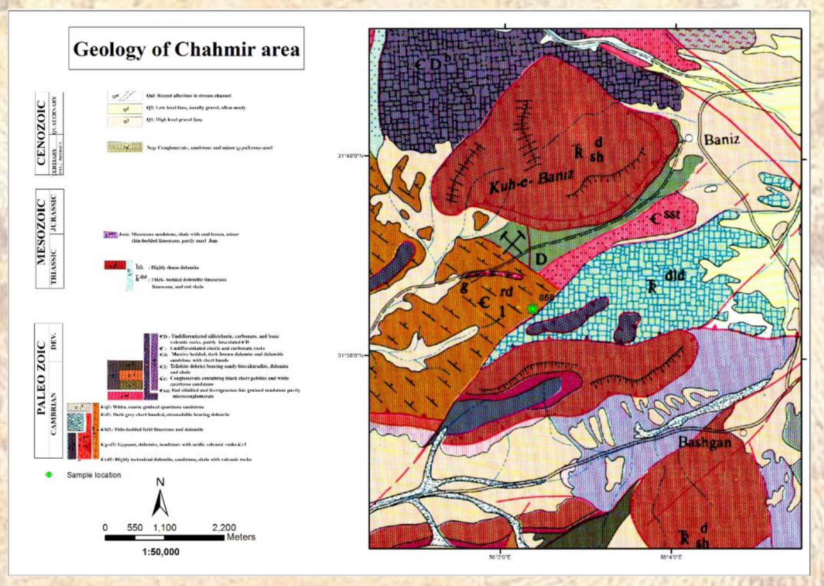


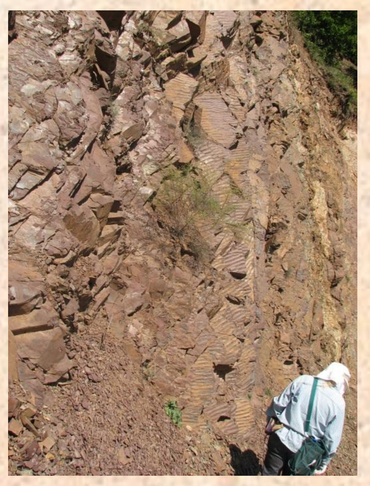
Fig. 7: Geological Map of Chahmir area (after Geological Map of BEHABAD 1:100000 by Mahdavi, M. A., 1996)

Fig. 8: Two views of Chahmir area

III. Elborz Mountains, Dalir

Hamdi, Brasier and Zhiwen (1989) Reported on early skeletal remains from the Elborz Mountains in northern Iran near the southern edge of the Caspian Sea. A recent visit was the beginning of a long term exploration of this region, and a variety of surface trace fossils were located, none with any indication of deep burrowing. Ripple marks were widespread, sometimes with associated surface burrows. Other possible fossil remains are enigmatic and will require further investigation both of their setting. *Persimedusites* has been reported by field expeditions in the Kahar Fm of the Elborz Mountain region.

Elborz Mountains terrain.


Ripple marks are abundant in the region.

Probably surface trace fossils.

Traces or enigmatic structures.

Structures to be determined…….

Preliminary Conclusions

The findings on the exploratory field work in 2015 posed more questions than answers. Some of the field areas visited in both central Iran and the northern slopes of the Elborz Mountains yielded both body fossils and traces that are evidently Neoproterozoic as mapped. However, one area near Bafq yielded a variety of corals in rocks previously mapped as Precambrian that were clearly Phanerozoic. What the remains that have been published as *Persimedusites* are need further investigation and the new forms recovered from the Koushk region are reminiscent of tubular forms such as *Conotubus* and *Sinotubulites* in morphology. Clearly more collection and investigation are needed before these enigmatic forms can be clearly places on the family tree.

Bafq area where Phaneozoic coral fossils were recovered from sequences mapped as Precambrian.

From a sequence near Bafq to the east of Yazd, previously mapped as Precambrian, came a variety of corals and other Phanerozoic forms.

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Field crew from the Iranian Geological Survey and Museum Victoria. Photo taken by final crew member from Monash University, Melbourne- on the way back to Tehran at the end of a successful trip with excellent driving and good cooking.

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