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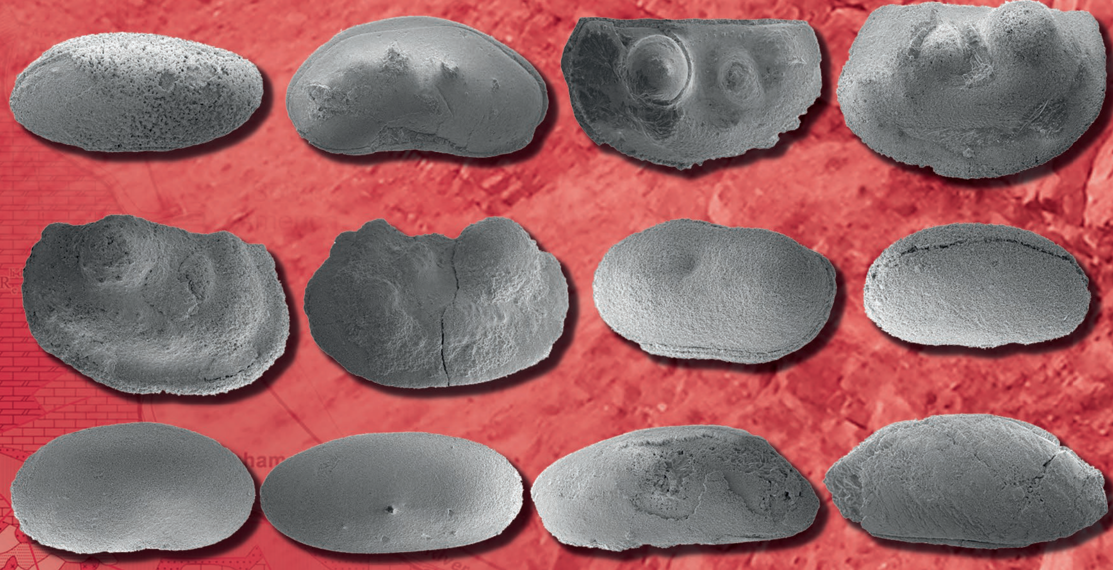

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Update and observations on the extraction of ostracods (Crustacea) from the Permian hard carbonate rocks of Iran

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ABSTRACT
Ostracod (Crustacea) fossils can only be determined by observation of the carapace and for this they have to be extracted from the rocks. Generally, in Late Palaeozoic rocks, these microfossils are preserved in hard limestones. The most common method of their extraction is hot acetolysis. We test here two other methods for ostracod extraction from the Guadalupian - Lopingian (Late Permian) Ali-Bashi section in the Northwest of Iran. The samples were prepared with cold 10% formic acid (CH_2O_2) or 15% acetic acid (CH_3COOH). The CH_2O_2 protocol was productive with well-preserved ostracods, allowed us to determine ten taxa as *Bairdia deducta deducta* (Zalányi, 1974), *Bairdia hungarica* Zalányi, 1974, *Bairdia* sp., *Fabalicypris parva* Wang, 1978, *Fabalicypris* sp. 1, *Fabalicypris* sp. 2, *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909), *Hollinella* sp., *Sargentina transita* (Kozur, 1985) and *Silenites* sp. Amongst these assemblages, *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909), *Fabalicypris* sp. 2, *Sargentina transita* (Kozur, 1985) and *Silenites* sp. were obtained exclusively through the diluted CH_2O_2 protocol from the hard dolomitized limestones, while the other hot and cold procedures were unsuccessful.

KEY WORDS
Guadalupian-Lopingian,
Northwest Iran,
Ostracods,
extraction process.
CH_2O_2,
CH_3COOH.

RÉSUMÉ

Mise à jour et observations sur l'extraction des ostracodes (Crustacea) des roches carbonatées dures du Permien d'Iran.

L'identification des fossiles d'ostracodes (Crustacea) dépend exclusivement de l'observation de leur carapace, ce qui requiert leur extraction des roches. Généralement, dans les couches du Paléozoïque supérieur, ces microfossiles sont préservés au sein de calcaires compacts et durs. L'acétolyse à chaud demeure la méthode la plus usitée pour leur récupération. Dans cette étude, nous explorons deux autres approches d'extraction des ostracodes de la coupe d'Ali-Bashi d'âge Guadalupien-Lopingien (Permien supérieur), située au nord-ouest de l'Iran. Les échantillons ont été préparés en utilisant à froid une solution d'acide formique à 10% (CH_2O_2) ou d'acide acétique à 15% (CH_3COOH). Le protocole à base de CH_2O_2 s'est révélé efficace en fournissant des spécimens d'ostracodes remarquablement bien préservés, permettant ainsi l'identification de dix taxons : *Bairdia deducta deducta* (Zalányi, 1974), *Bairdia hungarica* Zalányi, 1974, *Bairdia* sp., *Fabalicypris parva* Wang, 1978, *Fabalicypris* sp. 1, *Fabalicypris* sp. 2, *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909), *Hollinella* sp., *Sargentina transita* (Kozur, 1985) et *Silenites* sp. Parmi ces ensembles, les spécimens de *Hollinella* (*Hollinella*) *herrickana*, *Fabalicypris* sp. 2, de *Sargentina transita* et de *Silenites* sp., ont été exclusivement obtenus à l'aide du protocole de CH_2O_2 dilué à partir des calcaires dolomitisés indurés, tandis que les autres méthodes, qu'elles soient à chaud ou non, ont été infructueuses.

MOTS CLÉS
Guadalupien-Lopingien,
Nord-Ouest de l'Iran,
Ostracodes,
processus d'extraction.
CH_2O_2,
CH_3COOH.

GEOGRAPHICAL AND GEOLOGICAL SETTING

Julfa (= Jolfa, Dzhulfi, or Culfa) is a small town in the south of the Aras River (also known as the Araks, Arax, Araxes, or Araz) and in the vicinity of Iran's border with the Nakhichevan Autonomous Republic. This region is located in the southern limit of the mountains which is called the Southern Caucasus (= Trans Caucasus or Transcaucasia). Although the name Caucasus is usually not used for the southern mountains of Aras, there is no doubt that the major structural units of the Transcaucasia region continue in the south-southeast direction and spread from Aras Valley to East Azerbaijan province of Iran (Ghaderi *et al.* 2014a, b). The Julfa-Mishudagh-Sahand-Takab region in Azerbaijan province displays distinctive geological characteristics. It features horsts containing small outcrops of Precambrian rocks, while Proterozoic-Early Palaeozoic sedimentary rocks are either scarce or incomplete (Ghaderi *et al.* 2016). Within the area, a Late Palaeozoic-Triassic platform sequence is well developed, though Jurassic rock occurrences are limited (Stepanov *et al.* 1969). In Cretaceous deposits flysch and carbonate facies are present, whereas volcanic-pyroclastic rocks are notably absent. This region demonstrates a rapid transition from volcanic rocks to Palaeogene sedimentary rocks from East to West (Ghaderi 2014). Neogene molasses are widespread, with shield-shaped volcanoes like Sahand, Ararat, and Aragats. Folded structures reflect tectonics (Mohammadi *et al.* 2023).

In Iran, Permian sedimentary rocks are extended throughout the country (Aghanabati & Rezaee 2009), in Central Iran, Alborz, Sanandaj-Sirjan and Zagros structural zones that are considered terranes of Cimmeria (Stampfli & Borel 2002; Ruban *et al.* 2007). Except for Zagros which remained on the northern margin of Gondwana, the other terranes rifted from the Gondwanan margin at the beginning of Cisuralian to reach the Laurasian terranes in the Late Triassic (Muttoni *et al.* 2009; Zanchi *et al.* 2016). At the end of Lopingian, Northwest Iran and Transcaucasia regions which comprise the most famous Permian-Triassic Boundary (PTB) succession, were located in palaeo-equatorial areas, between the Neotethys in the South and the Palaeotethys in the North (Leda *et al.* 2014). This area was covered by a shallow to moderately deep-sea in outer shelf setting environment (Kozur 2007). The classic fossiliferous Lopingian succession in Northwest Iran, especially in the Ali-Bashi Mountain (Kuh-e-Ali-Bashi), near Julfa city, has been quite often studied. The main focus of these studies was on the PTB interval which provides an exceptional opportunity to conduct biostratigraphic, chemostratigraphic, and bioevent investigations on the most severe mass extinction event of the earth history (e.g.; Stepanov *et al.* 1969; Teichert *et al.* 1973, Partoazar 2002; Korte *et al.* 2004; Korte & Kozur 2005; Kozur 2004, 2005; Ghaderi *et al.* 2013, 2014a, b; Leda *et al.* 2014; Korn *et al.* 2016; Schobben *et al.* 2016, 2017; Kiessling *et al.* 2018; Korn *et al.* 2019; Gliwa *et al.* 2020, 2021; Tabrizi *et al.* 2021; Heuer *et al.* 2021; Mohammadi *et al.* 2023).

Despite the wide presence of Guadalupian rocks in Northwest Iran, zonal marker conodonts have never been extracted from these sequences perhaps due to the dominance of shallow platform carbonates (Clark & Hatleberg 1983; Ghaderi 2014; Leonhard *et al.* 2021). Therefore, the dating is based only on some small lagenid foraminifera, which may not be very indicative in this period (e.g., Partoazar 2002, Shabanian & Bagheri 2008). Furthermore, the exact position of the Guadalupian-Lopingian Boundary (GLB) continues to be debated, leading to discussions concerning the Permian geological period of Iran. Ghaderi *et al.* (2016) located this boundary, with a question mark, somewhere in the Khachik Formation (Khachik Beds *sensu* Stepanov *et al.*

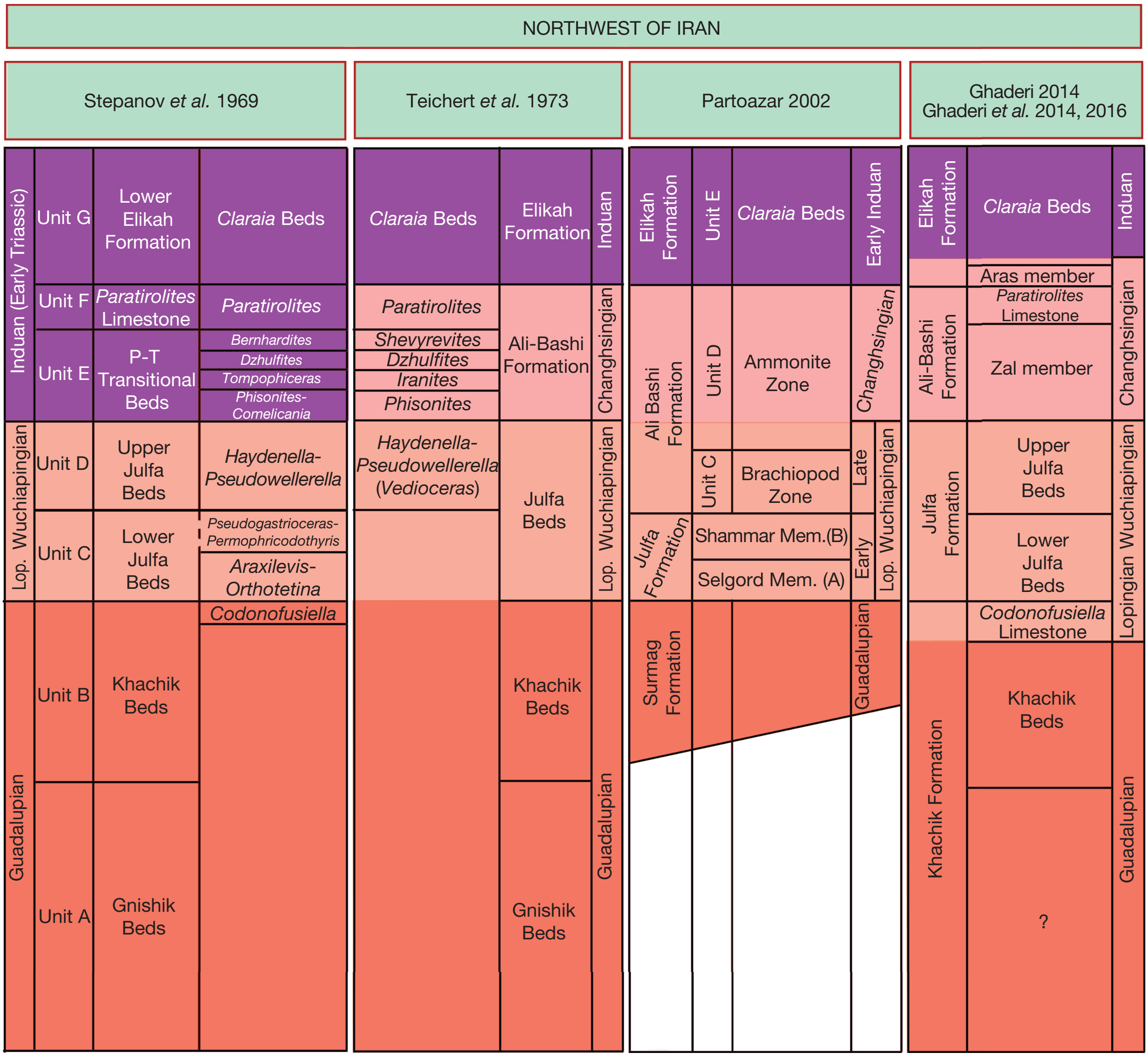


Fig. 1. — Historical background of the Guadalupian-Lopingian successions in the northwest of Iran; following Stepanov *et al.* (1969), Teichert *et al.* (1973), Partoazar (2002), Ghaderi (2014) and Ghaderi *et al.* (2014a, b, 2016).

1969), below the occurrence of *Codonofusiella* Limestone and underneath or inside the member VIII, above the last occurrence of Alatoconchidae bivalves and frondose bryozoans as suggested by Wood (1998) and Chen *et al.* (2018). The pioneering study of by Stepanov *et al.* (1969) on the Permian-Triassic succession in the west of Julfa city led to the introduction and naming of approximately 1100 m of sedimentary rocks in eight lithostratigraphic units such as units A to H (A, Gnishik Beds; B, Khachik Beds; C, Lower Julfa Beds; D, Upper Julfa Beds; E, Permian-Triassic Transition Beds; F, *Paratirolites* Limestone; G, Lower Elikah Formation; H, Upper Elikah Formation) and comprehensive comparison with those similar units in the Dorasham sections in the Transcaucasia, beyond the geographical border of Iran. Teichert *et al.* (1973) by unifying the units E and F in Stepanov *et al.* (1969), established a new formation called the Ali-Bashi Formation. Although in subsequent studies, the age and stratigraphic position of lithostratigraphic subdivisions by Stepanov *et al.* (1969) and Teichert *et al.* (1973) have been slightly changed and modified (Fig. 1), these initial studies have provided a very good basis for further research works.

In the last two decades, significant palaeontological investigations were done in various aspects of conodonts (Kozur 2004; Shen & Mei 2010; Ghaderi *et al.* 2014a), brachiopods (Ghaderi *et al.* 2014b; Ghaderi 2018), ammonoids (Korn *et al.* 2016, 2019; Kiessling *et al.* 2018; Ghanizadeh Tabrizi *et al.* 2022), ostracods (Gliwa *et al.* 2021) as well as different stratigraphic perspectives such as lithostratigraphy (Leda *et al.* 2014; Gliwa *et al.* 2020), sequence stratigraphy (Arefifard & Baud 2022) and isotopic geochemistry (Korte *et al.* 2004; Schobben *et al.* 2015, 2017, 2019; Korn *et al.*

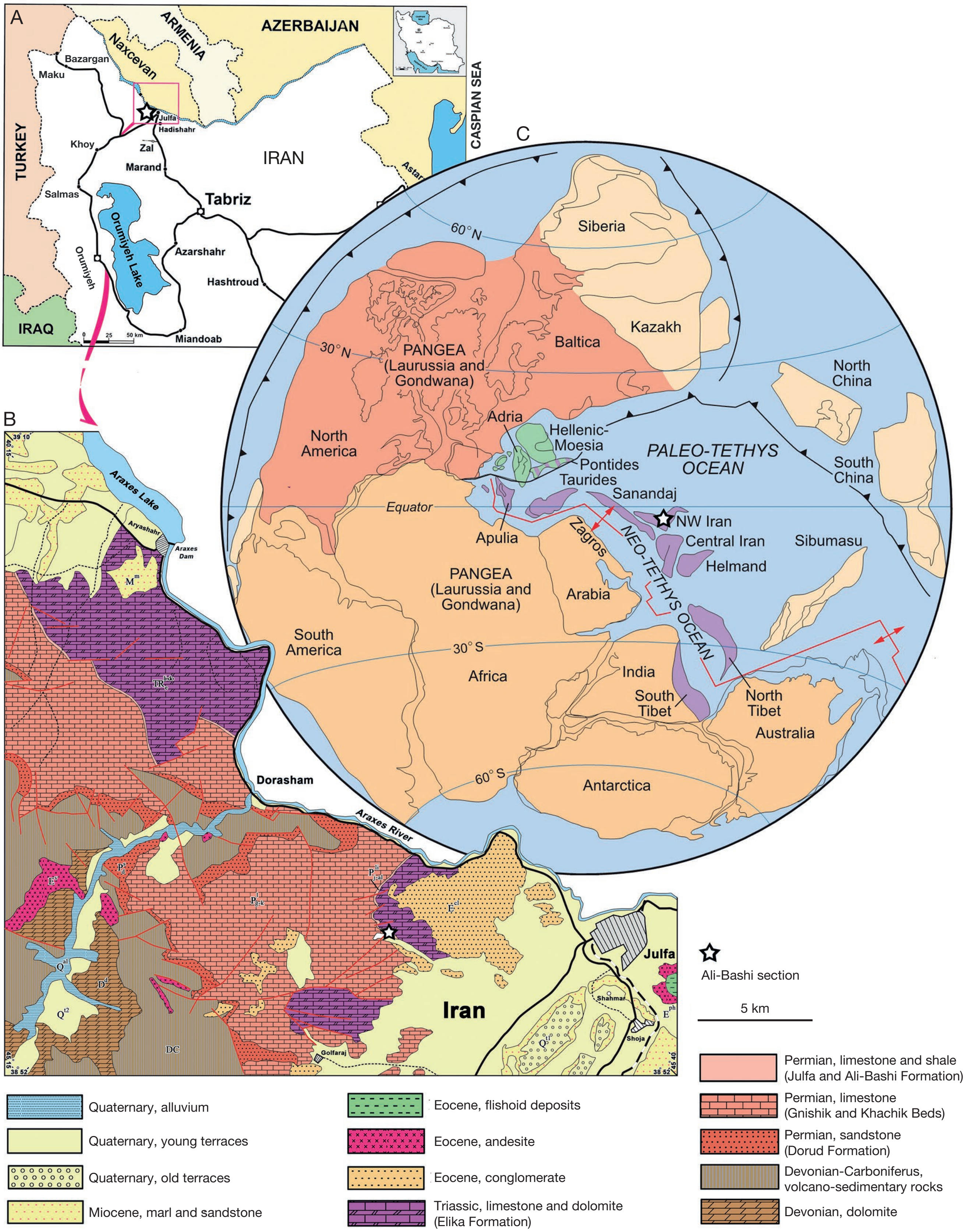


FIG. 2. — **A**, Location map of the study area in the northwest of Iran (from Ghaderi *et al.* 2016); **B**, geologic map of the study area at the west of Julfa City; the Ali-Bashi section is marked with a white star (from Ghaderi 2014); **C**, palaeogeographic map of the Lopingian and location of the study area (**white star**) as a part of a Cimmerian block, close to the equator in the southern hemisphere (from Ruban *et al.* 2007).

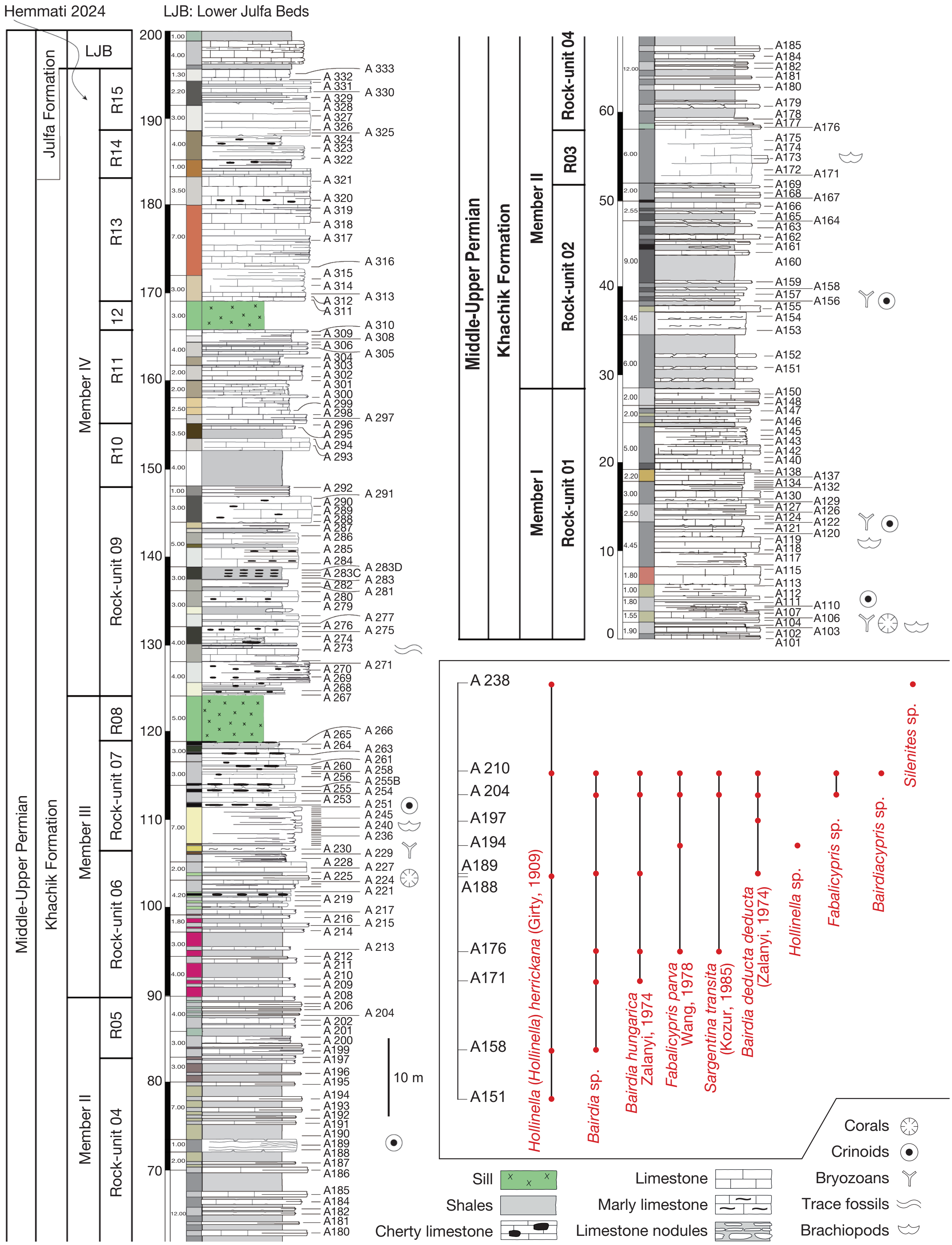


Fig. 3. — Stratigraphic log and vertical distribution of ostracods (obtained from CH_2O_2 protocol) in the Khachik Formation from the Ali-Bashi section.

2021) on this area. The Ali-Bashi section (38°56'42"N, 45°30'35"E) is located at the end of the main valley of the Ali-Bashi Mountains, nearly 9 km west of Julfa city (Fig. 2). This section comprises the Khachik beds (Khachik formation *sensu* Ghaderi *et al.* 2016) with 189 m thickness. Totally, more than 240 rock samples were collected (the weight of each sample 3 to 5 kg) (Figs 3; 4) for micropalaeontological studies (conodonts, ostracods, foraminifers, radiolarians, and calcareous algae), petrography, microfacies and geochemical analysis. Only ostracods are discussed here.

EXTRACTION METHODS

The extraction processes depend of the nature of the rocks and the nature of the microfossil. Ostracods have carapace in calcium carbonate. Sometimes, the carapaces are secondary silicified and can be extracted from siliceous rocks like cherts, cherty limestones, and siliceous shales using hydrofluoric acid (Horne & Siveter 2016). The main problem is to extract calcareous carapaces from hard carbonated rocks. To obtain ostracods from the fluvial sediments (large lowland of River Odra western part of Poland), Szlauer-Łukaszewska & Radziejewska (2013) used two different techniques of aeration and deterioration versus hand sorting to save time in the preparation of these sediments. The most common process to break up hard limestones is hot acetolysis with use of pure acetic acid at 60°C (Lethiers & Crasquin-Soleau 1988; Crasquin-Soleau *et al.* 2005). We explore here two alternative chemical extraction methods using cold diluted formic acid (CH_2O_2) and acetic acid (CH_3COOH), bypassing the need of sandbath heating system. The objective is to extract ostracods from Khachik Formation strata in the Ali-Bashi section. For both methods, 500 g of rocks were processed. The following sections detail these techniques.

CH_2O_2 protocol

Formic acid (CH_2O_2) is usually used in the chemical preparation of micro-vertebrate fossils. In this preparation protocol, after breaking rock samples into approximately 5 cm pieces with a hammer, dust and other pollution washed out by water. Then, samples immerse in 10% CH_2O_2 and after 24 hours, they are washed with water to neutralize the acid. Due to the heightened solubility of formic acid and its potential to affect the surface integrity of ostracod specimens, the subsequent neutralization step with water holds significant importance. Additionally, for the preservation of specimens, it is recommended to conduct a gradual and long sample washing. The sieving is the following step to wipe the argillaceous sediments. Due to the ostracod sizes, two sieves with 1 mm and 63 µm meshes should be used. Then the remaining sediments are transferred to a plastic bowl for drying. It is necessary to repeat three times this CH_2O_2 preparation.

Advantages and disadvantages of this technic could be investigated. The benefit of the CH_2O_2 preparation method included: a) the protocol is easy to set up and does not require any hi-tech laboratory equipment; b) the use of 10% CH_2O_2 is cheap; c) the protocol required less water for neutralization part than the other washing methods; d) repeating the protocol does not require a drying step and it is possible to sink again the sample in the acid immediately after the washing process so it is less time consuming; and e) environmental pollution is less important by using 10% of CH_2O_2, because the acidity level is lower.

However, this method has some weaknesses which are: a) CH_2O_2 as a relatively strong acid can cause damage to the most fragile shells; and b) CH_2O_2 is *combustible and can be ignited.*

CH_3COOH protocol

Acetic acid (CH_3COOH) is one of the simplest carboxylic acids. In the CH_3COOH technique, the immersion duration is linked to the acid concentration: four days with 10% CH_3COOH and three days with 15% CH_3COOH. In this method we used 10% CH_3COOH for soft and 15% CH_3COOH for hard rocks. Like the previous protocol, the advantages of this method are: a) setting up the protocol is very light, as it does not demand any advanced laboratory equipment. b) the use of 15% CH_3COOH makes it cheap; c) water washing part for neutralization requires less water; d) repeating the protocol does not require the drying part of rock samples; e) the environment is less polluted by using this protocol; and f) CH_3COOH as a weak acid has a less destructive effect on soft rocks and microfossils with fragile textures.

Comments on the hot acetolysis

Upon implementing the aforementioned two methods and assessing their outcomes (as detailed in the following section), and with the aim of increasing and comparing the data collected from these preceding methodologies, we opted to examine the hot acetolysis method put forth by Crasquin-Soleau *et al.* (2005). This particular technique is highly effective in extracting ostracods from sediment while preserving their shell structures, as it removes organic matter and sedimentary matrix. The process consists of four steps: crushing, dehydration, acetolysis, and settling and washing. To begin, rock samples weighing 400-500 grams are crushed into small pieces measuring several cm^3 in order to increase the reaction surface. These crushed rocks are then dehydrated to minimize the impact of humidity on the performance of CH_3COOH and prevent any reaction with acid. To achieve this, they are placed in a heatproof glass receptacle and left in a dryer (maximum 70°C) for 48-72 hours to eliminate all moisture. The third step involves acetolysis, where the samples are removed from the dryer and allowed to cool down for approximately 30 minutes. Next, CH_3COOH 99% is added to the glass container until the sample is completely covered with acid. The pot is then placed on a heating sand-bath set at a temperature of 60-80°C. Finally, the last step involves settling and washing the sample. After applying this method to the samples with

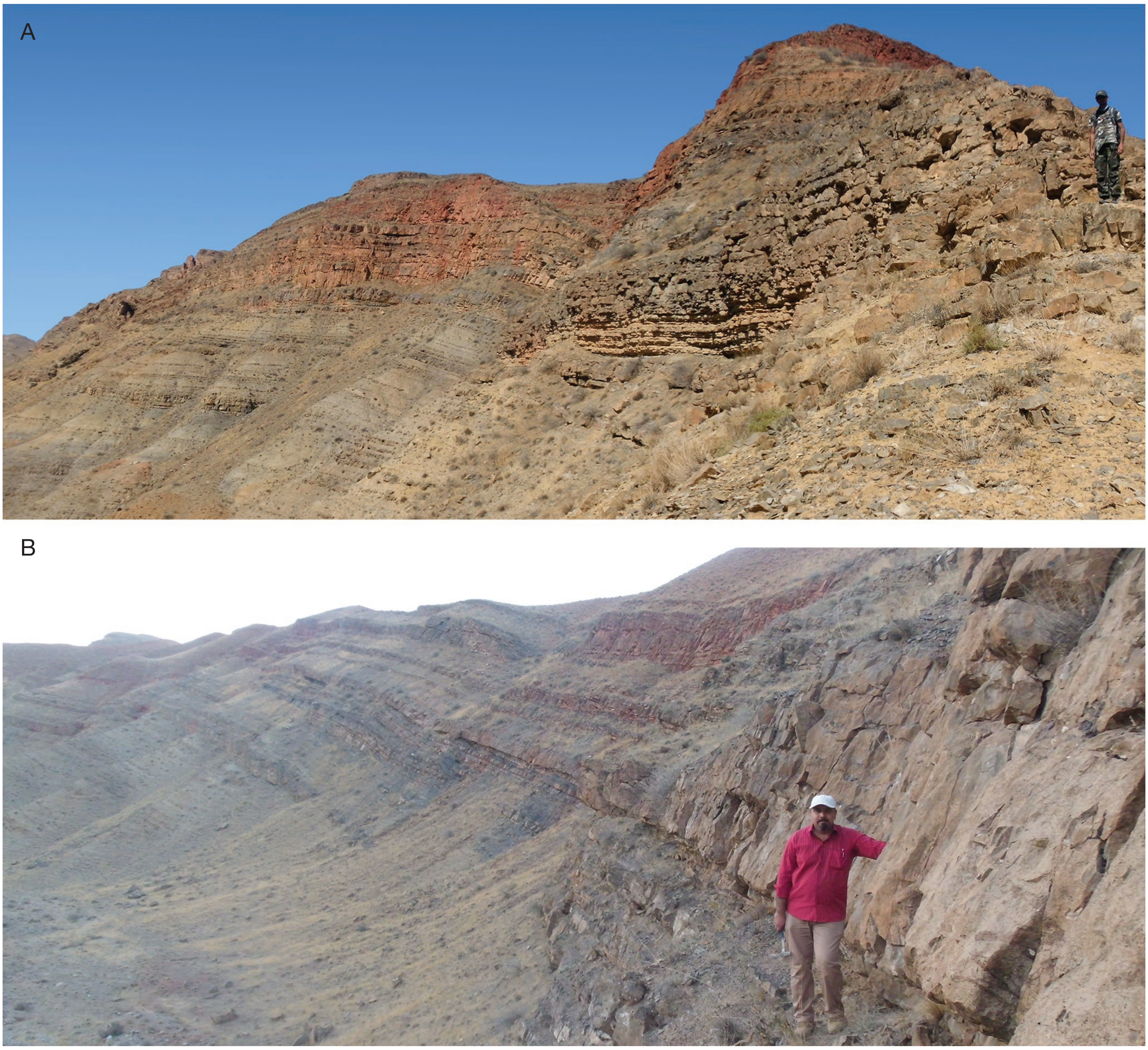


Fig. 4. — **A**, Field pictures of the Ali-Bashi section, with the succession of the Khachik Beds lower part (view Northward); **B**, general view of the upper parts of the Khachik Beds, include thick bedded to massive cherty limestones (view to the Northwest).

high-potential ostracod contents in the Ali-Bashi section, we have extracted a large number of ostracods which will be published (Hemmati *et al.* in prep.).

It is worth mentioning the multiple repetitions of this method have led us to make some remakes and updates on the Crasquin-Soleau *et al.* (2005) protocol. One significant change is in the crushing step, which is crucial for enhancing the performance of pure CH_3COOH. The reaction level increases by reducing the size of the samples to less than two centimetres. To conserve laboratory glassware, it is essential to cool the samples for approximately 30 minutes before transferring them to the acetolysis phase (It is recommended to use high lab glasses with narrow widths for optimal results in acetolysis). Additionally, if the sand-bath temperature is set between 60-80°C, it is important to verify the samples at least once a day to avoid acid boiling or glass fracturing (this verification can be skipped if the sand-bath temperature is lower than 40°C). During the neutralization step, it would be preferable to put the samples under a tap for up to 30 minutes and drain the water from the sample glass at least five times. To repeat the technique, the samples are placed in a heatproof glass container and dried in a drier (maximum 70°C) for 48-72 hours. If there is any acid residue on the sediments, they are rinsed once more. Furthermore, during the dissolution process, acid cement may be formed, especially in soft-rock samples, resulting in cemented sediments. If this occurs, it is crucial to stop the operation and submerge the samples underwater to prevent damage or loss of ostracods and samples. The immersion of samples in water should be done expertly and completed before any acid reactions occur because any extra acetic acid combined with water can generate an acid reaction that damages ostracod valves.

Outcomes from the protocols

CH_2O_2 was the first protocol chosen to process more than 240 samples of the Ali-Bashi section. Repetition of the CH_2O_2 technique was successful in achieving the desired outcome and results in significant improvement in the performance of the preparation methods. The obtained ostracods from this protocol have proper preservation and using this preparing method resulted in a determination of 10 species. These species are: *Bairdia deducta deducta* (Zalányi, 1974), *Bairdia hungarica* Zalányi, 1974, *Bairdia* sp., *Fabalicypris parva* Wang, 1978, *Fabalicypris* sp. 1, *Fabalicypris* sp. 2, *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909), *Hollinella* sp., *Sargentina transita* (Kozur, 1985) and *Silenites* sp., which will be systematically discussed in detail following. Interestingly, *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909), *Fabalicypris* sp. 2, *Sargentina transita* (Kozur, 1985), and *Silenites* sp. were only extracted via the CH_2O_2 protocol from dolomitized limestones. This is significant because these species were not commonly recovered from the hard-dolomitized rocks.

Despite our great efforts and following this protocol step by step, the use of CH_3COOH technique in the preparation of over 240 samples from the Ali-Bashi section failed. The utilization of varying concentrations of CH_3COOH (10% and 15%) in this research resulted in the observation that the ostracod valves were damaged. Despite attempting to repeat the diluted CH_3COOH process, the preservation of ostracods is affected. The occurrence of this phenomenon can be attributed to the interaction and mixture between water and CH_3COOH. The combined action of these substances induces the degradation of ostracod valves. This may result from chemical interaction between acetic acid and water that causes rapid acid attack that could harm the delicate valves of ostracods. Additionally, it was observed that an elevated concentration of acid leads to more severe damage to the valves, as a higher concentration results in a greater number of bubbles being released within a shorter timeframe (refer to Fig. 5K1-K3). We were disappointed by the low performance of the diluted CH_3COOH technique, as the formic acid method resulted in fewer separated ostracod valves. The higher solubility of formic acid in water and its superior ability to penetrate sediment particles made it a more effective technique for separating ostracod valves from the sediment matrix. The obtained ostracods using the formic acid technique were of higher quality compared to those obtained using the acetic acid technique, particularly in hard-rock carbonates. Furthermore, the formic acid technique proved to be more successful in preserving the original morphology of the ostracod valves in these rocks. At the end, a diligent effort was made to apply hot acetolysis techniques to the samples in the Ali-Bashi section that showed a high potential for harbouring ostracods. Consequently, a substantial quantity of ostracod bivalves was effectively recovered.

Conclusion

On Ali-Bashi section (northwestern Iran) samples, we tested two different acid-basic extraction procedures for ostracods. The CH_2O_2 method for preparing samples was repeated successfully, resulting in a significant improvement in the performance of the preparation procedures, and following the outcome of this technique, seven ostracod species were discovered and reported from hard-rock limestone samples. *Bairdia deducta deducta* (Zalányi, 1974), *Bairdia hungarica* Zalányi, 1974, *Bairdia* sp., *Bairdiacypris* sp., *Fabalicypris parva* Wang, 1978, *Fabalicypris* sp. 1, *Fabalicypris* sp. 2, *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909), *Hollinella* sp., *Sargentina transita* (Kozur, 1985) and *Silenites* sp., which characterized for the first time Guadalupian-Lopingian strata of Ali-Bashi section. *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909), *Fabalicypris* sp. 2, *Sargentina transita* (Kozur, 1985), and *Silenites* sp., were extracted with this protocol exclusively from dolomitized rocks. Using the diluted CH_3COOH method on the Ali-Bashi section samples resulted in failure because the acid attack as it mixed with the water could have caused this effect. Furthermore, the application of the pure CH_3COOH method (hot acetolysis) to these samples also resulted in the extraction of ostracod.

Abbreviations

AB	anterior border;
ADB	anterodorsal border;
AVB	anteroventral border;
DB	dorsal border;
H	height;
Hmax	maximum height;
L	length;
Lmax	maximum length;
LV	left valve;
PB	posterior border;
PDB	posterodorsal border;
PVB	posteroventral border;
RV	right valve;
VB	ventral border;
W	width;
Wmax	maximum width;
L_1, L_2, L_3	anterior, median and posterior lobes.

SYSTEMATIC PALAEONTOLOGY

Ten species belonging to six genera were identified with CH_2O_2 method and are figured. All the specimens are deposited in the collections of National Natural History Museum (MNHN) in Paris, France, under numbers MNHN.F.F72157-F72188 (Fig. 5). We use here the classification of Moore (1961), Lethiers (1981) and Horne *et al.* (2002).

Order PODOCOPIDA Sars, 1866
Suborder Podocopina Sars,1866
Superfamily Bairdioidea Sars, 1888
Family Bairdiidae Sars, 1888
Genus *Bairdia* McCoy, 1844

Bairdia deducta deducta Zalányi, 1974
(Fig. 5A1-A6)

Bairdia deducta deducta Zalányi, 1974: 196-197, pl. 12, figs 1a-c. — Crasquin-Soleau & Baud 1998: pl. 8, figs 10-13, 16. — Chitnarin *et al.* 2017: 666-667, fig. 11J-L.

Cryptobairdia deducta deducta – Kozur 1985a: pl. 6, fig. 2.

Material examined. — Six complete carapaces, MNHN.F.F72157-F72162.

Occurrences. — Lopingian, Nagyvisnýo Formation, Bükk Mountains, Hungary (Kozur 1985a); Late Guadalupian-Early Lopingian Episkopi Formation, Hydra Island, Greece (Crasquin-Soleau & Baud 1998); Cisuralian, Tham Nam Maholan section, Nam Maholan Formation, Loei Province, northeast Thailand; Guadalupian, Ban Naen Sawan I section, Pha Nok Khao Formation, Phetchabun Province, central Thailand, Late Guadalupian Khao Som Phot section, Tak Fa Formation, Lopburi Province, central Thailand, (Chitnarin *et al.* 2017). Khachik Formation Unit VI (samples A. 188, AH. 197, A. 204, and A. 210), Guadalupian, Ali-Bashi section, Iran (this study).

Dimensions. — L = 99.3-108.7 µm; H = 56.1-65.9 µm; H/L = 1.64-1.77.

Description
Carapace subtriangular; DB and VB irregularly arched; PDB, DB and ADB straight at RV and convex at RV; AB and PB with very small radius of curvature. Strong overlap of LV on RV particularly on all the dorsal part; flattening of AB and dorso-median part of the valves; thickening of the carapace in ventral part.

Bairdia hungarica Zalányi, 1974
(Fig. 5B1-B4)

Bairdia hungarica Zalányi, 1974: 192-193, pl. 9, figs 3a-d.

Fabalicypris hungarica – Kozur 1985a: pl. 3, fig. 3.

Material examined. — 10 complete carapaces, MNHN.F.F72163-F72166, six specimens without barcode.

Occurrences. — Lopingian, Nagyvisnýo Formation, Bükk Mountains, Hungary (Kozur 1985a). Khachik Formation Unit VI (samples A. 171, A. 176, A. 188, A. 204, and A. 210) Guadalupian, Ali-Bashi section, Iran (this study).

Dimensions. — L = 85.5-94.5 µm ; H = 52.8-62.1 µm; H/L = 0.61-0.65.

Description
Carapace subtriangular to rhomboidal; AB with large radius of curvature, PB tapered; ADB and PDB slightly concave at both valves; DB concave at LV and straight at RV; VB straight to gently convex and middle part is bulging (Zalányi 1974).

Bairdia sp.
(Fig. 5C1-C4)

Material examined. — Seven incomplete carapaces, MNHN.F.F72167-F72170, three specimens without barcode.

Occurrences. — Khachik Formation Unit VI (samples A. 158, A. 171, A. 176, A. 188, A. 204 and A. 210), Guadalupian, Ali-Bashi section, Iran (this study).

Dimensions. — L = 87.9-93.7 µm; H = 53.9-61.5 µm; H/L = 0.61-65.

Remarks
Carapace subtriangular to rhomboidal; strong dorsal overlap of LV on RV; straight DB, ADB and PVB at RV. There is no enough characteristics to give a species attribution.

Genus *Fabalicypris* Brady, 1880

Fabalicypris parva Wang, 1978
(Fig. 5D1-D6)

Fabalicypris parva Wang, 1978: 293, pl. 2, figs 12a, b, 13a, b. — Crasquin-Soleau *et al.* 2004: 286, pl. 3, figs 4-5. — Mette 2008: pl. 2, fig. 8. — Crasquin *et al.* 2010: 353, figs 9A', B'. — Forel 2012: fig. 11, I.

Fabalicypris hungarica – Kozur1985b: 82, pl. 2, figs 2, 9, 10.

Bairdiacypris opulenta – Shi & Chen 1987: 51, pl. 13, fig. 10.

Material examined. — Eight complete carapaces, MNHN.F.F72171-F72175, three specimens without barcode.

Occurrences. — Wuchiapingian and Changhsingian (Lopingian) Longtan and Changxing Formations, Guizhou and Yunnan Provinces, South China (Wang 1978). Lopingian, Bükk Mountains, Hungary, Late Moscovian, Carboniferous, (Kozur 1985b). Lopingian, Changxing formation, Meishan section, Zhejiang Province, South China, Changhsingian, (Shi & Chen 1987; Crasquin *et al.* 2010). Wuchiapingian and Changhsingian (Lopingian), Çürük dağ section, Western Taurus, Turkey, (Crasquin-Soleau *et al.* 2004). Lopingian, Zal section, Iran, Changhsingian, (Mette 2008). Lopingian- Early Triassic, Dajiang section in the southern Guizhou Province, South China, (Forel 2012). Khachik Formation Unit VI (samples A. 176, A. 194, A. 204 and A. 210), Guadalupian, Ali-Bashi section, Iran (this study).

Dimensions. — L = 84.9-94.9 µm; H = 32.4-47.7 µm; H/L = 0.38-0.50.

Description
Carapace with sub-bean shape; surface smooth; LV slightly overlaps RV all around the carapace; end margins broadly rounded; DB, ADB, PDB straight at RV, arched at LV; overlap moderate; VB slightly concave.

Remarks
Fabalicypris parva Wang, 1978 exhibits a bean-shaped carapace, and previous records indicate that it is present from the Late Moscovian (Carboniferous; Kozur 1985b) to the Changhsingian (Lopingian; Wang 1978; Shi & Chen 1987; Crasquin-Soleau *et al.* 2004; Mette 2008; Crasquin *et al.*

2010). Despite this extensive stratigraphic range, some Carboniferous occurrences are doubtful, since most are from the Lopingian period. In the context of designating *Fabalicypris hungarica* Kozur, 1985b as a synonym of *Fabalicypris parva* Wang, 1978, Crasquin *et al.* (2010) noted distinctions, such as *Fabalicypris hungarica* Kozur, 1985b displaying a more rounded PB and a higher location of maximum convexity compared to *Fabalicypris parva* (see more in Forel 2012).

Fabalicypris sp. 1
(Fig. 5E)

MATERIAL EXAMINED. — One incomplete carapace, MNHN.F.F72177.

OCCURRENCES. — Khachik Formation (sample A. 204), Guadalupian, Ali-Bashi section, Iran (this study).

DIMENSIONS. — L = 82.7 µm; H = 31.9 µm; H/L = 0.38.

REMARKS
Fabalicypris sp. 1 has sub-bean shaped carapace with valve surface smooth. Our specimens are not complete, particularly in the anterior region. Therefore, it is impossible to give specific attribution.

Fabalicypris sp. 2
(Fig. 5F)

MATERIAL EXAMINED. — One incomplete carapace, MNHN.F.F72178.

OCCURRENCES. — Khachik Formation Unit VI (sample A. 210), Guadalupian, Ali-Bashi section, Iran (this study).

DIMENSIONS. — L = 94.4 µm; H = 45.8 µm; H/L = 0.47.

REMARKS
Carapace sub-triangular with valve surface smooth; dorsal outline broadly arched.

Order PALAEOCOPIDA Henningsmoen, 1953
Superfamily HOLLINOIDEA Swartz, 1936
Family HOLLINELLIDAE Bless & Jordan, 1971
Genus *Hollinella* Coryell, 1928 emend. Kellett (1929)

Hollinella* (*Hollinella*) *herrickana (Girty, 1909)
(Fig. 5G1-G3)

Hollina herrickana Girty, 1909: 115, pl. 8, figs 10, 11.

Hollinella herrickiana [sic] – Kellett 1929: 197; 1934: 626. — Delo 1930: 156, pl. 12, fig. 4. — Bassler & Kellett 1934: 333.

Hollinella tuberculata – Belousova 1965: 254, pl. 46, figs 2a-c.

Hollinella (*Hollinella*) *herrickana* – Bless & Jordan 1972: 38, 39. — Lethiers *et al.* 1989: 230, pl. 1, figs 2-4. — Crasquin-Soleau *et al.* 1999: pl. 2, fig. 5. — Chitnarin *et al.* 2012: 828, fig. 19E, F.

MATERIAL EXAMINED. — Six complete carapaces, MNHN.F.F72179-F72181, three specimens without barcode.

OCCURRENCES. — Cisuralian, Yeso Formation, New Mexico (United States); Texas (United States), Late Carboniferous (Girty 1909; Kellett 1929; Delo 1930; Bassler & Kellett 1934); Caucasus (Russia), Lopingian (Belousova 1965). Late Guadalupian, Merbah el Oussif unit, Jebel Tebaga, Tunisia, (Lethiers *et al.* 1989). Guadalupian, Khuff Formation, Sultanate of Oman, (Crasquin-Soleau *et al.* 1999). Cisuralian, Khao Kana section, Pha Nok Khao Formation, Phetchabun Province, Central Thailand, (Chitnarin *et al.* 2012). Khachik Formation Unit VI (samples A. 151, A. 158, A. 188, A. 210 and A. 238), Guadalupian, Ali-Bashi section, Iran (this study).

DIMENSIONS. — L = 82.0-98.3 µm; H = 40.5-65.8 µm; H/L = 0.49-0.66.

DESCRIPTION
Straight-hinged reticulated carapace with two large lobes. L_1 connected with ventral lobe, L_2 quite well expressed, L_3 bulbous overpassing DB ; velate structure large; here the reticulation and punctuation of Thai specimens are not observable (Chitnarin *et al.* 2012).

Hollinella sp.
(Fig. 5H)

MATERIAL. — One incomplete carapace, MNHN.F.F72182.

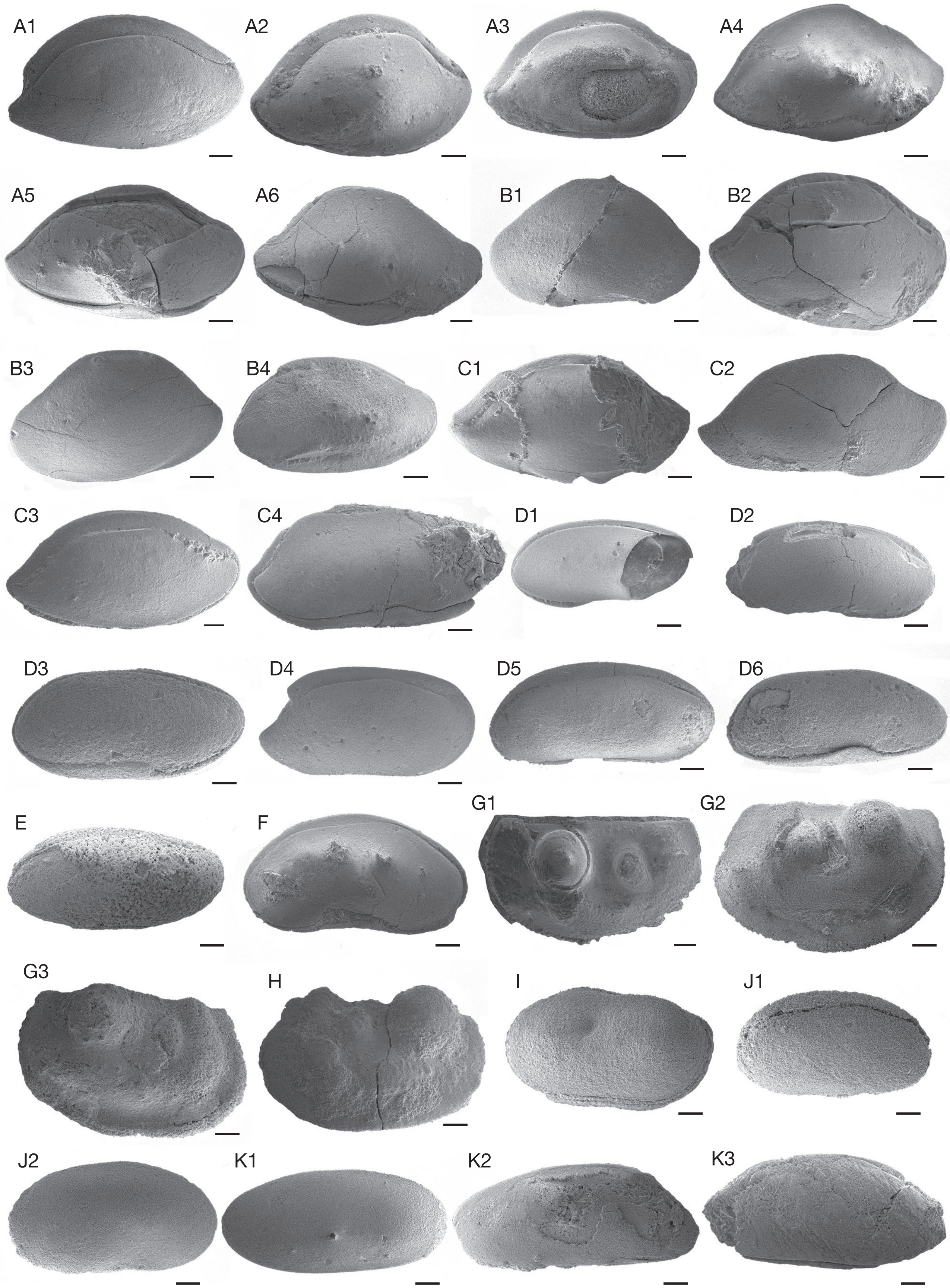
OCCURRENCES. — Khachik Formation Unit VI (sample A. 194), Guadalupian, Ali-Bashi section, Iran (this study).

DIMENSIONS. — L = 83.1-99.5 µm; H = 52.1-64.3 µm; H/L = 0.62-0.64.

REMARKS
This specimen is assigned to genus *Hollinella* based on the presence of bulbous L_3 and possible adventral structure, but preservation is too poor for specific assignation.

Suborder KLOEDENELLOCOPINA Scott, 1961
emend. Lethiers (1978)
Superfamily SANSABELLACEA Sohn, 1961

FIG. 5. — Ostracods from the Khachik beds of Ali-Bashi section, NW Iran, extracted by CH_2O_2 technique (**A1**-**J2**) and by CH_3COOH technique (**K1**-**K3**): **A1**-**A6**, *Bairdia deducta deducta* (Zalányi, 1974); **A1**, right lateral view, sample A. 197, MNHN.F.F72157; **A2**-**A4**, right lateral view, sample A. 210, MNHN.F.F72158-F72160; **A5**, right lateral view, sample A. 189, MNHN.F.F72161; **A6**, right lateral view, sample A. 207, MNHN.F.F72162; **B1**-**B4**, *Bairdia hungarica* Zalányi, 1974; **B1**, left lateral view, sample A. 189, MNHN.F.F72163; **B2**, right lateral view, sample A. 189, MNHN.F.F72164; **B3**, left lateral view, sample A.170, MNHN.F.F72165; **B4**, right lateral view, sample A. 176, MNHN.F.F72166; **C1**-**C4**, *Bairdia* sp.; **C1**, left lateral view, sample A. 189, MNHN.F.F72167; **C2**, right lateral view, sample A. 189, MNHN.F.F72168; **C3**, left lateral view, sample A.170, MNHN.F.F72169; **C4**, right lateral view, sample A. 176, MNHN.F.F72170; **D1**-**D6**, *Fabalicypris parva* Wang, 1978; **D1**, right lateral view, sample A. 194, MNHN.F.F72171; **D2**, right lateral view, sample A. 151, MNHN.F.F72172; **D3**, right lateral view, sample A. 158, MNHN.F.F72173; **D4**, right lateral view, sample A. 192, MNHN.F.F72174; **D5**, **D6**, right lateral view, sample A. 210, MNHN.F.F72175, F72176; **E**, *Fabalicypris* sp. 1., right lateral view, sample A. 207, MNHN.F.F72177; **F**, *Fabalicypris* sp. 2., right lateral view, sample A. 210, MNHN.F.F72178; **G1**-**G3**, *Hollinella* (*Hollinella*) *herrickana* (Girty, 1909); **G1**, left lateral view, sample A. 15, MNHN.F.F72179; **G2**, left lateral view, sample A. 238, MNHN.F.F72180; **G3**, right lateral view, sample



A. 238, MNHN.F.F72181; **H**, *Hollinella* sp., left lateral view, sample A. 188, MNHN.F.F72182; **I**, *Sargentina transita* (Kozur, 1985), left lateral view, sample A. 176, MNHN.F.F72183; **J1**, **J2**, *Silenites* sp.; **J1**, right lateral view, sample A. 238, MNHN.F.F72184; **J2**, ventral view, sample A. 238, MNHN.F.F72185; **K1**-**K3**, Ostracoda indet. Specimens are stored in the MNHN (Muséum national d'Histoire naturelle) collections (Paris, France). Scale bar: 100 µm.

Family Serenididae Rozhdesvenskaya, 1972
Genus *Sargentina* Coryell & Johnson, 1939

Sargentina transita (Kozur, 1985)
(Fig. 5I)

Italogesina transita Kozur, 1985b: 17, pl. 3, figs 9-11. — Gerry *et al.* 1987: 206, pl. 2, fig. 20.

Sargentina transita – Crasquin-Soleau *et al.* 1999: pl. 3, figs 5-8; 2005: pl. 4, figs 4.1-4.7. — Honigstein *et al.* 2005: 409, 419, pl. 2, fig. 13.

Material examined. — Three complete carapaces, MNHN.F.F72183, two specimens without barcode.

Occurrences. — Early Lopingian of Bükk Mountains, Hungary (Kozur 1985b), Lopingian of Israel (Gerry *et al.* 1987; Honigstein *et al.* 2005); Guadalupian of Sultanate of Oman (Crasquin-Soleau *et al.* 1999); Guadalupian of Saudi Arabia (Crasquin-Soleau *et al.* 2005). Khachik Formation Unit VI (samples A. 176, A. 204 and A. 210), Guadalupian, Ali-Bashi section, Iran (this study).

Dimensions. — L = 79.5 µm; H = 48.6 µm; H/L = 0.61.

Description

The specimens are attributed to *Sargentina transita* (Kozur 1985b) in regards of their sub-rectangular carapace, the slight overlap of LV on RV and sulcus (S_2) shallow for the genus. The figured specimen could be a female due to the rounder and large posterior part of the carapace.

Family Bairdiocyprididae Shaver, 1961
Genus *Silenites* Coryell & Booth, 1933

Silenites sp.
(Fig. 5J1, J2)

Material examined. — Two incomplete carapaces, MNHN.F.F72184, F72185.

Occurrences. — Khachik Formation Unit VI (sample A. 238), Guadalupian, Ali-Bashi section, Iran (this study).

Dimensions. — L = 58.0-98.1 µm; H = 31.0-53.8 µm; H/L = 0.52-0.54.

Remarks

The specimens are attributed to genus *Silenites* due to sub-oval carapace.

Other taxon

Ostracoda indet.
(Fig. 5K1-K3)

Remark

The purpose of presenting these ostracodes is evidence of the effect of the reaction of dilute acetic acid and water, which has caused the destruction of these samples. That's why we could not identify them and marked them as unidentifiable ostracods.

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