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Couverture / *Cover* :
*Cyathus* sp. 3, right lateral view of a juvenile, sample AL7122, Dahane Botyan, MNHN.F.F62682 (Fig. 3M)

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# Rediscovering the Lys collection in the Muséum national d'Histoire naturelle (Paris, France): first report on Middle Permian ostracods from occidental Hindu Kush, Afghanistan

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## ABSTRACT

The micropalaeontology collections of the Muséum national d'Histoire naturelle in Paris (France) house the abundant and diverse collections gathered by Maurice Lys, geologist at the Institut Français du Pétrole from 1945 to 1971. Samples from the Middle Permian of the occidental Hindu Kush (central Afghanistan) collected and studied by Lys and his colleagues have been processed for ostracods study. Here, ostracods are for the first time reported from the Middle Permian (Roadian and Wordian) carbonate sequence of central Afghanistan, corresponding to 31 species distributed into 12 genera. Only small portions of the original samples have been treated, explaining the low abundance of the assemblage and the necessity to keep most of the species in open nomenclature. This discovery is nevertheless of major importance as it extends the palaeobiogeographic distribution of ostracods during the Middle Permian and further increases their palaeobiodiversity on the brink of the two extinction events at the end of the Palaeozoic. Palaeoenvironmental preferences of the recovered taxa seem to record an increase in the water depth from the east to the west over the studied area. The first analysis of ostracods provincialism during the Roadian is performed and identifies two clusters with strong similarity between South China Block and North American Platform and between central Afghanistan and Indochina Block.

KEY WORDS
Ostracods,
Middle Permian,
Roadian-Wordian,
Hindu Kush,
central Afghanistan,
Cimmerian Blocks,
Maurice Lys collection.

## RÉSUMÉ

*Redécouverte de la collection Lys du Muséum national d'Histoire naturelle (Paris, France) : premier signalement d'ostracodes du Permien moyen de l'Hindou Kouch occidental (Afghanistan).*

Les collections de micropaléontologie du Muséum national d'Histoire naturelle de Paris (France) hébergent des collections abondantes et diversifiées regroupées par Maurice Lys, géologue à l'Institut Français du Pétrole de 1945 à 1971. Des échantillons du Permien moyen de l'Hindou Koush occidental (Afghanistan central) collectés et étudiés par Lys et ses collègues ont été préparés pour l'étude des ostracodes. La présence d'ostracodes est ici pour la première fois rapportée dans la séquence carbonatée du Permien moyen (Roadien et Wordien) d'Afghanistan central, correspondant à 31 espèces réparties parmi 12 genres. Seules de petites portions des échantillons d'origine ont été attaquées, expliquant la

**MOTS CLÉS**
Ostracodes,
Permien moyen,
Roadien-Wordien,
Hindou Kouch,
Afghanistan central,
blocs cimmériens,
collection Maurice Lys.

faible abondance de l'assemblage et la nécessité de conserver la majeure partie des espèces en nomenclature ouverte. Cette découverte est néanmoins d'importance majeure en étendant la distribution paléobiogéographique des ostracodes au Permien moyen et en accroissant la paléobiodiversité de ce groupe à l'orée des deux extinctions de la fin du Paléozoïque. Les préférences paléo-environnementales des taxons présents semblent montrer une augmentation de la bathymétrie de l'est vers l'ouest de la zone d'étude. La première analyse du provincialisme des ostracodes au Roadien est menée et met en évidence deux groupes de forte similarité entre le bloc de Chine du Sud et la plateforme Nord-américaine et entre l'Afghanistan central et le bloc d'Indochine.

## INTRODUCTION

The Late Palaeozoic was a period of major tectonic reconfiguration with the Variscan Orogeny leading to the formation of the Pangaea, as a result of the assembly of Gondwana and Laurasia (updated summary in Berra & Angiolini 2014). The opening of the Neo-Tethys Ocean along the eastern margin of the Gondwana started in the Carboniferous and was followed by continental breakup and formation of oceanic crust in the middle Sakmarian, Early Permian (Garzanti 1999; Angiolini *et al.* 2003a; Metcalfe 2006). These events created the Cimmerian terranes (including Iran, central Afghanistan, Karakorum and Qiangtang) which migrated northward during the Early Permian and reached subequatorial palaeolatitudes by the Middle Permian-Early Triassic (e.g. Sengör 1979; Dercourt *et al.* 1993; Besse *et al.* 1998; Metcalfe 2006; Muttoni *et al.* 2009).

The end of the Palaeozoic has also been a period of major biotic perturbations with the end-Guadalupian crisis (Sepkoski 1981; Jin 1993; Stanley & Yang 1994; Wang & Sugiyama 2000; Bambach *et al.* 2004) followed by the disappearance of more than 90% of marine species through the end-Permian mass extinction (EPE) about 252 My ago (e.g. Sepkoski 1984; Erwin 1993; Benton & Twitchett 2003 but see Stanley 2016 for a recent re-evaluation of extinction rates). Ostracods are micro-crustacean with a mainly benthic distribution throughout their life and a long stratigraphic record ranging from the Ordovician to present-days (e.g. Salas *et al.* 2007; Siveter 2008). The EPE has been a turning point in their history with severe losses and deep restructuration of their communities (see Crasquin & Forel 2014 for review). Marine ostracod assemblages are documented through the Permian system but they are still unknown from Cimmerian terranes during most of the Permian. Most of our knowledge on Permian ostracods from the Cimmerian terranes focuses on the Late Permian pre-extinction assemblages in Turkey (Crasquin-Soleau *et al.* 2004a, b; Forel 2014) and Iran (Mette 2008, 2010; Forel *et al.* 2015). Until today, scarce Middle Permian ostracods have been reported from Turkey (Crasquin-Soleau *et al.* 2004b) and Iran (Forel *et al.* 2015). An older mention of Wordian ostracods from Turkey (Güvenç 1964) is currently under re-description.

The micropalaeontology collections of the Muséum national d'Histoire naturelle in Paris, France (MNHN) house the Maurice Lys collection, which includes rock samples, thin sections and extracted microfossils issued from sections located all over the world and covering most of the Palaeozoic and the early Mesozoic. Some elements of this major collection have been gathered by Lys himself during his career at the Institut Français du Pétrole (1945-1971) and at the MNHN where he has been accommodated in 1945 by Camille Arambourg and Jacques Roger (Vénec-Peyré & Bartolini 2010). Other elements were donated to him by different researchers, including Albert-Félix de Lapparent, who, together with Pierre Bordet (expert in the volcanism of Hoggar), created the Institut géologique Albert de Lapparent at the Institut Catholique of Paris in 1959. From 1961 onwards, de Lapparent and his colleagues of the Mission Française d'Afghanistan collected abundant geological and palaeontological material from the Palaeozoic and Triassic successions in Afghanistan (Gaudant 2008; Montenat 2008). The analyses and descriptions of the fossils gathered were done by specialists: for instance, Carboniferous and Permian Spiriferacea of central Afghanistan have been described by Legrand-Blain (1968) and Devonian brachiopods and rugose by Brice (1970). Lys carried out the study of foraminifers, algae and microfacies of the Permian of central Afghanistan on the basis of the material collected by de Lapparent and his co-workers. Owing to a series of warlike events and ongoing security issues, field research in most areas of Afghanistan has not been possible since the late 1970s. All rock samples collected in such areas are rare and might provide new data on the Permian and Triassic history of the Cimmerian terranes, rifting and drifting of these tectonic units as well as associated faunas. In order to bring this unique but forgotten material to light, rock samples from three sections of the Kubergandian Tethyan stage (equivalent to the Roadian International stage; Henderson *et al.* 2012; Angiolini *et al.* 2013, 2015, 2016; Angiolini & Vachard 2015) located on the southern flank of the Hindu Kush Mountains (central Afghanistan) and described by Lys *et al.* (1990) have been gathered and investigated for ostracod analysis. Two additional samples from the same localities and attributed to the Murghabian Tethyan stage (Wordian International stage; Henderson *et al.* 2012; Angiolini *et al.* 2013, 2015, 2016; Angiolini & Vachard 2015) by Boulin & Bouyx (1977) and Lys (1977) are also analysed. The analysis of the Lys collection stored in the MNHN is an exceptional opportunity to fill in the gap in our knowledge of ostracod assemblages and to document the first known ostracods from the Permian *lato sensu* of Afghanistan.

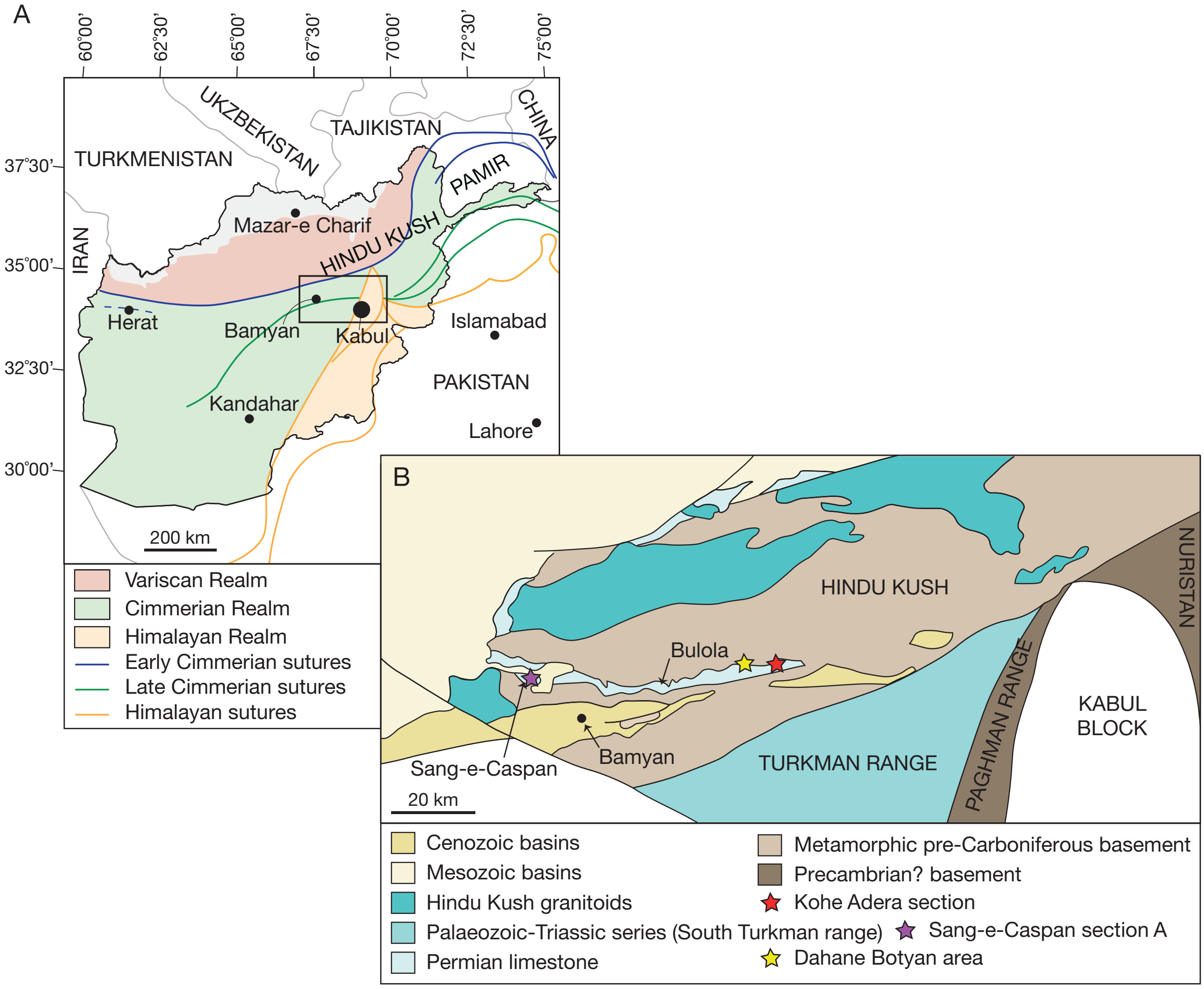


FIG. 1. — **A**, Geographical map of Afghanistan and simplified tectonic sketch (modified after Siehl 2017), rectangle corresponds to enlarged map in **B**; **B**, Geological map of the Hindu Kush (Afghanistan; modified after Vachard & Gaillot 2006) with the coloured stars showing the positions of the studied sections.

Roadian ostracod assemblages have been described from North America (Cooper & Grant 1972; Girty 1909, 1910), South China (Hou 1954), Thailand (Chitnarin *et al.* 2012, 2017) and Russia (Schneider 1956; Khivintseva 1969). Wordian ostracod assemblages have been reported from Sicily (Cooper & Grant 1972), Greece (Crasquin-Soleau & Baud 1998), Turkey (Kozur *et al.* 2000; Crasquin-Soleau *et al.* 2004a, b), Oman (Crasquin-Soleau *et al.* 1999; Angiolini *et al.* 2003b), Tibet (Crasquin-Soleau *et al.* 2007), Thailand (Chitnarin *et al.* 2008) and Iran (Forel *et al.* 2015). The present contribution is the first study of the Permian samples from Afghanistan since the work of Lys and his colleagues. It provides the first record and description of Permian ostracods of Afghanistan therefore extending their palaeobiogeographic distribution during the Roadian-Wordian time interval. It further increases their palaeobiodiversity in the Permian prior to the two extinctions marking the end of the Palaeozoic. This work is the first step of a large scale research project based on both collections exploitation and fieldwork, which will at terms provide answers to the three following questions:

1) is it possible to recognize spatial patterns in the global distribution of Permian ostracod faunas?

2) is it possible to identify key abiotic factors that influenced these spatial distribution patterns?

and 3) how did the spatial distribution patterns of ostracod faunas change through the Permian in relation to terranes migration and biotic perturbations?

## GEOLOGICAL SETTING

### UPPER PALAEOZOIC SERIES ON THE SOUTHERN HINDU KUSH

The tectonic setting of Afghanistan is complex and comprises several blocks of distinct ancestry, which are only briefly introduced here. A simplified tectonic sketch is shown in Fig. 1A and the reader is referred to Siehl (2017) for further details and complete references list. The Late Palaeozoic North Afghan Variscan domain forms the southern margin of the Turan Plate. The Early Cimmerian Palaeotethys suture zone (Late Triassic-Early Jurassic age) is located in Middle Afghanistan, with the associated magmatic arc and back-arc rift which extends from

TABLE 1. — Information on the studied samples including section, unit, Tethyan and International ages and original references, with: **1**, corresponding to Lys *et al.* (1990); **2**, corresponding to Boulin & Bouyx (1977); **3**, corresponding to Lys (1977).

| Sample | Section | Unit | Tethyan age | International age | References |
|---|---|---|---|---|---|
| C664 | Kohe Adera | 5 | Kubergandian *sensu lato* | Roadian | 1 |
| C667 | Kohe Adera | 7 | U. Kubergandian | Roadian | 1 |
| C669 | Kohe Adera | 7 | U. Kubergandian | Roadian | 1 |
| ML7973-1 | Sang-e-Caspan A | 4 | L. Kubergandian | Roadian | 1 |
| ML7973-2 | Sang-e-Caspan A | 4 | L. Kubergandian | Roadian | 1 |
| AL7121 | Dahane Botyan | na | L. Kubergandian | Roadian | 1 |
| AL7122 | Dahane Botyan | na | L. Kubergandian | Roadian | 1 |
| AL7120 | Dahane Botyan | na | Murghabian | Wordian | 2, 3 |
| AL7120bis | Dahane Botyan | na | Murghabian | Wordian | 2, 3 |

the western Hindu Kush to the northern Pamir Mountains. The Late Cimmerian domain (Late Jurassic-Early Cretaceous age) represents the Central Afghan Block mosaic with Gondwana-derived terranes. The Himalayan domain of Cenozoic age borders the Cimmerian domain along the transgressive boundary of the Indian Plate in the east and the accretionary complex of the Makran subduction zone in the south.

Thick Late Palaeozoic series termed “Calcaires à Fusulines” (Hayden 1911) are exposed on the southern flank of the Hindu Kush Mountains (Fig. 1A, B). They suffered multiple deformations including Cimmerian and Neogene tectonic movements, at the origin of the scarcity of continuous sections. The general lithological succession on the southern Hindu Kush is described by Lys *et al.* (1990) and can be summarized as follows in ascending order:

1) detrital-dominated formations of variable thickness exceeding several tenth of metres. They are composed of conglomerates, coarse to micro-conglomeratic sandstone, sandstone pelites, calcareous sandstones and scattered thin-bedded black limestone.

2) calcareous detrital horizons of Baschkirian and Moscovian, Pennsylvanian, age.

3) Thick Permian formations corresponding to the “Calcaires à Fusulines” of Hayden (1911) and Furon (1924), dominated by sandy limestone, centimetre-thick black limestone beds with algae, brachiopods, molluscs, bryozoans, fusulines, and massive limestone.

4) Calcareous detrital horizon with coarse to micro-conglomeratic sandstone, sandy limestone, marls and bioclastic limestone with fusulines. Its thickness reaches about 300m in the Bulola mountain range (Lys *et al.* 1973).

and 5) The sequence ends with decimetre-thick black limestone beds containing abundant fusulines, overlain by 50 to 100m or more of massive limestone where corals, *Bellerophon* brachiopods and large bivalves have been observed.

### STUDIED SECTIONS AND SAMPLES

The studied samples were collected by Lys and Lapparent from field sections located in the meridional Hindu Kush Mountains: in the Sang-e Caspan mountain range (Sang-e-Caspan section A) and about 60 km east in the High Ghorband (Kohe Adera section and Dahane Botyan area; Fig. 1A, B). The occurrence of these Permian layers of Kubergandian age has been acknowledged by several authors (e.g. Bouyx *et al.* 1970; Lys & Lapparent 1971; Bouyx 1972; Lys 1977; Vachard 1980) but they have only been thoroughly described by Lys *et al.* (1990). The stratotypes of certain regional stages of the Tethyan Scale (Leven 1980) have been revised and correlated with the International Stratigraphic Scale (Henderson *et al.* 2012; Angiolini *et al.* 2013, 2015, 2016; Angiolini & Vachard 2015). The good fusulinid and conodont records of the Kubergandian stratotype allows the correlation of the Kubergandian Tethyan stage with the Roadian international stage.

Key information on the studied sections are briefly reported (Fig. 2) and the reader is referred to Lys & Lapparent (1971) and Lys *et al.* (1990) for in-depth descriptions. Table 1 summarizes the samples studied and their ages in Tethyan and International timescales. It is worth reminding that these sections have not been sampled nor studied since the works of Lys and his associates so that most of the literature used here corresponds to the original literature cited by Lys *et al.* (1990).

#### *Kohe Adera section*

This section is located north east of Bamyan city (Fig. 1B) and has been coarsely sampled by de Lapparent. From the Ghorband valley in the south of the section, eight units have been defined by Lys *et al.* (1990) and their original log is redrawn in Fig. 2A. The Unit 1 is composed of limestone and detrital deposits (sandy pelites and thin-bedded sandstone) with a steep southward slope. The Unit 2 is composed of crystalline and highly refolded schists. The Unit 3 is a calcareous-detrital formation. The Unit 4 consists of thin-bedded black limestone. The Unit 5 (studied sample C664; Table 1; Fig. 2A) is the Kohe Adera Permian limestone organized into a syncline, composed of thick-bedded poorly stratified limestone beds, breccia and veins of black limestone with fusulines. The Unit 6 is covered with rock slide and might correspond to the continuation of Unit 4 on the northern flank of the syncline. This unit is not rich in microfauna and is attributed to the Kubergandian *sensu lato* (Lys *et al.* 1990). The Unit 7 (studied samples C667, C669; Table 1; Fig. 2A) is composed of sub-vertical beds followed by 3 to 4 metres of calcareous breccia. The nearly complete disappearance of *Misellina*, abundance of *Cancellina* and morphology of *Cancellina pamirica* and *Cancellina* cf. *praeneoschwagerinoides* led Lys *et al.* (1990) to attribute this unit to the Kubergandian. The Unit 8 consists of sub-vertical crystalline schists.

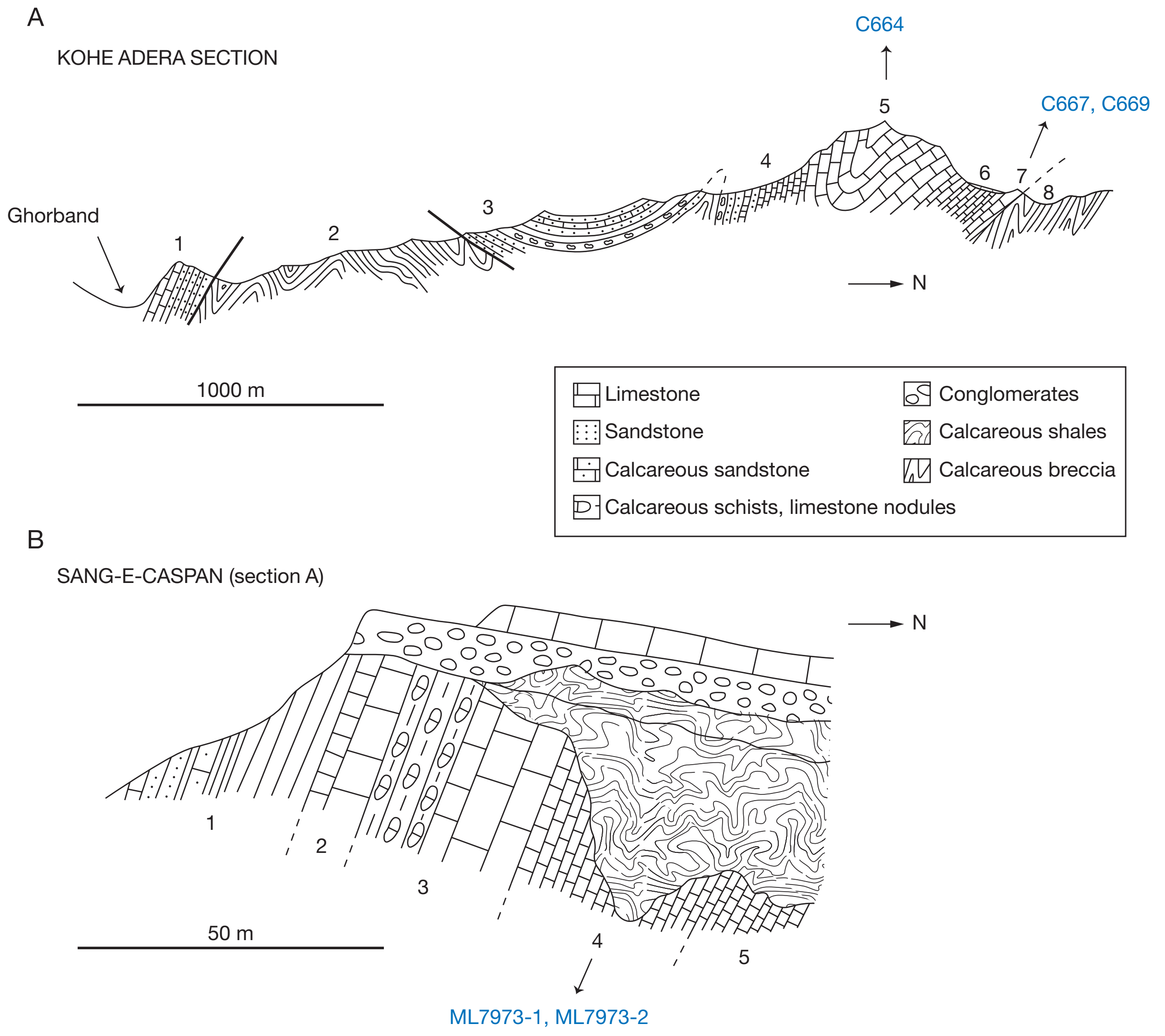


FIG. 2. — Schematic drawings of the outcrops of the studied sections in the Hindu Kush (Afghanistan; modified after Lys *et al.* (1990) to which the reader is referred for lithologies) with studied samples illustrated in blue; **A**, Kohe Adera section in High Ghorband (★ in Fig. 1B); **B**, Sang-e-Caspan section A on the meridional flank of Sang-e- Caspan (★ in Fig. 1B).

### *Sang-e-Caspan section A*

This section outcrops on the meridional flank of Sang-e-Caspan and beds are partially covered with conglomerates and Late Cretaceous calcareous shales. The section has been divided into successive units labelled from the south to the east, and is redrawn based on the original log of Lys *et al.* (1990) in Fig. 2B. The Unit 1 consists of an alternation of calcareous detrital layers made of coarse to micro-conglomeratic sandstone, calcareous sandstone, broken thin-bedded limestone and thin-bedded black limestone. The Unit 2 is made of thicker black limestone beds. The Unit 3 consists of calcareous schists with limestone nodules followed by black limestone with calcite veins. Ammonoid fauna indicates an Artinskian age [*Agathiceras sundaicum* Haniel, *Bamyaniceras bouyxi* Termier & Termier, *Prostacheoceras langi* Termier & Termier, *Perrinites hilli* (Smith); Bouyx *et al.* 1970]. The Unit 4 (studied samples ML7973-1, 7973-2; Table 1; Fig. 2B) is made of thin-bedded black limestone with abundant and diverse algae and foraminifers including fusulines, partially covered with rock slide. The foraminifer association indicates the *Cancellina* biozone, attributed to the lower Kubergandian. The topmost Unit 5 is composed of limestone plates covered with rock slide. It has been assigned to the Late Kubergandian-Early Murghabian based on the similarity of algae assemblage with limestone from the closely located Soghdar ravine (*Pseudovermiporella nipponica* (Endo *in* Endo & Kanuma, 1954) and Fusulina association (*Neofusulinella* sp., *Neofusulinella* cf. *lantenoisi* Deprat, 1913, *Polydiexodina* aff. *P. zulumartensis* Leven, 1967, *Pseudofusulina* sp., *Parafusulina* sp., *Staffella sphaerica* (Abich, 1859); Bouyx *et al.* 1970; Lys & Lapparent 1971; Lys *et al.* 1990).

### *Dahane Botyan area*

Few kilometres west of Kohe Adera (Fig. 1B), several outcrops are developed within 2 ravines where samples of “Calcaires à Fusulines” have been collected by Bouyx, Boulin and de Lap-

Table 2. — Taxonomic list and occurrence per sample studied.

Class OSTRACODA Latreille, 1802
Order PALAEOCOPIDA Henningsmoen, 1953
Suborder BEYRICHICOPINA Scott, 1961
Superfamily Aparchitoidea Jones, 1901
Family Aparchitidae Jones, 1901
*Cyathus* sp. 1 [C667, AL7121]
*Cyathus* sp. 2 [C667]
*Cyathus* sp. 3 [AL7121, AL7122]
*Cyathus* sp. 4 [AL7121]

Superfamily Paraparchitoidea Scott, 1959
Family Coelonellidae Sars, 1865
*Coelonella*? sp. [AL7121]

Family Paraparchitidae Scott, 1959
*Shemonaella*? sp. [C667]

Order PODOCOPIDA Sars, 1866
Suborder PODOCOPINA Sars, 1866
Superfamily Bairdiocypridoidea Shaver, 1961
Family Bairdiocyprididae Shaver, 1961
*Silenites limatus* Guan, 1978 [C667]
*Baschkirina* sp. 1 [AL7121]
*Baschkirina*? sp. 2 [AL7122]
*Baschkirina* sp. 3 [AL7121]

Family Pachydomellidae Berdan & Sohn, 1961
*Microcheilinella* sp. 1 [AL7122]
*Microcheilinella*? sp. 2 [C667]
*Microcheilinella* sp. 3 [AL7122]

Superfamily Bairdioidea Sars, 1880
Family Bairdiidae Sars, 1880
*Bairdia* sp. 1 [AL7120bis]
“*Bairdia*” sp. 2 [C667]
*Bairdia* sp. 3 [AL7120]
*Bairdia*? sp. 4 [AL7120]
*Bairdia* sp. 5 [AL7122]
*Bairdia* sp. 6 [AL7121]
*Bairdia* sp. 7 [AL7122]
*Bairdiacypris* sp. [AL7121]
*Cryptobairdia* sp. [AL7120]
*Orthobairdia* sp. 1 [AL7121]
*Orthobairdia* sp. 2 [AL7122]
*Orthobairdia* sp. 3 [C667]

Superfamily Cytheroidea Baird, 1850
Family Cytherideidae Sars, 1925
*Basslerella tota* Chen & Bao, 1986 [AL7121]
*Basslerella* sp. 1 [AL7121]
*Basslerella* sp. 2 [C667]
*Basslerella* sp. 3 [AL7122, AL7120bis]

Subclass MYODOCOPA Sars, 1866
Order MYODOCOPIDA Sars, 1866
Suborder MYODOCOPINA Sars, 1866
Superfamily Polycopoidea Sars, 1866
Family Polycopidae Sars, 1866
*Polycope* sp. 1 [C667]
*Polycope* sp. 2 [AL7122]

parent. They have been attributed to the Kubergandian and Murghabian (Boulin & Bouyx 1977; Lys 1977) but no field log has been drawn by Lys *et al.* (1990). Only Kubergandian samples (AL 7121, AL 7122: these samples have been collected from the same bed; Table 1) have been analysed by Lys *et al.* (1990) and they are re-investigated here in addition to samples AL 7120, AL 7120bis attributed to the Murghabian Tethyan stage (Wordian International stage; Table 1) by Boulin & Bouyx (1977) and Lys (1977). The Kubergandian beds consist of more or less dolomitic bioclastic limestone with brachiopods, bryozoans, crinoids, sponges, gastropods with sometimes silicified oncolites.

## MATERIAL AND METHODS

Of the numerous Lys samples stored in the micropalaeontology collections in the MNHN, I selected nine samples for ostracod analysis: three from the Kohe Adera section (labelled C664, C667, C669; Fig. 2A), four from the Dahane Botyan area (labelled AL7120, AL7120bis, AL7121, AL7122) and two from the Sang-e-Caspan section A (labelled ML7973-1, ML7973-2; Fig. 2B). All samples correspond to the analyses published by Lys *et al.* (1990), Boulin & Bouyx (1977) and Lys (1977) and are recognizable thanks to their storage organization, precise labels, fieldwork information and details provided by Lys when the materiel was deposited in the MNHN collections. They were carefully chosen not to contain macroscopic fusulines which would be broken during the processing; their characteristics are summarized in Table 1. The disaggregation of limestone samples and release of the enclosed ostracod carapaces were performed by the hot acetolysis technique (Lethiers & Crasquin-Soleau 1988; Crasquin-Soleau *et al.* 2005). To preserve material for future works, only small portions of the above-mentioned samples have been etched. For this reason, the present assemblage is not abundant and most of the species recovered are kept in open nomenclature. The left/right lateral, ventral and dorsal views of important and/or well preserved species are illustrated because of the significance of this material and to allow for future comparisons. All specimens are deposited in the micropalaeontology collections stored in the Muséum national d’Histoire naturelle, Paris.

### Abbreviations

| | |
|---|---|
| MNHN.F. | Muséum national d’Histoire naturelle, collections de Paléontologie, Paris; |
| L | length; |
| H | height; |
| W | width; |
| LV | left valve; |
| RV | right valve; |
| AB | anterior border; |
| PB | posterior border; |
| VB | ventral border; |
| DB | dorsal border; |
| AVB | antero-ventral border; |
| PVB | postero-ventral border; |
| ADB | antero-dorsal border; |
| PDB | postero-dorsal border. |

## SYSTEMATIC PALAEONTOLOGY

The classification used in this paper follows Horne *et al.* (2002) for taxa with Quaternary and living representatives, and Moore (1961) and Becker (2002) for extinct ones. Most of the species recovered from the studied samples have to be kept in open nomenclature because the scarcity of the material prevents the appreciation of their intraspecific variations, ontogeny and possible sexual dimorphism. When species are represented by one specimen, I consider them as adult forms in first approximation. The length convention is: < 0.40 very small, 0.40-0.50 small, 0.50-0.70 medium, 0.70-1.00 large, > 1.0 very large. Following Maddocks (2015), the slope of the antero-dorsal and postero-dorsal borders is measured on external lateral views of the carapaces with 0 being horizontal. In the following descriptions, "dorsal margin" corresponds to the entire dorsal area, which subdivides into postero-dorsal, dorsal and antero-dorsal borders; the same rule is used for the "ventral margin". For all species, I follow a simplified notation which does not use open nomenclature qualifiers such as confer but rather open nomenclature associated with synonymies and detailed discussions. All the specimens are preserved as complete carapaces, which hampers the observation of internal structures of the valves. Only significant, well preserved species or species morphologically close to already known taxa are described and/or discussed but all are illustrated to allow for future comparisons and understanding of this unique assemblage. The complete taxonomic list is available in Table 2.

### Class OSTRACODA Latreille, 1802
### Order PALAEOCOPIDA Henningsmoen, 1953
### Suborder BEYRICHICOPINA Scott, 1961
### Superfamily APARCHITOIDEA Jones, 1901
### Family APARCHITIDAE Jones, 1901

### Genus *Cyathus* Roth & Skinner, 1930

TYPE SPECIES. — *Cyathus ulrichi* Roth & Skinner, 1930 by original designation.

### *Cyathus* sp. 1
(Fig. 3A-H)

EXAMINED MATERIAL. — One complete adult carapace (MNHN.F.F62679; Fig. 3A-D, sample C667); one complete juvenile carapace (MNHN.F.F62680; Fig. 3E-H, sample AL7121).

DIMENSIONS. — L = 568 µm; H = 306 µm; W = 281 µm (Fig. 3A-D); L = 312 µm; H = 189 µm; W = 183 µm (Fig. 3E-H).

OCCURRENCE. — Sample C667, Kohe Adera section, High Ghorband; sample AL7121, Dahane Botyan area. All occurrences are from the southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

#### DESCRIPTION (ADULT)
Carapace of medium size, elongate, sub-rectangular and slightly asymmetrical in lateral view with Hmax at mid-L and Lmax above mid-H; biconvex in dorsal view with extremities thinned out at around ⅓rd of L, lateral sides straight, parallel and longer in the adult than in the juvenile, with Wmax developed along the straight portion; hinge line straight; DB overhanging hinge line at both valves, slightly higher at RV; dorsal margin long with convex median portion and slightly concave slopes to anterior and posterior extremities; AB and PB asymmetrical; AB rounded, shorter than PB, with maximum of convexity located slightly above mid-H, with ventral slope short and convex; PB rounded and more tapered ventrally than AB, maximum of convexity around mid-H, with ventral slope longer and straighter than at AB; ventral margin straight in median portion which is about 80% of Lmax; surface smooth.

#### DISCUSSION
The only juvenile found (Fig. 3E-H) is characterized by shorter anterior and posterior extremities and lateral sides more convex in dorsal view compared to the adult individual (Fig. 3A-D). The systematic position of *Cyathus* sp. 1 is complex to establish as its morphology is reminiscent of several genera belonging to different families. *Cyathus* sp. 1 is first evocative of some species of the genus *Cavellina* Coryell, 1928 (e.g. *Cavellina* sp. *in* Sohn 1975 from the Mississippian of Wyoming) but the high PB, channelled dorsum, symmetrical position of anterior and posterior maxima of curvature and tapered PB in dorsal view clearly precludes such generic attribution. *Cyathus* sp. 1 is also comparable to the genera *Coelonella* Stewart, 1936 and *Microcoelonella* Coryell & Sohn, 1938 because of its channelled hinge line and lateral morphology. However, *Coelonella* and *Microcoelonella* both belong to the Coellonellidae Sohn, 1971 characterized, among others, by their broad ventral overlap which is not observed on the present material. I rather attribute the present species to the Aparchitidae Jones, 1901, genus *Cyathus* Roth & Skinner, 1930 which displays a canoe-shape, no overlap, depressed hinge line and surface lineated to more rarely smooth (e.g. *Cyathus barmariensis* Crasquin-Soleau, 1998 from the Capitanian, Middle Permian of Greece; Crasquin-Soleau & Baud 1998). The lateral outline of *Cyathus* sp. 1 is close to *Cyathus ulrichi* Roth & Skinner, 1930 from the Pennsylvanian of Colorado (Roth & Skinner 1930). However, *Cyathus ulrichi* is shorter and biconvex in dorsal view, lacking the flat and parallel sides in median portion and the tapered extremities. *Cyathus* sp. 1 is also similar to *Cyathus striatus* Cooper, 1946 from the Pennsylvanian of Illinois (Cooper 1946) but *Cyathus striatus* has a significantly less elongated carapace (*Cyathus striatus*: L = 480 µm; H = 300 µm; W = 280 µm), a lenticular morphology in dorsal view and lateral striations. Because of its elongate subrectangular carapace and smooth surface, *Cyathus* sp. 1 is unquestionably a new species which will be fully described when additional material is discovered.

### *Cyathus* sp. 2
(Fig. 3I-L)

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62681).

OCCURRENCE. — Sample C667, Kohe Adera section, High Ghorband, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L = 521 µm; H = 319 µm; W = 368 µm.

### DESCRIPTION

Carapace of medium size, thicker than high; sub-ovoid and symmetrical in lateral view with Hmax at mid-L and Lmax around mid-H; biconvex and massive in dorsal view with Wmax located close to mid-L; RV slightly larger than LV, overhanging LV along dorsum; dorsal margin regularly arched at RV, long and close to straight at LV; ADB-DB and PDB-DB transitions are gently concave and symmetrical; AB and PB symmetrical, rounded with medium radius of convexity, maxima located above mid-L; ventral margin regularly arched; in dorsal view, anterior and posterior ends large and only slightly tapered; lateral surface uniformly covered with very thin and weak ridges extending from AB to PB, parallel to ventral margin in the lower ⅔rd of the carapace, and to dorsal margin in the upper ⅓rd.

### DISCUSSION

*Cyathus* sp. 2 shows morphological proximity with several *Cyathus* species documented in the literature. Of them, *Cyathus caperata* (Guan *in* Guan *et al.* 1978) is common in Permian strata of Asia: in the Early and Middle Permian of Thailand (Chitnarin *et al.* 2012; Burrett *et al.* 2015) and in the Early to the Late Permian of South China (Guan *et al.* 1978; Chen & Bao 1986; Shi & Chen 1987; Yuan *et al.* 2009; Crasquin *et al.* 2010; questionable occurrence in the Middle Permian: Zazzali *et al.* 2015) and Iran (Forel *et al.* 2015). *Cyathus caperata* (Guan *in* Guan *et al.* 1978) is characterized by convex DB and VB, a concave ADB, a slightly upraised antero-cardinal angle and coarse ridges covering the lateral surface. *Cyathus* sp. 2 is more rectangular and elongate in lateral view with a weaker dorsal inflation, less tapered extremities and has finer lateral ridges. In dorsal view, *Cyathus* sp. 2 is more rounded than *Cyathus caperata*, with less slender anterior and posterior extremities. The present species also shares morphological affinities with the rarer *Cyathus klimakiensis* Crasquin-Soleau *in* Crasquin-Soleau & Baud, 1998 only known from the Capitanian, Middle Permian, of Hydra Island, Greece (Crasquin-Soleau & Baud 1998). The shared characteristics are the fine striation expressed on the lateral surface of both species as well as the carapace dimensions. *Cyathus* sp. 2 also differs from *Cyathus adornatus* (Hoare, 2004) and *Cyathus ulrichi* (Roth & Skinner, 1930) respectively from the Pennsylvanian, Carboniferous, of Ohio (Hoare 2004) and Colorado (Roth & Skinner 1930), in being more uniformly ovoid and symmetrical in lateral view and by its finer ridges.

### *Cyathus* sp. 3
(Fig. 3M-T)

EXAMINED MATERIAL. — One complete juvenile carapace (MNHN.F.F62682; Fig. 3M-P, sample AL7122); one complete adult carapace (MNHN.F.F62683; Fig. 3Q-T, sample AL7121).

OCCURRENCE. — Samples AL7121, AL7122, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — Sample AL7122: L = 269 µm; H = 184 µm; W = 215 µm (Fig. 3M-P); Sample AL7121: L = 458 µm; H = 319 µm; W = 368 µm (Fig. 3Q-T).

### DESCRIPTION (ADULT)

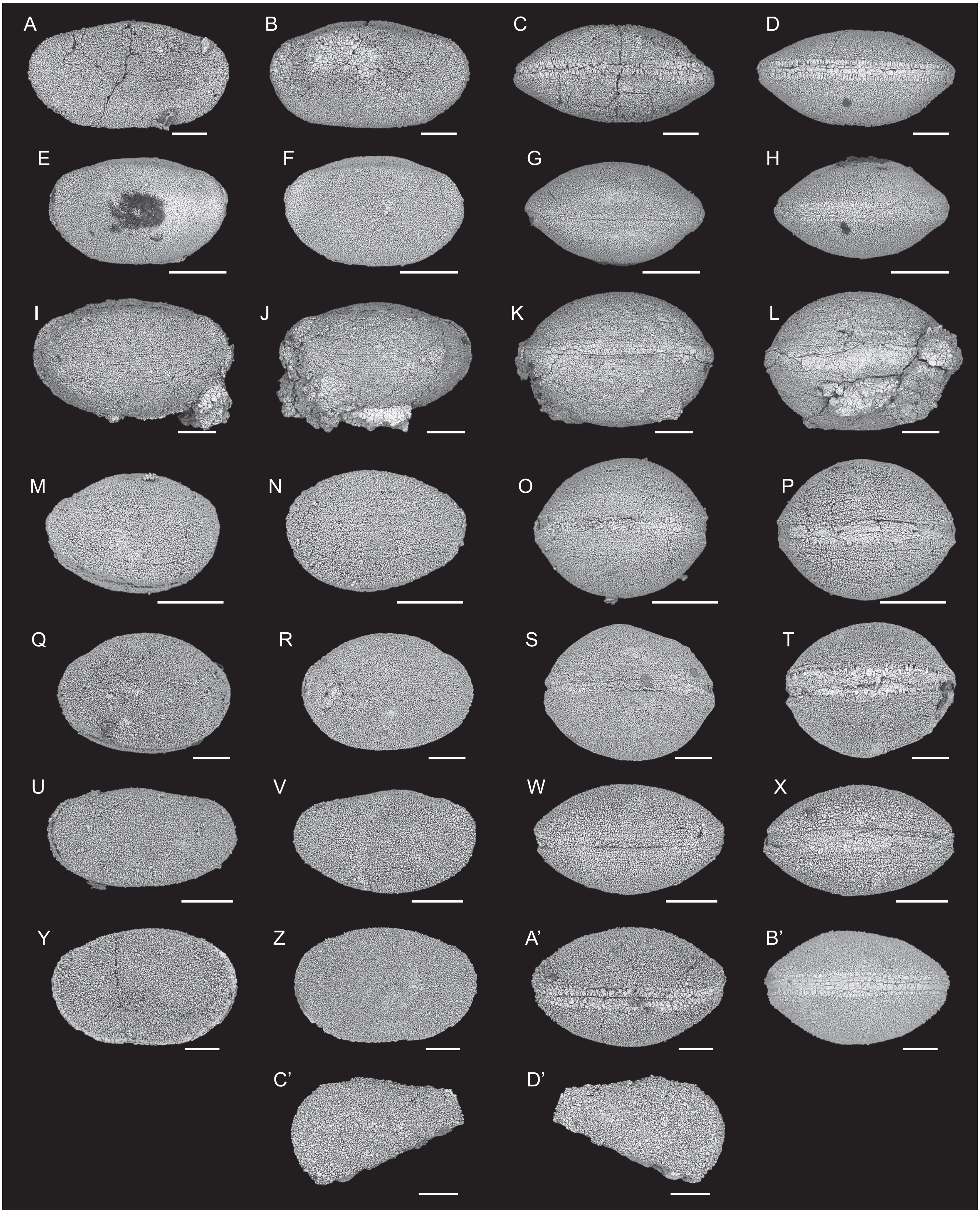
Carapace of small size, thicker than high, ovoid compact in lateral view with Hmax at mid-L and Lmax at mid-H; biconvex in dorsal view with Wmax around mid-L; RV slightly overlapping LV along ventral margin; high and rounded overreach at both valves along the long and straight dorsal border; cardinal angles obscure; AB and PB large and symmetrical with maximum of convexity at mid-H; ventral margin uniformly convex; surface with fine striation, only visible on the latero-ventral surface of the adult specimen.

### DISCUSSION

*Cyathus* sp. 3 is characterized by RV slightly overlapping LV along ventral margin, a high overreach at both valves and fine striation which is only visible on the ventral view of the adult specimen in hand (Fig. 3T). This prominent overreach is unique among *Cyathus* species and could be mistakenly related to the Coellonellidae Sohn, 1971, genera *Coelonella* Stewart, 1936 and *Microcoelonella* Coryell & Sohn, 1938. Such familial and generic attributions are nonetheless discarded by the presence of striation on the lateral surface of the valves, which is absent from Coellonellidae (Sohn 1971). *Cyathus* sp. 3 can be compared to *Microcoelonella takliensis* Chitnarin *in* Chitnarin *et al.* 2012 from the Wordian, Middle Permian, of Central Thailand (Chitnarin *et al.* 2012) because of the high overreach of both species. However, the present material is more rounded in dorsal view and the presence of striations clearly indicates that these taxa are neither congeneric nor confamilial. The large AB and PB, the fine lateral striation and the high overreach differentiates *Cyathus* sp. 3 from the widespread *Cyathus caperata* (Guan *in* Guan *et al.* 1978) and *Cyathus elliptica* Shi *in* Shi & Chen, 1987, the latter described from the Changhsingian, Late Permian of Meishan section, Zhejiang province, China (Shi & Chen 1987) and subsequently documented from the Early and Middle Permian of Thailand (Chitna-

→

FIG. 3. — Ostracods (Palaeocopida) from the southern Hindu Kush, Afghanistan, Roadian, Middle Permian. All specimens are stored at the Muséum national d'Histoire naturelle (Paris, France) under collection numbers MNHN.F.xx. All specimens are represented by complete carapaces. **A**-**H**, *Cyathus* sp. 1; **A**, right lateral view of an adult, sample C667, Kohe Adera section, MNHN.F.F62679; **B**, left lateral view, same specimen; **C**, dorsal view, same specimen; **D**, ventral view, same specimen; **E**, right lateral view of a juvenile, sample AL7121, Dahane Botyan, MNHN.F.F62680; **F**, left lateral view, same specimen; **G**, dorsal view, same specimen; **H**, ventral view, same specimen; **I**-**L**, *Cyathus* sp. 2; **I**, left lateral view, sample C667, Kohe Adera section, MNHN.F.F62681; **J**, right lateral view, same specimen; **K**, dorsal view, same specimen; **L**, ventral view, same specimen; **M**-**T**, *Cyathus* sp. 3; **M**, right lateral view of a juvenile, sample AL7122, Dahane Botyan, MNHN.F.F62682; **N**, left lateral view, same specimen; **O**, dorsal view, same specimen; **P**, ventral view, same specimen; **Q**, right lateral view, sample AL7121,



Dahane Botyan, MNHN.F.F62683; **R**, left lateral view, same specimen; **S**, dorsal view, same specimen; **T**, ventral view, same specimen; **U**-**X**, *Cyathus* sp. 4; **U**, right lateral view, sample AL7121, Dahane Botyan, MNHN.F.F62684; **V**, left lateral view, same specimen; **W**, dorsal view, same specimen; **X**, ventral view, same specimen; **Y**-**B'**, *Coelonella*? sp.; **Y**, right lateral view, sample AL7121, Dahane Botyan, MNHN.F.F62685; **Z**, left lateral view, same specimen; **A'**, dorsal view, same specimen; **B'**, ventral view, same specimen; **C', D'**, *Shemonaella*? sp., sample C667, Kohe Adera section, MNHN.F.F62686; **C'**, right lateral view, **D'**, left lateral view, same specimen. Scale bars: 100 µm.

rin *et al.* 2012; Burrett *et al.* 2015), questionably from the Middle Permian of South China (Zazzali *et al.* 2015) and from the Changhsingian, Late Permian of South China (Yi 2004; Crasquin *et al.* 2010) and Iran (Forel *et al.* 2015). The juvenile and adult specimens document the relatively conservative morphology of *Cyathus* sp. 3 through its ontogenetic development.

### *Cyathus* sp. 4
(Fig. 3U-X)

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62684).

OCCURRENCE. — Sample AL7121, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L = 366 μm; H = 193 μm; W = 214 μm.

#### DISCUSSION

*Cyathus* sp. 4 differs from *Cyathus striatus* Cooper, 1946 from the Pennsylvanian of Illinois (Cooper 1946) by its different H/L ratio (*Cyathus striatus*: 0.62; *Cyathus* sp. 3: 0.53) and by lacking the strictly straight dorsal margin and the broad and shallow channel along venter. It is also close to *Cyathus densistriata* Kozur, 1991 described from deep-water of Sicily during the Wuchiapingian, Late Permian (Kozur 1991) and more recently discovered in the Kungurian, Early Permian, of the same area (Crasquin *et al.* 2008). However, *Cyathus* sp. 4 has a more rounded anterior margin and finer striation on the lateral surface. *Cyathus elliptica* Shi *in* Shi & Chen, 1987 has been described from the Changhsingian, Late Permian of Meishan section, Zhejiang Province, China (Shi & Chen 1987). Although closely related to *Cyathus elliptica* as shown by its thin and elongate morphology in lateral outline, the present material lacks the diagnostic sub-rectangular shape in dorsal view. Conversely, *Cyathus* sp. 4 might be conspecific with *Cyathus*? aff. *striatus* Cooper, 1946 from the Artinskian, Early Permian of south-central British Columbia, Canada (Crasquin-Soleau & Orchard 1994). The two species have similar H/L ratio (*Cyathus*? aff. *striatus* Cooper, 1946: L = 525 μm; H = 262.5 μm; H/L = 0.5), fine striation covering the lateral surface but their dimensions are different and the DB of *Cyathus* sp. 4 is longer with more pronounced cardinal angles. Both discussed species is represented by one specimen so I choose to keep them as distinct species until more material can be observed and confirm that their size disparity might relate to ontogeny.

### Superfamily PARAPARCHITOIDEA Scott, 1959
### Family COELONELLIDAE Sohn, 1971

### Genus *Coelonella* Stewart, 1936

TYPE SPECIES. — *Isochilina scapha* Stewart, 1930 by original designation.

### *Coelonella*? sp.
(Fig. 3Y-B')

*Coelonella* aff. *scapha* – Fohrer 1997: 118, taf. 13/4, 8.

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62685).

OCCURRENCE. — Sample AL7121, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work); Carnic Alps, Gzhelian-Asselian, Late Carboniferous-Early Permian, Southern Austria (Fohrer 1997).

DIMENSIONS. — L = 546 μm; H = 344 μm; W = 339 μm.

#### DISCUSSION

The specimen in hand and the one illustrated from the Late Carboniferous-Early Permian of Austria (Fohrer 1997) are conspecific on the basis of their lateral and dorsal morphologies, dimensions and H/L ratios (L = 530 μm; H = 310 μm; W = 318 μm; Fohrer 1997). Before the works of Fohrer (1989, 1991, 1997), the genus *Coelonella* was only known in the Devonian. However, I cast doubt on the generic and familial attributions of this species because both specimens lack the channelled dorsum and thick overlap along the free margin which are two of the diagnostic characters for the Coellonellidae and genus *Coelonella*. Following the conception of Sohn (1971) regarding the Paraparchitidae, the present species could be attributed to this family and to the genus *Shemonaella* Sohn, 1971. *Shemonaella* correspond to unspined Paraparchitidae, lacking an incised dorsum, subovate to elongate-ovate in lateral view, with a slight overlap of one valve along the free margin of the other, without necessary overreach. During the Early and Middle Permian, *Shemonaella* is only known from Central Thailand (Chitnarin *et al.* 2012; Burrett *et al.* 2015). Its distribution enlarged in the Late Permian, with occurrences in China (Crasquin *et al.* 2010; Forel 2012), Hungary (Forel *et al.* 2013) and Iran (Forel *et al.* 2015). All these Permian species as well as the Carboniferous specimens illustrated by Sohn (1971) have straight dorsal margins. For this reason, more material is needed to clarify the taxonomic uncertainty related to *Coelonella*? sp. and until additional thorough observations can be performed, it is kept in its original generic attribution proposed by Fohrer (1997).

### Order PODOCOPIDA Sars, 1866
### Suborder PODOCOPINA Sars, 1866
### Superfamily BAIRDIOCYPRIDOIDEA Shaver, 1961
### Family BAIRDIOCYPRIDIDAE Shaver, 1961

### Genus *Silenites* Coryell & Booth, 1933

TYPE SPECIES. — *Silenites silenus* Coryell & Booth, 1933 by original designation.

### ***Silenites limatus*** Guan, 1978
(Fig. 4A-C)

*Silenites limatus* Guan *in* Guan, Sun, Jiang, Li, Zhao, Zhang, Yang & Feng, 1978: 323, pl. 86, figs 8, 9 (non *Silenites limatus*

Guan, 1978 *in* Shi & Chen, 1987: 62, pl. 15, figs 15-19). — Shi & Chen 2002: 95, pl. 27, figs 2-17.

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62687).

OCCURRENCE. — Heshan section, Guangxi province, Late Permian, South China (Guan *et al.* 1978); Heshan and Yishan sections, Guangxi province, Late Permian, South China (Shi & Chen 2002); sample C667, Kohe Adera section, High Ghorband, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L = 847 µm; H = 542 µm; W = 362 µm (this work).

### DISCUSSION

*Silenites limatus* has been described from the Late Permian of Heshan section, Guangxi province, South China (Guan *et al.* 1978). Later it was recognized from the Late Permian of Heshan and Yishan sections, Guangxi province, South China (Shi & Chen 2002). Our specimen is slightly shorter than the Late Permian specimens from South China but all diagnostic characters are present. Such variations can be related either to sexual dimorphism as we know it for modern Bairdiidae (e.g. Maddocks 2015) or to ontogeny. However, specimens documented for *Silenites limatus* are still too few to discuss this issue. The present record is the first occurrence of *Silenites limatus* outside of South China and it represents its oldest occurrence worldwide.

## Genus *Baschkirina* Rozdestvenskaja, 1959

TYPE SPECIES. — *Baschkirina memorabilis* Rozdestvenskaja, 1959 by original designation.

## *Baschkirina* sp. 1
(Fig. 4D-F)

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62688).

OCCURRENCE. — Sample AL7121, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L = 306 µm; H = 177 µm; W = 159 µm.

### DISCUSSION

*Baschkirina* sp. 1 is close to *Basslerella firma* Kellett, 1935 *in* Yan, Wang & Qi, 2005 and *Basslerella crassa* Kellett, 1935 *in* Chen & Bao, 1986 from the Carboniferous of Kansas (Kellett 1935), and to *Basslerella obesa* Kellett, 1935 *in* Cooper, 1946 from the Pennsylvanian of Illinois (Cooper 1946). However, the morphology of the carapace in dorsal view precludes the attribution of our material to the genus *Basslerella*, which is plump and posteriorly strongly inflated. Similarly, the material identified as *Basslerella firma* from the Sakmarian, Early Permian, of Zhejiang province, China (Yan *et al.* 2005) should be re-attributed to the genus *Baschkirina* on the basis of its biconvex dorsal view with Wmax thinner and located around mid-L. *Basslerella crassa* from the Kungurian, Early Permian, of Jiangsu province, China (Chen & Bao 1986) has a lateral morphology similar to *Baschkirina* sp. 1 but no dorsal view is provided in the original work of Chen & Bao (1986). As a consequence, it is presently impossible to further discuss the possibility that the Chinese and Afghan specimens are conspecific or to unquestionably confirm that the taxa illustrated by Chen & Bao (1986) is *Basslerella crassa*.

## *Baschkirina*? sp. 2
(Fig. 4G, H)

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62689).

OCCURRENCE. — Sample AL7122, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L > 308 µm; H = 155 µm; W = 141 µm.

### DISCUSSION

*Baschkirina*? sp. 2 is attributed with doubt to the genus *Baschkirina* because of the preservation state of the specimen in hand. *Baschkirina*? sp. 2 is morphologically close to a species illustrated from the Kungurian, Early Permian, of Guatemala (Lethiers *et al.* 1995: fig. 3Q) for which the legend and taxonomic attribution are missing; it is furthermore impossible to determine the size of this specimen as no magnification or scale bar is available. Both taxa might be conspecific but the specimen extracted from the Dahane Botyan area is altered, precluding the comparison of anterior and posterior margins, which are of peculiar morphology in the Guatemalan species.

## *Baschkirina* sp. 3
(Fig. 4I-K)

*Baschkirina* cf. *ballei* – Chitnarin *et al.* 2017: 679, fig. 24I-L.

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62690).

OCCURRENCE. — Sample AL7121, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work); Asselian, Sakmarian and Kungurian, Early Permian, central Thailand (Chitnarin *et al.* 2017).

DIMENSIONS. — L = 264 µm; H = 172 µm; W = 147 µm.

### DISCUSSION

*Baschkirina* sp. 3 is distinct from *Baschkirina ballei* Crasquin *in* Crasquin, Forel, Feng, Yuan, Baudin & Collin, 2010 from the Changhsingian, Late Permian of Meishan section, Zhejiang province, China (Crasquin *et al.* 2010), by its more inflated biconvex morphology in dorsal view with Wmax located around mid-L. The present specimen is conspecific with *Baschkirina* cf. *ballei* from the Early Permian of central Thailand (Chitnarin *et al.* 2017). This species is new and characterized by its higher H/L ratio (0.65 to 0.75 for Thai specimens), short and sub-vertical PB. More material is still required to completely analyse and describe its characters, owing to the difficulty of the taxonomy of the genus *Baschkirina*.

### Family Pachydomellidae Berdan & Sohn, 1961

### Genus *Microcheilinella* Geis, 1933

Type species. — *Microcheilus distortus* Geis, 1932 by original designation.

### *Microcheilinella* sp. 1
(Fig. 4L-O)

Examined material. — One complete carapace (MNHN.F.F62691).

Occurrence. — Sample AL7122, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

Dimensions. — L = 330 µm; H = 184 µm; W = 228 µm.

#### Discussion

*Microcheilinella* sp. 1 is close to some specimens of *Microcheilinella rectodorsata* Forel *in* Crasquin, Forel, Feng, Yuan, Baudin & Collin, 2010 described from the Changhsingian, Late Permian, of Meishan section, Zhejiang province, China (Crasquin *et al.* 2010) and later reported from the same time interval in central Alborz, Iran (Forel *et al.* 2015). *Microcheilinella rectodorsata* is characterized by a straight and long DB at RV, AVB quite vertical and Wmax located near mid-L in dorsal view. The dorsal margin of *Microcheilinella* sp. 1 is also long and straight but the AB of the specimen in hand is close to vertical, leading to a longer and more prominent ADB. Another discordant character comes from the ventral overlap which is thick in *Microcheilinella rectodorsata* but absent in *Microcheilinella* sp. 1. Furthermore, Wmax in *Microcheilinella* sp. 1 is located more anteriorly than in *Microcheilinella rectodorsata*. In spite of all these morphological differences, *Microcheilinella rectodorsata* appears to be the closest species related to *Microcheilinella* sp. 1. Both species are unique among *Microcheilinella* species, in being characterised by their long and straight dorsal margin. *Microcheilinella* sp. 1 is a new species endemic to the Dahane Botyan area which will be fully described when further material is discovered.

### *Microcheilinella*? sp. 2
(Fig. 4P-R)

Examined material. — One complete carapace (MNHN.F.F62692).

Occurrence. — Sample C667, Kohe Adera section, High Ghorband, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

Dimensions. — L = 303 µm; H = 153 µm; W = 196 µm.

#### Discussion

*Microcheilinella*? sp. 2 is attributed with doubt to the genus *Microcheilinella* because of the lack of asymmetry of the valves and of the resulting thick overlap around all or part of the margins. The lateral morphology is reminiscent of the Bythocytheridae, Cytheridea with tapered posterior extremity in lateral view but the lack of any hint of a median sulcus and of ventro-lateral inflation tends to reject this attribution. Until more material is discovered, I attribute the present species with doubt to the genus *Microcheilinella* on the basis of its massive outline in dorsal view, asymmetric and rounded AB and PB.

### *Microcheilinella* sp. 3
(Fig. 4S-W)

*Microcheilinella shicheni* – Chitnarin *et al.* 2017: 680, fig. 26R, S.

Examined material. — One complete carapace (MNHN.F.F62693).

Occurrence. — Sample AL7122, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work); Roadian, Middle Permian, central Thailand (Chitnarin *et al.* 2017).

Dimensions. — L = 504 µm; H = 254 µm; W = 358 µm.

#### Description

Carapace of medium size, subrectangular and massive in lateral view with Hmax constant along DB, symmetrical along the AD-PV axis; pear-shape in dorsal view, tapered anteriorly, with Wmax close to PB; LV larger, overlapping all along PDB, DB and ADB; DB long and straight, parallel to VB; ADB more rounded than PDB; AB largely rounded with maximum of convexity around mid-H; AVB and PDB mirror-images, both long and slightly convex, PDB more slopping; PB slightly narrower than AB, with maximum of curvature located more ventrally; in posterior view, the valves are subtriangular with Wmax located close to VB, ventral area flat; surface smooth.

#### Discussion

The present material is morphologically close to *Microcheilinella subreniformis* Chen, 1958 from the Kungurian, Early Permian of Guangshan section, Nanjing, China (Chen 1958), from which it differs by its more tapered anterior margin in dorsal view and a smaller H/W ratio (H/W = 0.71 for the present specimen, against 0.81-0.84 for *Microcheilinella subreniformis*). These two species might be conspecific and the observed differences might relate to sexual dimorphism or ontogeny so that additional material is necessary to propose an explanation to the observed differences. *Microcheilinella* sp. 3 also differs from *Microcheilinella shicheni* Crasquin *in* Crasquin, Forel, Feng, Yuan, Baudin & Collin, 2010 from the Changhsingian, Late Permian, of Meishan section, Zhejiang province, China (Crasquin *et al.* 2010) by its rectangular PB, wider ADB and larger posterior margin relatively to the anterior margin in dorsal view. Two carapaces (one complete and one broken) from the Roadian of central Thailand (Chitnarin *et al.* 2017) have been wrongly attributed to *Microcheilinella shicheni*: the dimensions of the complete specimen (L = 560 µm; H = 240 µm) as well as its PB in lateral and dorsal views preclude its attribution to *Microcheilinella shicheni*. The Thai and Afghan specimens are conspecific but material is still lacking to define all the diagnostic characters of this typically Roadian new species.

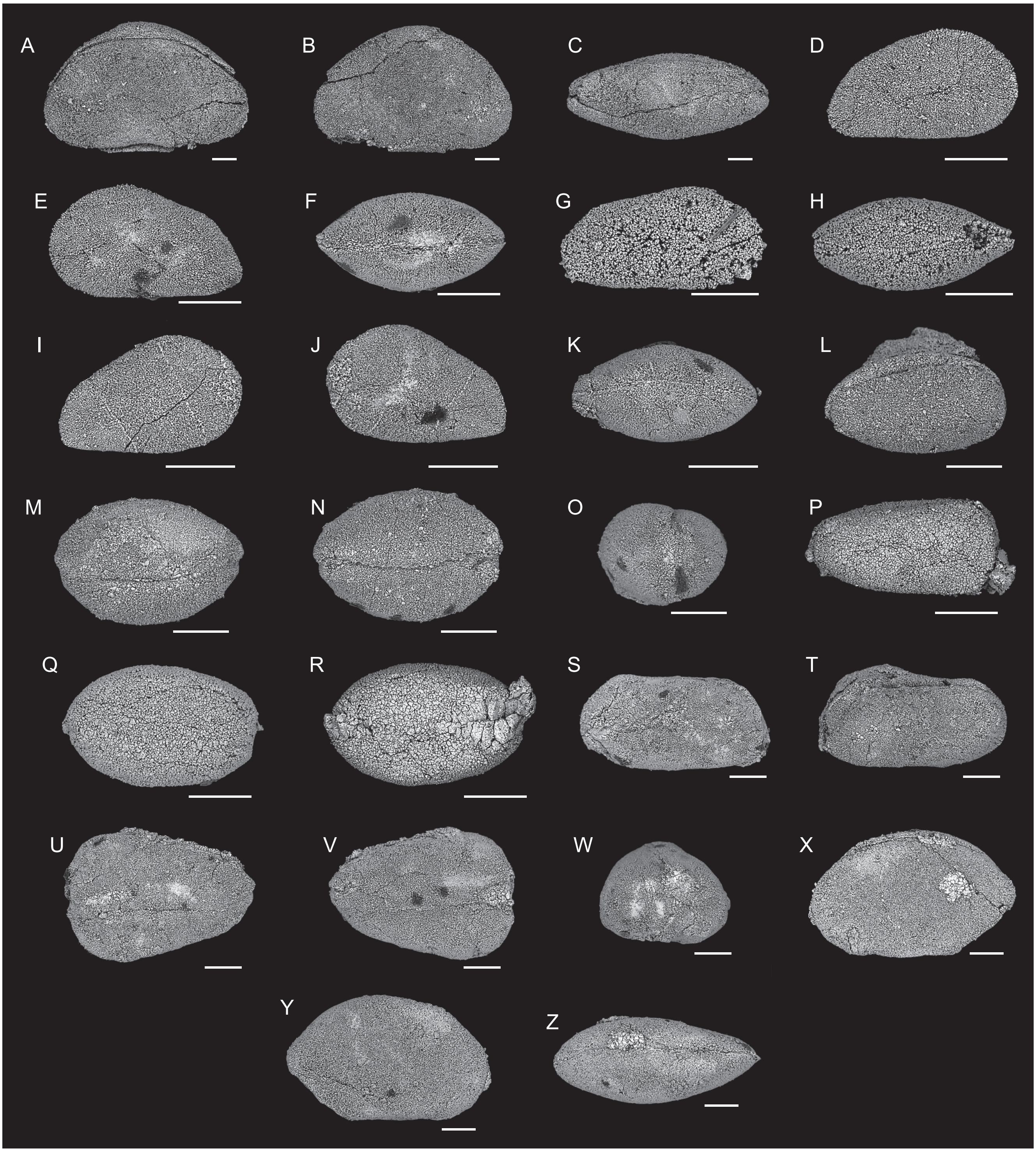


Fig. 4. — Ostracods (Podocopida) from the southern Hindu Kush, Afghanistan, Roadian-Wordian, Middle Permian. All specimens are stored at the Muséum national d'Histoire naturelle (Paris, France) under collection numbers MNHN.F.xx. All specimens are represented by complete carapaces. **A**-**C**, *Silenites limatus* Guan *in* Guan, Sun, Jiang, Li, Zhao, Zhang, Yang & Feng, 1978; **A**, right lateral view, sample C667, Kohe Adera section, Roadian, MNHN.F.F62687; **B**, left lateral view, same specimen; **C**, dorsal view, same specimen; **D**-**F**, *Baschkirina* sp. 1; **D**, right lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62688; **E**, left lateral view, same specimen; **F**, dorsal view, same specimen; **G**, **H**, *Baschkirina*? sp. 2; **G**, right lateral view, sample AL7122, Dahane Botyan, Roadian, MNHN.F.F62689; **H**, dorsal view, same specimen; **I**-**K**, *Baschkirina* sp. 3; **I**, right lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62690; **J**, left lateral view, same specimen; **K**, dorsal view, same specimen; **L**-**O**, *Microcheilinella* sp. 1; **L**, right lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62691; **M**, dorsal view, same specimen; **N**, ventral view, same specimen; **O**, posterior view, same specimen; **P**-**R**, *Microcheilinella*? sp. 2; **P**, right lateral view, sample C667, Kohe Adera section, Roadian, MNHN.F.F62692; **Q**, dorsal view, same specimen; **R**, ventral view, same specimen; **S**-**W**, *Microcheilinella* sp. 3; **S**, left lateral view, sample AL7122, Dahane Botyan, Roadian, MNHN.F.F62693;**T**, right lateral view, same specimen; **U**, dorsal view, same specimen; **V**, ventral view, same specimen; **W**, posterior view, same specimen; **X**-**Z**, *Bairdia* sp. 1; **X**, right lateral view, sample AL7120bis, Dahane Botyan, Wordian, MNHN.F.F62694; **Y**, left lateral view, same specimen; **Z**, dorsal view, same specimen. Scale bars: 100 μm.

## Superfamily BAIRDIOIDEA Sars, 1888

## Family BAIRDIIDAE Sars, 1888

REMARKS
For the sake of simplicity, the morphological description and taxonomic discussion of Bairdiidae is limited to taxa for which comparison with closely related species is possible.

## Genus *Bairdia* McCoy, 1844

TYPE SPECIES. — *Bairdia curta* McCoy, 1844 by subsequent designation (Ulrich & Bassler 1923: 320).

### *Bairdia* sp. 6
(Fig. 5L-N)

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62699).

OCCURRENCE. — Sample AL7121, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L > 964 µm; H = 453 µm; W = 322 µm.

DISCUSSION
*Bairdia fangnianqiaoi* Crasquin *in* Crasquin, Forel, Feng, Yuan, Baudin & Collin, 2010 has been described from the Changhsingian, Late Permian, of Meishan section, Zhejiang province, China (Shi & Chen 1987; Crasquin *et al.* 2010). Recently, it has also been documented from the Early and Middle Permian of Central Thailand (Chitnarin *et al.* 2017). The present specimen is close to *Bairdia fangnianqiaoi* but the incompleteness of the specimen precludes to go further in its specific attribution.

### *Bairdia* sp. 7
(Fig. 5O, P)

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62700).

OCCURRENCE. — Sample AL7122, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L > 551 µm; H = 349 µm; W = 336 µm.

DISCUSSION
The preservation of *Bairdia* sp. 7 is poor as both the anterior and posterior margins are broken. The specific attribution of this taxa is hardened by the lack of material, as only one specimen has been found in Dahane Botyan area. In spite of these limitations, *Bairdia* sp. 7 is characterized by a strong overlap of LV over RV along the dorsal margin, an incised hinge line associated with a plump dorso-lateral area and a spindle-shape morphology in dorsal view, which are reminiscent of *Bairdia incisedorsa* Chitnarin *in* Chitnarin, Crasquin, Forel & Tepnarong, 2017 from the Roadian of central Thailand (Chitnarin *et al.* 2017). *Bairdia* sp. 7 might be conspecific with *Bairdia incisedorsa* but this hypothesis can only be verified with additional material from central Afghanistan.

## Genus *Orthobairdia* Sohn, 1960

TYPE SPECIES. — *Bairdia centriensis* Ulrich, 1891 by subsequent designation (Sohn 1960: 65).

### *Orthobairdia* sp. 3
(Fig. 5C'-F')

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62705).

OCCURRENCE. — Sample C667, Kohe Adera section, High Ghorband, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L = 368 µm; H = 196 µm; W = 125 µm.

DISCUSSION
*Orthobairdia lemairei* Crasquin *in* Crasquin, Forel, Feng, Yuan, Baudin & Collin, 2010 has been described from the Wuchiapingian-Changhsingian, Late Permian, of Guangxi (Shi & Chen 2002) and Zhejiang provinces, China (Shi & Chen 1987; Crasquin *et al.* 2010). *Orthobairdia* sp. 3 is close to *Orthobairdia lemairei* and shares the same H/L ratio (ranging from 0.52 to 0.59 for the figured specimens in Crasquin *et al.* 2010). However, the dimensions of the Afghan specimen correspond to the lower size-range of the Late Permian material from China. In the absence of additional material to understand its ontogenetic variations and relationship to *Orthobairdia lemairei*, the present species is kept under open nomenclature.

## Superfamily CYTHEROIDEA Baird, 1850
## Family CYTHERIDEIDAE Sars, 1925

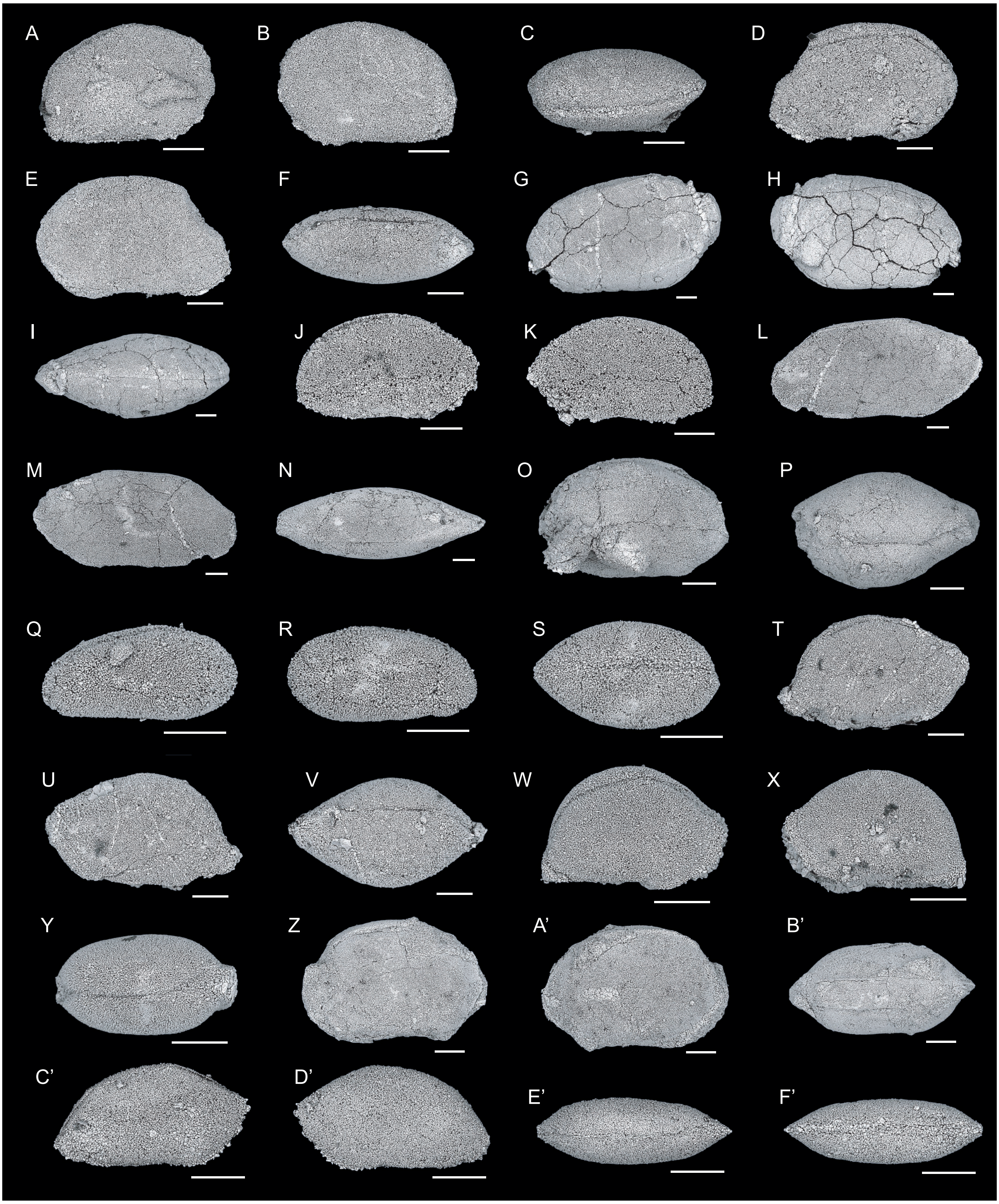
## Genus *Basslerella* Kellett, 1933

TYPE SPECIES. — *Basslerella crassa* Kellett, 1933 by original designation.

### ***Basslerella tota*** Chen & Bao, 1986
(Fig. 6A-D)

*Basslerella tota* Chen & Bao, 1986: 123, pl. I, figs 31, 32; pl. IV, figs 7, 8. — Yi 1992: pl. I, fig. 6; 2004: pl. 2, fig. 20 — Crasquin-Soleau & Baud 1998: pl. 6, figs 9, 12. — Crasquin-Soleau *et al.*

FIG. 5. — Ostracods (Podocopida) from the southern Hindu Kush, Afghanistan, Roadian-Wordian, Middle Permian. All specimens are stored at the Muséum national d'Histoire naturelle (Paris, France) under collection numbers MNHN.F.xx. All specimens are represented by complete carapaces. **A**-**C**, "*Bairdia*" sp. 2; **A**, right lateral view, sample C667, Kohe Adera section, Roadian, MNHN.F.F62695; **B**, left lateral view, same specimen; **C**, dorsal view, same specimen; **D**-**F**, *Bairdia* sp. 3; **D**, right lateral view, sample AL7120, Dahane Botyan, Wordian, MNHN.F.F62696; **E**, left lateral view, same specimen; **F**, dorsal view, same specimen; **G**-**I**, *Bairdia*? sp. 4; **G**, right lateral view, sample AL7120, Dahane Botyan, Wordian, MNHN.F.F62697; **H**, left lateral view, same specimen; **I**, dorsal view, same specimen; **J**, **K**, *Bairdia* sp. 5; **J**, right lateral view, sample AL7122, Dahane Botyan, Roadian, MNHN.F.F62698; **K**, left lateral view, same specimen; **L**-**N**, *Bairdia* sp. 6; **L**, right



lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62699; **M**, left lateral view, same specimen; **N**, dorsal view, same specimen; **O**, **P**, *Bairdia* sp. 7; **O**, right lateral view, sample AL7122, Dahane Botyan, Roadian, MNHN-F.62700; **P**, dorsal view, same specimen; **Q**-**S**, *Bairdiacypris*? sp.; **Q**, right lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62701; **R**, left lateral view, same specimen; **S**, dorsal view, same specimen; **T**-**V**, *Cryptobairdia* sp.; **T**, right lateral view, sample AL7120, Dahane Botyan, Wordian, MNHN.F.F62702; **U**, left lateral view, same specimen; **V**, dorsal view, same specimen; **W**-**Y**, *Orthobairdia* sp. 1; **W**, right lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62703; **X**, left lateral view, same specimen; **Y**, dorsal view, same specimen; **Z**-**B'**, *Orthobairdia* sp. 2; **Z**, right lateral view, sample AL7122, Dahane Botyan, Roadian, MNHN.F.F62704; **A'**, left lateral view, same specimen; **B'**, dorsal view, same specimen; **C'**-**F'**, *Orthobairdia* sp. 3; **C'**, right lateral view, sample C667, Kohe Adera section, Roadian, MNHN.F.F62705; **D'**, left lateral view, same specimen; **E'**, dorsal view, same specimen; **F'**, ventral view, same specimen. Scale bars: 100 µm.

2004b: 286, pl. 4, figs 9, 10; 2007: figs 3Q, R. — Forel 2012: 22, fig. 14 O-Q. — Sebe *et al.* 2013: 518, pl. IV, figs 10, 11. — Chitnarin *et al.* 2017: 682, fig. 26R, S.

EXAMINED MATERIAL. — One complete carapace (MNHN.F.F62706).

OCCURRENCES. — Jiangsu province, Kungurian, Early Permian, China (Chen & Bao 1986); Fujian province, Changhsingian, Late Permian, China (Yi 1992); Hydra Island, Wuchiapingian, Late Permian, Greece (Crasquin-Soleau & Baud 1998); Western Taurus, Wordian & Capitanian, Middle Permian, Turkey (Crasquin-Soleau *et al.* 2004b); Fujian province, Changhsingian, Late Permian, China (Yi 2004); Tibet, Wordian, Middle Permian, Changhsingian, Late Permian, China (Crasquin-Soleau *et al.* 2007); Guizhou province, Changhsingian, Late Permian, South China (Forel 2012); Dobrogea, Spathian-Anisian, Early-Middle Triassic, Romania (Sebe *et al.* 2013); Asselian-Kungurian, Early Permian, central Thailand (Chitnarin *et al.* 2017); sample AL7121, Dahane Botyan area, southern Hindu Kush, Roadian, Middle Permian, central Afghanistan (this work).

DIMENSIONS. — L = 387 µm; H = 297 µm; W = 251 µm; see Fig. 7.

### DISCUSSION

*Basslerella tota* Chen & Bao, 1986 has been described from the Kungurian, Early Permian, of Jiangsu province, China (Chen & Bao 1986). Since then, it has been recognized from the base of the Early Permian to the Middle Triassic worldwide as detailed in the occurrences list. All figured specimens attributed to *Basslerella tota* during this time interval have been measured and their H/L scatter plot is illustrated in Fig. 7. Noteworthy, specimens from the Middle-Late Permian of Tibet have not been measured (Crasquin-Soleau *et al.* 2007) because of their incompleteness. All specimens of *Basslerella tota* display a large range of H/L ratio (Fig. 7), the widest range being recorded for Late Permian specimens. These size variations are related to the co-occurrence of juvenile and adult ontogenetic stages. Previous works have demonstrated the reduction of the body size of juveniles and adults of several Podocopida and Palaeocopida species during the Permian (Forel *et al.* 2015) and through the EPE (Ketmuangmoon *et al.* 2017), highlighting the importance of considering the ontogeny separately in the different time slices. Based on the first approximation that the largest specimens are adults, five ontogenetic stages are recognized for Late Permian specimens, from the juvenile A-4 to the Adult stage (Fig. 7C). The Middle Permian specimens illustrated in Fig. 7B correspond to one adult and two juveniles for which any conclusion on the corresponding ontogenetic stage is impossible because of the lack of material. Similarly, the Early Permian specimens appear to correspond to the Adult stage and an unidentifiable juvenile stage (Fig. 7A). Middle Triassic specimens from the Anisian of Romania (Sebe *et al.* 2013) are listed in the synonyms and are represented on the Fig. 7C. However, the material illustrated by Sebe *et al.* (2013) is extremely poorly preserved and in my opinion, doesn't support a specific attribution.

## RESULTS

### OSTRACOD ASSEMBLAGES & PALAEOENVIRONMENTAL IMPLICATIONS

The ostracod assemblage presented in this article is important because it is the first report on ostracods in the Permian carbonate sequence in Afghanistan. Six of the nine studied samples provided ostracods (Table 1): none of the Sang-e-Caspan section A samples was productive; at Kohe Adera, the samples C664 and C667 provided ostracods but only C667 yielded identifiable specimens; in Dahane Botyan area, all samples have been productive and yielded identifiable specimens. A total of 31 species belonging to 12 genera and eight families are recognized and illustrated in Figures 3-6, a complete taxonomic list and the species occurrence among samples is available in Table 2. Five of the species discovered from the Roadian and Wordian of central Afghanistan are known from other localities during the Late Carboniferous-Permian interval (*Coelonella*? sp., *Silenites limatus*, *Baschkirina* sp. 3, *Microcheilinella* sp. 3, *Basslerella tota*; cf. Systematic Palaeontology section).

In the Roadian (productive samples C667, AL7121 and AL7122; Table 1), 27 species distributed among 11 genera are reported (Table 2). The assemblage is dominated by Bairdiidae which represent about 29% of the species (genera *Bairdia*, *Bairdiacypris* and *Orthobairdia*). Bairdiocyprididae (genera *Silenites* and *Baschkirina*), Aparchitidae (genus *Cyathus*) and Cytherideidae (genus *Basslerella*) each account for 15% of the assemblage. Pachydomellidae represent 11% of the species (genus *Microcheilinella*). Secondary components of this assemblage are Polycopidae with about 7% of the species (genus *Polycope*), while Coelonellidae (*Coelonella*) and Paraparchitidae (*Shemonaella*) respectively account for about 4% of the species. In the Wordian (productive samples AL7120 and AL7120bis; Table 1), only five species distributed into three genera have been discovered (Table 2). This poor assemblage is dominated by Bairdiidae which are four of the five species (genera *Bairdia* and *Cryptobairdia*), accompanied by one species of the Cytherideidae (genus *Basslerella*). In terms of diversity dynamic in the studied area, it is worth noting that only the genera *Bairdia* and *Basslerella* occur both in the Roadian and Wordian assemblages; as for the species, only *Basslerella* sp. 3 is common to both assemblages. In the present state of our knowledge of Permian ostracods in the studied area, *Cryptobairdia* is restricted to the Wordian. The future analysis of the material stored in the MNHN collections will be of great importance to better understand these biotic characteristics.

All the specimens are represented by complete carapaces, documenting the limited/ absence of post-mortem transportation associated with low hydrodynamism and/ or rapid burial by high sedimentation rates (Oertli 1971). Because of the poverty of the Wordian assemblage, it is hard to reach detailed environmental conclusions. However, the absence of typical deep-water taxa and the relative importance of Bairdiidae tend to indicate the deposition in neritic conditions under relatively shallow water depth (shallow subtidal) and in normal open-marine salinity and oxygenation.

Conversely, more information can be obtained from the Roadian assemblages in Kohe Adera and Dahane Botyan area. Noteworthy, it is impossible to determine the sam-

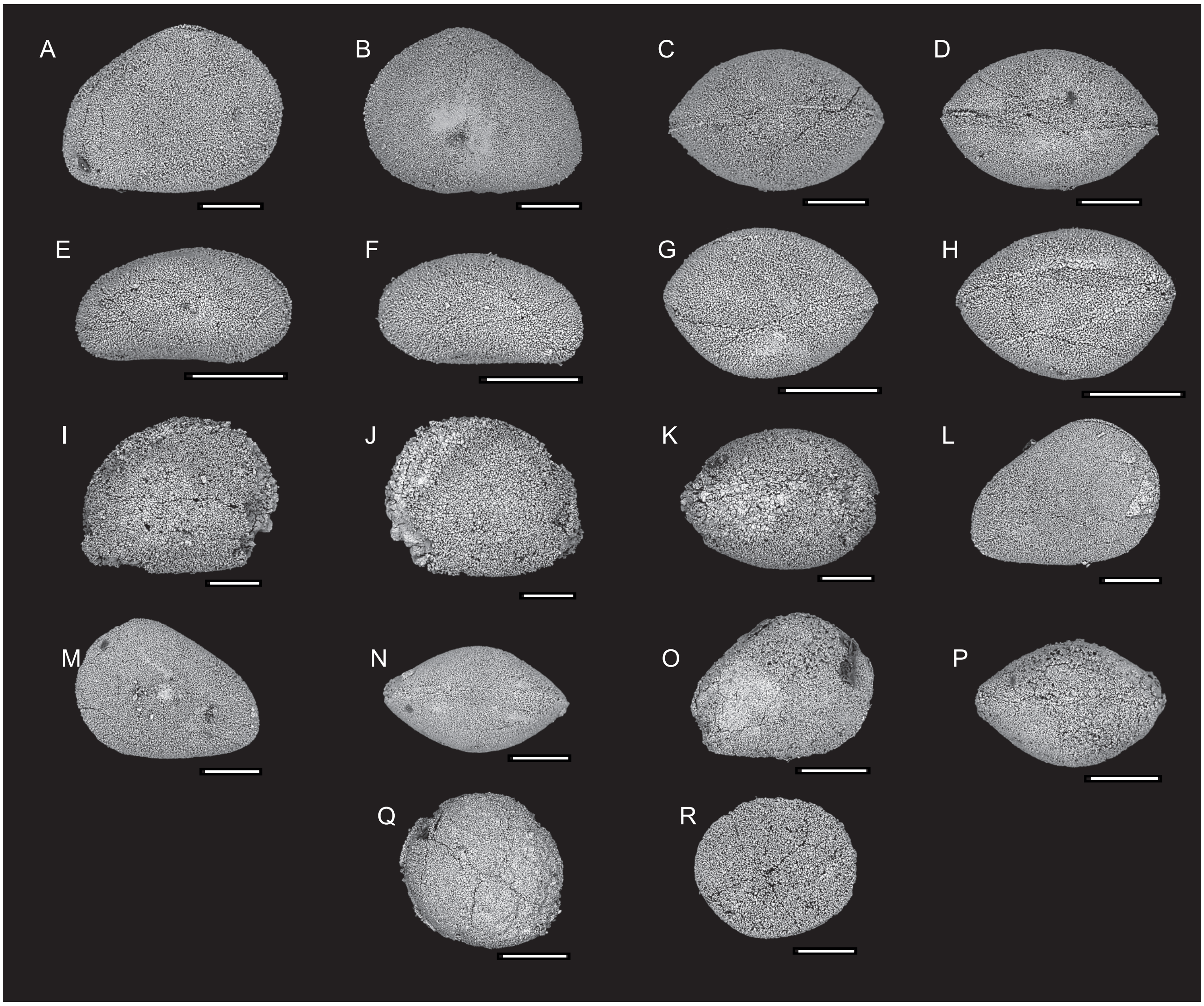


Fig. 6. — Ostracods, Podocopida and Myodocopida, from the southern Hindu Kush, Afghanistan, Roadian-Wordian, Middle Permian. All specimens are stored at the Muséum national d'Histoire naturelle (Paris, France) under collection numbers MNHN.F.xx. All specimens are represented by complete carapaces. **A**-**D**, *Basslerella tota* Chen & Bao, 1986; **A**, right lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62706; **B**, left lateral view, same specimen; **C**, dorsal view, same specimen; **D**, ventral view, same specimen; **E**-**H**, *Basslerella* sp. 1, **E**, right lateral view, sample AL7121, Dahane Botyan, Roadian, MNHN.F.F62707; **F**, left lateral view, same specimen; **G**, dorsal view, same specimen; **H**, ventral view, same specimen; **I**-**K**, *Basslerella* sp. 2, **I**, right lateral view, sample C667, Kohe Adera section, Roadian, MNHN.F.F62708; **J**, left lateral view, same specimen; **K**, dorsal view, same specimen; **L**-**P**, *Basslerella* sp. 1; **L**, right lateral view, sample AL7122, Dahane Botyan, Roadian, MNHN.F.F62709; **M**, left lateral view, same specimen; **N**, dorsal view, same specimen; **O**, right lateral view, sample AL7120bis, Dahane Botyan, Wordian, MNHN.F.F62710; **P**, dorsal view, same specimen; **Q**, *Polycope* sp. 1, right lateral view, sample C667, Kohe Adera section, Roadian, MNHN.F.F62711; **R**, *Polycope* sp. 2, right lateral view, sample AL7122, Dahane Botyan, Roadian, MNHN.F.F62712. Scale bars: 100 µm.

ples succession as no log of the Dahane Botyan sampled section was drawn in Lys *et al.* (1990). For this reason, I will consider these two samples (AL7121 and AL7122) as a whole labelled "Dahane Botyan assemblage". Circular diagrams of the faunal composition in Dahane Botyan and Kohe Adera are illustrated in Figure 8.

Most of the taxa under scrutiny are typical of intertropical warm waters (Crasquin-Soleau *et al.* 1999; 2004a, b). Their palaeoenvironmental preferences can be summarized as follows (Peterson & Kaesler 1980; Costanzo & Kaesler 1987; Melnyk & Maddocks 1988; Crasquin-Soleau *et al.* 1999):

1) Bairdiocyprididae: euryhaline environments on the proximal platform;

2) Paraparchitidae: euryhaline environments, shallow to very shallow waters on the intermediate platform.;

3) Aparchitidae, Bairdiidae, Pachydomellidae: open carbonate environments with normal salinity and oxygenation on the distal platform. Cytherideidae are generally distributed in shallow environments and can tolerate terrigenous substrate, but *Basslerella* is exclusively offshore;

and 4) The genus *Polycope* is eurytopic and in modern environments, it is interpreted as an opportunistic group

FIG. 7. — Length/Height scatter plots of all known specimens of *Basslerella tota* Chen & Bao, 1986: **A**, proposed ontogenetic stages for the Early Permian materials from China (Chen & Bao 1986) and central Thailand (Chitnarin *et al.* 2017); **B**, proposed ontogenetic stages for all known Middle Permian specimens from Turkey (Crasquin-Soleau *et al.* 2004b) and Afghanistan (this work); **C**, proposed ontogenetic stages for all Late Permian specimens from China (Yi 1992, 2004; Forel 2012) and in Middle Triassic of Romania (Sebe *et al.* 2013). In ascending order, ontogenetic stages are labelled **A-3** to **A-1** for successive juvenile stages and **Ad.** for Adults.

indicator of organic rich, fine grained sediment and high productivity (Karanovic & Brandão 2016).

The ostracod assemblages in Dahane Botyan and Kohe Adera during the Roadian are both dominated by Aparchitidae and Bairdiidae (Fig. 8), indicating the subtidal zone on a carbonate platform of an open marine environment in warm water. Bairdiidae are however more abundant in Dahane Botyan and are associated with more taxa which are less tolerant to onshore conditions such as *Orthobairdia* and *Basslerella*. These characteristics tend to indicate a relatively deeper position on the platform in Dahane Botyan compared to Kohe Adera. It is noteworthy that the genus *Microcheilinella* (Pachydomellidae) has similar proportions in both assemblages but two species occur in Dahane Botyan, against one in Kohe Adera, owing to lower diversity in Kohe Adera (nine species) compared to Dahane Botyan (20 species). The genus *Microcheilinella* is generally dominant offshore so that its slightly higher abundance in Dahane Botyan seems to further confirm the suggestion of a greater water depth in this area. This aspect is also supported by the occurrence of Paraparchitidae in Kohe Adera, witnessing shallower waters. The present environmental conclusions are only preliminary but they seem to document relatively deeper water conditions in Dahane Botyan compared to Kohe Adera.

### First insight into the provincialism of Roadian ostracods

An analysis of the distribution of neritic ostracod species led to the proposal of a global circulation scheme for the Late Carboniferous-Early Permian time interval (Lethiers & Crasquin-Soleau 1995). A close relationship between the south-western Tethys realm and South China was later evidenced, favouring the reduction of the oceanic area between South China and Arabian plate (Pangaea B) during the Wordian (Crasquin-Soleau *et al.* 2001). More recently, faunal linkage in the Late Permian has been identified between Saudi Arabia, Tunisia and Greece, all of which were located on the shelf of the Pangea Continent, associated with the relative isolation of the Caucasus faunas (Crasquin-Soleau *et al.* 2006). With the aim of providing the first insight into the spatial distribution of neritic ostracods during the Roadian, all generic occurrences have been compiled from the literature and gathered into five localities: South China Block (Hou 1954), Indochina Block (Chitnarin *et al.* 2012, 2017), North American Platform (Girty 1909, 1910; Sohn 1954), Volga Region (Schneider 1956; Khivintseva 1969) and central Afghanistan (this work). All eventual revisions in the generic attribution of the scrutinized material have been added, such as *Hollina occidentalis* Girty, 1910 re-attributed to the genus *Hollinella* by Delo (1930). To precisely ascertain the age of the assemblages, the latest updates provided by the Paleobiology Database are here used (data downloaded on 04 November, 2017, using the group name ‘ostracoda’ and the time interval ‘Roadian’).

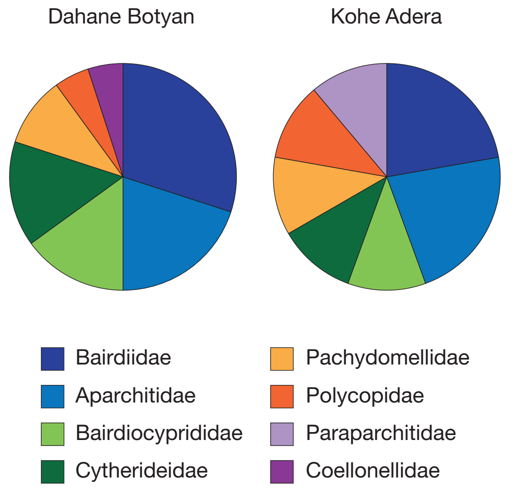


Fig. 8. — Circular diagrams of familial composition (number of species per family) of Roadian assemblages in Dahane Botyan (samples AL7121, AL7122) and Kohe Adera (sample C667), Hindu Kush, Afghanistan.

In the current state of our knowledge, a total of 11 genera occur in the Roadian of central Afghanistan, of which six are common with the coeval faunas of the Indochina Block (central Thailand; Chitnarin *et al.* 2012, 2017), one with the Volga Region (Schneider 1956; Khivintseva 1969), one with the South China Block (Hou 1954) and one with the North American Platform (Girty 1909, 1910; Sohn 1954). A similarity symmetrical matrix has been produced, following the Q-mode analysis (presence/absence matrix in Table 3; e.g. Henderson & Heron 1976; Pielou 1979; Janson & Vegelius 1981; Digby & Kempton 1987). Following Arias & Whatley (2009), the Jaccard’s similarity coefficient (Jaccard 1912) was used because it ranges from 0 to 1, emphasizes the presence rather than absence and is not influenced by the differences in sample size (e.g. Cheetham & Hazel 1969; Baroni-Urbani & Buser 1976; Wolda 1981; Magurran 1988). The agglomerative clustering method UPGMA (Unweighted Pair Group Method with Arithmetic mean) was used as it provides an unweighted arithmetic average between individuals (e.g. Hazel 1970; Anderberg 1973; Podam 1989; Shi 1993). All analyses were carried out with the statistical software package PAST (Hammer *et al.* 2001; Hammer & Harper 2005). The abundance of the Wordian assemblage in the studied area is still too low to perform provincialism analysis for this stage.

The similarities of ostracod asemblages of the five areas during the Roadian are shown in Fig. 9. Two major clusters stand out, with the Volga Region assemblage being the least similar to any other assemblage. The assemblages from the South China Block and the North American Platform are related by high levels of similarity, illustrating the existence of past and/or maintained trans-panthalassic connection. The highest level of similarity is reconstructed between the Indochina Block and central Afghanistan, which highlight the faunal isolation of the closely located South China Block. One possible explanation to this observed isolation is that the pattern might be facies-dependent, owing that the ostracods presented by Hou (1954) were obtained from shales

Table 3. — Matrix of ostracod genera distribution during the Roadian, Middle Permian.

| | Central Afghanistan | Indochina Block | Volga Region | South China Block | North American Platform |
|---|---|---|---|---|---|
| *Acratia* | 0 | 1 | 0 | 0 | 0 |
| *Actuaria* | 0 | 0 | 1 | 0 | 0 |
| *Aechminella* | 0 | 0 | 1 | 0 | 0 |
| *Aparchites* | 0 | 0 | 0 | 1 | 0 |
| *Bairdia* | 1 | 1 | 1 | 1 | 1 |
| *Bairdiacypris* | 1 | 1 | 0 | 0 | 0 |
| *Baschkirina* | 1 | 0 | 0 | 0 | 0 |
| *Basslerella* | 1 | 1 | 0 | 0 | 0 |
| *Bythocypris* | 0 | 0 | 0 | 1 | 0 |
| *Cavellina* | 0 | 0 | 0 | 1 | 1 |
| *Coelonella* | 1 | 0 | 0 | 0 | 0 |
| *Cornigella* | 0 | 0 | 1 | 0 | 0 |
| *Cribroconcha* | 0 | 0 | 1 | 0 | 0 |
| *Cryptobairdia* | 0 | 1 | 0 | 1 | 0 |
| *Cyathus* | 1 | 0 | 0 | 0 | 0 |
| *Fabalicypris* | 0 | 1 | 0 | 0 | 0 |
| *Fascianella* | 0 | 0 | 1 | 0 | 0 |
| *Hollinella* | 0 | 1 | 0 | 1 | 1 |
| *Jonesina* | 0 | 0 | 0 | 0 | 1 |
| *Kellettina* | 0 | 0 | 0 | 1 | 0 |
| *Kindlella* | 0 | 0 | 0 | 0 | 1 |
| *Kirkbya* | 0 | 0 | 1 | 0 | 0 |
| *Knightina* | 0 | 1 | 0 | 1 | 0 |
| *Lobobairdia* | 0 | 1 | 0 | 0 | 0 |
| *Macrocypris* | 0 | 0 | 0 | 1 | 0 |
| *Microcheilinella* | 1 | 1 | 0 | 0 | 0 |
| *Monoceratina* | 0 | 0 | 1 | 0 | 0 |
| *Orthobairdia* | 1 | 0 | 0 | 0 | 0 |
| *Petasobairdia* | 0 | 1 | 0 | 0 | 0 |
| *Polycope* | 1 | 1 | 0 | 0 | 0 |
| *Reviya* | 0 | 1 | 0 | 0 | 0 |
| *Shemonaella* | 1 | 0 | 0 | 0 | 0 |
| *Shleesha* | 0 | 1 | 0 | 0 | 0 |
| *Silenites* | 1 | 1 | 0 | 0 | 0 |

while both Afghan and Thai assemblages were obtained from limestone sequence. However, this hypothesis is partially ruled out because several benthic groups display the same geographical pattern, such as brachiopods (e.g. Sone *et al.* 2003; Shen *et al.* 2009; Shen 2016), corals (e.g. Wang & Sugiyama 2002) or bryozoans (e.g. Clapham 2010). More precisely, the ostracod distribution pattern is evocative of the brachiopod provinces during the Roadian-Wordian time interval, for which a Sino-Mongolian-Japanese Province and a Cathaysian Province have been distinguished (Shen *et al.* 2009; Shen 2016). The palaeogeographic map used in these brachiopod reconstructions is significantly different from the one used here, which corresponds to the most up-to date geographic reconstructions of the Cimmerian terranes and closely related blocks, gathering multidisciplinary constraining data including fossil affinities, palaeomagnetism, palaeoclimatology and structural geology (e.g. Metcalfe 2006; Angiolini *et al.* 2013; Berra & Angiolini 2014). Within the scope of the present analysis, the major discrepancy regards the position of the Indochina Block (as well as most Cimmerian terranes), which is closer to South China Block in our reconstruction than in the reconstruction of Ziegler *et al.* (1997) used for the brachiopod reconstructions. For this reason and because the present interpretation is only preliminary, it is not possible to equate the ostracod record to the Sino-Mongolian-Japanese Province of brachiopods.

The hypothesis that the close relationship between the south-western Tethys realm and South China identified during the Wordian (Crasquin-Soleau *et al.* 2001) was already established during the Roadian cannot be discussed with the present dataset as no ostracod from Roadian deposits of the south-western Tethys have been studied so far. The strong trans-Panthalassic links established between the North American Sea and the western Tethys shelves during the Early Permian, illustrated by the 9 to 57% of common species (Lethiers & Crasquin-Soleau 1995), cannot either be discussed in the Roadian for the same reason. Lethiers & Crasquin-Soleau (1995) hypothesized that these trans-Panthalassic communications might have been made possible thanks to the presence of equatorial archipelagos as relay stations, including blocks east of the Sino-Korean continent. In this scheme, the South China Block (Fig. 9) might have served this function and should display high similarity with the North American Platform if such communications were already active during the Roadian. As detailed higher, the South China Block and the North American Platform form a distinct faunal unit as regard to the similarities to their ostracod assemblages. More precisely, these localities share three common genera during the Roadian, namely *Bairdia*, *Cavellina* and *Hollinella* (Table 3) which were all inhabitants of both areas prior to the Roadian (e.g. Kellett 1933, 1934; Zhang & Liang 1987; Yi 1993; Olempska 1999; Ma *et al.* 2002). They therefore witness the existence of relatively strong past and/or maintained trans-Panthalassic communications already in the Roadian. Such conclusions will be substantiated when a work at the specific level can be carried out.

## CONCLUSIONS

Limestone samples from Hindu Kush (central Afghanistan) collected by Lys and his colleagues and housed in the MNHN collections have been investigated for ostracods. They provided the first ostracod assemblage from the Middle Permian (Roadian and Wordian) from central Afghanistan, including 31 species distributed into 12 genera. Most of these species are left in open nomenclature because of too few specimens; five species occur in other localities during the Late Carboniferous-Permian time interval. The analysis of palaeoenvironmental preferences of the taxa record an increasing depth from the east to the west of the studied area in the occidental Hindu Kush. The preliminary analysis of the distribution of ostracod genera during the Roadian is coherent with several other benthic groups documenting the existence of strong links between all Cimmerian blocks and the existence already in the Roadian of trans-Panthalassic communications between the South China Block and the North American Platform.

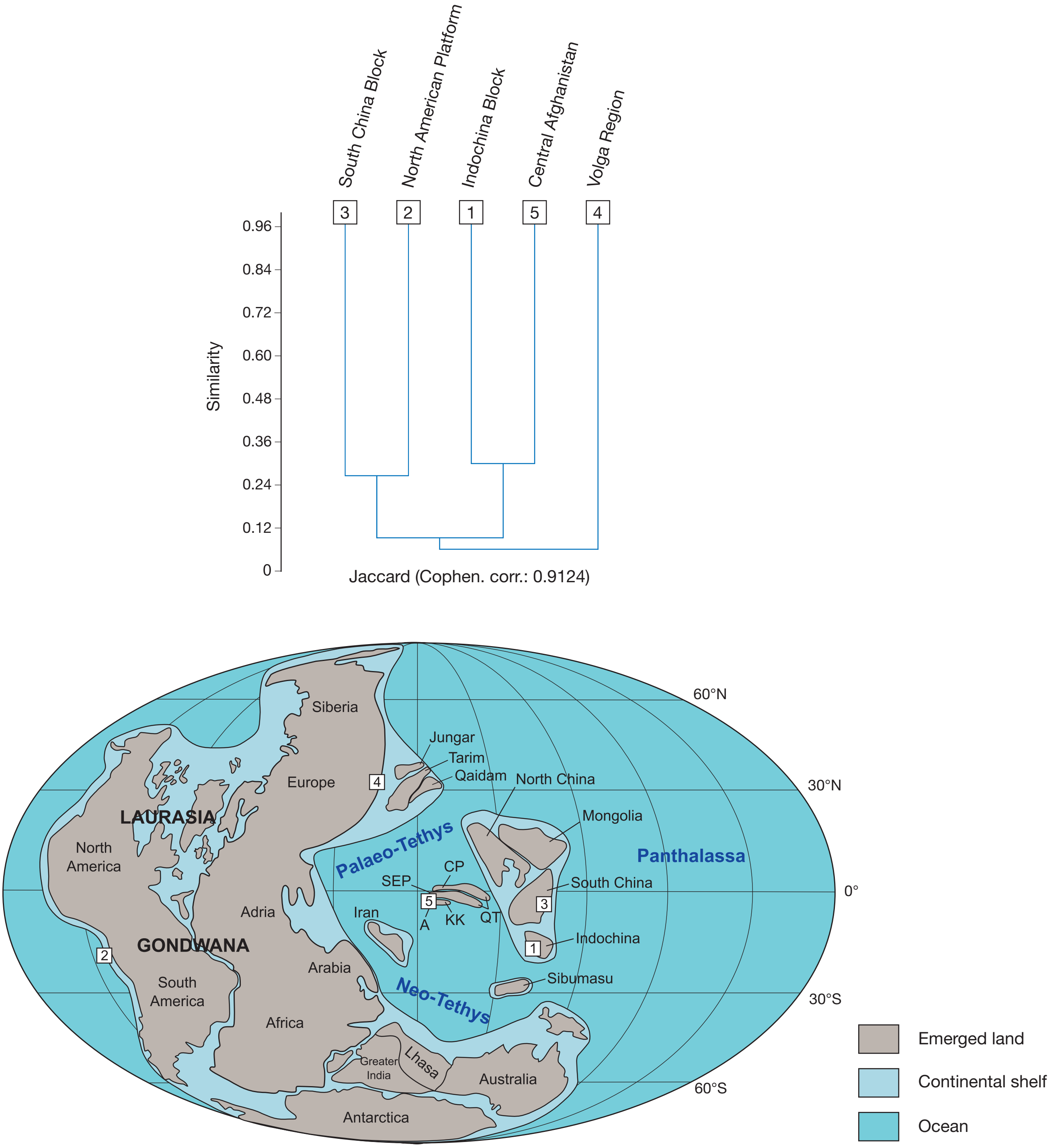


Fig. 9. — Dendrograms of UPGMA analysis based on 5 loci during the Roadian, Middle Permian. The scale indicates the grade of similarity as determined with the Jaccard coefficient of similarity. Schematic reconstruction map of Roadian-Wordian global palaeogeography (modified from Angiolini *et al.* 2013) with: **A**, Central Afghanistan; **SEP**, South East Pamir; **CP**, Central Pamir; **QP**, Qiangtang; **KK**, Karakoram.

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