

Ordovician Trilobites from Iran

by

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with 10 plates, 4 text-figures and 1 table

Zusammenfassung

Zwanzig Arten aus 19 Gattungen ordovizischer Trilobiten werden aus der Shirgesht-Formation des Derenjal-Gebirges und aus der Katkoyek-Formation des Kerman-Gebietes (beide im östlichen Mittel-Iran) sowie aus der Lashkerak-Formation des Alborz-Gebirges (nördlicher Iran) nachgewiesen. Für die häufigste Art der Shirgesht-Formation, *Pseudocalymene superba* (PILLET, 1973), die hier zusammen mit anderen von PILLET (1973) aufgestellten Arten revidiert wird, wird ein Neotypus festgelegt. Erstmals beschriebene Arten sind *Megalaspides winsnesi* n. sp. und *Neseuretus ghavideli* n. sp. Die Shigesht-Fauna gehört dem Tremadoc und wahrscheinlich dem Arenig an. Die aus zwei Gebieten stammende Katkoyek-Fauna ist in das Arenig und die Lashkerak-Fauna in das Tremadoc einzustufen. Eine einzelne spätkambrische Art, *Mictosaukia* cf. *rotunda* KUSIAN, wird aus den oberen Schichten der Derenjal-Formation des Derenjal-Gebirges nachgewiesen.

Die vorliegende Arbeit bestätigt die eindeutige Verbindung der Derenjal- und Kerman-Region im östlichen Mittel-Iran und des Alborz-Gebietes Nord-Irans zu Gondwana im Tremadoc und frühen Arenig. Beide Gebiete nahmen eine paläobiogeographische Schlüsselposition zwischen Ost-Gondwana und den asiatischen Gebieten ein, mit Faunen, die enge Beziehungen zu denen Nord- und Süd-Chinas aufweisen. Im einzelnen zeigen Teile der iranischen Fauna Affinitäten zu Trilobiten Afrikas, des anglo-walischen Raumes, Südamerikas, Australiens, des Baltikums und Spitzbergens, und belegen, daß die traditionellen Grenzen zwischen den ordovizischen Faunenprovinzen Gondwanas (*Selenopeltis*), Baltica (Asaphiden), Laurentia (Bathyuriden) und Südamerikas (*Asaphopsis*) unscharf waren, und daß die Migration und Verbreitung bestimmter Trilobiten zwischen allen Gebieten innerhalb von 30° bis 60° südlicher Breite möglich war. Das Auftreten von paläoäquatorialen Arten im Tremadoc-Arenig, wie *Carolinites* und *Peltabellia* zeigt, daß diese entweder warmen Meeresströmungen folgten, oder daß die geographische Breite selbst deren Migration nicht beeinschränkte.

Schlüsselwörter: Trilobiten – Ordovizium – Iran – Taxonomie – Paläobiogeographie

Summary

Twenty species from 19 genera of Ordovician trilobites are documented from the Shirgesht Formation of the Derenjal Mountains and the Katkoyeh Formation of the Kerman area (both East-Central Iran) and from the Lashkerak Formation of the Alborz Mountains (northern Iran). A neotype is chosen for *Pseudocalymene superba* (PILLET, 1973), the most common species in the Shirgesht Formation, which is revised here, along with other species proposed by PILLET (1973). New species described are: *Megalaspides winsnesi* n.sp. and *Neseuretus ghavideli* n.sp.

The Shirgesht fauna is Tremadoc to probably Arenig, and the Katkoyeh fauna, from two areas, is Arenig; the Lashkerak fauna is Tremadoc. A single Late Cambrian species, *Mictosaukia* cf. *rotunda* KUSIAN, is recorded from the upper beds of the Derenjal Formation in the Derenjal Mountains.

This work confirms that, during the Tremadoc and early Arenig, the Derenjal Mountain and the Kerman areas of east-central Iran and the Alborz area of northern Iran had clear Gondwanan connections and both occupied a crucial palaeobiogeographic position between East Gondwana and the Asian regions with faunas closely linked to those of north and south China. More specifically, constituents of the Iran fauna have affinities with trilobites from Africa, the Anglo-Welsh area, South America, Australia, Baltica and Spitsbergen showing that the traditional boundaries between the Ordovician faunal provinces of Gondwanaland (*Selenopeltis*), Baltica (Asaphid), Laurentia (Bathyurid) and South America (*Asaphopsis*) are blurred and migration and dispersal of particular trilobites was possible between all areas between 30°

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and 60° S latitude. The occurrence of Tremadoc-Arenig palaeo-equatorial taxa such as *Carolinites* and *Peltabellia* shows that these either followed warm water currents or that latitude in itself was no hindrance to their migration.

Key words: Trilobites – Ordovician – Iran – Taxonomy – Palaeobiogeography.

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Introduction

By D. L. BRUTON, A. J. WRIGHT & M. A. HAMEDI

Ordovician strata occur in three main regions of Iran, and their occurrences were summarized by HAMEDI et al. (1997). These occurrences are in the Alborz Mountains, in East-Central Iran and in southern Iran. This paper focuses on the Early Ordovician trilobites from the first two regions; available data indicate that the lithofacies of the Ordovician in southern Iran is very different from that of the other two principal regions (RICKARDS et al. 2001), and Ordovician faunas from southern Iran are rare (HAMEDI et al. 1997, RICKARDS et al. 2001).

Ordovician trilobites from Iran have been described only from East-Central Iran by PILLET (1973, 1975), but lists have been given by many authors. Late Ordovician trilobites from Iran were reported by DEAN (1980), WHITTINGTON & ORCHARD (1977) and MÜLLER & WALTER (1984); more details about Late Ordovician faunas

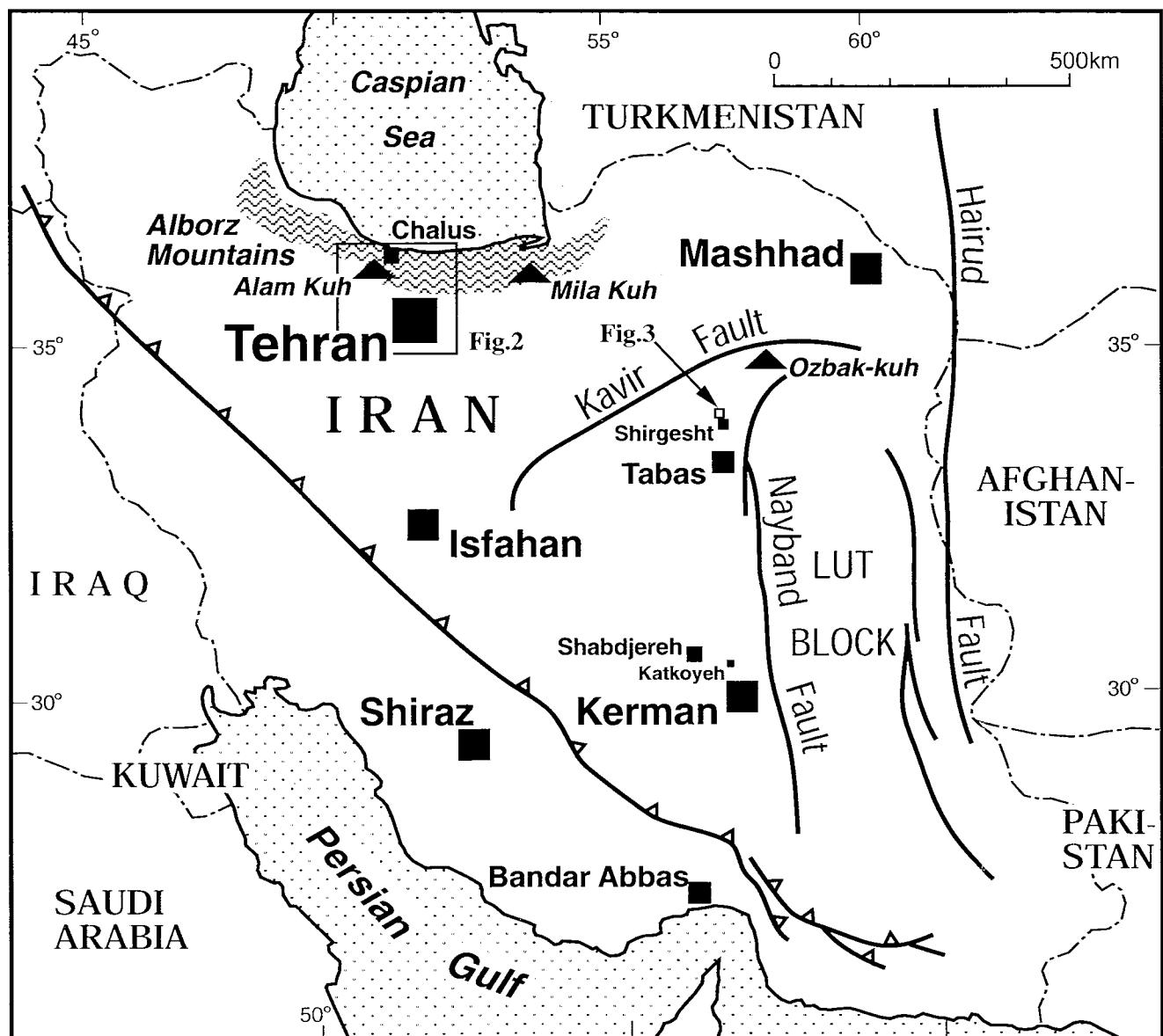
were given by HAMEDI et al. (1997), but these are all substantially younger occurrences than those documented in this paper.

Stratigraphic setting of trilobite occurrences

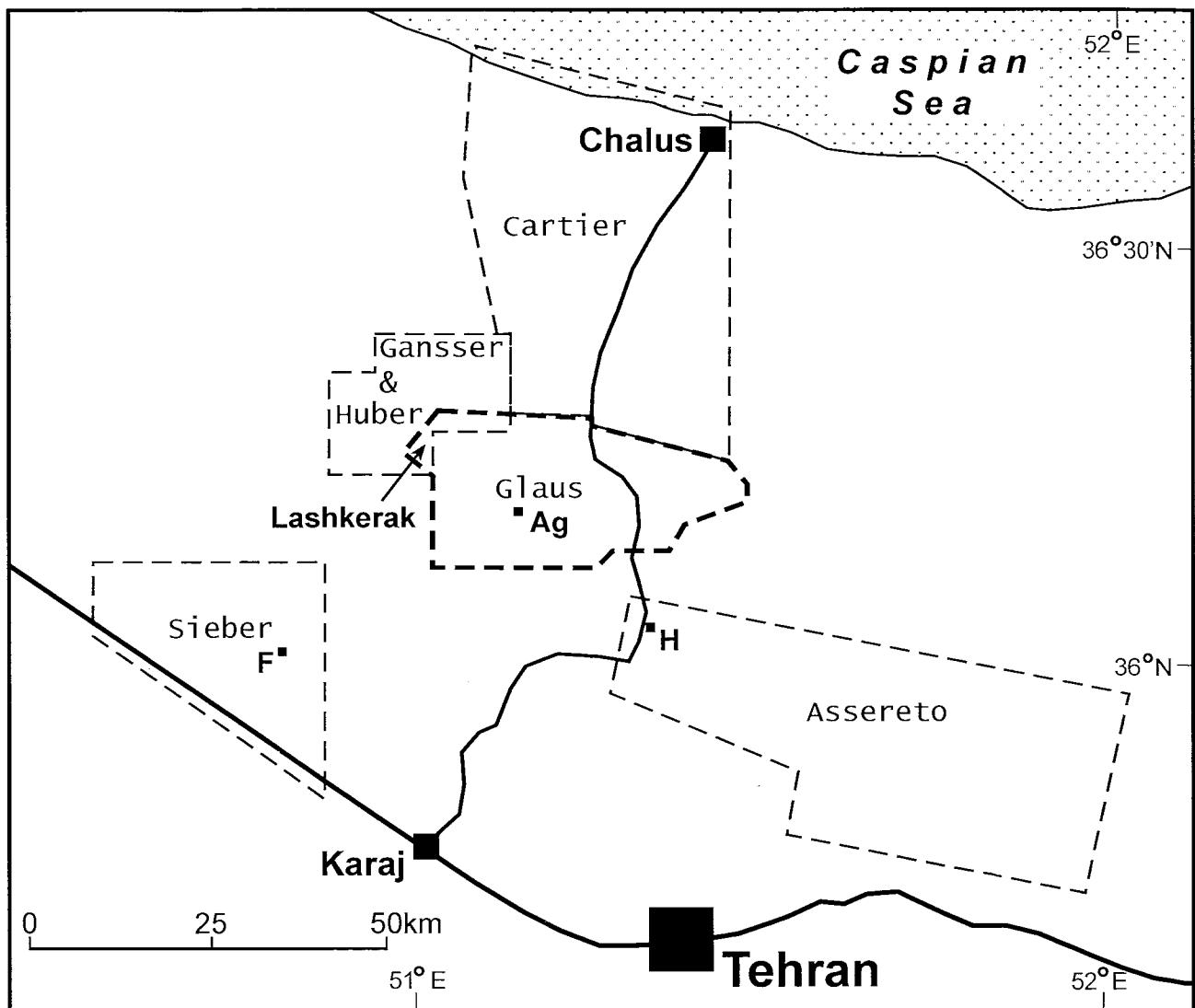
1. Alborz Mountains

Lashkerak Formation, Alam Kuh region of the central Alborz (Elburz) Mountains

A detailed discussion of the overall Precambrian and Lower Palaeozoic sequence of North Iran was given by STÖCKLIN et al. (1964), including a very brief discussion of the Ordovician Lashkerak Formation. Ordovician strata in the Alborz Mountains are known in particular from regions known as the Alam Kuh and the Mila Kuh (Fig. 1). Theses from the University of Zürich mentioned Ordovician strata from the Alborz Mountains were by GLAUS (1965), SIEBER (1970) and CARTIER (1971) (see Fig. 2).



Text-Fig. 1. Simplified map of Iran showing the principal place names mentioned in the text. Location of Text-Figs 2, 3 indicated by boxes.



Text-Fig. 2. Simplified sketch map of Alborz Mountains with outlined thesis and other areas for Tremadoc Lashkerak Formation referred to in text.

Ordovician strata in the Alborz Mountains between Tehran and the Caspian Sea (Figs 1, 2) were first described formally by GANSSE & HUBER (1962), who also listed trilobites, determined by R. TRÜMPY, from the Lashkerak Formation, which they named after the Lashkerak area of the Alam Kuh (Figs 1, 2). They noted that trilobites were first collected from the Alam Kuh region by BOBEK (1934) and that these were initially identified by DIETRICH (1937). The Lashkerak Formation (and its probable correlative, Member V of the Mila Formation, see below) is the only unit in this region that has yielded Ordovician trilobites.

GLAUS (1965, p. 44) gave a valuable, detailed discussion of this formation, and showed (his fig. 4) that the formation has a faulted base, and is overlain disconformably by Late Palaeozoic strata including the Mobarak Formation (Early Carboniferous). GLAUS (1965, fig. 4, p. 39) cited a maximum thickness of about 220 m in his Anguran section (Fig. 2), and showed (p. 36) a thickness of 175 m on the east face of Lashkerak peak. GLAUS recognized a 6-fold subdivision of the formation as follows:

VI (uppermost unit): sandstone and quartzarenite;

V: dark, silty shales;

IV: fossiliferous red calcareous beds and limey shales;

III: silty, sandy shales;
II: red to white quartzarenite;
I (lowest unit): cherty dolomite.

Lashkerak faunas. The faunas he found were from his unit IV. The position of this fossiliferous level varies from slightly above the middle of the unit at Lashkerak to below that level in the Anguran section where unit I has a reduced thickness, possibly being faulted. Faunas listed by GLAUS (1962) include: trilobites *Sympysurus* (S.) sp., *Presbynileus* (*Protopresbynileus*) sp., *Protopyge* cf. *cincta* (BRÖGGER), *Megalaspis* sp. and cf. *Ogygites yunnanensis* REED; nautiloids *Endoceras* sp. and *Michelinoceras* sp.; cystoids *Archegocystis*? sp., *Aristocystis* sp., *Cordiacystis* (*Craterina*)? sp., *Echinospaerites* sp. and *Sinocystis* cf. *loczyi* REED; gastropods; and brachiopods *Hemipronites* sp., *Orthis* cf. *calligramma* DALMAN and *Holopea*? sp. Faunas cited by GLAUS were identified, at least in part, by H. K. ERBEN and T. WINSNES. The faunal list given for the Lashkerak Formation by GANSER & HUBER (1962, p. 616) is: *Illaenus* (*Illaenus*) sp., *Asaphus* sp. and Illaenidae indet. (*Panderia*?), as well as cystoids and nautiloids.

Conodont data from the Lashkerak Formation are very limited, so the age is poorly constrained. However, MÜLLER (1973, p. 14) listed conodonts from a section described by ASSERETO (1963, pp. 521–524) from near the village of Hassanakdar on the Karadj-Chalus road (Fig. 2). The faunas listed by MÜLLER include *Furnishina furnishi*, *F. asymmetrica*, *Hirsutodontus* sp., *Hirsutodontus* (?) n. sp. and *Prooneotodus tenuis*, and MÜLLER (1973, p. 17) assigned this fauna to the Mila Formation and his Assemblage zone 2, of Late Cambrian age.

From the southern part of the Taleghan Valley to the south of the Alam Kuh, SIEBER (1970, p. 36–38) noted that member V of [what he called] the Mila Formation yielded Ordovician fossils ('*Illaenus* sp., *Dicellograptus* (?) sp. and *Paurorthis* ex. gr. *elegantula* Dalman') north of Fashand. He noted that the brachiopods occurred in brown 'knollenkalk', whereas the trilobites and graptolites were in green-grey shale. Further, he noted similarities between this member, the Shirgesht Formation of east-central Iran and the Lashkerak Formation from Alam Kuh in the Alborz Mountains. The occurrence of graptolites in this fauna is obviously of considerable age significance, and the presence of *Dicellograptus* indicates a post-Tremadoc age. This occurrence of graptolites at two levels in the member was not included in their review of Ordovician Iranian graptolite occurrences by RICKARDS et al. (2001) as SIEBER's thesis had not been seen at that time.

The Mila Formation was described by STÖCKLIN et al. (1964) from the Mila Kuh from the eastern Alborz (see Fig. 1), from which Ordovician trilobites have not been reported. From Mila Kuh, MÜLLER (1973) described Early Ordovician conodonts from the topmost member (V) of the Mila Formation. SIEBER (1970) listed faunas from what he identified as member V of the Mila Formation in the region to the south of the Alam Kuh and, on this basis, MÜLLER (1973) assigned a Late Ordovician or Early Silurian age to the member V and suggested a correlation with the Lashkerak and Shirgesht formations. The cited graptolite precludes a post-Ordovician age and, draws attention to suggestions by STÖCKLIN et al. (1964) and SIEBER (1970) that the sandstone and conglomerate separating the members IV and V indicate a significant break between the members.

According to GANSER & HUBER (1962) and GLAUS (1965), the Lashkerak trilobites occur in red nodular calcareous marls. Lashkerak trilobites from GANSER's original collection, kindly made available to us by Dr T.S. WINSNES, are very different in preservation and aspect to those of the Shirgesht Formation and are, for the most part, enrolled specimens of asaphids and nileids.

The following trilobites are described here from the Lashkerak Formation: *Pseudoasaphus* sp., *Asaphellus* sp., *Nileus* sp. cf. *armatus* TJERNVIK, 1956, *Sympysurus* sp. cf. *subquadratus* LU, 1975 and *Illaenus* sp. cf. *himotoensis* KOBAYASHI, 1934.

2. East-Central Iran

Trilobites from this region are described from three areas: the Derenjal Mountains (19 species), the Katkoyeh area (one species) and the Shabdjereh area (three species).

Shirgesht Formation in the Derenjal Mountains

The geology of the Derenjal Mountains in the Shirgesht area, about 75 km N of Tabas in east-central Iran (Fig. 1), was first studied and elucidated by RUTTNER et al. (1968), who recognized most important occurrences

there of Precambrian to Neogene strata reaching a total thickness of some 15 000 m, with abundant shelly fossils in the Cambrian, Ordovician and Silurian in what they described as ‘dark, bleak-looking hills’ and whose maximum elevation above sea level is about 1200 m (RUTTNER et al. 1968). Additional mapping of the area was carried out by HAMEDI (1995) during PhD studies at the University of Wollongong.

The hamlet known as Shirgesht (altitude 1.010 m, according to RUTTNER et al. 1968) lies outside the Derenjal Mountains, near the main highway between Tabas and Masshad (Fig. 1). The term Dahaneh-e-Kolut refers to a small, ephemeral stream draining South through the southern margin of the Derenjal Mountains (Fig. 2). Immediately to the North of the mountains lies the Great Kavir (desert or ‘salt waste basin’) and to the East lies the Kavir-e-Namak.

The Dahaneh-e-Kolut area in the southern part of the Derenjal Mountains has been subjected to intensive tectonic activity, producing a complicated structure discussed by RUTTNER et al. (1968, pp. 120–122). The broad geological structure of the Derenjal Mountains area is a north-plunging overturned anticline.

The Shirgesht Formation

This formation, first defined and described by RUTTNER et al. (1968), was based on a composite assessment and measurement of exposures on the east and west sides of Dahaneh-e-Kolut valley. The Shirgesht Formation (1.013 m thick) is considered to form the upper part of the Mila Group (Middle Cambrian to Early Ordovician, consisting of the Kalshaneh, Derenjal and Shirgesht formations (RUTTNER et al. 1968) in this region. The Shirgesht Formation in East-Central Iran and Member V of the Mila Formation in the Alborz Mountains and many parts of Central Iran show a transitional contact with Cambrian strata.

In addition to its principal development at Dahaneh-e-Kolut, the Shirgesht Formation is developed farther to the N, in Chah-e-Baba Ali, 26 km N of Shirgesht village, in the NE part of the Derenjal Mountains. There the Shirgesht Formation is reduced in thickness to 285 m from more than 1 000 m. in the Derenjal Mountains. Deposition of the upper part of the upper shale unit of the Shirgesht Formation at Chah-e-Baba Ali to the north of Shirgesht (Fig. 1) was accompanied by extensive volcanic activity, and RUTTNER et al. (1968) reported only pyritized brachiopods. Samples collected by HAMEDI yielded Tremadoc to possibly Arenig conodonts (HAMEDI et al., 1997). According to HAMEDI (1995) the Shirgesht Formation in the southern part of the Daroneh Fault, 212 km NE of Tabas, yielded the following fossils and was assigned an Ordovician age (BEHROOZI 1987; determined by Dr F. GOLSHANI): cf. *Flexicalymene* sp. or *Platycalyomene* sp., cf. *Cyrtinotella* sp., cf. *Ogygiocaris* sp., *Paurorthis* sp., cf. *Austinella* sp., *Resserella* sp., *Salopina* sp., cf. *Onniella* and *Dalmanella* sp.

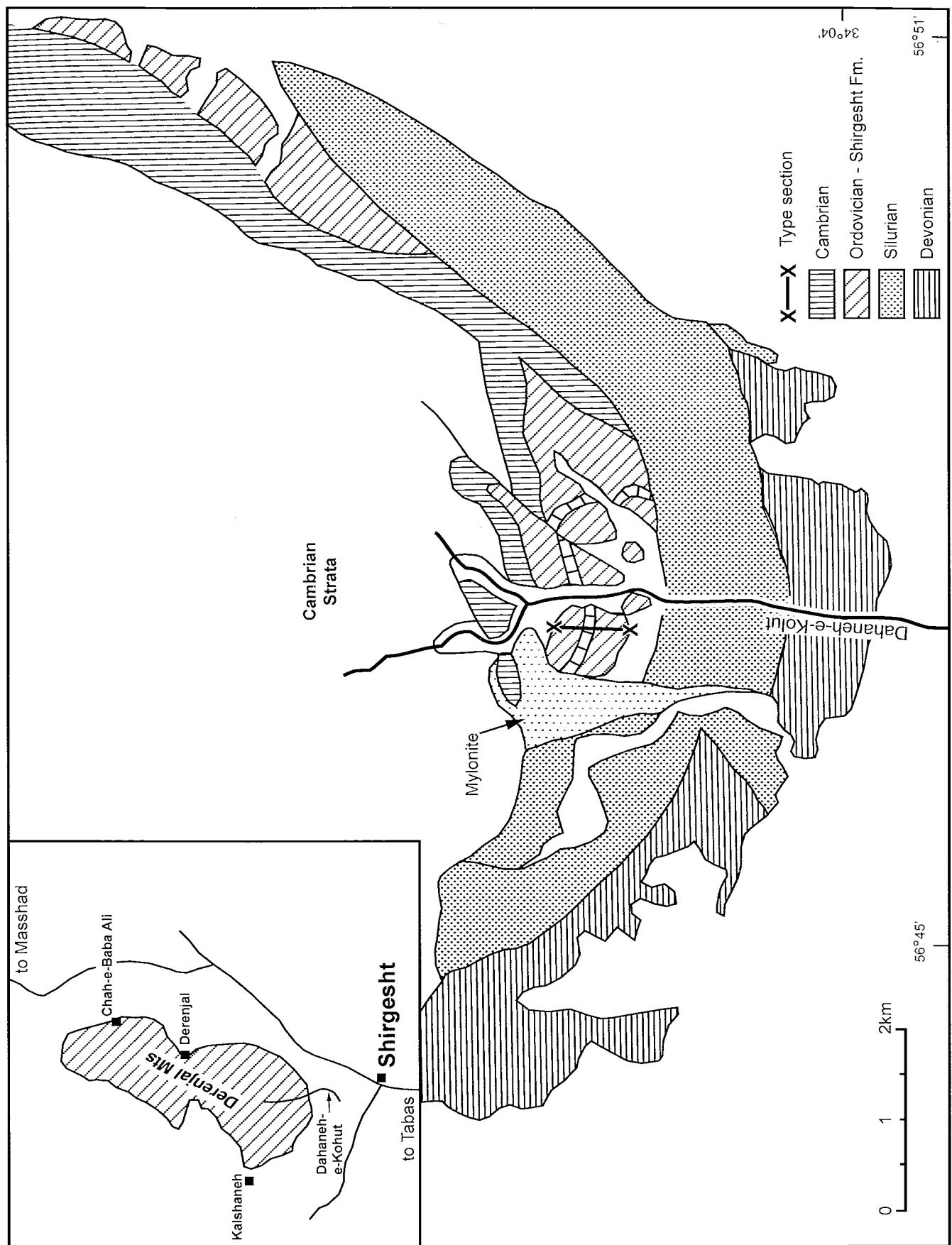
Subdivision and sequence of the Shirgesht Formation

The type locality for the formation is in the area known as Dahaneh-e-Kolut (Dahaneh Stream), 75 km N of Tabas (Fig. 1). The originally designated type section of the Shirgesht Formation is a composite section, 1.236 m thick, measured on both the east and west sides of the Dahaneh-e-Kolut, by WINSNES & EMAMI (in RUTTNER et al. 1968) in an overturned sequence. They divided the Shirgesht Formation into three parts: a basal unit of limestone and marl (570 m thick); a middle fossiliferous sequence of red sandy limestone and green marl (166 m thick); and an upper unit of green-grey marl, shale and siltstone (500 m thick). As the basal limestone and marl unit (570 m) in the original type section of the formation are here regarded as part of the Derenjal Formation, and many details of the previous composite type section do not fit with HAMEDI’s field data, a new and less disturbed type section is selected for the Shirgesht Formation on the W side of Dahaneh-e-Kolut (Fig. 2).

New measured section

As recognized here, the Shirgesht Formation consists of two siliciclastic and one carbonate lithofacies, as follows: siliciclastic facies dominate in the lower and upper parts of the formation, whereas a red, trilobite-bearing carbonate facies is developed in the middle part (see Fig. 3).

The lower shale unit (200 m) consists of green silty and muddy shale and sandstone with intercalations of thin to lenticular sandy muddy limestone. Bouma sequences and a few thin horizons of intermediate to mafic volcanic rocks are preserved in this unit.



Text-Fig. 3. Sketch map of the geology of the southern part of the Derenjal Mountains and new type section of Shirgesht Formation, west side of Dahaneh-e-Kohut. After RUTTNER et al. (1968) and HAMEDI (1995).

The middle carbonate unit (351 m) consists of three major sandy, marly red limestone horizons with trilobites, brachiopods and cephalopods separated by thin intercalations of marl, shale and sandstone.

The upper shale unit (462 m thick) consists of alternations of green, grey shale, siltstone and sandstone. Primary current lineations and load casts are the main sedimentary structures in this unit. The measured section is given in Fig. 2.

Boundaries of the Shirgesht Formation

The uppermost fossiliferous beds of the Derenjal Formation with *Billingsella* were considered late Middle to Late Cambrian by RUTTNER et al. (1968), and to the Ordovician by WOLFART (1981). The new formation boundary may correlate with the Cambro-Ordovician boundary of the Mila Formation (i.e. between Members IV and V) in the Alborz Mountains. The Cambro-Ordovician boundary is drawn at Dahaneh-e-Kolut at the termination of the carbonate facies, i.e., at the top of laminated red and green limestone previously considered the basal unit of the Shirgesht Formation by RUTTNER et al. (1968). Trilobites listed from the Derenjal Formation by RUTTNER et al. (1968, p. 30) are: *Iranaspis* sp., *Idahoia* sp., *Chelidonocephalus* sp., *Saukia* sp., *Chuangia* sp. and '*Lioparella* sens. lat.'. Although the focus of this paper is the Ordovician trilobites, we describe and illustrate *Mictosaukia* sp. cf. *rotunda* KUSHAN, 1973 from the topmost beds of the formation at Dahaneh-e-Kolut.

Lower contact. The lower boundary of the Shirgesht Formation was previously defined at the top of the massive, dark, richly fossiliferous *Billingsella* limestone, a good marker unit in the Derenjal Formation (RUTTNER et al. 1968). A new boundary is proposed here, separating two different lithofacies and depositional environments: the thin to laminated red and green limestones of the Derenjal Formation were deposited in lower energy, more oxidising conditions than the relatively deeper facies of the lower shale unit of the Shirgesht Formation. This contact is conformable; the change proposed here results in units 1 to 8 of the previous type section (RUTTNER et al. 1968) of the Shirgesht Formation being transferred to the Derenjal Formation. The new stratigraphic boundary between the Derenjal and Shirgesht formations is thus drawn within the upper part of the lower unit of the Shirgesht Formation as previously defined; it also agrees with the discovery (R.S. NICOLL, pers comm.) of *Furnishina* sp. (Late Cambrian) in the lower carbonate unit of the previous type section of the Shirgesht Formation (i.e. in what is now regarded as Derenjal Formation).

Upper contact. The upper boundary of the Shirgesht with the Niur Formation was described as transitional and was drawn in a brown-red, sandy, brachiopod-bearing limestone by RUTTNER et al. (1968). HAMEDI's mapping has shown that this contact is a major disconformity, but it is also faulted (HAMEDI & WRIGHT 1992). The same conclusion has been reached by BASSETT, DASTANPOUR & POPOV (1999). The major hiatus demonstrated between the Ordovician and Silurian occurs throughout Iran and neighbouring countries (HAMEDI 1995).

Previous palaeontological data and age

The history of study of fossils described from the Derenjal Mountains has been summarized by HAMEDI et al. (1997). BASSETT, DASTANPOUR & POPOV (1999) have investigated aspects of the geology of the Derenjal Mountains with particular reference to the *Billingsella* Limestone of the Derenjal Formation.

Bryozoans, brachiopods, gastropods, cephalopods and trilobites were listed from the middle carbonate unit of the Shirgesht Formation by RUTTNER et al. (1968; determined by SPJELDNÆS & WINSNES): bryozoans: *Hallopore* sp., *Nicholsonella* sp., *Ceramoporella* sp., *Anolotichia* aff. *rombica*, *Stictoporella* sp., *Strombopora* sp., *Escharopora* sp. and *Nicolella* sp.; brachiopods *Dalmanella* sp., *Plectambonites*? sp.; gastropod *Ophileta*? sp.; nautiloids *Michelinoceras* sp., *Endoceras* sp.; trilobites *Megalaspides* sp., *Illaneus* cf. *centaurus*, *Sympphysurus* sp., *Hystricurus* sp., *Ningkiangolithes* (sic.) cf. *welleri* and *Marrolithus*? sp. This assemblage in the carbonate unit in the lower part of the formation was considered Middle Ordovician, possibly early Late Ordovician (RUTTNER et al. 1968), largely on the basis of the bryozoans, although an earlier Ordovician age was indicated by the trilobites. Subsequently MÜLLER (1973) described large conodont faunas from mainly the Shirgesht Formation, with minor faunas from the Derenjal Formation, and assigned these Shirgesht Formation faunas MÜLLER (1973, p. 20) to Assemblage zones IV to VII, all being Early Ordovician.

PILLET (1973) described four species of trilobites from this unit, based on the private collections of LAPPARENT & BOZORGIA; the fauna as described included: *Paraonychopyge iranicus* gen. et sp. nov., *Parabasilicus kolutensis* sp. nov., *Nileus* sp. and *Pseudocalymene superba* gen. et sp. nov., retaining the previously assigned age. PILLET (1976) discussed the synonymy of *Pseudocalymene* PILLET, 1973 and *Eucalymene* LU, 1975.

The Shirgesht trilobite fauna has been restudied on the basis of original collections held by WINSNES, as well as new collections made during this study, principally by HAMEDI. The fauna consists of the following 17 species: *Shumardia (Conophrys)* sp. cf. *pentagonalis* LU, 1962; *Carolinites* sp. cf. *ichangensis* LU, 1975; *Pseudocalymene superba* (PILLET, 1973) [includes *Paraonychopyge iranicus* PILLET, 1973]; *Megalaspides kolutensis* (PILLET, 1973); *Megalaspides winsnesi* sp. nov.; *Asaphellus* sp.; *Gog* sp.; *Nileus* sp. cf. *exarmatus* TJERNVIK, 1956; ?*Dikelocephalina* sp.; *Asaphopsoidea* sp.; *Dactylocephalus* sp. cf. *D. latus* PENG, 1990; *Illaenus* sp. cf. *I. hinomotoensis* KOBAYASHI, 1934; *Peltabellia* sp.; *Brachyhipposiderus* sp. cf. *B. logimus* JELL, 1985; *Ampyx* sp.; *Nesuretus ghavideli* sp. nov.; and ?*Sinoparapilekia* sp. Of the taxa we list, none is known from outcrops of the Shirgesht Formation at Chahe-e-Ali Baba (Fig. 2). Only three of these species are also found in the Lashkerak fauna. In our material we have not seen any trace of the trinucleids '*Ningkiangolites* (sic.) cf. *welleri* and *Marrolithus?* sp.' listed by RUTTNER et al. (1968).

Conodonts from the trilobite-bearing horizons of the middle unit indicate (R.S. NICOLL, pers. comm. 1993) an Early Ordovician (Tremadoc) age for this part of the formation. Conodonts from the Shirgesht Formation were first described by MÜLLER (1973) and further data were added by HAMEDI et al. (1997). All conodont faunas that are definitely from the formation are Tremadoc. HAMEDI et al. (1997) reported a conodont fauna including the *Cordylodus prion* from the trilobite-bearing middle portion of the formation, indicating the early Tremadoc *angulatus* conodont zone. No conodonts have been reported from the lower part of the formation. One sample at Dahaneh-e-Kolut is probably Arenig, but the sample was collected from a fault-bounded slice of limestone; all other Arenig samples we have from the region are from the Katkoyeh Formation. BASSETT, DASTANPOUR & POPOV (1999) have indicated that the age of the upper unit of the Shirgesht Formation can be no younger than Arenig.

In this study the lower boundary of the Shirgesht Formation, with the Derenjal Formation, is taken as approximately the Cambrian-Ordovician boundary. MÜLLER (1973) and HAMEDI et al. (1997) reported the Late Cambrian conodonts *Proconodontus* and *Furnishina* from the Derenjal Formation. BASSETT, DASTANPOUR & POPOV (1999) placed the Cambrian-Ordovician boundary within the Shirgesht Formation, between MÜLLER's (1973) zone 4 and zone 5 (i.e. between the *Cordylodus proavus* – *Furnishina* fauna and the *Corylodus prion* – *Cordylodus angulatus* fauna. It seems that placement of the Cambrian-Ordovician boundary must remain arbitrary for the present, as no conodonts have been reported from the lower part of the formation, and reinterpretation of the age of the sequence needs to take into account the new definition of the Shirgesht Formation by Hamedi herein. Shirgesht and Derenjal formation conodont faunas are the subject of further research by Dr R.S. NICOLL.

HAMEDI et al. (1997) indicated that the Cambrian-Ordovician boundary lay within the formation, based on the former type section of RUTTNER et al. (1968). This was essentially confirmation of MÜLLER's (1973) results where, as pointed out by BASSETT et al. (1999), the boundary lies between his assemblages 4 and 5. The same results were also obtained from the carbonate unit of the Shirgesht Formation in Chah-e-Baba Ali. An Arenig conodont fauna has been extracted from a fault-bounded sliver of limestone at Dahaneh-e-Kolut; the limestone cannot be confidently assigned to a formation, but probably should be assigned to the Shirgesht Formation. The presence of *Dalmanella* sp., *Platystrophia* sp., *Dinorthis* sp. and *Paurothis* sp. (HAMEDI 1990, determined by Dr F. GHOLSHANI) also suggests the formation is Early Ordovician.

BASSETT et al. (1999) identified a Tremadoc shelly fauna in calcareous siltstones low in the Shirgesht Formation at Dahaneh-e-Kolut. They also suggested that rare shells in 'mid – upper horizons' of the formation possibly indicate that these beds are no younger than early Arenig. They also noted that the upper beds of the formation, from which BERRY & BOUCOT (1972) reported 'late Ordovician gonambonitid brachiopods', possibly for the Niur Formation, are no younger than Arenig. This work stresses the major break, previously recognized by HAMEDI et al. (1997) between the Shirgesht and Niur formations, which must include all of the post-Arenig Ordovician as well as the earliest Silurian.

Reassessment of the Shirgesht Formation

Detailed reassessment of the Shirgesht Formation in the study area by HAMEDI has shown that the type section of the Shirgesht Formation measured by RUTTNER et al. (1968) in the Dahaneh-e-Kolut valley, 75 km N of Tabas ($56^{\circ} 48' E$; $34^{\circ} 06' N$) is not accurate. A high angle reverse fault, called the Dahaneh-e-Kolut Fault (HAMEDI 1990), caused structural problems; remnants of the *Billingsella* limestone and repetition of the Shirgesht Formation in the Dahaneh-e-Kolut Fault zone (between the upper Shirgesht and Niur Formations) are evidence of the fault (HAMEDI 1990). Thus the 1.236 m thickness recorded by WINSNES (in RUTTNER et al. 1968) results from infaulting of the upper part of the Derenjal Formation; layers 1–8 of the section measured by WINSNES (in RUTTNER et al. 1968) are here removed from this formation. Revised measurement of the type section shows it to be 1.013 m thick.

Material

Trilobites from the Shirgesht Formation of east-central Iran described by PILLET (1973, 1975) were solely from the collections of DE LAPPARENT & BOZORGNA. It has been possible to locate only part of the collection studied by PILLET (Table 1). The LAPPARENT collection was deposited in the IGAL (Institut Géologique Albert-de-Lapparent), Institut Polytechnique Saint-Louis at Cergy-Pontoise, Paris, where five LAPPARENT specimens, plus one specimen (of *Pseudocalymene superba*) from the BOZORGNA collection have been found. The BOZORGNA collection (which originally consisted of 13 cited specimens) is said to have been returned to Tehran but we have been unable to locate it there. Regrettably, additional collections made from this formation by numerous geologists and visitors are mostly missing or in private hands, and trilobites are rare now on the outcrops. The original collections made by A. GANSER were found in Oslo in the possession of T.S. WINSNER who generously donated these, together with his own collections, to the Paleontologisk Museum, University of Oslo (hereafter abbreviated PMO). Additional specimens donated by Dr M. YAZDI, Dr M. GHAVIDEL-SYOOKI and Dr M. KHOSRAVI together with those collected by two of us (A.J.W. and M.A.H.; the latter made most of the recent collections), are also housed in Oslo and registered with PMO numbers.

2. Fauna from the Katkoyeh Formation at Shabdjereh

In the Shabdjereh section near Kerman, HAMEDI (1995) recognised a thin (34 m) sequence of Arenig beds unconformably overlain by Silurian strata. The Ordovician strata are locally richly fossiliferous although the diversity is low, and the beds have a striking red colour reminiscent of the Lashkerak lithology. The fauna at this locality (locality numbers AH 7-9, AH 9.5; also WCH-1, WCH-2) contains *Nesuretus ghavideli* n. sp., *Nileus* cf. *exarmatus*, ?*Sinoparapilekia* sp. and two common species of brachiopods (one dalmanellid and one strophomenacean). The brachiopod shells are mostly articulated, as are some of the trilobites. The conodont fauna determined by Dr R.S. NICOLI includes: ?*Amorphognathus* sp., *Erraticodon* cf. *E. balticus*, *Drepanoistodus* sp. and *Prioniodus* sp.; Dr Nicoll assigned the fauna an Arenig age, to either the ‘*Oepikodus communis*/O. evae or *Baltoniodus navis* zone.’

3. Fauna from limestone at Katkoyeh

In the stratigraphic section in the gorge above the village of Katkoyeh, high in the hills above and to the east of Zarand, the Katkoyeh Formation is well exposed, and aspects of this section at Katkoyeh and to the north at Banestan have been described by RICKARDS et al. (1994), BASSETT et al. (1999), RICKARDS et al. (2001) and ZHEN et al. (2002). The conodont fauna from the brachiopod-rich limestone near the base of the formation at Katkoyeh was listed by the latter authors, and the graptolite fauna from the formation at Banestan was described in the first two papers. The conodont fauna is Arenig (Bendigonian), and the graptolites from overlying clastic beds (see RICKARDS et al. 2001) are late Arenig, probably early Darriwilian). The solitary trilobite specimen at our disposal from the limestone (locality AH 8-262) is described here as *Taibungshania* cf. *shui*. Fragmental asaphid trilobites were noted in the black shales overlying the limestone. Conodonts from this limestone listed by ZHEN et

Table 1. List of the 18 (our numbering) specimens described by PILLET (1973) from the Shirgesht Formation, using his nomenclature. The three holotypes, of which only one survives (that of *Parabasilicus kolutensis*), are denoted by (H). Boz. indicates specimens from the Bozorgnia collection; only one (number 10) survived, having been deposited in the IGAL. Lapp. 1-5 indicates the illustrated specimens (numbers 14, 5, 9, 6, 2) from the intact LAPPARENT collection. Thus, only 6 of the 18 illustrated specimens have been found; 12 of the BOZORGIA collection of 13 have not been found. **Bold type** across the line indicates surviving specimens.

	Pillet Plate, Fig.	Specimen no.	Status
<i>Paraonychopyge iranicus</i> :	Pl. VI, fig. 1	Boz. 3013 (11)	1 (H) missing
	Pl. VI, fig. 2	Lapp. 5	2 IGAL
	Pl. VI, figs 3-4	Boz. 3013	3 missing
	Pl. VIII, figs 7-8	Boz. 3013	4 missing
<i>Pseudocalymene superba</i> :	Pl. VI, fig. 5-6	Lapp. 2	5 IGAL
	Pl. VI, fig. 7	Lapp. 4	6 IGAL
	Pl. VI, fig. 8	Boz. 3013 (7a)	7 missing
	Pl. VII, figs 1-4	Boz. 3013 (20)	8 (H) missing
	Pl. VII, figs 5-6	Lapp. 3	9 IGAL
	Pl. VIII, fig. 9	Boz. 3013 (7b)	10 IGAL
<i>Nileus</i> sp.:	Pl. VIII, figs 1-2	Boz. 3013	11 missing
	Pl. VIII, figs 3-4	Boz. 3013 (12)	12 missing
	Pl. VIII, figs 5-6	Boz. 3013	13 missing
<i>Parabasilicus kolutensis</i> :	Pl. IX, fig. 1	Lapp. 1	14 (H) IGAL
	Pl. IX, fig. 2	Boz. 3013 (5)	15 missing
	Pl. IX, fig. 3	Boz. 3013 (8)	16 missing
	Pl. IX, fig. 4	Boz. 3013 (9)	17 missing
	Pl. IX, fig. 5	Boz. 3013 (6)	18 missing

al. (2002) are: *Bergstroemognathus hubeiensis*, *Juanognathus variabilis*, *Drepanoistodus* spp. and *Baltoniodus* sp.; they were considered Early Ordovician (Bendigonian, *elegans* zone) by the above authors.

Faunal association and distribution (by D. L. BRUTON)

Altogether 19 genera and 20 species, 8 of which are not assigned, have been identified from the Shirgesht Formation. They include 1 species of Shumardiidae, 1 of Telephinidae, 1 of Leiostegiidae, 5 of Asaphidae, 2 of Nileidae, 1 of Taihungshaniidae, 3 of Dikelokephalinidae, 1 of Illaenidae, 1 of Bathyuridae, 1 of Harpetidae, 1 of Raphiophoridae, 1 of Pilekiidae and 1 of Calymenidae. One genus and species of Saukiidae is identified from the latest Cambrian at the base of the section in the Derenjal Mountain Region at the locality Dahaneh-e-Kolut.

The distribution of species is as follows:

Alborz Mountains, Lashkerak Formation (Tremadoc)

Pseudoasaphus sp.

Asaphellus sp.

Nileus cf. *exarmatus* TJERNVIK, 1956

Sympphysurus cf. *subquadratus* LU, 1975

Illaenus binomotoensis KOBAYASHI, 1934

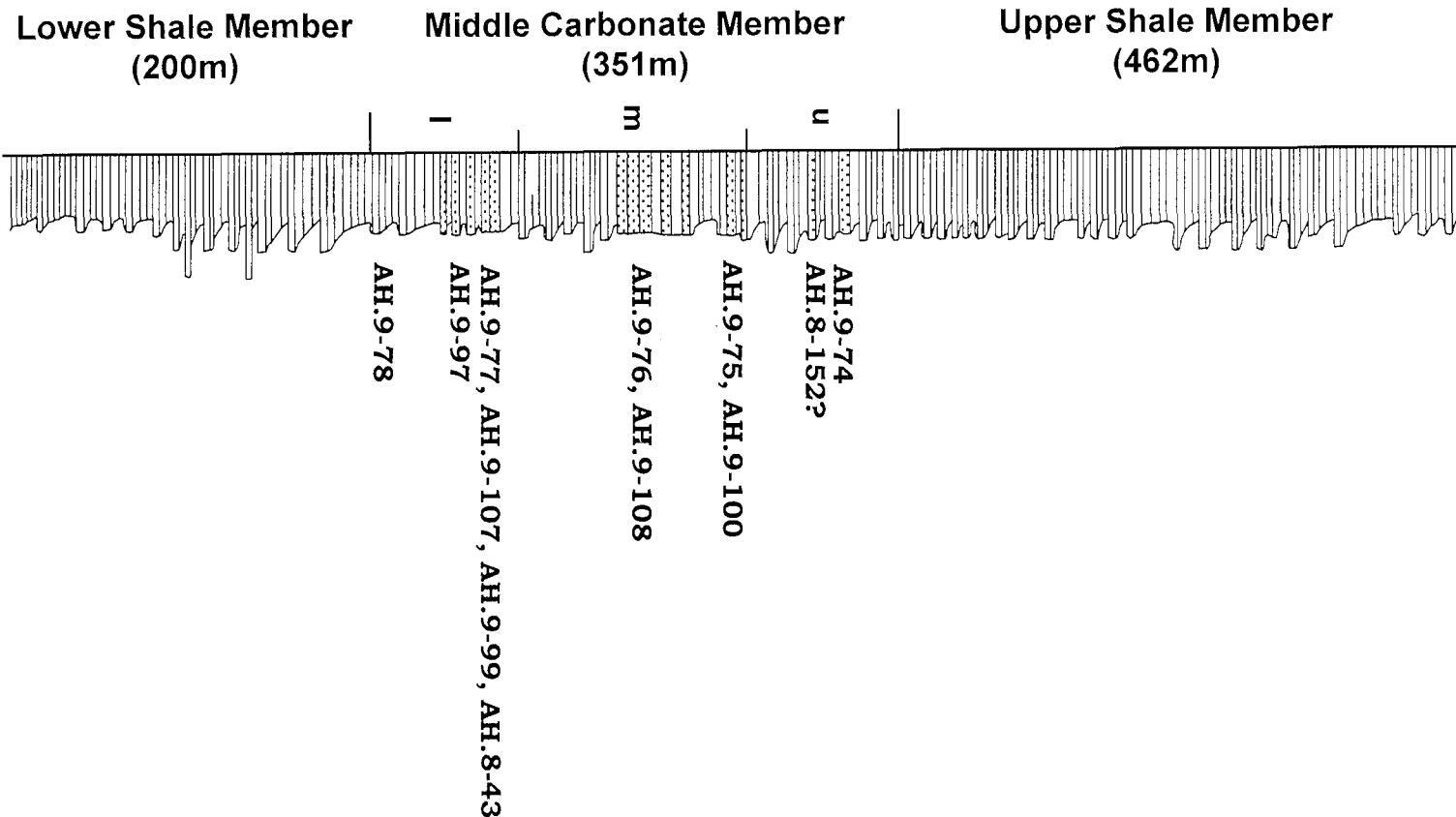
Derenjal Mountains, Shirgesht Formation (Tremadoc-Arenig)

Locality: Dahaneh-e-Kolut (numbered level ordered from top to bottom of section: see Fig. 4).

9-75: *Asaphellus* sp.

9-108: *Asaphellus* sp.; *Carolinites* cf. *ichangensis* LU, 1975; *Illaenus binomotoensis* Kobayashi, 1934; *Ampyx* sp.

CAMBRIAN	ORDOVICIAN	
	TREMADOC	2 ARENIG
DERENJAL FM	SHIRGESHT FORMATION	



'Text-Fig. 4. Schematic stratigraphic succession of the new type section of the Shirgesht Formation designated on the west side of Dahaneh-e-Kolut. Sample numbers on right are those referred to in text. After Hamidi (1995).'

indet.; *Nileus* cf. *exarmatus* TJERNVIK, 1956; *Pseudocalymene superba* PILLET, 1973; *Megalaspides kolutensis* (PILLET, 1973); *M. winsnesi* n.sp.; Gog sp. indet.; *Dactylocephalus* cf. *latus* PENG, 1990; *Peltabellia* sp. indet.; *Brachyhipposiderus* cf. *logimus* JELL, 1985; ?*Dikelokephalina* sp. indet.; and *Neseuretus ghavideli* n.sp. 9-77, 9-99: *Megalaspides winsnesi* n.sp.; *Nileus* cf. *exarmatus*, *Pseudocalymene superba* 9-97: *Pseudocalymene superba*, *Shumardia* (*Conophrys*) cf. *pentagonalis* LU, 1962 6-22, 6-23: (? Cambro- Ordovician boundary) *Asaphopsoides* sp. indet., *Dactylocephalus* cf. *latus*.

Derenjal Mountains, Derenjal Formation (latest Cambrian)

Locality: WT98-4; probably uppermost beds of the Derenjal Formation, Dahaneh-e-Kolut *Mictosaukia* cf. *rotunda* (KUSHAN, 1973)

Katkoyeh, near Zarand, Kerman area, Katkoyeh Formation (Arenig)

Locality: 8-262: *Taihungshania* cf. *shui* SUN, 1931

Shabdjereh, Kerman area. Katoyeh Formation (Arenig)

Locality: AH7-9 (= AH9-5, WCH-1, WCH2): *Neseuretus ghavideli* n.sp., *Nileus* cf. *exarmatus*, ?*Sinoparapilekia* sp.

Palaeobiogeography

by D. L. BRUTON

As noted by HAMEDI et al. (1997) our previous knowledge of Ordovician shelly faunas from Iran has, save for the trilobite descriptions of KUSHAN (1973) and PILLET (1973, 1975), been based on faunal lists and preliminary identifications which need careful evaluation before their palaeobiogeographical significance can be ascertained. Thus Iran is normally shown 'floating' on the northern margin of Gondwanaland in Early Palaeozoic reconstructions, based on structural rather than faunal evidence (cf. COCKS & TORSVIK 2002, fig. 1; FORTHEY & COCKS 2003, p. 216, fig. 6). The present work leaves no reason to contradict this. On the contrary it confirms that during the Tremadoc and early Arenig, the Derenjal Mountain and Kerman areas of east-central Iran and the Alborz area of northern Iran had clear Gondwanan connections and both occupied a crucial palaeobiogeographic position between East Gondwana (FORTHEY & COCKS, 2003, fig. 6) and the Asian regions with faunas closely linked to those of China (N & S). More specifically, constituents of the Iran fauna have affinities with trilobites from Africa, the Anglo-Welsh area, South America, Australia, Baltica and Spitsbergen showing that the traditional boundaries between the Ordovician faunal provinces of Gondwanaland (*Selenopeltis*), Baltica (Asaphid), Laurentia (Bathyurid) and South America *Asaphopsis*, (WHITTINGTON & HUGHES (1972) are blurred and migration and dispersal of particular trilobites was possible between all areas (ZHOU & DEAN, 1989).

Moreover, as more Early Ordovician faunas are made known, a picture emerges showing that the origin of particular trilobite groups was not necessarily in the province they later came to dominate. This is particularly true of the benthic Asaphidae (of which there are at least 154 genera according to JELL & ADRAIN 2003) no longer restricted to the Baltoscandian province. The cosmopolitan pelagic form *Carolinites* (see MCCORMICK & FORTHEY, 1999) occurs in the present fauna during the Tremadoc and *Carolinites* cf. *ichangesis* LU, 1975 (Pl. 1, Figs 5, 6) is one of the earliest occurrences of the genus known. Common in the present Tremadoc fauna is the leiostigiid *Pseudocalymene* (type species *Pseudocalymene superba* PILLET, 1973), which has features of the glabella, pygidium, hypostoma and mode of enrolment shared by members of both the Saukiidae and Bathyuridae. It is also closely related to species of *Annamitella* one of the most widely distributed Arenig genera which links faunas in China, Kazakhstan, Australia and Wales (for summary see FORTHEY & SHERGOLD, 1984) with insular faunas described from the Norwegian Caledonides (BRUTON & HARPER, 1981), northeastern U.S.A. (WHITTINGTON in NEUMANN 1964) and central Newfoundland (DEAN, 1973) all assumed to be outboard of Laurentia during the period.

The Tremadoc trilobites

Faunas of this period are rather uniform across much of Gondwana in Wales, the Montagne Noire, France, Spain, China, eastern Australia, New Zealand and Argentina where species of *Asaphellus* and *Shumardia* are

common. Faunas from Tasmania described by JELL & STAIT (1985) and from Central Australia by SHERGOLD (1991) include *Asaphellus* with species resembling those known from China and Korea. The Dikelocephalinidae with *Dikelocephalina*, *Asaphopsoides* (= *Asaphopsis* of ZHOU & FORTHEY 1986), link China (north and south) with Tasmania and Iran whilst from the latter area the occurrence of *Dactyocephalus* cf. *latus* PENG, 1990, is probably the first record outside China.

The bathyurid genus *Peltabellia* is palaeo-equatorial in distribution linking tropical Gondwana with Laurentia, Siberia (*Biolgina* MAKSIMOVA, 1955 is a synonym), South America (VACCARI & WAISFELD, 1994), north east China (ZHOU & FORTHEY, 1986) and Iran. Tremadoc Illaenidae are rare but *Illaenus binomotoensis* is the earliest known species with links to Korea and northeast China (KOBAYASHI, 1934; ZHOU & FORTHEY, 1986). The harpedid *Brachyhipposiderus*, first defined from Victoria (JELL, 1985), occurs in south China (PENG 1990b) and its presence in the Iran fauna is of interest. The genus is regarded here as being more primitive than the contemporaneous *Australoharpes*, known also from Argentina (HARRINGTON & LEANZA, 1957). The origin of the pilekiids is questionable and they were widespread during the Tremadoc and Arenig. Recognition of *Sinoparapilekia* in the Iran fauna suggests links with both Argentina and south China (PENG, 1990b).

The late Tremadoc-Arenig Trilobites

During the late Tremadoc and early Arenig, endemic asaphids become characteristic in South America (HARRINGTON & LEANZA, 1957), Laurentia (western USA and Canada; DEAN 1989), Siberia (CHUGAEVA, 1958), Australia (LEGG, 1976; WEBBY, WANG & MILLS, 1988) and Baltoscandia (BALASHOVA, 1976; JAANUSSON, 1953). The Baltic genera *Pseudoasaphus* and *Megalaspides* occur in Iran; a species of the latter has affinities with a form from the Tarim area, western China (ZHOU et al., 1998) and those from Turkey (DEAN 1971a). In addition, the Turkish and Iranian faunas contain *Nileus* and *Sympysurus* with a clear Baltic affinity and East Gondwanan endemics such as *Neseuretus* and *Taihungshania*. The asaphid genus *Gog*, first described from Spitsbergen (FORTHEY, 1975), has a wide distribution in marginal facies of Baltoscandia, northwest China (ZHOU in ZHOU et al., 1982), the Urals and Central Asia (BURSKIJ, 1970; CHUGAEVA, 1958) and Iran.

In summary, the Early Ordovician trilobite faunas confirm that north and East-Central Iran lay in the southern hemisphere outboard of East Gondwana in a position affording contact with all continents lying between 30° and 60° S latitude (FORTHEY & COCKS 2003, fig. 6). The presence of paleo-equatorial taxa such as *Carolinites* and *Peltabellia* shows that these either followed warm water currents or that latitude in itself was no hindrance to their migration.

Material, methods and terminology

by D. L. BRUTON

The majority of trilobites figured herein are strongly weathered and abraded, and surface details are rarely preserved. Where possible, preparation has been made with the help of a pneumatic power tool using small chisel bits or fine, hardened needles. All specimens were coated with black 'opaque' and whitened with ammonium chloride before being photographed using ring-light illumination with an additional highlight from the NW quadrant.

In the descriptions of the trilobites, the terminology used follows mainly that of WHITTINGTON & KELLEY in KAESLER (1997) except for where the description of the harpedid follows that of EBACH & McNAMARA (2002). In HAMEDI (1995) specimens from the Shirgesht Formation are cited as coming from the Tabas area; this is more strictly the locality that we refer to below as Dahaneh-e-Kolut at the south end of the Derenjal Mountains (see Fig. 3).

Systematic Palaeontology

by D. L. BRUTON

Family Saukiidae ULRICH & RESSER, 1930

Genus *Mictosaukia* SHERGOLD, 1975

Type species: *Tellerina orientalis* RESSER & ENDO in ENDO, 1931, from Late Cambrian Wan'an Formation, Tawenkou, Liaoning, China.

Mictosaukia cf. *rotunda* (KUSHAN, 1973)

Plate 3, Fig. 12

Discussion: The incomplete cranidium, an external mould (Pl. 3, fig. 12), was collected from near the base of the Shirgesht Formation at the type section, but probably from the top of the underlying Derenjal Formation (late Upper Cambrian) and thus this sample (98-T4) is the lowest in our collections. The cranidium resembles those of *M. rotunda* (KUSHAN, 1973, p. 157, pl. 33, figs 9, 13, 14; pl. 34, figs 1, 2, 6, 8) described from an approximately equivalent horizon in the Alborz Mountains of northern Iran but has a longer glabella which is constricted and a slightly expanded frontal lobe. Glabellar furrows are lacking forward of the entire S_1 which curves backwards and in this respect is not unlike the *Mictosaukia* sp. indet. figured by SHERGOLD (1991, pl. 5, figs 8, 9) from the Late Cambrian of the Amadeus Basin, Northern Territory, Australia. On the present specimen the palpebral lobe, preserved on the left side, is mainly behind S_1 and is about the same size as that of *M. rotunda*. The surface of the glabella appears smooth, with no signs of the granulation (on the external mould) characteristic of *Mictosaukia* sp. and *M. rotunda*. SHERGOLD (1991) has shown that differences between *Saukia* WALCOTT, 1914, *Sinosaukia* SUN, 1935 and *Mictosaukia* are slight and the glabella of the present material seems transitional between *Sinosaukia* and *Mictosaukia*. SHERGOLD (1991, p. 23) listed the numerous known species of *Mictosaukia*, shown to have a wide geographical distribution all over southeast Asia including nearby areas of Afghanistan and SE Turkey where it is restricted to a narrow stratigraphic interval about the Cambrian/Ordovician boundary.

Family Shumardiidae LAKE, 1907

Genus *Shumardia* BILLINGS, 1862

Subgenus *Conophrys* CALLAWAY, 1877

Type species: *Conophrys salopiensis* CALLAWAY, 1877, p. 677, pl. 24, fig. 7, from the Shineton Shale Formation (Tremadoc), Shropshire, England; by subsequent monotypy.

Remarks: A literature survey reveals at least 50 species assigned to *Shumardia*, the systematics of which has been greatly clarified by FORTEY & OWENS (1987) who recognised four subgenera: *Shumardia* (*Shumardia*), *Shumardia* (*Conophrys*), *Shumardia* (*Kweichowilla*) and *Shumardia* (*Shumardella*), to embrace many of the species listed by FORTEY (1980). Criteria distinguishing genera include: anterior definition of the glabella at or inside the cephalic margin, size and inflation of glabellar lobes, shape of pygidium (elongate-triangular, oval or semicircular) rachis reaching posterior border or not, and latter with raised rim or lacking this feature. Features of the thorax are also important but are not considered here because the present material does not include this part. FORTEY & OWENS (1991) also pointed out that surface sculpture is important but this depends on whether external or internal moulds are being studied. The depth of glabellar furrows is also more obvious on internal moulds.

The present material seems best assigned to *Shumardia* (*Conophrys*), detailed discussions of which are to be found in PENG (1990a), FORTEY & OWENS (1991), EBBESTAD (1999) and WAISFIELD et al. (2001). The latter authors distinguished *Shumardia* from *Conophrys* but this is not followed here because, as shown below, there are species which are morphologically transitional between the two.

Shumardia (Conophrys) cf. pentagonalis LU, 1962.

Plate 1, Figs 1-3

Material: Three crania (of which two are figured) and one incomplete pygidium, all internal moulds from Dahaneh-e-Kolut. An additional cranium occurs among hash on the same block as *Dactylocephalus* sp. from Dahaneh-e-Kolut (Pl. 8, figs 7-8).

Discussion: The defined glabella inside the cephalic margin, the weakly inflated glabellar lobes and the pygidium with rachis reaching the posterior marginal rim, allow closest comparison with the Tremadoc species *Shumardia (Conophrys) salopiensis* CALLOWAY (1877), *S. (C.) pusilla* (SARS, 1835), *S. (C.) gaoluoensis* ZHOU, 1977, and *S. (C.) pentagonalis* LU, 1962. The combination of an arrow-shaped glabella, short median lobe widening towards the occipital furrow and wide pre-glabellar field is most like that of *S. (C.) pentagonalis* LU 1962 (in LU 1975, pl. 1, figs 18-23) from the Tremadoc Panho Formation, China to which the present material is tentatively assigned. However, the pygidium of *S. (C.) pentagonalis* has a sinuous posterior margin apparently lacking on the specimen figured herein (Pl. 1, Fig. 3). *S. (C.) salopiensis*, from the latest Tremadoc of Shropshire, has been described in great detail by FORTEY & OWENS (1991). These authors pointed out the differences between this species and *S. (C.) pusilla*, type and additional material of which has been excellently described and figured by EBBESTAD (1999) from the Tremadoc of the Oslo Region, Norway and in the adjacent Caledonide fold belt. The present material (Pl. 1, figs 1-2) has an arrow-shaped frontal glabellar lobe similar to that of *S. (C.) pusilla*, but has a shorter (sag.) median glabellar lobe and longer (sag.) preglabellar area with rounded, rather than a flattened or weakly indented anterior margin. In this respect it is more like the internal mould specimen of *S. (C.) gaoluoensis* illustrated by PENG (1990a, pl. 2, fig. 4). In which the pitted sculpture is about as weak as it is in the present material. In both species the median glabellar lobe widens towards the occipital furrow, a feature not shown in *S. (C.) pusilla* (cf. EBBESTAD, 1999, fig. 24). The posterior margin of the incomplete pygidium (Pl. 1, Fig. 3), lacks the embayment shown on specimens belonging to *S. (C.) pusilla* and *S. (C.) gaoluoensis*, and the shape seems to have been more oval with a well marked rim. At least four well-defined Rachial rings are present, each carrying a row of coarse granules. Small specimens of *S. (C.) salopiensis* from the Tremadoc of Nova Scotia (FORTEY & OWENS 1991, fig. 8, O, P, Q) have an oval pygidium but both small and large specimens of this species have a less define arrow-shaped glabella and a longer median lobe. *Shumardia (C.) nericiensis* WIMAN (see HOEL 1999b, p. 267), has been compared with Tremadoc species from Sweden, South America and Korea, but all have a more pear-shaped rather than the arrow-shaped glabella of *S. (C.) pusilla*, *S. (C.) gaoluoensis* and the present material.

Shumardia (C.) changshaniensis LU (in LU et al. 1976, pl. 9, figs 8, 9) appears to have an arrow-shaped glabella, but the median lobe is considerably longer than the present material while in *S. (C.) minitula* and *S. (C.) erquensis* from the late Tremadoc and early Arenig of Argentina (see HARRINGTON & LEANZA 1957, fig. 24, 1a-e, 2a-b), and *S. (C.) fabiani* from the early Tremadoc of Argentina (see WAISFELD et al. 2001, fig. 13) the preglabellar field is extremely narrow.

Family Telephinidae MAREK, 1952

Genus *Carolinites* KOBAYASHI, 1940

Type species: *Carolinites bulbosus* KOBAYASHI, 1940 = *Carolinites tasmaniensis* (ETHERIDGE, 1919).

***Carolinites* cf. *ichangensis* LU, 1975**

Plate 1, Figs 5-6

Material: One incomplete cranium from level 8-43, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. Hamedi.

Discussion: JELL & STAIT (1985b, p. 40) have outlined arguments for considering *Ptychoparia?* *tasmaniensis* ETHERIDGE (1919, pl. 1, fig. 19) a synonym of *Carolinites bulbosa* KOBAYASHI, 1940 from Tasmania, and that it is identical to *Carolinites genacinaca nevadensis* HINTZE, 1953. The latter and *Carolinites genacinaca* *genacinaca* Ross, 1951 occur in succession in the Arenig of Nevada and Spitsbergen (FORTEY 1975). MCCORMICK & FORTEY 1998; 1999) have discussed these and other species, as well as providing a comprehensive survey of the genus and discussed its cosmopolitan distribution (see MCCORMICK & FORTEY 1999, figs 2, 12). There seems no

doubt that *C. genicinaca nevadensis* is a junior synonym of *C. tasmaniensis tasmaniensis*, and that this and *C. genicinaca genicinaca* are distinguished by the smaller bacculae and narrow fixed cheeks of the former. There are several subjective synonyms of *C. g. genicinaca* (for discussion see MCCORMICK & FORTHEY 1999, p. 204); among those closest to the present incomplete cranium (Pl. 1, Figs 5, 6) are those from the Canning Basin, Western Australia assigned to *C. bulbosa* by LEGG (1976, pl. 1, figs 26, 30) and *C. ichangensis* from the Arenig of central and eastern China figured by LU (1975, p. 288, pl. 2, fig. 16, 17). These and the specimen described by DEAN (1973, pl. 3, figs 4, 12–13) from the Arenig of Turkey have a prominent anterior border and furrow, straight dorsal furrows inside the prominent bacculae and narrow fixed cheeks. LEGG's material is of somewhat flattened internal moulds, whilst the Chinese material shows the convexity which, with the glabellar proportions, fit the present material well. The present material has a slight median cleft in the front of the glabella, a feature noted by DEAN (1973, p. 301; pl. 3, fig. 4) and also present, albeit faintly, on well preserved material of other species from the Arenig of Spitsbergen (cf. FORTHEY 1975, pl. 39, fig. 3; pl. 40, fig. 5; MCCORMICK & FORTHEY 1999, figs 3–16, 25); this may be diagnostic for the genus. The present material from Iran is a new point to add to the Gondwana area together with the already known broad paleogeographic distribution of *Carolinites* elsewhere (see MCCORMICK & FORTHEY 1999, fig. 12).

Family Leiotegiidae BRADLEY, 1925

Synonym: Eucalymenidae LU 1975 (see PILLET 1976; FORTHEY & SHERGOLD 1984).

Genus *Pseudocalymene* PILLET, 1973

Type species: By original designation *Pseudocalymene superba* PILLET, 1973 from the Shirgesht Formation, Dahaneh-e-Kolut, Iran.

Synonyms: *Paraonychopyge* PILLET, 1973; *Eucalymene* LU, 1975; *Paraszechuanella* LIU in ZHOU et al., 1977; and *Madaoyites* LIU in ZHOU et al., 1977.

Discussion: FORTHEY & SHERGOLD (1984) discussed the concept of the Leiotegiidae pointing out a number of similarities shared by a group of Early Ordovician genera formerly regarded as bathyurids. Included in these were *Szechuanella* (for discussion of authorship, LU 1959 contra CHANG & FAN 1960, see SHERGOLD et al. 1988, p. 313), *Eucalymene* LU, 1975, (considered a possible synonym of *Pseudocalymene* PILLET, 1973; see PILLET, 1976, p. 96) and *Paraszechuanella* LIU in ZHOU et al., 1977 (see PENG 1990a,b).

PILLET (1973) established two new genera based on material collected by F. BOZORGNA and A.F. LAPPARENT from the Shirgesht Formation at Dahaneh-e-Kolut. These were *Paraonychopyge* (type species *P. iranicus* PILLET), and *Pseudocalymene* (type species *P. superba* PILLET). Regrettably I have not been able to trace the holotypes of these but the best material available from the PILLET Collection is that of *Pseudocalymene* (Pl. 1, figs 7, 8–10). This is identical with the many tens of specimens collected by T.S. WINSNES (in RUTTNER et al. 1968) and M.A. HAMEDI from the type locality and horizon and assigned herein to *P. superba*. I have seen the incomplete cephalon of *Paraonychopyge iranicus* figured by PILLET (1973, pl. 6, fig. 2,) and conclude that this is the same as *Pseudocalymene superba*. Thus *Pseudocalymene* becomes a senior subjective synonym of *Paraonychopyge*.

Characteristic for *Szechuanella*, *Eucalymene*, *Paraszechuanella*, *Pseudocalymene*, *Annamitella* MANSUY, 1920 (see FORTHEY & SHERGOLD 1984; with synonyms), and *Pagodia* (*Whittekindtia*) WOLFART, 1970 (see SHERGOLD & SDZUY 1991 for discussion), is the rectangular glabella, slightly tapering forwards, the turned back anterior border, pygidial axis with defined axial rings and pleural ribs, the first four axial rings always prominent, the remainder less so, fused or up to 7 or more and the border is usually narrow and convex. Glabellar furrows are best seen on internal moulds, the most prominent being S₁, inclined steeply backwards, S₂ and S₃ close together and directed transversely.

All genera show similar co-aptative structures, the most obvious being the long spine on the doublure of the pygidium at the antero-lateral corner (cf. Pl. 2, fig. 7; Pl. 3, figs 1, 2, 7 with those on *Pagodia* (*Whittekindtia*) WOLFART, 1970, pl. 8, figs 5b, 6b; SHERGOLD & SDZUY 1991, pl. 4, fig. 68; *Paraszechuanella*, PENG, 1990a, pl. 4, figs 10d, 10c, 12; and *Annamitella*, FORTHEY & SHERGOLD 1984, pl. 84, fig. 11). *Annamitella* is clearly related to *Pseudocalymene* and the pygidium is similar to those figured here. However, the cephalon differs in having very narrow free cheeks and larger eyes. Apart from lacking the reclined anterior border of the cephalon, many of the

features outlined above apply to certain saukiids such as *Eosaukia latilimbata* LU, 1954 (holotype figured by SHERGOLD (1991, pl. 5, figs 20–22) and hypostoma associated with *Platysaukia* (SHERGOLD 1991, pl. 3, fig. 11), *Lichengia*, *Platysaukia* and *Thailandia* (SHERGOLD 1991, pl. 4, figs 7, 14, 20) are remarkably like the hypostoma of *Pseudocalymene* (Pl. 1, figs 4, 12–14) in the shape of the median body and the constriction behind the anterior wings. Pits in the posterior border furrow are also present in the well preserved specimen assigned to *Thailandia* by SHERGOLD (1991, pl. 4, fig. 20).

The deep maculae present in both *Thailandia* and *Pseudocalymene* result in a median body which is anchor shaped as in the case of specimens assigned to *Bathyurus* by LUDVIGSEN (1979, pls 1–6). WHITTINGTON (1988, p. 328, fig. 10 and references) has pointed out that a long anterior wing characterises hypostoma of bathyurids (see LUDVIGSEN 1979, pl. 6, fig. 3) and this is like that in *Pseudocalymene* (Pl. 1, figs 12–14). The rostral plate is similar though in the latter the median flange is apparently lacking.

There seems no doubt that *Pseudocalymene* (and synonyms) belongs to the Leiostigiidae but details of the ventral sutures and hypostoma suggest closeness to both the Saukiidae ULRICH & RESSER, 1930 and the Bathyuridae WALCOTT, 1886.

Pseudocalymene superba PILLET, 1973

Plate 1, Figs 4, 7–16; Plate 2, Figs 1–8; Plate 3, Figs 1–4, 6–7, 10

- 1968 *Hystricurus* sp.; WINSNES in RUTTNER et al., p. 34.
1973 *Pseudocalymene superba* nov.sp. PILLET, pl. 6, figs 5–8; pl. 7, figs 1–6; pl. 8, fig. 9.
1973 *Paraonychopyge iranicus* nov. sp. PILLET, pl. 6, figs 1–4; pl. 8, figs 7, 8.
1976 *Pseudocalymene superba* PILLET, 1973; PILLET, p. 96.
1981 *Fencriinus* [sic] cf. *mitchelli* FOERSTE; KALANTARI, pl. 3, figs 1–5.
1981 *Proetus* sp.; KALANTARI, pl. 3, fig. 9.
1981 *Dalmanites* sp.; KALANTARI, pl. 3, figs 12, 13, 15, non 10, 11, 14, 16, 17 (= *Neseuretus* cf. *ghavideli* n.sp.).
1997 *Paraszechuanella iranicus* (PILLET, 1973); BRUTON in HAMEDI et al., p. 418.
2000 *Paraszechuanella iranicus* (PILLET, 1973); HAMMER, p. 262, fig. 11.

Neotype (here selected): an enrolled specimen lacking the pygidium, figured by PILLET (1973, pl. 7, figs 5–6) and refigured herein as Pl. 1, Figs 8–10, from the Shirgesht Formation, Dahaneh-e-Kolut.

Material: In addition to the figured specimens, a cephalon with four thoracic segments from the PILLET collection; one pygidium and one enrolled exoskeleton collected by M. GHAVIDEL-SYOKI; sixteen specimens including four cephalon with thorax, three pygidia with thorax and four isolated pygidia collected by F. BOZORGNA (ref. no. BZ 3013), and nine incomplete thorax with pygidium and three pygidia collected by T.S. WINSNES from the type locality and horizon.

Additional material from the type section collected by M.A. HAMEDI is from levels 8.43 (one thorax with pygidium and one pygidium), 8.59 (one pygidium), 9.77 (one cephalon and one thorax with pygidium) and 9–108 (two pygidia).

Description: Cephalon rectangular in outline with anterior margin straight between sutures, curving strongly backwards laterally and extending into enlarged base of librigenal spine. Anterior border flattened backwards onto glabella and separated from latter by narrow furrow. Glabella outlined by broad, deep dorsal furrows, tapering only slightly forwards with three weak lateral furrows. L_1 most prominent, directed backwards and outlining basal lateral lobes, L_2 , transverse smooth area opposite anterior edge of eye lobe, L_3 , weak to lacking a short distance behind front of frontal lobe. Occipital ring narrow, furrow transverse and deep. Fixed cheek, broad, outlined by aligned facial sutures, the anterior branches curved sharply inwards and defining broad anterior border medially, and separating this from narrow rostral plate. Posterior suture curved sharply outwards from base of eye and crossing border furrow and rolled margin of fixed cheek. Free cheek strongly convex, border furrow deep, especially posteriorly, border rolled anteriorly becoming flatter and broad at base of librigenal spine. Latter apparently short and directed backwards. Eye lobe large with well developed socle defined by smooth area at base.

Hypostoma waisted at mid length (sag.) with anterior margin slightly curved forwards medially becoming straight laterally and curving to form very large anterior wing. Median body widest (trans.) at mid-length with anchor-shaped posterior part defined by deep, backwardly inclined furrows. Posterior border widening outwards from mid-length with angular postero-lateral corner from here curved inwards to form a median projection. Border furrow broad and deep, margin upturned.

Thorax of 10 segments. Rachis broad only slightly tapering towards posterior, rachial rings narrow and

outlined by well defined dorsal furrows. Pleura with median furrow separating convex posterior and median bands which fuse laterally to form tapering pleural spines. Latter shortened on first two segments to fit into vincular furrow on underside of margin of free cheek. Remainder, longer but terminations short and stumpy. Short spines occur ventrally beneath the anterior band, each spine fitting into the vincular furrow of the free cheek during enrolment, whilst the pleural spines lie dorsally along the border of the free cheek.

Pygidium with well defined rachis of at least 6 rings and terminal portion containing a faint seventh ring, smooth, not reaching posterior border. Dorsal furrows well defined tapering to opposite third ring furrow, then straightening. Up to 5 pleural ribs curved outwards and downwards and progressively backwards. Furrows on internal moulds less defined. Antero-lateral border prolonged laterally into stout, curved spine directed backwards and downwards. During enrolment this hooks against the shoulder of the vincular furrow of the free cheek. Above this point the cheek border is slightly swollen.

Cranidium and free cheeks coarsely tuberculate, the tubercles becoming smaller along the margin of the free cheek and continuing in a narrow strip along the inner portion of the turned back anterior border of the glabella, the wider outer portion with coarse, parallel terrace lines. These occur laterally on the ventral margin of the free cheek and on the rostral plate. A pattern of wavy terrace lines occurs on the lateral border of the pygidium, while the dorsal surface has a finer, less dense granulation than on the cephalon. A finer granulation occurs on the rachis and posterior pleural fields of the thorax with a few coarser granules on the anterior band of the pleura which is otherwise smooth.

Discussion: The holotype is missing from the PILLET collection and a neotype is chosen from the best remaining figured specimens. This species is among the most common at the type locality of the Shirgesht Formation and all collections contain many specimens, the largest number at hand being more than 25 collected by WINSNES in RUTTNER et al. (1968). Many are flattened, others, like those figured, are in full relief and show many well preserved morphological details including those of the ventral sutures, rostral plate, hypostoma and coaptative features connected with enrolment. There seems no doubt that *Pseudocalymene* and *Annamitella* are closely related as pointed out by FORTEY & SHERGOLD (1984) but they cast doubt on the presence in the latter of a rostral plate identified by DEAN (1973, pl. 7, fig. 8). What DEAN identified as a rostral plate is the inclined anterior border of the glabella but, in *Pseudocalymene*, the latter is clearly separated by a rostral suture from a narrow rostral plate (Pl. 2, fig. 2). In a second specimen (Pl. 2, figs 3, 5) the rostral plate is displaced along the rostral suture and is pushed askew under the glabella. The shape of the posterior margin matches the anterior margin of the hypostoma, the anterior wings of which lie below the deepened border furrow at the anterior ends of the dorsal furrows of the glabella. Details of the median body and wings of the hypostoma can be compared with those known from a calymenid though the posterior border is not forked as in both Ordovician and Silurian calymenids (cf. SIVETER 1976, 1983). Whether this resemblance is superficial is difficult to say, but an early calymenid, such as *Calymenidius* RASETTI, 1944 is known from a presumed late Cambrian boulder in Quebec and from the Early Ordovician at Table Head, Newfoundland (WHITTINGTON 1965, p. 419), whilst *Pharostomina* SDZUY, 1955 (= *Colpocoryphoides* HARRINGTON & LEANZA) is known from the Tremadoc of Germany, Argentina and China (see PENG 1990b, p. 117).

The complete enrolled specimen (Pl. 3, figs 1–4) shows how the anterior pleural spines (Pl. 2, figs 7, 8) fit into the vincular furrow successively in front of the huge hooked spine of the pygidium (Pl. 3, fig. 7) which locks against the vincular notch (Pl. 2, fig. 5). PENG (1990a, pl. 4, figs 10d, c, 12; pl. 10, figs 4a, b, 12b, c) shows this feature well on specimens of *Paraszechuanella* and of *Chosenia (Madaoyites)*. The glabella of both genera and the thoracic segments of *Chosenia (Madaoyites)* are extremely similar to those of *Pseudocalymene*. The pygidium of *Chosenia (Madaoyites)* differs in having paired border spines and the anterior pleural spines on the thorax seem to be lacking (cf. PENG 1990b, pl. 9a, b; pl. 10, 1c).

Family Asaphidae BURMEISTER, 1843

Discussion: In attempting the generic assignment of the asaphid species identified herein, attention has been paid to glabellar shape, the course of the anterior facial sutures, position of eyes and segmentation of the pygidium. When present, shape of the hypostoma has been decisive.

Genus *Pseudoasaphus* SCHMIDT, 1904

Type species: *Ptychopyge globifrons* EICHWALD, 1858 (= *Pseudasaphus* SCHMIDT, 1904; cf. JAANUSSON 1953, p. 417; 1959, p. O337).

Pseudoasaphus sp.

Plate 4, Figs 1-3

Material: One flexed exoskeleton, PMO 170.072, from the Lashkerak Formation, Alborz (= Elburz) region, collected by A. GANSER.

Discussion: The pear-shaped, strongly waisted glabella with a prominent node immediately in front of the occipital ring furrow, the very large eyes, the cephalon and pygidium with broad concave border, and the smooth pleural areas of the pygidium, allow the specimen to be assigned to *Pseudoasaphus*. The anterior border of the cephalon is broken in front of the frontal lobe of the glabella and only the divergent section of the anterior facial suture is visible. On the left side, the mould of the cheek doublure shows that the genal angle is pointed backwards but lacks a spine. JAANUSSON (1953) discussed the genus in detail as well as a number of Baltoscandian species. He figured material from Sweden and the Oslo Region, Norway, including pygidia which have smooth or weakly ribbed pleural areas. A similar situation is the case with material of the type species figured by BALASHOVA (1976, pl. 1, fig. 4, 5; pl. 2, fig. 6) which is remarkably like that figured here except the latter has a longer glabella and a more rectangular cephalon. This material and the cephalon with part thorax figured by LU (1975, p. 311, pl. 5, fig. 24), is possibly younger (Llanvirn) than the present material and LU's specimen of *P. hananicus* has genal spines. Such spines are absent on older material described by BOHLIN (1955, p. 138, pl. 5, figs 2-5, 7; pl. 6, figs 1-4) from the Arenig of Dalarne and Öland, Sweden. Details of the glabella with median node in front of the occipital ring furrow and the broad border of the pygidium all fit with the present material which is regrettably not preserved well enough to show the terrace line pattern shown to be specifically distinctive by JAANUSSON (1953) and BOHLIN (1955).

Genus *Megalaspides* BRØGGER, 1886

Type species: *Megalaspis dalecarlicus* HOLM, 1882, from the lower Arenig, Skattungbyn, Dalarne, Sweden.

Diagnosis: Asaphidae with glabella indistinct, flattened between eyes, gently sloping forwards to flattened border. Eyes large, placed far back. Anterior sutures curved strongly outwards in front of eyes less curved inwards towards mid-line anterior border of the glabella with slight median projection. Free check with genal spine. Occipital ring indistinct, median node behind transverse line through base of eyes. Thoracic pleurae pointed distally. Pygidium smooth or weakly ribbed, with marked concave border on internal mould. Hypostoma with arcuate outline curving inwards posteriorly, posterior margin rounded or weakly notched.

Discussion: FORTHEY (1975) and more recently HOEL (1999a) discussed species assigned to *Megalaspides* and concluded that differences between them do not warrant retention of the subgenera *Megalaspides* (*Megalaspides*) and *M. (Lannacus)* erected by TJERNVIK (1956), even though HOEL (1999a, fig. 5) used the latter name in the figure description. Species possessing the above diagnostic features have been assigned to various genera including *Pseudobasilicus* REED, 1930 (for history of genus see JAANUSSON 1953, p. 443; pl. 8, figs 7-9; pl. 9, figs 1-3) with younger material from Baltoscandia and Russia (BALASHOVA 1976, p. 59, pl. 10, figs 1-3, 5-6) resembling that included herein. These are clearly different from species formerly assigned to *Pseudoasaphus*. BALASHOVA (1964) considered these species to be closely related to those of both *Pseudobasilicus* and *Paraptychopyge*. FORTHEY (1975, p. 32, pl. 8) assigned *Paraptychopyge disputa* FORTHEY to the subfamily Ptychopyginae BALASHOVA, 1964.

Megalaspides kolutensis (PILLET, 1973)

Plate 4, Figs 4-14, 16

1968 *Megalaspides* sp. WINSNES in RUTTNER et al., p. 34.

1973 *Parabasilicus kolutensis* nov. sp. PILLET, p. 35, fig. 2, pl. 9, figs 1-5. = *Parabasilicus iranicus* nov. sp. (*nomen nudum* PILLET, 1973).

1998 ?*Megalaspides* sp. ZHOU et al. pl. 2, figs 1-2.

Holotype: By original designation, the incomplete cephalon with half thorax attached figured by PILLET (1973, pl. 9, fig. 1); figured herein as Pl. 4, Figs 5-6, from an unknown horizon of the Shirgesht Formation, Dahaneh-e-Kolut. The material was described as

Parabasilicus kolutensis nov. sp. by PILLET (1973, p. 35), but identified as *Parabasilicus iranicus* nov. sp. on the plate explanations (PILLET 1973, p. 38); *Parabasilicus iranicus* is therefore regarded as a nomen nudum.

Additional material: One complete flexed individual, two incomplete cephalas and part thorax and one pygidium all figured herein, collected by T.S. WINSNES from bed 22–33, at the type locality (RUTTNER et al. 1968, fig. 11).

Discussion: From the LAPPARENT Collection, I have only seen the holotype; the remaining four specimens figured by PILLET (pl. 9, figs 2–5) from the BOZORGIA collection have not been traced.

Two cephalas from the WINSNES Collection (Pl. 4, figs 9, 10, 11–12) show a better preserved glabella than that of the holotype where the frontal lobe is compressed. Both in dorsal and lateral view the glabella is extremely flat (tr.) with a gentle slope (tr.) down to the anterior border. In the specimen (Pl. 4, fig. 10) the exoskeleton is cracked and the semi-circular frontal outline is an artifact. However, signs of glabellar muscles seem to be real. The complete, flexed specimen (Pl. 4, figs 4, 7–8) shows a smooth pygidium with a flat to concave border but this is an internal mould. A second pygidium assigned here (Pl. 4, figs 13–14) is not well preserved but shows a well defined rachis with faint pleural ribs and a concave border. Details of the thoracic pleural tips (Pl. 4, fig. 6, 15) show these to be more pointed than is usual for asaphids. This species resembles closely *Megalaspides striatellus* described by FORTEY (1975, p. 16, pl. 7) from the early Arenig of Spitsbergen. Both have a weakly defined glabella, a similarly placed median tubercle and glabellar muscle pattern. The pygidium of *M. kolutensis* is known only from the incomplete internal mould (Pl. 4, figs 4, 8) of a partially enrolled exoskeleton. Both this and a second specimen (Pl. 4, figs 13, 14) exhibit a similar concave border present on specimens of *M. striatellus* and the pleural field is smooth to very faintly ribbed. As seen in dorsal view, cranidia of *M. kolutensis* are extremely like the specimen figured by ZHOU et al. 1998, pl. 2, figs 1, 2) as *Megalaspides* sp. from the late Tremadoc, early Arenig of the Tarim area, western China. Associated hypostoma, including that of *M. striatellus* (FORTEY, 1975, pl. 7, fig. 6) and of material assigned by HOEL (1999a, fig. 5, G.H.) to *M. nericiensis* WIMAN (type species of *M. (Lannacus)* TJERNVIK, 1956) have a shallow, forked posterior border whilst the hypostoma of *M. winsnesi* n. sp. (Pl. 5, figs 1, 3, 14) is only very slightly indented. The hypostoma of *M. nericiensis* figured by TJERNVIK (1956, pl. 9, fig. 4) is even more strongly notched and seems more likely to belong to *Promegalaspides* figured on the same plate. FORTEY (1975, p. 19) pointed out that the thoracic rachial rings of *M. dalecarlicus* and *M. nericiensis* expand slightly posteriorly so that the dorsal furrow is zig-zag in shape, a feature shown on *M. kolutensis* but it is less obvious on *M. winsnesi* n. sp. and *M. striatellus*. LU (1975, p. 312, pl. 5, fig. 25, pl. 6, figs 1–3, 4–6,) figured material of two species assigned to *Pseudobasilicus* REED, 1930 from the Arenig-Llanvirn of western Hubei, China which may belong to *Megalaspides*.

Megalaspides winsnesi n. sp.

Plate 3, Fig. 13; Plate 5, Figs 1–14; Plate 6, Fig. 6; Pl. 7, Fig. 4

Holotype: Almost complete individual PMO 170.216, from the Shirgesht Formation, bed 22.23 (see RUTTNER et al. 1965, fig. 11).

Origin of name: After TORE S. WINSNES, Norwegian palaeontologist and collector assigned to the United Nations in Iran, spring 1964.

Material: In addition to the holotype, one external mould with hypostoma collected by K.S. EMANI and T.S. WINSNES, one enrolled specimen, one incomplete cephalon with part thorax, two cephalas and one hypostoma collected by WINSNES from the type section, one incomplete exoskeleton collected by M.A. HAMEDI from level 9–99 at the type section one pygidium and one cephalon with part thorax collected by M. GHAVIDEL-SYOKI and F. BOZORGIA respectively from the type section, level unknown.

Diagnosis and description: Cranidia of *M. winsnesi* n. sp. differ from those of *M. kolutensis* in having a shorter glabella in front of the eyes a broader (tr.) occipital ring and narrower (tr.) free cheeks (cf. Pl. 4, figs 5, 11 with Pl. 5, figs 2, 9, 10). The left genal spine in *M. winsnesi* n. sp. is complete and long, reaching to the last thoracic segment (Pl. 5, fig. 2). The cranidium of *M. angustus* (see ZHOU et al. 1998, pl. 1, figs, 1, 8) from the Arenig of the Tarim area, western China, has smaller palpebral lobes and the pygidium is more pointed. The pygidium of *M. winsnesi* n. sp. resembles very closely that of *M. nericiensis* figured by HOEL (1999a, fig. 5E, F) from the Hagastrand Member (early Arenig) of the Oslo Region, Norway, showing on the external surface of the exoskeleton, faint traces of up to at least seven rachial rings and even fainter radiating lines corresponding to interpleural furrows. A latex cast from an external mould of the pygidium (Pl. 5, Fig. 4) shows the first rachial rings and interpleural furrows and the broad doublure. When photographed in dorsal view, the pygidium of both *M. nericiensis* and *M. winsnesi* n. sp. appear to slope steeply downwards, but in reality the border is more

concave as shown in the specimen Pl. 7, fig. 4. The concave border is obvious on the pygidium of cf. *Megalaspides* sp. (LEGG 1976, pl. 2, fig. 9) from the Canning Basin and the associated cranidium (pl. 2, fig. 14), is flattened between the eyes. A second cranidium (LEGG 1976, pl. 2, fig. 22) lacks this feature. The hypostoma (Pl. 3, fig. 13; Pl. 5, figs 1, 3, 14) has long anterior wings which curve steeply downwards from a band-like area which is flat medially with a rim along the hypostomal suture. Along the sagittal line, the band is flush with the median body but the outline of the latter is marked by a raised ridge which becomes the incurved lateral margin posteriorly. This is widest postero-laterally and the posterior margin is straight without a notch. Maculae form short, deep, transverse notches. As noted above, this hypostoma is unlike that associated with *M. striatella* and *M. nericiensis* but resembles more the type figured by TJERNVIK & JOHANSSON (1979, fig. 8, E-H) and associated with *Megistaspis* (*Varvaspis*) = *M. (Paramegistaspis)* BALASHOVA, 1976. Clearly isolated hypostoma cannot be assigned with certainty and species of *Megalaspides* do occur together with the various forms of *Megistaspis* described by TJERNVIK (1956); TJERNVIK & JOHANSSON (1979); see also HOEL (1999a, p. 184). The Baltoscandian and Spitsbergen species of *Megalaspides* are younger than the present material the hypostoma of which resembles more the presumed primitive hypostomal morphology of Asaphidae (FORTHEY & CHATTERTON 1988, p. 176, text-fig. 8), including *Asaphellus* from the Tremadoc (FORTHEY & OWENS 1991, figs 7f; 8b).

Genus *Asaphellus* CALLAWAY, 1877

Type species: *Asaphus (Isotelus) Homfrayi* SALTER, 1866, from the Tremadoc, Portmadog, Gwynedd, Wales.

Diagnosis and synonyms: see FORTHEY & OWENS (1987, p. 132); SHERGOLD (1991, p. 36).

Asaphellus sp.

Plate 5, Fig. 15; Plate 6, Figs 1-5, 7-8

Material: Two incomplete exoskeletons and one pygidium from the type Shirgesht Formation, level unknown at Dahaneh-e-Kolut in collections by T.S. WINSNES and by M. GHAVIDEL-SYOOKI. One pygidium from level 9-108 collected by M. A. HAMEDI and one enrolled individual from the Lashkerak Formation, Alborz (Elburz) collected by A. GANSER.

Discussion: ZHOU & FORTHEY (1986), FORTHEY & OWENS (1987; 1991), RABANO (1989) and SHERGOLD (1991) have extensively discussed this genus and have remarked on the numerous species described from Britain, France, Spain, North America, China, Korea and Australia. This assortment, together with the fact that at least six genera are considered subjective synonyms of *Asaphellus* (see FORTHEY & OWENS 1987, p. 132) results in considerable confusion. Material of the type species is usually flattened and distorted, but a calcareous nodule containing several excellently preserved specimens from the late Tremadoc of Shropshire (FORTHEY & OWENS 1991, figs 7a-b, 8a) allows a better understanding of it. This shows the weakly concave cephalic and pygidial borders, the forward position of the eyes which seem smaller than is usual for *Asaphellus*, the well defined rachis of the pygidium and smooth pleural areas. The glabella is compressed and is not as well defined as is usual nor does the material show the characteristic waisting at the eyes shown herein (Pl. 6, figs 1, 3, 5), on the cranidium of *A. pricensis* (see LEGG 1976, pl. 4, fig 17) from the Arenig of the Canning Basin, western Australia and on specimens from the Tremadoc of the Amadeus Basin, Northern Territory, Australia figured by SHERGOLD (1991, pl. 9, figs 11, 12, 19, 20). A similar waisting of the glabella and more defined dorsal furrows, is shown on cranidia of *Asaphellus whittardi* (BATES, 1969), figured by FORTHEY & OWENS (1987, fig. 24) from the Upper Arenig of South Wales. The latter seems closest to material figured herein, except that the Welsh material is distinctive in having a pygidium with well marked rachial and pleural furrows, whereas the Iran material is smooth. The pygidium of *A. homfrayi* figured by FORTHEY & OWENS (1991, figs 7a-b, 8a) is likewise smooth and resembles that figured (Pl. 6, fig. 8). Others figured here (Pl. 5, fig. 15; Pl. 6, figs 4-5, 7) are more elongate and in this respect resemble that illustrated by LU (1975, pl. 13, fig. 3) and assigned to *Liomegalaspides*, LU, 1975, those of *Asaphellus inflatus* (LU 1975, pl. 14, figs 21-29) from the Tremadoc of western Hubei and the Yangtze Platform of northwestern Hunan (PENG 1990a) and pygidia of *A. trinodus* CHANG, 1950 figured by ZHOU & FORTHEY (1986, pl. 8) from the Tremadoc, Upper Yehli Formation, North China Platform.. Likewise the cranidium of this and a second species described by ZHOU & FORTHEY (1986, pl. 8, figs 1, 12-13, 20, 21; pl. 9, figs 1, 2) show a waisting of the glabella at the eyes. PENG (1990a, pls 6, 7) figured internal moulds of cranidia and pygidia, somewhat crushed together with hypostoma and free cheeks with a characteristic panderian organ (PENG 1990a,

pl. 6, fig. 16) known also from the type species, *A. homfrayi* (FORTHEY & OWENS 1991, fig. 7c) which it resembles closely.

Genus *Gog* FORTHEY, 1975

Type species: *Gog catillus* FORTHEY, 1975 from the middle part of the Olenidsletta Member, Valhallfonna Formation (late Arenig), Ny Friesland, Spitsbergen.

Gog sp.

Plate 6, Figs 9–11; Plate 8, Fig. 13

Material: Two pygidia from the Shigesht Formation, bed 22–33, type section (see RUTTNER et al. 1965, fig. 11) collected by T.S. WINSNES.

Discussion: The larger pygidium, an internal mould (Pl. 6, fig. 11) has a well defined rachis with six or more backwardly curved pleural ribs and broad border with a scalloped inner margin of the doublure. A smaller pygidium (Pl. 8, fig. 11) still retains part of the exoskeleton and shows similar features including details of the rachial rings which have a slight median projection from the posterior margin and the corresponding ring furrow curves backwards. This feature is present on the type species, *G. catillus* (especially FORTHEY 1975, pl. 3, fig. 4) from the Arenig of Spitsbergen, and on *Gog* n.sp. (HOEL 1999a, fig. 12) from the Tremadoc of the Oslo Region, Norway and Närke, Västergötland, Dalarne, Uppland and Jämtland, Sweden. It is not so obvious on *G. explanatus* (ANGELIN, 1851) from the Arenig of Scania and Bornholm (NIELSEN 1995, fig. 142 G, J, K, L; fig. 143 A–B). Terrace lines are present along the postero-lateral margin of the smaller pygidium (Pl. 8, fig. 11) but do not appear to extend onto the pleural areas of material as well preserved as that figured by FORTHEY (1975) and by NIELSEN (1995). The latter author and HOEL (1999a) have discussed the aforementioned and other species in detail and remarked on the rare but widespread distribution of the genus in marginal facies of Baltoscandia, Spitsbergen, NW China (ZHOU in ZHOU et al. 1982), the Northern Urals (BURSKIJ 1970) and Central Asia (*Gog tenuistriata* (CHUGAEVA, 1958)). HOEL (1999a, p. 198) believed that *Niobe vogti* STRAND, 1949 from the allochthonous Hølonda Limestone of the Trondheim region, Norway (BRUTON in NEUMAN & BRUTON, 1974, fig. 16 F, H) to be a species of *Gog*, but the material is not good enough to decide with certainty. If correct, then this (together with an associated fauna which has a North American affinity of Whiterock- late Arenig- early Llanvirn age) is the first record of *Gog* from the Bathyurid trilobite province outside Spitsbergen.

Family Nileidae ANGELIN, 1854

For discussion on classification of the family see WHITTINGTON (2000, p. 880–881; 2003).

Genus *Nileus* DALMAN, 1827

Type species: *Asaphus (Nileus) armadillo* DALMAN, 1827 from the Arenig at Flusbyfjöl, Östergötland, Sweden.

Nileus cf. *exarmatus* TJERNVIK, 1956

Plate 7, Figs 1–3, 5–13

Material: One cephalon with part thorax, one incomplete cephalon and part thorax one enrolled exoskeleton and one pygidium with part thorax from the Shigesht Formation, bed 22–33, type section (see RUTTNER et al. 1965, fig. 11), collected by T.S. WINSNES; one incomplete cephalon, one partly complete exoskeleton and one pygidium with thorax from levels 9–77 and 9–108 from the type formation at Dahaneh-e-Kolut, collected by M. A. HAMEDI; one cephalon with thorax from the Lashkerak Formation, Alborz (Elburz), collected by A. GANSSE; and two cephalas from the Katoyeh Formation, Shabdjereh, Kerman area collected by A. J. WRIGHT and M. A. HAMEDI. All but one of the cephalas from Shabdjereh are figured herein.

Discussion: NIELSEN (1995) has provided a comprehensive survey of the Arenig Baltoscandian species of *Nileus* which follows on from the work of SCHRANK (1972) based on material from erratic boulders of the region and FORTHEY (1975) who described material from the Valhallfonna Formation of Spitsbergen. EBBESTAD (1999) has discussed species from Baltoscandia and described material of *N. limbatus*, the oldest known species, from the

Tremadoc of the Oslo Region, Norway. FORTEY (1975, p. 34–35) outlined the features useful in discriminating between species and recognized (p. 40–41) that a successful taxonomy of this group relies on well-preserved material showing both internal and external features, especially details of the rachis and furrows on the internal mould and terrace line patterns on the exoskeleton. This was discussed in detail by NIELSEN (1995, pp. 195–197) who distinguished three basic types based on the terrace line pattern of the pygidium. Following this, the present material belongs to what he called the *N. exarmatus*-type (see TJERNVIK 1956, pl. 2, 16–21) with a smooth pygidium and marginal terrace lines only. TJERNVIK (1956, pp. 209–210) described *N. exarmatus* from the early Arenig of Närke, Sweden but noted its upward extended range in the late Arenig since confirmed by NIELSEN (1995, p. 225, figs 164, 165) who discusses the species in detail and provides excellent illustrations of material from Sweden, Bornholm and the Oslo Region. The present material shows how the dorsal furrows are deeply incised in front of the eyes and how the frontal lobe of the glabella is extended laterally as in *N. exarmatus* (cf. Pl. 7, figs 1–3 and NIELSEN 1995, fig. 164 C, D, F, K), and the frontal lobe is longer (sag.) than in the older *N. limbatus* (cf. EBBESTAD 1999, fig. 63, A, B, G). However, the free cheek in the latter is broader than in *N. exarmatus* and resembles more that of the present material. The pygidium of the lectotype of *N. limbatus* (EBBESTAD 1999, fig. 64 A–C) and those of *N. exarmatus* are very similar and are apparently smooth with a well defined border. The large pygidium (Pl. 7, fig. 4) is incomplete and is more rounded but not unlike a specimen of similar size of *N. exarmatus* figured by NIELSEN (1995, fig. 164 H). The doublure of the cephalon with hypostoma in place is figured here for the first time (Pl. 7, fig. 7) and shows up to 12 terrace lines medially, extending onto the upturned central area in front of the hypostomal suture. The one incomplete cephalon and thorax from the Lashkerak Formation is assigned here on account of the broad free cheeks and large eyes, even though the frontal lobe seen in lateral view seems steeper than material from the Shirgesht Formation at the type locality. Pygidia of *Nileus* figured by LU 1975 (pl. 20, figs 21, 22; pl. 23, figs 3–11) resemble *N. exarmatus*, but the glabella broadens posteriorly and is more convex. In my view much of Lu's material seems closer to *Sympphysurus* than it does to *Nileus*.

Genus *Sympphysurus* GOLDFUSS, 1843

Type species: Subsequently designated by BARRANDE (1852, p. 654), *Asaphus palpebrosus* DALMAN, 1827 from the Arenig of Västanå (= Husbyfjöl), Östergötland, Sweden. For synonymy list and description see FORTEY (1986).

Sympphysurus cf. *subquadratus* LU, 1975

Plate 7, Figs 14–15; Plate 8, Figs 1–6

1968 *Sympphysurus* sp.; WINSNES in RUTTNER et al., p. 34.

1975 *Sympphysurus subquadratus* LU (sp.nov.) LU, p. 356, pl. 25, figs 1–5.

Type locality and horizon: Late Lower Ordovician (zone of *Yangtzeella poloii*), Liangshan, Hanchung, South Shensi, China.

Material: Twenty-five enrolled specimens from the Lasherak Formation, Alborz (Elburz), collected by A. GANSSE; and one enrolled specimen and two incomplete glabellas from the Shirgesht Formation, levels 22–33 (RUTTNER et al. 1968, fig. 11) collected by T.S. WINSNES.

Discussion: LU (1975, p. 357) believed this species had features of both *Nileus* and *Sympphysurus*, but chose the latter genus on account of the stronger dorsal furrows and the more prominent rachis. The clearly defined convex (tr.) glabella and the longer, more prominent rachis of the pygidium are features distinguishing *Sympphysurus* from *Nileus* (see FORTEY 1986, p. 256), to which can be added the marked anterior rim of the cephalon.

In both lateral (Pl. 7, fig. 15; Pl. 8, figs 2, 4) and frontal view (Pl. 8, fig. 6), specimens of *S. cf. subquadratus* are remarkably like those of the type species (FORTEY 1986, fig. 1 A, B, D) but differ in dorsal view where the glabella is almost parallel-sided and rectangular rather than the more rounded shape of *S. palpebrosus*. In addition, the pygidium of the latter is shorter (sag) and more convex. EBBESTAD (1999 figs 66, 67, 68) and WHITTINGTON (2003, text-fig. 1 A–C) figured well preserved material of the Tremadoc species *S. angustatus* (SARS & BOECK in BOECK, 1838) from the Oslo Region, Norway and this species has a rectangular glabella and a pygidium like that of *S. cf. subquadratus*, but in the latter the glabella is much higher at the position of the glabellar organ and has a more convex profile when viewed laterally. For similar reasons, the present material differs from that of *S. pannuceus*

DEAN, 1973 from the early Arenig of Turkey. The material from Iran, for the most part is of internal moulds but where the exoskeleton is preserved it appears smooth and not terraced as in *S. angustatus*.

The well-preserved specimen (Pl. 7, fig. 15) shows the broad postero-lateral margin of the free cheek and notch in the anterior border associated with enrolment. Posterior pleural tips are tucked under the cheek flap and the notched border receives the pygidium and boss (cf. DEAN 1973, pl. 9, fig. 10; FORTÉY 1986, fig. 5, C, D, F; EBBESTAD 1999, fig. 66 G, fig. 67 F, G). The anterior border notch becomes less prominent on larger specimens.

Family Taihungshaniidae SUN, 1931

For discussion of inclusion of this family together with the Nileidae and Cycopygidae to the Superfamily Cyclopogacea of Suborder Asaphina, see FORTÉY & CHATTERTON (1988).

Genus *Taihungshania* SUN, 1931

Type species: *Taihungshania shui* SUN, 1931, p. 8, pl. 2, fig. 1a, b, from the Arenig of Wenshui, Hishui district, China. For discussion of the genus, see FORTÉY (1981) and BERARD et al. (1999).

Taihungshania cf. *shui* SUN, 1931

Plate 4, Fig. 15

Material: One pygidium, part internal mould (PMO 140.779) from the Katkoyeh Formation, locality 8-262 of M. A. Hamedí at Katkoyeh, east of Zarand, Kerman area.

Discussion: LU (1975, p. 340) has discussed the genus in great detail and figured material of the type species and others from the Arenig-Llanvirn of China. Material of *T. miqueli* from the Arenig of the Montagne Noire, first described by BERGERON (1893) has since been figured by DEAN (1966, pl. 16, figs 3, 4) and more recently BERARD et al. (1999) have provided a detailed description of its ontogeny. A general evolutionary trend shown by pygidia of tihungshaniids is an increase in the number of segments and an elongation of the border spines. The present specimen is not well preserved but at least 7 segments can be distinguished, a number closer to that of the type species than other species discussed by the authors above. The length of the border spines is at least two thirds the total length of the pygidium and this is about the same as in material figured by LU (1975, pl. 17, fig. 17; pl. 18, figs 1-3). Of interest is the chevron pattern of terrace lines on the dorsal and ventral surface of the spine similar to that seen on *T. omeishanensis* SHENG, 1958 (see LU 1975, pl. 19, figs 3, 4).

In the present material which is 13 mm long, the most complete border spine on the left side extends from the anterior border, its base being incorporated in the first two pleural ribs. This is a much more anterior position of the spine than in specimens of *T. shui* illustrated by LU (1975) and is associated with growth of the holaspisid (BERARD et al. 1999).

Family Dikelocephalinidae KOBAYASHI, 1936

For discussion see JELL & STAIT (1985, p. 15) and EBBESTAD (1999, p. 81)

Genus *Dikelocephalina* BRØGGER, 1896

Type species: *Centropleura? dicraneura* ANGELIN, 1854 from the Bjørkåsholmen Formation (Tremadoc), Oslo city, Norway (VODGES 1925, p. 98).

?*Dikelocephalina* sp.

Plate 9, Fig. 2

Material: One pygidium, internal mould, Shirgesht Formation, level 9-108, Dahaneh-e- Kolut, collected by M. A. HAMEDÍ.

Discussion: EBBESTAD (1999, fig. 62 A-G) has provided new figures of the type species, a cranium and refigured pygidia provided by HENNINGSMOEN (1959). The large pygidium (Pl. 9, fig. 2) is an internal mould preserved in calcareous sandstone. Details of the rachis and the broad, backwardly curved pleural ribs suggest it

is more like pygidia of *Dikelokephalina* (cf. JELL & STAIT 1985a, pl. 8, figs 2, 3, 5) than *Asaphopsoides*. Regrettably the posterior border with characteristic broad doublure and paired median spines is missing.

Genus *Asaphopsoides* HUPÉ, 1955

Type species: by original designation, *Dicellocephalus? villebruni* BERGERON, 1895 from the earliest Arenig, Montagne Noire, France.

Discussion: JELL & STAIT (1985a, p. 18) and PENG (1990b, p. 100) have discussed in detail the relationship between this genus and *Asaphopsis* MANSUY, 1920 and conclude that the latter does not belong within the family Dikelokephalinidae. This is followed here.

Asaphopsoides sp.

Plate 8, Fig. 10

Material: One pygidium, internal mould, from the Shirgesht Formation, level 6-22 at the type section and one pygidium from level 8-152 in the same area, both collected by M. A. HAMEDI.

Discussion: The figured pygidium (Pl. 8, fig. 10) has an incomplete posterior margin, but the combination of a broad doublure, the presence of at least six-seven rachial rings and the way the corresponding pleural ribs and furrows are swept backwards, suggest that it belongs to *Asaphopsoides*, material of which has recently been figured by JELL & STAIT (1985a, pls. 9, 10) from the Tremadoc of Tasmania and by PENG (1990b, pl. 15, 16, 18) from the Tremadoc of Northern Hunan. ZHOU & FORTHEY (1986, p. 191, pl. 10, figs 1, 2) used the name *Asaphopsis* for a cranidium and pygidium, both from the late Tremadoc of northern China. Their pygidium is preserved in relief, in limestone and resembles the present material more clearly than material from Tasmania and China which is somewhat flattened.

Genus *Dactylocephalus* Hsü in Hsü & Ma, 1948

Type species: *Dactylocephalus dactyloides* Hsü in Hsü & Ma, 1948 from the Tremadoc, *D. dactyloides* Zone, western Hubei, China.

Dactylocephalus cf. *latus* PENG, 1990

Plate 3, Figs 5, 9, 11; Plate 8, Figs 7-8

Material: One cranidium from level 6-23, one pygidium and joined librigenae from level 8-152 one hypostoma from level 9-108 from the type section of the Shirgesht Formation, collected by M. A. HAMEDI, one incomplete cranidium and pygidium from the type section collected by A.J. WRIGHT.

Discussion: The subquadrate glabella, large palpebral lobes lying at about mid length of glabella, the conical axis of the pygidium with posterior border spines and the characteristic terrace line pattern of forwardly curved ridge on the glabella, suggest that the material assigned herein closely resembles that of *D. latus* PENG from the Tremadoc of the Yangtze Platform, China. The present best cranidium (Pl. 8, fig. 8) lacks the anterior border but details of the glabella and terrace line pattern are diagnostic. However, the palpebral lobe appears larger than on *D. latus* and is more asymmetrical with a longer anterior portion. The incomplete pygidium (Pl. 8, fig. 7) shows the posterior tapered end of the rachis almost at the posterior margin and the mould of the doublure with the paired spine bases. A second fragment of a pygidium (Pl. 3, fig. 9) shows a tapering rachis and curved pleural furrows and also seems to belong here. The very incomplete, rectangular hypostoma (Pl. 3, fig. 5) resembles those illustrated by PENG (1990a, pl. 8, figs 6, 7; pl. 9, figs 2, 10) with an oval median body with incised maculae and broad arrow-like terminal portion. The external mould of joined librigenae (Pl. 10, fig. 2) is assigned here mainly because the doublure of the cranidium lacks a median suture excluding it from the asaphids identified herein. Apart from the complete inner margin of the right librigenal spine, the inner margins are incomplete and the dorsal surface of the free cheek is lacking. PENG (1990a, p. 26) has given a thorough description of the species and lists others described from China. The present report is probably the first outside China.

Family Illaenidae HAWLE & CORDA, 1847

Genus *Illaenus* DALMAN, 1827

Type species: *Entomostracites crassicauda* WAHLENBURG, 1818, from the Crassicauda Limestone, Fjäcka, Siljan, Sweden.

Illaenus hinomotoensis KOBAYASHI, 1934

Plate 8, Figs 9, 11–12, 14–16; Plate 9, Figs 1, 4

For synonymy see ZHOU & FORTEY (1986, p. 193).

Material: One cranium from bed 22–33, Shirgesht Formation type section, RUTTNER et al. (1965, fig. 11) collected by T.S. WINSNES, one incomplete flexed individual from level 8–152 collected by M.A. HAMEDI and one enrolled individual from the Lashkerak Formation, Alborz (Elburz), collected by A. GANSER.

Discussion: The cranium (Pl. 8, figs 9, 16) is slightly distorted but is comparable in size to that figured by ZHOU & FORTEY (1986, pl. 10, figs 5–7) from the late Tremadoc of northeast China and has a similar, dense terrace line pattern. In frontal view (Pl. 8, fig. 16) the glabella is slightly longer, but this is a result of the distortion. The terrace line pattern is distinctive and is similar to that of the *Illaenus schroeteri*-type of the *Illaenus* ss. group (see JAANUSSON 1954, pl. 1, fig. 9). Members of this group, of which *I. sarsi* is typical (see JAANUSSON, 1954, text-fig. 10a; pl. 2), have a cuspatate inner margin of the doublure, whilst *I. hinomotoensis* (Pl. 8, fig. 15) has a shallow, curved margin indented at the median furrow but lacking cusps (see also ZHOU & FORTEY 1986, pl. 10, fig. 11). The Chinese specimens of *I. hinomotoensis* and *I. cf. hinomotoensis* (see ZHOU & FORTEY 1986, pl. 10, figs 12, 14–23) are much smaller than the enrolled specimen from the Lashkerak Formation (Pl. 8, figs 11, 12, 14, 15; Pl. 9, fig. 1) and an incomplete, flexed individual from the Shirgesht Formation at the type locality (Pl. 9, fig. 4). Both Iranian specimens are badly worn and it is not possible to discern the terrace line pattern of the exoskeleton. The glabella of the enrolled specimen (Pl. 8, fig. 12) is waisted level with the eyes, becoming slightly wider (tr.) at the occipital ring than anteriorly, and the rachis of the thorax is broad until the sixth segment, from here narrowing backwards. In lateral view the, the broad, flap-like free cheek projects posteriorly beyond the distal portions of the first four thoracic segments which are bent steeply downwards and tucked beneath the free cheek during enrolment (Pl. 9, figs 1, 4). A similar feature of the free cheek is characteristic for various *Illaenus* species described by WHITTINGTON (1965, pl. 45, figs 17, 18, 20; pl. 51, fig. 12) from the Arenig-Llanvirn of Table Head, Newfoundland. The present material and that from China is amongst the oldest *Illaenus* known. Younger species, including Arenig material of *I. oscitatus* from Spitsbergen (FORTEY 1980, p. 60, pl. 10, figs 1–13) and species such as *I. consimilis* BILLINGS, 1865 and *I. gelasinus* WHITTINGTON, 1965 from the Table Head, Newfoundland. These possess a similar terrace line pattern on the cephalon but on the pygidium, all seem to have a cuspatate inner margin of the doublure. The significance of this feature is not known but a cuspatate inner margin is characteristic for the younger genus *Stenoparia* (see OWEN & BRUTON (1980, pl. 4, figs 3, 6, 14) and may indicate a possible relationship even though details of the rostral plate and flange in *Illaenus* and *Stenoparia* are quite different (cf. JAANUSSON 1954, pl. 2, figs 1, 2, and OWEN & BRUTON, 1980, pl. 4, fig. 9).

Family Bathyuridae WALCOTT, 1886

Genus *Peltabellia* WHITTINGTON, 1953

Type species: *Jeffersonia peltabellia* Ross, 1951, from the Garden City Formation (Zone G), Hillyards Canyon, north eastern Utah, U.S.A.

Peltabellia sp.

Plate 3, Fig. 8

Material: One pygidium from level 9–108 of the Shirgesht Formation, type locality.

Discussion: The semi-circular pygidium is incomplete, but the conical rachis with four rings and rounded terminal portion separated by deep furrows laterally, shallower sagittally, the three pleural furrows, not reaching border which is convex with a series of terrace lines, fits well the description of pygidia assigned to the Early Ordovician bathyurid, *Peltabellia* (for recent discussion see ZHOU & FORTEY, 1986, p. 196), including *P?*

lata described by them (pl. 12, figs 9, 14, 17) from the Tremadoc of north east China. The genus has a wide distribution during the early Ordovician and links tropical Gondwana with Laurentia.

Family Harpetidae HAWLE & CORDA, 1847

Genus *Brachyhipposiderus* JELL, 1985

Type species: *Brachyhipposiderus logimus* JELL, 1985, from the Lancefieldian (Tremadoc), Digger Island Formation, Victoria, Australia.

Brachyhipposiderus cf. *logimus* JELL, 1985

Plate 9, Figs 5-7

Material: One external and one internal mould of incomplete cephalon from the Shirgesht Formation, type locality, collected by M. YAZDI.

Discussion: The original diagnosis given by JELL (1985, p. 71) is perfectly adequate and has not been improved by amendments made by EBACH & McNAMARA (2002, p. 243). The present material shows that pitting on the cheeks and brim can be finer than on the type species and considerably finer than on material of *B. secundus* PENG, 1990 from the Tremadoc of the Jiannan Slope Belt, northwestern Hunan. Otherwise, the present material is closer to the type species, material of which is somewhat distorted and the eye ridges are not as transverse. The upturned rim of the cephalon seems characteristic and is obvious on the latex cast of the external mould (Pl. 9, fig. 5) and is very obvious on *B. secundus* (see PENG, 1990b, pl. 20, figs 1, 2). Genal spines are lacking on the internal mould (Pl. 9, fig. 7) but a well developed spine is preserved on the left side of the external mould although it is not visible on the latex cast. In *B. longus* and the present material the area within the girder (for terminology cf. EBACH & McNAMARA 2002, fig. 1) is narrower than in *B. secundus*.

Both *B. cf. logimus* and *B. secundus* have a longer prolongation than in *B. logimus* but the inner margin is straight in *B. cf. logimus* whilst it is directed outwards and backwards in *B. secundus*.

Family Raphiophoridae ANGELIN, 1854

Genus *Ampyx* DALMAN, 1827

Type species: *Ampyx nasutus* DALMAN, 1827, from the *Asaphus* Limestone (Upper Arenig), Västergötland, Sweden (see WHITTINGTON 1950).

Ampyx sp.

Plate 9, Figs 8-9, 13

Material: One cranidium and one incomplete pygidium from level 9-108 of the Shirgesht Formation, at the type section.

Discussion: Both cranidium and pygidium are incomplete and are assigned to *Ampyx* on account of the glabellar spine and the shape of the pygidium. The latter is triangular, about 2.5 times as wide (tr.) as long (sag.) with steeply sloping border laterally, becoming slightly less steep towards rachis and with at least five terrace lines. The rachis tapers backwards to the posterior border and shows some poorly preserved ring furrows. The pleura is smooth. The long anterior projection of the glabella resembles that of *Lonchodus* but unlike in this genus and as in *Ampyx*, the spine is round and there is no keel at the base. The spine is almost complete and is curved upwards at the distal end. The triangular shape of the pygidium is very like that of *A. punctolineatus* ZHOU & FORTEY, 1986 from the Llanvirn of North East China (see ZHOU & FORTEY 1986, p. 199, pl. 12, fig. 7) which these authors compared with *A. porcus* FORTEY (1975, p. 70, pl. 24, figs 1, 3, 6, 7) from Spitsbergen and *A. blackstonensis* (LEGG 1976, p. 16, pl. 6, figs 28, 23) from the Llanvirn of the Canning Basin, Western Australia. The latter was formerly assigned to *Lonchodus* but the shape of the glabella and spine together with that of the pygidium, suggests it is an *Ampyx*. NIELSEN (1995, p. 340) has discussed the family Raphiophoridae in detail and figured material of the type species and closely related forms assigned to *Rhombampyx* FORTEY, 1975. Pygidia of the latter are short with a steeply sloping border delimited from the pleura by a narrow rim. The latter feature is

lacking in the present material as in *Raphiophorus? lamasi* HARRINGTON & LEANZA, 1957, assigned to *Rhombampyx* by FORTHEY (1975). Although incomplete, *Rhombampyx lamasi*, together with *R. rhombos* (type species) and *R. tragula* FORTHEY, 1975 the latter two from the Arenig of Spitsbergen and the present material, have apart from the shape of the spine, a glabella more like *Lonchodus* than *Ampyx*.

Family Pilekiidae SDUZY, 1955

Subfamily Sinoparapilekiinae PENG, 1990

Genus *Sinoparapilekia* PENG, 1990

Type species: *Sinoparapilekia taoyuanensis* PENG, 1990, lower part of the Madaoyu Formation (Tremadoc), northwest Hunan, China.

?*Sinoparapilekia* sp.

Plate 9, Figs 10–12; Pl. 10, Figs 3–4

Material: One cranium, two incomplete cephalas and two pygidia all from level 8-152, Shirgesht Formation, Dahaneh-e-Kolut.

Discussion: PENG (1990b, p. 112) discussed the Pilekiidae in detail and pointed out the significant differences between *Pilkeia*, *Parapilkeia*, and *Sinoparapilekia*. The present material is not well preserved and details of the anterior border are missing and the position of the eye is difficult to determine. Nevertheless, it appears as if the eye lobe was positioned farther back than in *Parapilekia* and, unlike the latter, lacks eye ridges. This feature, plus the stout librigenal spine, suggests the present material is best assigned to *Sinoparapilekia*. It differs from the type species (PENG 1990b, pl. 22, figs 1–5) in having a coarser granulation and the first glabellar furrow does not extend as far backwards towards the occipital furrow. The cephalon illustrated (Pl. 9, fig. 11), has an incomplete anterior border and the glabella seems shorter than in the other specimens and the dorsal furrows are curved and not unlike those seen in a second species, *S. expansa* (see PENG 1990b, pl. 22, figs 6–8).

FORTHEY (1980, p. 80) and PENG (1990b, p. 112) listed numerous species assigned to *Parapilekia* many of which are known only from cephalas and cranidia and lack pygidia. Where known the pygidium has numerous border spines as in *Sinoparapilekia*, and is completely different from two specimens of a cheirurid pygidium (Pl. 10, figs 3–4) occurring together with the cranidia (Pl. 9, figs 11–12) and it is tempting to suggest that they may belong here. The lateral border carries a pair of stout major spines at least twice as long as the pygidium extending outwards and backwards and gently curved inwards distally. The remainder of the border is smooth. There is a prominent rachis consisting of three distinct rings and a terminal portion with slight annulation. The pleura is short with two pleural ribs.

Family Calymenidae MILNE EDWARDS, 1840

Subfamily Reedocalymeninae HUPÉ, 1955

Genus *Neseuretus* HICKS, 1873

Type species: *Neseuretus ramseyensis* HICKS, 1873 from the Arenig, Moridunian, Ogof Hen Formation, Ramsey Island, Wales.

Discussion: I follow here the classification as outlined by FORTHEY & OWENS (1987, p. 237) who have reviewed British Arenig species including the type species, *N. ramseyensis* (note publication date of 1873 not 1872; FORTHEY & MORRIS 1982, p. 69); *N. murchisoni* (SALTER, 1865), wrongly quoted by WHITTARD (1960, p. 14) as the type species and followed in this by LU (1975, p. 451), and *N. cf. complanatus* WHITTARD, 1960. WHITTINGTON (1966) described better material of *N. murchisoni* and excellent material of *N. parvifrons* (M'Coy) the latter showing details of the rostral plate and hypostome in place (pl. 5, figs 5–6, 8, 10). This evidence confirmed without doubt that *Neseuretus* is a calymenid and not a homalonotid.

FORTHEY & MORRIS (1982) described *N. tristani* (DESMAREST, 1817) from the Llanvirn of Saudi Arabia and discussed the geographical distribution of the genus during the Ordovician based mainly on the work of DEAN (1966) and HENRY (1970, 1980 and references) and concluded that during the Arenig and Llanvirn it was an

important indicator of the former extent of inshore facies in cooler waters surrounding Gondwanaland. Of all the areas in this setting (cf. FORTEY & MORRIS 1982, fig. 2, based on WHITTINGTON & HUGHES 1972) reports of *Neseuretus* from Iran have been lacking until now.

Neseuretus ghavideli n. sp.

Plate 10, Figs 1, 5–13

Holotype: PMO 170.056 an enrolled specimen figured on Pl. 10, Figs 1, 10–13, from the Shirgesht Formation, type section, collected by M. GHAVIDEL-SYOOKI.

Origin of name: The species is named in honour of the collector.

Material: In addition to the holotype, two enrolled specimens (PMO 170.567, 201.943) both paratypes, and three incomplete parts of enrolled specimens, all from the type lot. One incomplete enrolled specimen (PMO 170.067) from the Shirgesht Formation, bed 22–33, type section, RUTTNER et al. (1968, fig. 11) collected by T.S. WINSNES and one enrolled specimen from the Katkoyeh Formtion, Shabdjerch, Kerman area.

Diagnosis: A *Neseuretus* with well defined triangular glabella and bulbous anterior border not expanded laterally. Pygidia with 6 obvious bands and furrows reaching lateral margin.

Description: The largest specimen has a cephalon which is 20 mm wide (tr.) and 12 mm long (tr.). The glabella tapers forwards and is separated from the preglabellar area by a well marked furrow (Pl. 10, figs 7–8). The preglabellar area is strongly convex, and bulbous in lateral view (Pl. 10, fig. 12) and slopes down to a narrow anterior border furrow. The glabellar lobes are prominent, L₁ rounded and partly subscribed by the backwardly curved deep inner end of S₁ and a smooth, oval area, L₂ and L₃ diminishing in size, lateral furrows short and transverse. Dorsal furrows, well defined, narrow anteriorly especially wide, deep and smooth lateral to L₁. Occipital ring strongly convex with deep, narrow occipital furrow. Eyes broken but situated opposite S₂. Anterior suture straight, slanting inwards, crossing border furrow and delimiting small rostral plate. Latter broadest at connecting suture, turned under medially and anterior arch (Pl. 10, fig. 10) accommodates terminal section of pygidial rachis (Pl. 10, fig. 7). Posterior facial suture straight, extending backwards to border furrow, curving over posterior border of fixed cheek and directed backwards (Pl. 10, figs 1, 12–13), gonatoparian. Free cheek thus delimited, triangular with well developed border furrow and margin which is flat and vertical at genal angle becoming broad upturned and rolled towards connecting suture of rostral plate (Pl. 10, fig. 10).

Thorax with 13 segments. Rachis strongly convex, tapering only at last three segments. Rachial rings narrowest medially, broader towards dorsal furrow, half-ring narrow, ring furrow deep. Pleura with weakly convex posterior band, short and horizontal proximally, separated by marked change in slope from long downwardly directed distal portion which occupies more than two thirds of the total pleural length. Anterior band with articulating boss which fits below posterior band of preceding segment where latter bends down distally. Distal articulating facets covered during enrolment, first four segments accommodated under genal angle (Pl. 10, fig. 1) remainder under doublure of free cheek (Pl. 10, fig. 13).

Pygidium (Pl. 10, figs 7, 9) with 7 rachial rings and short, flat terminal portion separated by marked change in slope from longer section which slightly expands laterally and reaches posterior margin of pygidium. Rachis tapering backwards for first three segments, straighter thereafter. Pleura with at least 6 obvious bands curving progressively backwards, bent distally and forming marked vertical area inside posterolateral border.

Exoskeleton with both, coarse and fine granulation, most obvious on glabella and lobes, rachis and pleura. Finest granulation, on the free cheek doublures and rostral plate.

Discussion: Amongst material collected by WINSNES (in RUTTNER et al. 1965) is the incomplete enrolled part thorax and cephalon (Pl. 10, fig. 6) and the best evidence for the occurrence of *Neseuretus* in the Shirgesht Formation at the type locality, presumably from bed 22–33 at the type section. The excellent additional figured material has been supplied by M. GAHVICEL-SYOOKI who informs us that the material was collected from the type section together with material identified herein as *Megalaspides winsnesi* n. sp. and *Asaphellus* sp. Thus, this probably is among the earliest records of *Neseuretus* the majority of species of which have been recorded from the Arenig and Llanvirn (for lists see FORTEY & MORRIS 1982; FORTEY & OWENS 1987; RABANO 1990). In addition, the present material is among the best preserved, being in full relief, minimally distorted and with the exoskeleton preserved.

Depth of furrows and convexity of lobes are well shown as is the almost smooth circular area on the glabella at the inner end of S₁ and the broad expansion of the dorsal furrow alongside L₁, features obvious on specimens

mainly of internal moulds of *N. tristani* figured by HENRY (1970, pl. A, fig. 3a; 1980, pl. 10, figs 1a, 3, 5a-b; HAMMANN 1983, pl. 4, fig. 49; pl. 5, figs 50, 55; pl. 6, fig. 57a; RABANO 1990, pl. 15), *N. murchisoni* (WHITTARD 1960, pl. 20, fig. 8), *N. parvifrons* (WHITTINGTON 1966, pl. 4, fig. 7) and *N. avus* (HAMMANN 1983, pl. 4, fig. 40a). The preglabellar process is especially prominent in *N. ghavideli* n.sp., less obvious in the above mentioned species and is lacking in *Colpocoryphe* NOVAK in PERNER, 1918 and *Saltercoryphe* HAMMANN, 1977 (see HAMMANN, 1983), species of which have otherwise a similar glabella. Differences among pygidia in species of *Neseuretus* are small and all have a characteristic rachis with a flat smooth area beyond the last rachial ring and a long, rectangular terminal portion which slopes down to the posterior margin. In *N. ghavideli* n.sp., the pleural bands and furrows are especially diagnostic in almost reaching the margin.

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Explanation of plates

Plate 1

Shumardia (*Conophrys*) cf. *pentagonalis* LU, 1962 (Figs 1, 2, 3)

Fig. 1. PMO 140.788. Cranidium, dorsal view, $\times 20$.

Fig. 2. PMO 140.787. Cranidium, dorsal view, $\times 20$.

Fig. 3. PMO 140.786. Incomplete pygidium, dorsal view, $\times 18$.

All from level 8-152, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Carolinites cf. *ichangensis* LU, 1975 (Figs 5, 6)

Figs 5, 6. PMO 140.771. Cranium, dorsal and oblique lateral views, $\times 3$. Level 9-108, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Pseudocalymene superba PILLET, 1973 (Figs 4, 7-16)

Fig. 4. PMO 140.763. Hypostoma, oblique right lateral view, $\times 6$. Level 8-43, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Fig. 7. Pygidium, dorsal view, $\times 2$. Shirgesht Formation, exact horizon unknown, Dahaneh-e-Kolut. Original of PILLET (1973, pl. 8, fig. 9).

Figs 8, 9, 10. Neotype. Incomplete cephalon and thorax, anterior, oblique lateral and dorsal view, $\times 1.8$. Original of PILLET (1973, pl. 7, figs 5, 6).

Fig. 11. Pygidium, dorsal view, $\times 2$. Original of PILLET (1973, pl. 6, fig. 7).

Figs 12, 13, 14. PMO 201.939. Hypostoma, dorsal, anterior and right lateral view, $\times 7$. Shirgesht Formation, bed 22-33, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Figs 15, 16. PMO 140.761. Pygidium, dorsal and oblique posterior view, $\times 3$. Same field data as Figs 12-14.

Plate 2

Pseudocalymene superba PILLET, 1973 (Figs 1-8)

Figs 1, 3, 5. PMO 140.762. Cephalon with incomplete thorax, dorsal view, anterior and ventral view, $\times 3$. Arrow marks vincular notch.

Fig. 2. PMO 140.780. Incomplete cephalon, frontal view with arrow marking rostral suture, $\times 3$.

Fig. 4. PMO 201.940. Enrolled cephalon and part thorax, oblique lateral view, $\times 3$.

Fig. 6. PMO 201.941. Flattened, enrolled individual, dorsal view of cephalon and part thorax, $\times 3$.

Figs 7, 8. PMO 168.403. Incompletely enrolled individual prepared to show: in Fig. 7 ventral spines of thorax and hooked spine of pygidium (arrows); and in Fig. 8, dorsal view, $\times 3$. Specimen original of HAMMER (2000, fig. 11).

All material from Shirgesht Formation, bed 22-33, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Plate 3

Pseudocalymene superba PILLET, 1973 (Figs 1-4, 6, 7, 10)

Figs 1, 2, 4. PMO 201.942. Completely enrolled individual, lateral and oblique lateral view prepared to show vincular notch and pygidial spine (arrows), $\times 2.5$ and anterior view, $\times 3$. Shirgesht Formation, bed 22-33, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Figs 3, 6. PMO 140.760. Flexed cephalon and thorax, dorsal and right lateral view, $\times 1.5$. Level 8-43, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Fig. 7. PMO 140.761. Pygidium, right lateral prepared to show anterior border spine, $\times 5$. Same specimen as Pl. 1, figs 15, 16.

Fig. 10. PMO 140.765. Large pygidium, latex cast from external mould, $\times 3$. Level 9-97, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Dactyocephalus cf. *latus* PENG, 1990 (Figs 5, 9, 11)

Fig. 5, PMO 140.776. Incomplete hypostoma, dorsal view, $\times 6$. Level 9-108. Same stratigraphy and collection as Pl. 3, Fig. 10.

Fig. 9. PMO 170.060. Pygidium, dorsal view, $\times 3$. Locality 23A, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Fig. 11, PMO 170.059. Incomplete cranidium, dorsal view, $\times 1.5$. Specimen on same rock piece as Fig. 9.

Peltabellia sp. (Fig. 8)

PMO 140.778. Pygidium, dorsal view, $\times 7$. Level 9-108. Same stratigraphy and collection as Fig. 10.

Mictosaukia sp. (Fig. 12)

PMO 170.061. Cranidium, dorsal view of latex cast from external mould, $\times 2.5$.

Upper Derenjal Formation, Dahaneh-e-Kolut. Coll. A.J. WRIGHT: 98-T4.

Megalaspides winsnesi n.sp. (Fig. 13)

PMO 170.068. Paratype. Hypostoma, dorsal view, $\times 5$. Same stratigraphy and collection as Figs 1, 2, 4.

Plate 4

Pseudoasaphus sp. (Figs 1-3)

Figs 1, 2, 3. PMO 170.072. Dorsal view of cephalon, pygidium and oblique lateral view of flexed individual, $\times 1.25$. Lashkerak Formation, Alborz (= Elburz) region. Coll. A. GANSER.

Megalaspides kolutensis (PILLET, 1973) (Figs 4-14, 16)

Figs 5, 6. Holotype. Dorsal and lateral view of cephalon with part thorax, $\times 1.5$.

Shirgesht Formation, horizon unknown, Dahaneh-e-Kolut. Original of PILLET (1973, pl. 9, fig. 1). Coll. LAPPARENT.

Figs 4, 7, 8. PMO 170.231. Flexed individual, lateral, dorsal view of cephalon and dorsal view of pygidium and part thorax, $\times 1.6$. Shirgesht Formation, bed 22-33, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Figs 9, 11, 12. PMO 170.225. Lateral view of flexed cephalon and part thorax, dorsal and anterior view of cephalon, $\times 2.3$.

Fig. 10. PMO 170.219. Dorsal view of cephalon, $\times 1.25$.

Figs 13, 14. PMO 170.266. Pygidium, dorsal and posterior view, $\times 2$.

Fig. 16. PMO 170.235. Details of cephalon and thorax, $\times 2$. Same stratigraphy and collection as Figs 4, 7, 8.

Taihungshania cf. *shui* SUN, 1931 (Fig. 15)

PMO 140.779. Pygidium, dorsal view, internal mould, $\times 3$. Shirgesht Formation, 8-262, Katkoych, east of Zarand, Kerman area. Coll. M.A. HAMEDI.

Plate 5

Megalaspides winsnesi n. sp. (Figs 1-14)

Figs 1, 3, 14. PMO 170.217. Paratype. Incomplete individual, external mould with displaced hypostoma. Fig. 1, ventral view, $\times 1$. Figs 3, 14, dorsal and oblique lateral view of hypostoma, $\times 2.5$. Shirgesht Formation, bed 22-33, RUTTNER et al. (1968, fig. 11). Coll. K.S. EMAMI and T.S. WINSNES, 1964.

Fig. 2. PMO 170.216. Holotype. Almost complete individual, dorsal view, $\times 1$. Shirgesht Formation, bed 22-33, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Fig. 4. PMO 170.054. Paratype. Pygidium, dorsal view of latex cast from external mould, $\times 2$. Shirgesht Formation, type section. Coll. M. GHAVIDEL-SYOOKI (ref.no. MG5924).

Figs 5, 6, 7. PMO 170.220. Paratype. Enrolled individual, dorsal view of cephalon and part thorax, pygidium with part thorax and lateral view, $\times 1.4$. Shirgesht Formation, bed 22-33, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Figs 8, 9. PMO 170.218. Paratype. Lateral and dorsal view of cephalon with two thoracic segments, $\times 1.5$. Arrow indicates cephalic node.

Fig. 10. PMO 170.234. Paratype. Dorsal view of cephalon lacking right free cheek, $\times 2$. Arrow indicates cephalic node. Same stratigraphy as Fig. 1. Coll. T.S. WINSNES.

Figs 11, 12. PMO 140.769. Paratype. Flexed individual, dorsal view of incomplete cephalon, part thorax and pygidium, $\times 2$. Level 9-99, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Fig. 13. PMO 170.064. Paratype. Dorsal view of cephalon and part thorax, $\times 1.3$. Shirgesht Formation, type section. Coll. F. BOZORGNA (ref. no. BZ 3013).

Asaphellus sp. (Fig. 15)

PMO 170.053. Pygidium with attached incomplete segments, dorsal view, $\times 1$.

Shirgesht Formation, type section. Coll. M. GHAVIDEL-SYOOKI (ref.no. MG 5952a).

Plate 6

Asaphellus sp. (Figs 1-5, 7, 8)

Figs 1, 2. PMO 170.221. Enrolled individual, dorsal view of cephalon, dorsal view of pygidium, $\times 3$. Lashkerak Formation, Alborz (Elburz). Coll. A. GANSER (ref. no. Ga 1241).

Fig. 3. PMO 170.223. Incomplete individual, dorsal view, $\times 1.25$. Shirgesht Formation, ?horizon, type section, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Fig. 4. PMO 140.770. Pygidium, dorsal view, $\times 1.5$. Level 9-108, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Fig. 5. PMO 170.055. Incomplete individual, dorsal view, $\times 1.3$. Shirgesht Formation, type section. Coll. M. GHAVIDEL-SYOOKI (ref. no. 5952a).

Fig. 7. PMO 140.768. Partly exfoliated pygidium, dorsal view, $\times 1.3$. Level 9-75, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Fig. 8. PMO 140.784. Pygidium, dorsal view, $\times 3$. Level 8-152, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M.A. HAMEDI.

Megalaspides winsnesi n. sp. (Fig. 6)

PMO 170.224. Paratype. Incomplete cephalon and part thorax, dorsal view, $\times 1.25$. Shirgesht Formation, bed 22-33, type section, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Geg sp. (Figs 9-11)

PMO 170.222. Incomplete pygidium, anterior, lateral and dorsal view, $\times 1.25$. Same stratigraphy and collection as Fig. 6.

Plate 7

Nileus cf. *exarmatus* TJERNVIK, 1956 (Figs 1–3, 5–13)

Fig. 1. PMO 140.789. Incomplete cephalon, dorsal view, $\times 5$. Level 9–77, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.
Fig. 2. PMO 170.242. Cephalon with part thorax, dorsal view, $\times 1.5$. Shirgesht Formation, bed 22–33, type section, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Fig. 3. PMO 170.233. Incomplete cephalon with left anterior thorax, oblique view, $\times 1.5$. Same locality and collection as Fig. 2.

Fig. 5. PMO 170.230. Pygidium with part thorax, posterior view, $\times 1.4$. Same locality and collection as Fig. 2.

Figs 6, 7. PMO 170.232. Partly enrolled individual, dorsal view and ventral view prepared to show cephalic doublure, $\times 1.8$. Same locality and collection as Fig. 2.

Figs 8, 9, 10. PMO 170.236. Dorsal, oblique lateral and anterior view of flexed cephalon and thorax, $\times 1.3$. Lashkerak Formation, Alborz (Elburz). Coll. A. GANSER. Fig. 11. PMO 140.767. Pygidium with part thorax, dorsal view, $\times 1.4$. Level 9–108, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Figs 12, PMO 140.790. Incomplete individual with flexed cephalon, dorsal view, $\times 1.4$. Same locality and collection as Fig. 11.

Fig. 13. Incomplete cephalon with part thorax, prepared from ventral surface to show doublure and incomplete hypostoma, $\times 2$. Katoyeh Formation, Shabdjereh, Kerman area. Coll. A. J. WRIGHT.

Sympysurus cf. *subquadratus* LU, 1975 (Figs 14, 15)

PMO 170.239. Enrolled individual, dorsal view of pygidium and part thorax, left lateral view, $\times 1.5$. Same locality and collection as Figs 8, 9, 10.

Megalaspides winsnesi n. sp. Fig. 4.

PMO 140.775. Paratype. Incomplete pygidium, dorsal view, $\times 5$. Level 9–108, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Plate 8

Sympysurus cf. *subquadratus* LU, 1975 (Figs 1–6)

Figs 1, 2, 3. PMO 170.240. Enrolled individual, dorsal view of cephalon (arrow at glabellar tubercle), left lateral view and anterior view prepared to show cephalic doublure, $\times 1.2$.

Figs 4, 5. PMO 170.238. Enrolled individual, right lateral view and dorsal view of pygidium prepared to show doublure, $\times 1.2$.

Fig. 6. PMO 170.073. Enrolled individual with damaged thorax, anterior view, $\times 1.3$.

All material from Lashkerak Formation, Alborz (Elburz). Coll. A. GANSER.

Dactylocephalus cf. *latus* PENG, 1990 (Figs 7–8)

Fig. 7. PMO 140.785. Incomplete pygidium, dorsal view, $\times 5$. Level 8–152, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Fig. 8. PMO 140.058. Cranidium, dorsal view, $\times 2.5$. Level 6–23 (? Cambrian–Ordovician boundary) Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Illaenus hinomotoensis KOBAYASHI, 1934 (Figs 9, 11, 12, 14–16)

Figs 9, 16. PMO 170.069. Slightly distorted cranidium, oblique frontal and frontal view, $\times 2$. Shirgesht Formation, bed 22–33, type section, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNES.

Figs 11, 12, 14, 15. PMO 170.237. Enrolled individual, left lateral view, dorsal view of cephalon, dorsal view of thorax and dorsal view of pygidium with prepared doublure, $\times 1.2$. Same locality and collection as Figs 1–6.

Asaphopoides sp. (Fig. 10)

PMO 140.792. Pygidium, dorsal view, $\times 1.5$. Level 6–22 (? Cambrian–Ordovician boundary) Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Gog sp. indet. (Fig. 13)

PMO 170.227. Pygidium, dorsal view, $\times 1.8$. Same locality and collection as Figs 9, 16.

Plate 9

Illaenus hinomotoensis KOBAYASHI, 1934 (Figs 1, 4)

Fig. 1. PMO 170.237. Detail of thorax and cheek. Oblique lateral view, $\times 3$. Same specimen as Pl. 8, Figs 11, 12, 14, 15.

Fig. 4. PMO 140.766. Incomplete flexed individual, $\times 3$. Level 9–108, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Dikelokephalina sp. (Fig. 2)

PMO 140.791. Incomplete pygidium, dorsal view, $\times 1$. Level 8–152, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Megalaspides winsnesi n. sp. (Fig. 3)

PMO 140.765. Paratype. Incomplete pygidium, dorsal view, $\times 1.4$. Same locality and collection as Fig. 2.

Brachyhipposiderus cf. *logimus* JELI, 1985 (Figs 5-7)

Figs 5, 6. PMO 170.063. Latex cast from external mould. Incomplete cephalon, dorsal view, $\times 1.5$; detail of fringe, $\times 4.5$.

Fig. 7. PMO 170.062. Incomplete cephalon, dorsal view, $\times 1.5$. Both specimens from Shirgesht Formation at type area. Coll. MEHDI YAZDI.

Ampyx sp. indet. (Figs 8, 9, 13)

Figs 8, 9. PMO 170.774. Incomplete cranium, lateral and dorsal views, $\times 6$.

Fig. 13. PMO 140.771. Incomplete pygidium, dorsal view, $\times 8$. Same locality and collection as Fig. 4.

Sinoparapilekia sp. indet. (Figs 10-12)

Fig. 10. PMO 140.783. Incomplete cranium with overturned free cheek below, dorsal view, $\times 6$.

Fig. 11. PMO 140.782. Incomplete cephalon, dorsal view, $\times 5$.

Fig. 12. PMO 140.781. Incomplete cranium, dorsal view, $\times 6$.

All material from Level 8-152, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

Plate 10

Nesuretus ghavideli n.sp. (Figs 1, 5-13)

Fig. 1, 10-13. Holotype. PMO 170.056 Enrolled individual, oblique right lateral view, showing details of pleura and free cheek during enrolment, $\times 6$; anterior view, dorsal view of thorax, lateral and oblique later views, all $\times 3$. Shirgesht Formation, type section, exact level unknown. Coll. M. GHAVIDEL-SYOOKI.

Fig. 5. PMO 140.785/1. Paratype. Incomplete small cranium. Dorsal view, $\times 7$. Shirgesht Formation, Dahaneh-e-Kolut Coll. M. A. HAMEDI.

Fig. 6. PMO 170.067. Paratype. Incomplete, enrolled thorax and cephalon, anterior view, $\times 3$. Shirgesht Formation, bed 22-33, type section, RUTTNER et al. (1968, fig. 11). Coll. T.S. WINSNER.

Figs 7-9. PMO 170.057. Paratype. Enrolled individual, anterior, dorsal and posterior views, $\times 3$. Same collection as Fig. 1.

?*Dactylocephalus* cf. *latus* PFNG, 1990 (Fig. 2)

PMO 140.785/2. Joined librigenae, $\times 1.5$. Level 8-152, Shirgesht Formation, Dahaneh-e-Kolut. Coll. M. A. HAMEDI.

?*Sinoparapilekia* sp. (Figs 3, 4)

Fig. 3. PMO 140.785/3. Pygidium, ventral view, $\times 5$.

Fig. 4. PMO 140.785/4. Pygidium, dorsal view, $\times 6$.

Same collection as Fig. 2.

