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Conodonts, radiolarians and ostracodes in the Permian E-Lert Formation, Loei Fold Belt, Indochina Terrane, Thailand

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Abstract – Conodonts are rare in the Permian carbonates of Indochina but abundant conodonts and ostracodes have been obtained from turbiditic limestones of the Permian E-Lert Formation along with radiolarians from overlying cherts, all deposited on the margins of the interplatform Nam Duk Basin. Conodonts are typically Tethyan and are very similar to faunas from Sicily and south China. They include *Hindeodus gulloides*, *Pseudohindeodus oertlii*, *Mesogondolella siciliensis* and *Sweetognathus subsymmetricus* which indicate a probable late Kungurian – Roadian age range although a Wordian age cannot be excluded. *M. siciliensis*, which has a high blade and small cusp supposedly typical of warm-water conodonts, is found in deep (<500 m) carbonate turbidites in Thailand and in very deep deposits in Oman and Sicily, but generally not in shallow-water tropical limestones in Thailand, Oman and Sicily. The chert sequence yields a radiolarian fauna consisting of 11 confidently assigned species of which *Albaillella asymmetrica*, *A. sinuata*, *Tormentum delicatum* and *Latentifistula patagilaterata* suggest a latest Kungurian – earliest Roadian age, deposited at a palaeodepth of *c.* 500 m. Ostracodes consist of 16 genera and 23 species which belong to *Shivaella*, *Paraberounella*, *Carinaknightina*, *Paraparchites*, *Shemonaella*, *Bairdia*, *Cryptobairdia*, *Bairdiacypris?*, *Spinocypris*, *Pseudobythocypris*, *Baschkirina*, *Microcheilinella*, *Basslerella*, *Polycope* and *Cyathus*, of which *Shivaella elertensis sp. nov.* Chitnarin is newly described. The ostracodes are a palaeoecologically mixed assemblage comprising external platform and deeper-water forms, suggesting that the limestone turbidites were deposited on the proximal part of the slope. *Cyathus caperata* and *C. elliptica* show a palaeobiogeographic link to south China.

Keywords: Biostratigraphy, palaeoecology, Permian correlation, palaeogeography, deep-water fauna.

1. Introduction

Pennsylvanian – Permian limestones are widespread in outcrop and subcrop in Thailand and adjacent countries (Fig. 1) and provide important hosts and reservoirs for both metal and petroleum deposits (Booth & Sattayarak, 2011; Khin Zaw *et al.* 2014). The Permian Ratburi Group limestone of the Sibumasu Terrane (or Shan–Thai Terrane in part) conformably overlies glaciomarine siliciclastics of the Kaeng Krachan Group. The Ratburi limestones are cool-water deposits in the Artinskian and contain an increasing percentage of warm-water elements through the Guadalupian and range up to the Lopingian (J. W. Hills, unpub. thesis, University of Tasmania, 1989; Ueno & Charoentitirat, 2011). In contrast, Carboniferous–Lopingian limestones of the Inthanon and Indochina terranes (Doi Chiang Dao Limestone and Saraburi Group, respectively) contain diverse tropical faunas (Ueno & Charoentitirat, 2011). It was mainly this palaeoclimatic dichotomy that first led Ridd (1971) and Bunopas (1982) to suggest that the Sibumasu Terrane was part of Gondwana until Guadalupian time. Indochina separated from the Himalayan sector of Gondwana possibly during Devonian time (Burrett *et al.* 2014) and a collision of these SE Asian terranes occurred during Late Triassic time (Bunopas, 1982). During Permian time, carbonate platforms and basins probably covered most of the Sibumasu and Indochina terranes and were deformed during terrane suturing events during the late Permian and Triassic fusion of the Asian tectonic collage (Bunopas, 1982; Burrett, 1974; Burrett *et al.* 1991, 2014; Metcalfe, 2013; Morley *et al.* 2013; Khin Zaw *et al.* 2014). The Loei–Petchabun Fold Belt wraps around the western and probably southern margin of the Indochina Terrane (Fig. 2) and was deformed during late Permian time by collision with south China and during Late Triassic time by collision with the Sibumasu and other terranes (Kamata *et al.* 2013; Morley *et al.* 2013; Khin Zaw *et al.* 2014). A generalized cross-section of part of the Permian limestones of the Loei–Petchabun Fold Belt shows seven folded and thrust fault-bounded blocks within the Saraburi Group near Saraburi (Dawson & Racey, 1993). However, other than the recent work of Morley *et al.* (2013), there has been very little detailed structural work carried out on the Loei–Petchabun

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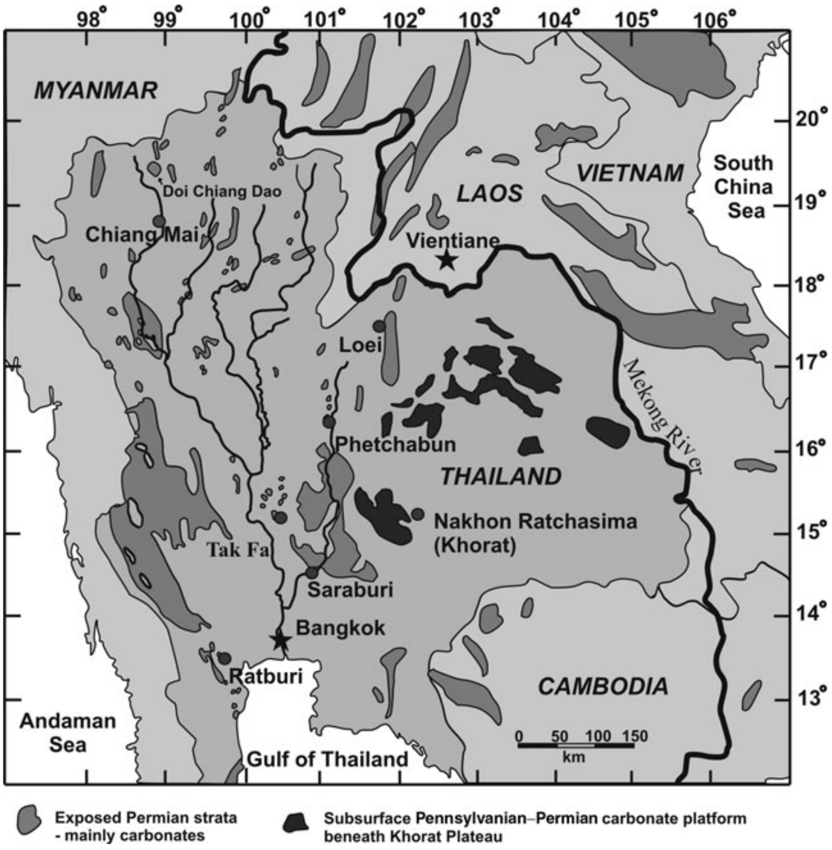

Figure 1. Map of part of SE Asia showing generalized distribution of Pennsylvanian–Permian mainly carbonate sequences in Thailand, Laos, Cambodia and Vietnam, based on Pitkapaivan (1965). Permian subcrop beneath Khorat Plateau after Booth & Sattayarak (2011).

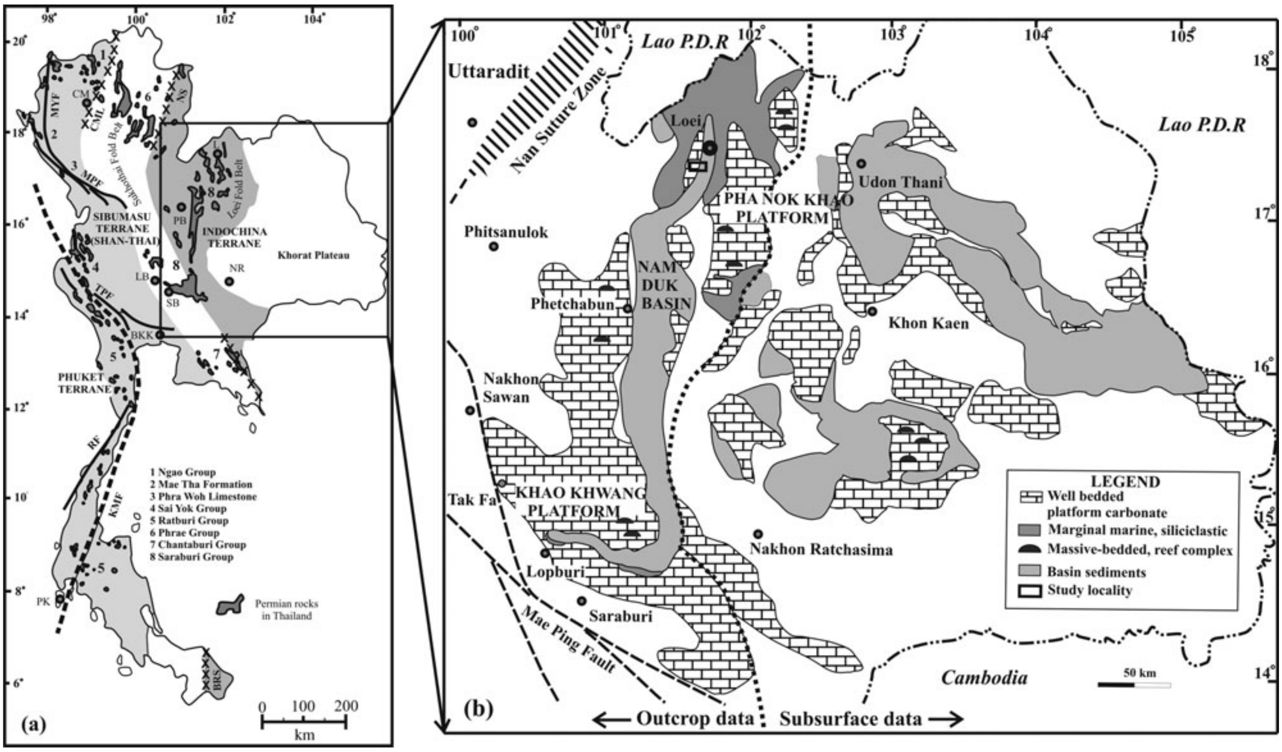

Figure 2. Generalized Cisuralian–Guadalupian palaeogeographic map of NE Thailand modified from Wielchowsky & Young (1985) (outcrops) and Chantong *et al.* (2013) (subcrops).

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Fold Belt and the palinspastic relationship between the Permian palaeogeographic elements has yet to be established.

The current palaeogeographic model for Permian time of the Loei–Petchabun Fold Belt, as developed by Wielchowsky & Young (1985), has the Saraburi Group limestones being deposited on the Pha Nok Khao and Khao Khwang carbonate platforms separated by the deep-water Nam Duk Basin containing mainly siliciclastic and volcaniclastic sequences with minor limestones (Fig. 2).

Thrusted-and-folded Permian carbonates extend as discontinuous but extensive subcrops eastwards under the Mesozoic siliciclastic cover (Khorat Group) of the Khorat Plateau region of NE Thailand and Laos to crop out in Laos as the Khammouan Limestone (Booth & Sattayarak, 2011) and in Cambodia as the Sisophon Limestone and correlates (Ishii, Kato & Nakamura, 1969; Waterhouse, 1976). The E-Lert Formation is interpreted as having been deposited in deep water on the western side of the Pha Nok Khao Platform and possibly grading westwards into the siliciclastic turbidites of the Nam Duk Basin and eastwards into the shallow-water formations of the Pha Nok Khao Platform (Chonglakmani & Sattayarak, 1978; Ueno & Charoentitirat, 2011, fig. 5.11). Although Ueno & Charoentitirat (2011, fig. 5.10) show the E-Lert deep-water sediments deposited in or on the margins of a northern continuation of the Nam Duk Basin, an alternative model has the E-Lert sediments as flanking isolated carbonate platforms and not connected to the Nam Duk Basin (Chantong *et al.* 2013, fig. 6). Based on interpretations of seismic profiles across the Khorat Plateau, Chantong *et al.* (2013) show that the Permian palaeogeography of NE Thailand consisted of small carbonate platforms separated by deep-water basins (Fig. 2).

Although the Saraburi Group limestones and correlatives contain horizons with abundant fusulinids, corals and other fauna (e.g. Dawson & Racey, 1993; Fontaine *et al.* 2005; Chitnarin *et al.* 2008, 2012; Udchachon *et al.* 2014), very few conodont faunas have been recovered and published. The Cisuralian conodonts described from the Nam Mahoran Formation in Loei province (Igo, 1974) were re-identified as Pennsylvanian species by Mei & Henderson (2002*b*). Metcalfe & Sone (2008) described the Cisuralian (early Kungurian) conodonts *Sweetognathus subsymmetricus* and *Pseudosweetognathus costatus* from shallow-water limestone of the Tak Fa Formation of the Khao Khwang Platform, 275 km SSW of Loei (Fig. 1). Here we describe conodonts and ostracodes from thinly bedded limestone and radiolarians from overlying chert and silicified shale of the E-Lert Formation.

2. E-Lert Formation

The E-Lert Formation of Loei Province (Fig. 3) crops out along a belt of over 80 km on the western limb but close to the axis of an anticline, and consists of *c.* 70 m of shales, thinly bedded limestones and interbedded cherts and silicified shales (Fig. 4) (Charoenpravat & Wongwanich, 1976). The type section is at Huai E-Lert (E-Lert Creek, also translated as Haui I-Lert and also known as Huai Sampod, Huey Sampod or Huai Sam Pot) around the Huai E-Lert Reservoir (at 101° 43′ 35″ E, 17° 18′ 29″ N and grid reference 47Q 0789502, 1915622, *c.* 24 km south of Loei City). The E-Lert Formation is overlain, with possible conformity, by sandstones and shales of the Lopingian Pha Dua Formation and interdigitates eastwards with the shallow water, sandstones and shales of the Wang Saphung Formation and the carbonates of the Nam Mahoran Formation which were deposited on the Pha Nok Khao Platform (Ueno & Charoentitirat, 2011, fig. 5.11). Based on previous data and on our preliminary studies, the E-Lert Formation is contemperaneous with the basinal turbiditic siliciclastics and volcaniclastics of the Nam Duk, Khao Luak, Nong Pong and Pang Asok formations which are the constituent formations successively from north to south of the Nam Duk Basin and its margins (Altermann *et al.* 1983; Malila *et al.* 2008; Ueno & Charoentitirat, 2011).

Very few microfossils have previously been found in the type section of the E-Lert Formation (Fontaine *et al.* 2005) and radiolarians, ostracodes and conodonts have not previously been described or figured. Ishibashi, Fujiyama & Nakornsri (1996) and Fujikawa & Ishibashi (2006) described and identified ammonoids from mudstones from the lower part of the E-Lert Formation (at Ban Na Pong, 13 km north of the type section) and suggested a Bolorian age. The Bolorian is correlated with the Kungurian by Jin *et al.* (1997). Zhou & Liengjarern (2004) examined and re-identified the previously described ammonoids, collected many more specimens and assigned all of the identifiable E-Lert fauna to the upper Artinskian *Metaperrinites* Zone. This ammonoid fauna is discussed in more detail in the biostratigraphy section (Section 4.1).

2.a. Lithology of the E-Lert Formation

We have collected specimens from the limestone section at Huai E-Lert reservoir and from overlying silicified shales and cherts (Figs 4, 5). The limestone beds are between 10 cm and 26 cm thick and are overlain by *c.* 5 cm thick interbeds of silicified shale (Fig. 5). The limestones have often been described as turbidites (e.g. Ueno & Charoentitirat, 2011). They show ripple cross-lamination representing Bouma division C which indicates that the sequence is not overturned and is younging to the east. The A division has an irregular base and the B division is graded and is succeeded by a ripple cross-laminated C division, which in turn is succeeded by a shale E division. In thin-section, the matrix is mostly micritic with concentrations of bioclasts just below the middle of the beds, consisting mainly of simple foraminiferans with some echinodermal debris (Fig. 5f). Ostracodes with complete carapaces are scattered through the micritic matrix. There

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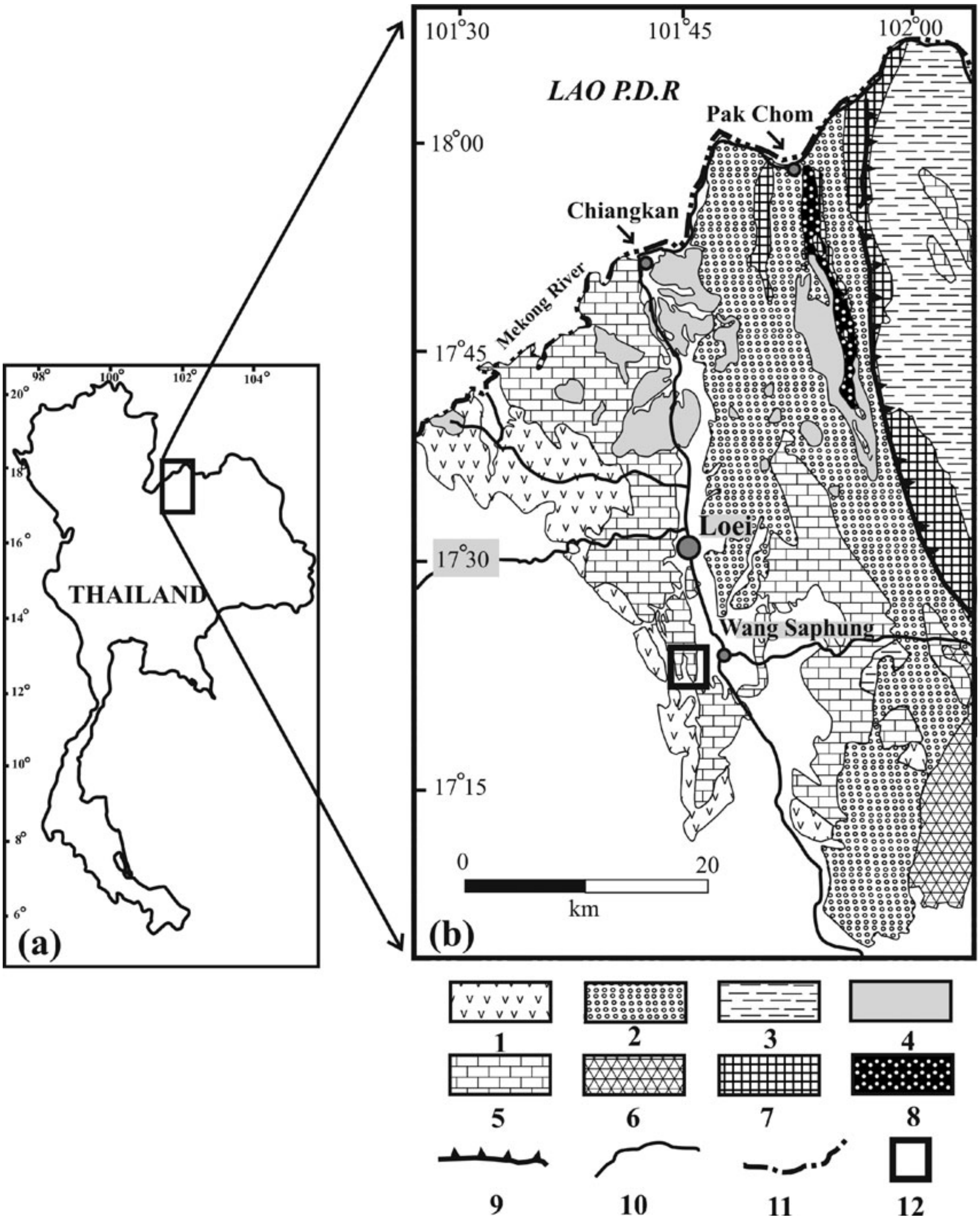

Figure 3. Geological map of the Loei region, NE Thailand. Adapted from Charoenpravat & Wongwanich (1976). 1, Permo-Triassic volcanic rocks including rhyolite, andesite, tuff and agglomerate; 2, Carboniferous rocks including conglomerate, sandstone, shale, chert and limestone; 3, Permo-Trassic rocks including sandstone, argillaceous limestone, rhyolitic tuff, shale, limestone and chert; 4, Permo-Trassic granite; 5, Permian rocks including limestone, shale and sandstone; 6. Triassic rocks including sandstone, siltstone and mudstone; 7, Devonian rocks including chert, shale and tuff; 8, Devonian–Carboniferous volcanic rocks including basalt, andesite and tuff; 9, thrust fault; 10, road; 11, country boundary; 12, study locality.

is no obvious detrital quartz. Wispy pelitic intraclasts are present in the upper part of division C (Fig. 5e).

The acetic acid insoluble residues contain rare rock fragments of mafic and ultramafic composition that are not obvious in thin-section. These range up to 1.5 mm in diameter, are irregular and not obviously weathered and contain abundant pyrite. Clasts such as these are very unusual in residues of dissolved limestones and their abundant pyrite and unweathered appearance suggest relative proximity to a source region such as an older uplifted mafic igneous body or a contemporaneous active and uplifting volcanic arc. The Devonian–Carboniferous mafics and ultramafics of the Eastern Loei Fold Belt (e.g. Intasopa & Dunn 1994; Khositanont *et al.* 2013) represent the first possibility and suggest an eastern provenance; the Permian vol-

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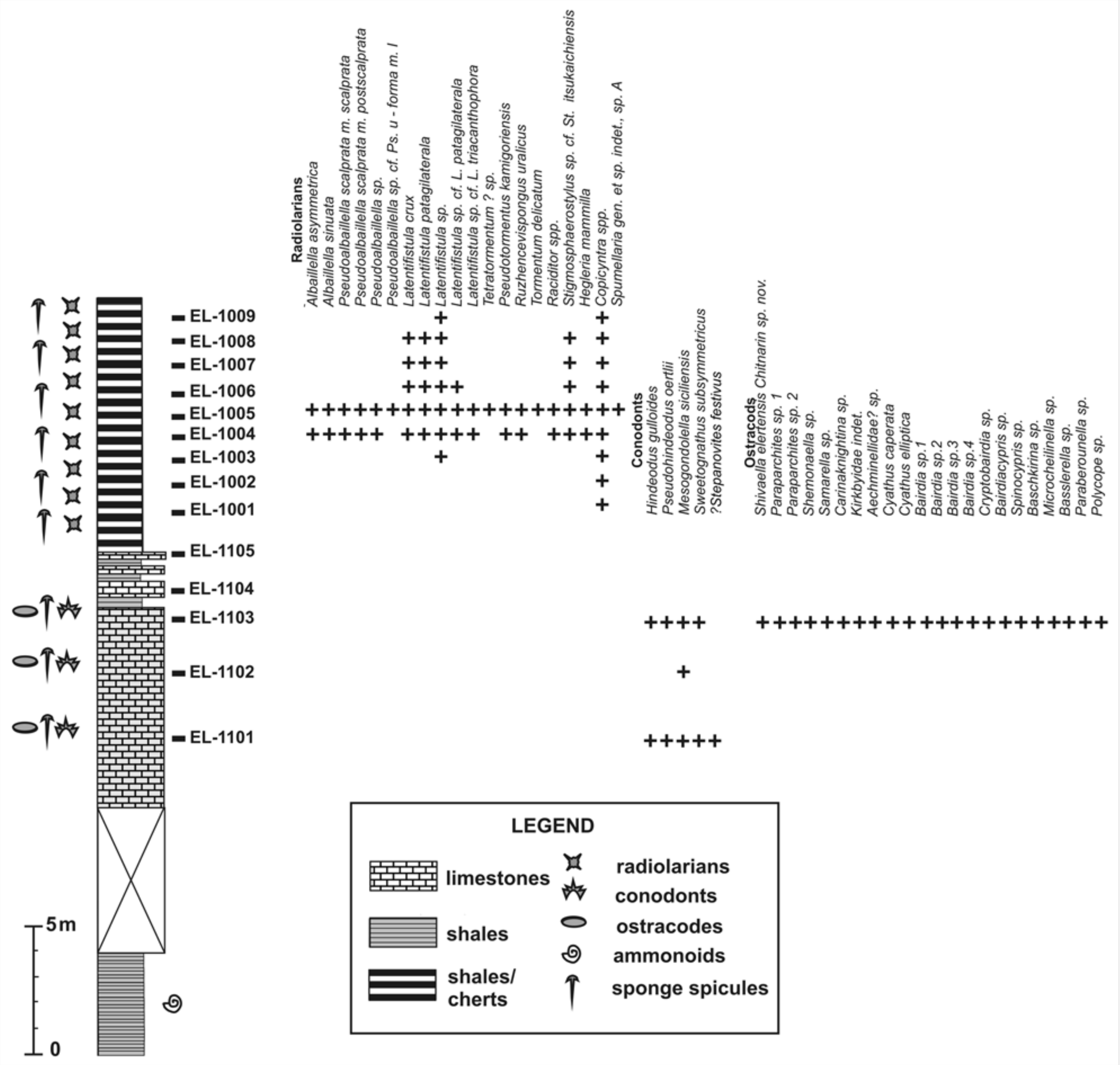

Figure 4. Preliminary stratigraphic column for the E-Lert Formation based on Ishibashi *et al.* (1996) and the authors showing ranges of radiolarians, conodonts and ostracodes. Ammonoids studied by Zhou & Liengjarern (2004) come mainly from a lower shale sequence at Ban Na Pong which is 7 km north of the Huai E-Lert (reservoir) locality; structural and stratigraphic relationships between these two localities have not yet been established.

canism of the western Loei Fold Belt (e.g. Khositanont *et al.* 2013; Khin Zaw *et al.* 2014) represents the second possibility and suggests a western source.

3. Taxonomic notes

In the following sections, Anisong Chitnarin is responsible for the ostracode taxonomy and palaeoecology sections and is the author of a new species of ostracode. Clive Burrett is responsible for conodonts and Hathaithip Thassanapak for radiolarians.

The acid-insoluble conodont residues yielded numerous silicified but highly corroded ostracode specimens. The same limestone samples were then processed using the acetolysis technique (Lethiers & Crasquin-Soleau, 1988; Crasquin–Soleau, Vaslet & Le Nindre, 2005), which allowed the recovery of well-preserved identifiable specimens. Ostracodes recovered by both methods are described here.

All ostracode specimens are deposited in the collections of Suranaree University of Technology (Nakhon Ratchasima) and given SUT collection numbers. Conodonts and radiolarians are deposited in the collections of the Palaeontological Research and Education Centre, Mahasarakham University and given PRC numbers.

3.a. Conodonts

All conodonts are reasonably well preserved but are often fractured. They have a Color Alteration Index of about 3, indicating minimum and maximum heating of 190 °C and 300 °C (Epstein, Epstein & Harris, 1977).

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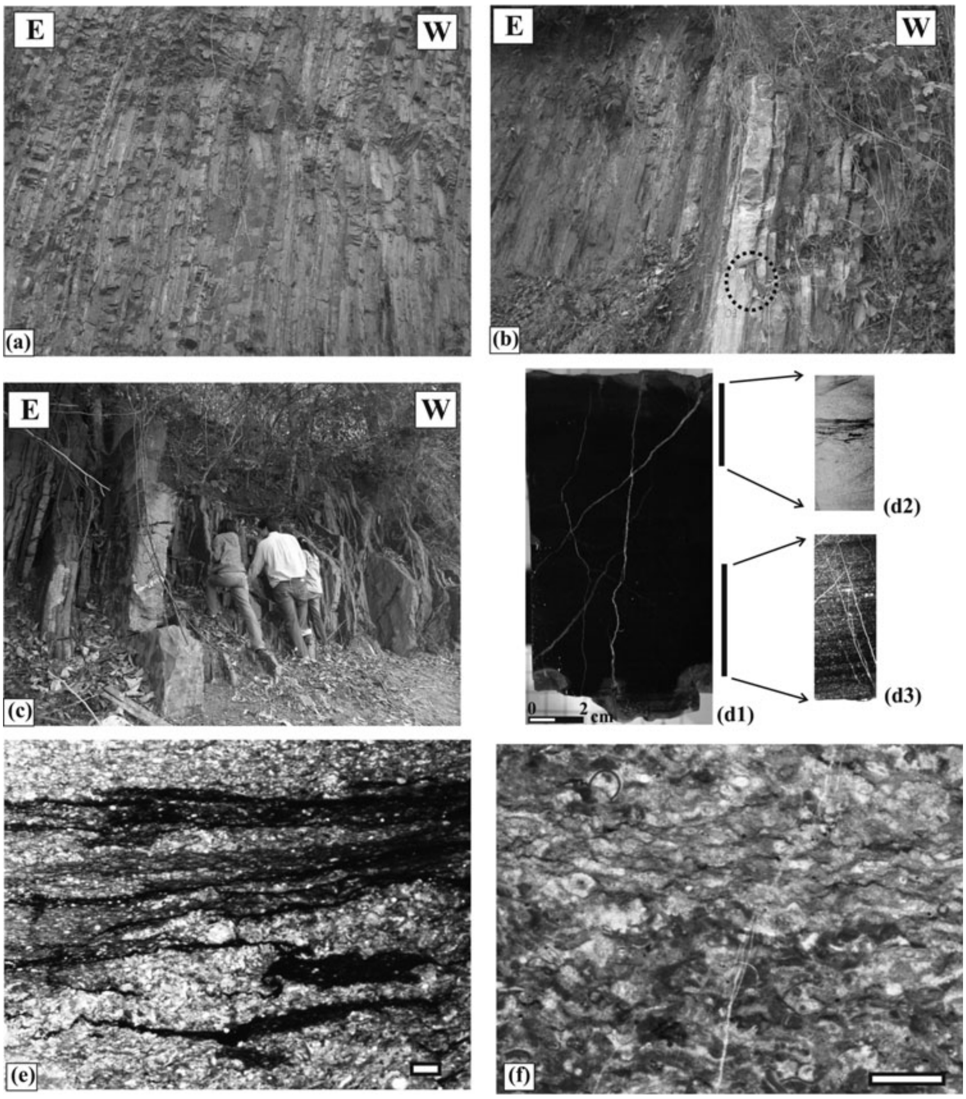

Figure 5. Photographs of E-Lert Formation. (a) Cherts and silicified shales, upper part of sequence dipping steeply east. Field of view is 3 m wide. (b) Contact between cherts (to east) and silicified shales of upper sequence and turbiditic limestones (to west). Outcrop is along track above reservoir at Huai E-Lert. Geological hammer is circled and rests on 20 cm thick limestone bed sampled as EL-1103. (c) Sequence below (b) seen only during dry season. (d) Slab of turbiditic limestone from sample EL-1101, showing position of thin-sections d2 and d3. (e) Wispy cross-lamination from near top of turbiditic unit in d2. Scale bar 500 μm. (f) bioclastic limestone near centre of unit (in d3) consisting mainly of small foraminifera and some ostracodes. Scale bar 500 μm.

Phylum CHORDATA Bateson, 1886
Class CONODONTA Eichenberg, 1930
Subclass CONODONTI Branson, 1938
Order OZARKODINIDA Dzik, 1976
Family ANCHIGNATHODONTIDAE Clark, 1972
Genus *Hindeodus* Rexroad & Furnish, 1964
Hindeodus gulloides (Kozur & Mostler, 1995)
Figure 6a–m

1995 *Hindeodus gulloides* Kozur and Mostler, 1995, plate 1, fig. 2.

?2008 *Hindeodus excavatus* (Behnken, 1975); Sun *et al.* 2008, plate 1, fig. 21.

Diagnosis. (Modified from Kozur and Mostler, 1995.) Spathognathodiform Pa (P_1) element with a short anterior blade with none–three mainly separated, triangular denticles and a much larger cusp and with a posterior blade with between 9 and 15 (average 11) triangular, partially fused denticles. On those forms that have three denticles on the anterior blade the most anterior third denticle is small compared to the other, much larger and broader denticles. The anterior part of the posterior blade is almost straight, with erect denticles and the posterior part is curved downwards, with slightly inclined denticles. All denticles are striated with striae sometimes extending onto a wide flared cupola which is widest beneath the third–fifth denticle on the posterior blade and narrows to the ends of both blades. Kozur & Mostler (1995) note that the cusp in *Gullodus* is either very indistinct or, in typical forms, missing and therefore the relatively large cusp of the E-Lert specimens differentiates this species from the *Gullodus* species *G.catalonoi*, *G.siciliensis*, *G.hemicircularis* and *G.duani* which have cusps only slightly higher or the same height as adjacent denticles.

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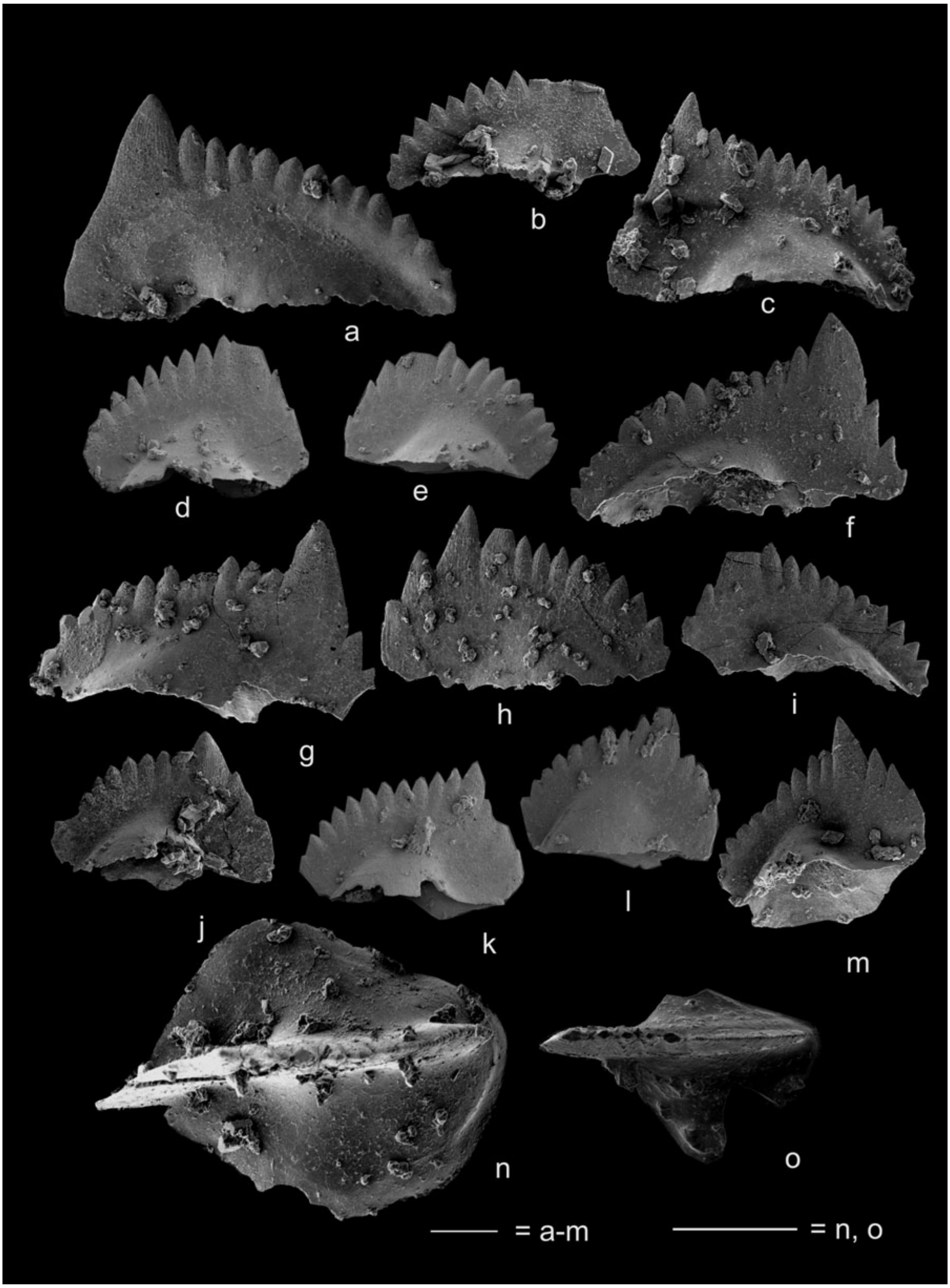

Figure 6. Conodonts from the E-Lert Formation. (a–m) *Hindeodus gulloides* (Kozur & Mostler, 1995). All Pa elements from sample EL-1101. Lateral views except for (m). (a) PRC 117; (b) PRC 118; (c) PRC 119; (d) PRC 120; (e) PRC 121; (f) PRC 122; (g) PRC 123; (h) PRC 124; (i) PRC 125; (j) PRC 126; (k) PRC 127; (l) PRC 128; (m) oblique lateral basal view, PRC 129; (n,o) *Pseudohindeodus oertlii* (Kozur, 1975); (n) upper view, PRC 130; (l) upper view, PRC 131. Scale bars 100 μm.

Remarks. Kozur & Mostler (1995, p. 114) erected *Hindeodus gulloides* and named it *gulloides* because of its '. . . transitional character to *Gullodus*'. Our material suggests a transition within this species from a *Hindeodus* morphotype (Fig. 6a) through to a *gulloides* morphotype (Fig. 6m).

Kozur (1993*a*) noted the similarity of *Gullodus* to *Hindeodus*. This is clear in our specimens that grade from a *Hindeodus* morphotype through to elements with an increasing number of denticles on the anterior blade (Fig. 6a–m). Several Permian species of *Hindeodus* Pa (P_1) elements have anterior denticles but these

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are always small (e.g. Nicoll, Metcalfe & Wang, 2002; Wardlaw, 2000). The *Hindeodus* morphotype (Fig. 6a) could be a separate species within *Hindeodus* but is included here in the apparatus of *H. gulloides* because of its general morphological and micromorphological similarity.

A possibly broken specimen assigned to *Hindeodus excavatus* by Sun *et al.* (2008, plate 1, fig. 21) from the Wordian–Capitanian of Sichuan, south China may belong to this species.

Occurrence. Texas, south China, Sicily and NE Thailand. 22 specimens from EL-1101, EL-1103.

Genus *Pseudohindeodus* Gullo & Kozur, 1992

Pseudohindeodus oertlii (Kozur, 1975)

Figure 6n, o

Type species. *Diplognathodus oertlii* Kozur, 1975.

1965 *Gnathodus siciliensis* Bender & Stoppel, 1965, p. 34, plate 14, fig. 2a, b.

1975 *Diplognathodus oertlii* Kozur, 1975, p. 11.

?1981 *Diplognathodus oertlii* Kozur; Igo, 1981, p. 32, plate 8, figs 9–16.

1987 *Diplognathodus oertlii* Kozur; Van den Boogaard, 1987, pp. 22–23, fig. 6C, D.

2010 *Pseudohindeodus oertlii* (Kozur); Zhang *et al.* 2010, Fig. 5N.

Diagnosis. 'Small conodont with relatively high blade and greatly expanded basal cavity. Anterior part of the blade consists of 5–6 fused denticles with free tips which become gradually smaller in posterior direction up to about mid-length. The posterior part of the blade is a smooth ridge which gently slopes towards the posterior and then falls off steeply, more or less vertical to the upper side of the basal cavity' (Van den Boogard, 1987).

Remarks. Our Thailand specimens agree well with this diagnosis. This species is very close to *D. nassichuki* Kozur but differs in that the posterior part of the blade slopes down to the posterior end of the posterior cavity. For that reason, Van den Boogard (1987) refers the *D. oertlii* of Igo (1981, plate 8, figs 9–16) to *D. nassichuki*. *P. augustus* (Igo, 1981) differs from *P. oertlii* in having '. . . much more discrete and less compressed denticles' (Shen *et al.* 2013, p. 512).

Occurrence. South China, Timor, Central Asia, ?Japan, Sicily and NE Thailand. 25 specimens from EL-1101, EL-1103.

Order OZARKODINIDA Dzik, 1976

Superfamily GONDOLELLACEA Lindström, 1970

Family GONDOLELLIDAE Lindström, 1970

Genus *Mesogondolella* Kozur, 1989

Smooth Pa (P_1) specimens from the E-Lert Formation are similar to several species of *Mesogondolella*, including *M. gujioensis*, *M. idahoensis*, *M. intermedia*, *M. lamberti*, *M. omanensis*, *M. gracilis*, *M. szuzsannae*, *M. phosphoriensis*, *M. saraciniensis* and *M. siciliensis*. General means for discrimination of Mesogondolella species are provided by Lambert, Wardlaw & Henderson (2007), Mei & Henderson (2002*b*), Wardlaw (2001) and Zhang *et al.* (2010) but substantial disagreement exists on the assignment of specimens. Our Pa (P_1) specimens consist of forms with a small cusp and a platform usually widest around the middle part, and which are assigned to *M. siciliensis*.

Mesogondolella siciliensis (Kozur, 1975)

Figure 7a–v, Figure 8a, c–j, l.

Synonymy. See Zhang *et al.* (2010).

Diagnosis. 'A species of *Mesogondolella* in which the Pa (P_1) element of juvenile and adult specimens has a small cusp that is equal to or only slightly larger than the posterior denticles, a brim that is narrow or absent, and high largely fused denticles on the anterior blades. It has a platform that is usually widest around the middle part. The posterior denticles are more discrete than the anterior ones' (Zhang *et al.* 2010, p. 151).

Remarks. The type specimens of this species are from Sicily and were placed in their new species *Gondolella rosenkrantzi* by Bender & Stoppel (1965) with a holotype from Greenland. Kozur (1975) placed only the Sicilian specimens of *G. rosenkrantzi* into his new species *G. siciliensis*. Mei & Henderson (2002*a*) and Zhang *et al.* (2010) placed several selected, previously figured specimens of *M. zsuzsannae*, *M. idahoensis*, *M. phosphoriensis* and *M. slovenica* into synonymy with *M. siciliensis* which indicates the difficulty of confident identification of this species. Zhang *et al.* (2010, p. 152) note that *M. lamberti* is very similar to *M. siciliensis* but that the anterior blade is always slightly higher and more fused in *M. siciliensis*, and that 'the platform is usually widest in the middle part in *M. siciliensis* but in *M. lamberti*, parallel-sided in the middle and the posterior part, rarely in the middle part' (Zhang *et al.* 2010, p. 152). Although the diagnosis of Zhang *et al.* (2010) states that juvenile forms have small cusps, Henderson & Mei (2003, p. 307, plate 1, fig. 14b) state that '. . . cusps are generally small, but they are higher than posterior denticles in juveniles'. Our specimens are very similar to and have a similar morphological range to those illustrated from Luodian, south China, Sicily, Texas and Oman (Wang, 1994, plates 3, 9–12; Kozur, 1995, plate 4, fig. 21; Henderson & Mei, 2003, plates I–III; Kozur & Wardlaw, 2010, plates 3–4). A very small percentage of our specimens have a very weak striation on the anterior platform (Fig. 7i).

The non-Pa elements of *M. siciliensis* have been rarely determined Bender & Stoppel (1965) and Mei & Henderson (2002*a*) provide a few figures. Because of the potential problem of sorting and reworking in carbonate turbidites we have tentatively assigned some of our non-Pa elements to *M. siciliensis* (Fig. 8). The Pb (P_2) element is shown in Figure 8c and possibly in Figure 8a and the former is closely comparable to the *M. siciliensis* Pb element illustrated by Henderson & Mei (2003, plate 1, fig. 13). The Sa (S_0) element (Fig. 8i) is also comparable to that illustrated by

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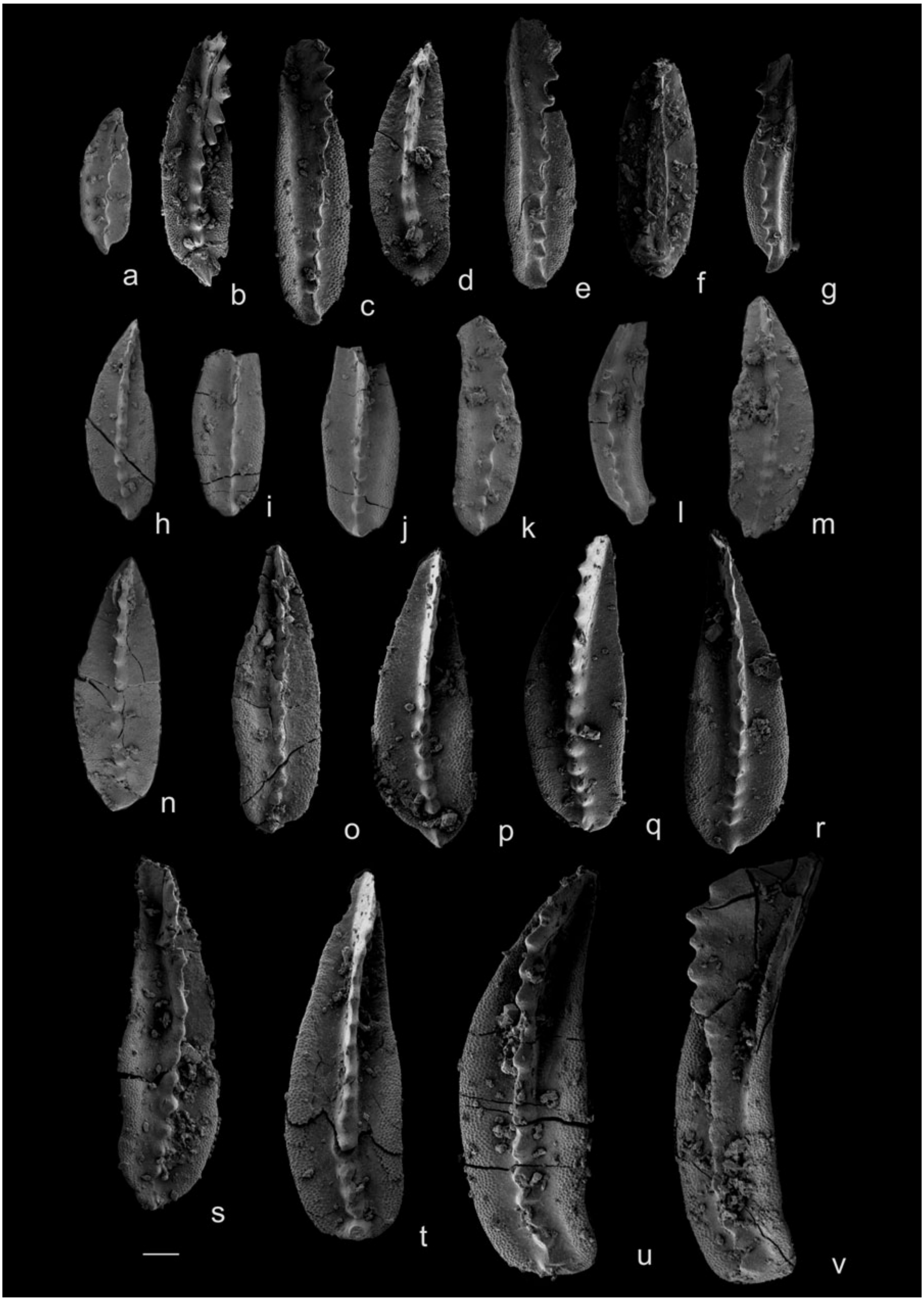

Figure 7. Conodonts from the E-Lert Formation. (a–v) specimens PRC 132–153, Pa (P_1) elements of *Mesogondolella siciliensis* (Kozur) all from sample EL-1101. All upper views or oblique upper views except for basal view in (h). (a) upper view, PRC 132; (b) upper view, PRC 133; (c) oblique upper view, PRC 134; (d) oblique upper view, PRC 135; (e) upper view, PRC 136; (f) oblique upper view, PRC 137; (g) upper view, PRC 138; (h) basal view, PRC 139; (i) upper view, PRC 140, note slight striations on anterior platform; (j) upper view, PRC 141; (k) upper view, PRC 142; (l) upper view, PRC 143, broken blade; (m) oblique upper view, PRC 144; (n) oblique lateral view, PRC 145; (o) upper view, PRC 146; (p) upper view, PRC 147; (q) slightly oblique upper view, PRC 148; (r) upper view, PRC 149; (s) slightly oblique upper view, PRC 150; (t) upper view, PRC 151; (u) slightly oblique upper view, mature specimen, PRC 152; (v) oblique upper view, mature specimen, PRC 153. Scale bar 100 µm.

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Figure 8. Conodonts from the E-Lert Formation. (a–l) non-Pa elements from sample EL-1101. (a) Pb (P_2) element, outer lateral view, possibly *M. siciliensis*, PRC 154; (b) Pa (P_1) or Pb (P_2) element, possibly *Xaniognathus* sp., or *Jinogondolella* sp., PRC 155; (c) Pb (P_2) element of *M. siciliensis*, PRC 156; (d) Sc (S_3) element of *M. siciliensis*? PRC 157; (e) Sb (S_2) element, *M. siciliensis*, compares with *Lonchodina mulleri* Bender & Stoppel, 1965, plate 15, fig. 13, PRC 158; (f) ?Sb (S_2) element, *M. siciliensis*? PRC 159; (g) M element, *M. siciliensis*? PRC 232; (h) M element, *M. siciliensis*? PRC 233; (i) Sa (S_0) element, *M. siciliensis*, PRC 234; (j) M element, *M. siciliensis*, PRC 235; (k) M element, similar to *Sweetina festiva* (Bender & Stoppel, 1965, plate 15, fig. 9), PRC 236; (l) M element, *M. siciliensis,* PRC 237. Scale bar 100 μm.

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Henderson & Mei (2003, plate 1, fig. 11). Some or all M elements shown in Figure 8g–j and l may belong to the *M. siciliensis* apparatus. Further studies are needed in order to clarify the full apparatus of *M. siciliensis*, its ontogeny, intraspecific variation and geographic and stratigraphic range.

Pa elements from the deep-water Permian of Rustaq and Wadi Wasit in Oman have been studied by Mei & Henderson (2002*a*), Henderson & Mei (2003) and by Kozur & Wardlaw (2010). The first two authors identified *M. siciliensis* co-occurring with their new species *M. rustaquensis*, plus *Sweetoganthus subsymmetricus* and *Waagenoceras* and succeeded by *M. idahoensis lamberti* and argued for a latest Kungurian age. However, Kozur & Wardlaw (2010) re-identified the Omani *M. rustaquensis* and *M. idahoensis lamberti* as either their new species *M. omanensis* or as *Jinogondolella aserrata*. Globally, the first appearance datum (FAD) of *J. aserrata* is taken as the base of the Wordian (Henderson, Davydov & Wardlaw, 2012). Henderson & Mei's (2003) *M. idahoensis lamberti* Pa specimens referred to *J. aserrata* by Kozur & Wardlaw (2010) are similar to some of our Pa specimens. Most *J. serrata* specimens have a low blade but the specimen of Henderson & Mei (2003, plate IV, fig. 4) has a high blade and a moderate height cusp with a platform outline similar to some of our specimens shown in Figure 8 (o, s) whereas the smaller specimen illustrated by Henderson & Mei (2003, plate IV, fig. 6) has a small cusp and a very low blade. If Kozur & Wardlaw's (2010) wide definition of *J. aserrata* is accepted then some of our Pa specimens may belong in *J. serrata* and a Wordian age for the E-Lert section would then be indicated.

Occurrence. ?Texas, South China, Oman, Central Asia and NE Thailand. 86 specimens from EL-01101 to EL-1103.

Family SWEETOGNATHIDAE, Ritter, 1986
Genus *Sweetognathus* Clark, 1972
Type species *Sweetognathus whitei* (Rhodes)

Discussions of this genus are found in Ritter (1986), Wang, Ritter & Clark (1987), Mei, Henderson & Wardlaw (2002) and Boardman, Wardlaw & Nestell (2009). Boardman, Wardlaw & Nestell (2009, p. 140) note that *Sweetognathus* species are '. . . very plastic, showing a lot of variability'.

Sweetognathus subsymmetricus Wang, Ritter and Clark 1987, fig. 6.1–6.7
Figure 9a–n.

Synonymy. See Metcalfe & Sone (2008).

2010 *Sweetognathus subsymmetrica* [sic] Wang, Ritter & Clark (1987); Zhang *et al.* 2010, fig. 5M.

Pa (P_1) elements that may be assigned to *Sweetognathus whitei* or to *S. subsymmeticus* morphotypes are found in our samples. A full discussion of these two species is provided by Wang, Ritter & Clark (1987) and updated diagnoses and a synonymy list of *S. subsymmetricus* can be found in Mei, Henderson & Wardlaw (2002) and Metcalfe & Sone (2008). *S. subsymmetricus* is defined as having a '. . . Pa element possessing a discrete carina on which the anterior ridges reduce in width anteriorally, but distinctly more on one side than the other in the asymmetrical morphotype' (Mei, Henderson & Wardlaw, 2002, p. 86). This anterior reduction is clear in our specimens shown in Figure 9g, j. Other nearly symmetrical morphotypes in our collections are closer to *S. whitei* (e.g. Fig. 9e). A similar co-occurrence of forms close to *S. whitei* and to *S. subsymmetricus* was found in the shallow-water lower Kungurian Tak Fa Formation, Central Thailand, 275 km SSW from our collections by Metcalfe & Sone (2008, p. 150) who suggested that their '. . . population represents an early development of *S. subsymmetricus* (post *S. whitei*)'. However, Wang (1994, fig. 1) notes that in the Nashui section in Guizhou, south China, *S. whitei* ranges from just above the *M. bisselli* Zone to the *M. idahoensis* Zone (sensu lato) but that *S. subsymmetricus* has an overlapping but restricted distribution in the middle of this range. Wang (2002) also records the co-occurrence of *S. whitei* and *S. subsymmetricus* in Guangxi, south China. Co-occurrences of *S. whitei* and *S. subsymmetricus* morphotypes in several sections, such as in south China and Thailand, suggest that both these morphotypes are found in *S. subsymmetricus*. Shen *et al.* (2013) note that *S. subsymmetricus* is highly likely a synonym of *S. paraguizhouensis* Wang *et al.* 1987.

Occurrence. South China, USA, Oman, Sicily, Central Asia, Central and NE Thailand. 28 specimens from EL-1101, EL-1103.

Family ELLISONIIDAE Clark, 1972
Genus ?*Stepanovites* Kozur, 1975
?*Stepanovites*? *festivus* (Bender & Stoppel, 1965)
Figure 8k.

Type specimen. *Lonchodina festiva* Bender & Stoppel, 1965, plate 15, fig. 9.

Synonymy. See Kozur & Wardlaw (2010). Also
1990 *Sweetina festiva* (Bender & Stoppel, 1965), Wardlaw & Grant 1990, plate 3, figs 18–25.

Remarks. Only one M element has been found but appears to be characteristic of this species.

The type specimens come from the limestone olistoliths of the Rupe del Passo di Burgio, Sicily.

Occurrence. Wordian–Capitanian. Sicily, Oman, Texas, NE Thailand. 1 specimen from sample EL-1101, E-Lert Formation.

3.b. Ostracodes

The E-Lert Formation ostracodes belong in three orders, four superfamilies, ten families, 16 genera and 23 species consisting of *Bairdia*, *Cryptobairdia*, *Bairdiacypris?*, *Spinocypris*, *Baschkirina*, *Pseudobythocypris*, *Microcheilinella*, *Basslerella*, *Paraberounella*, *Cyathus*, *Paraparchites*, *Samarella*, *Shemonaella*,

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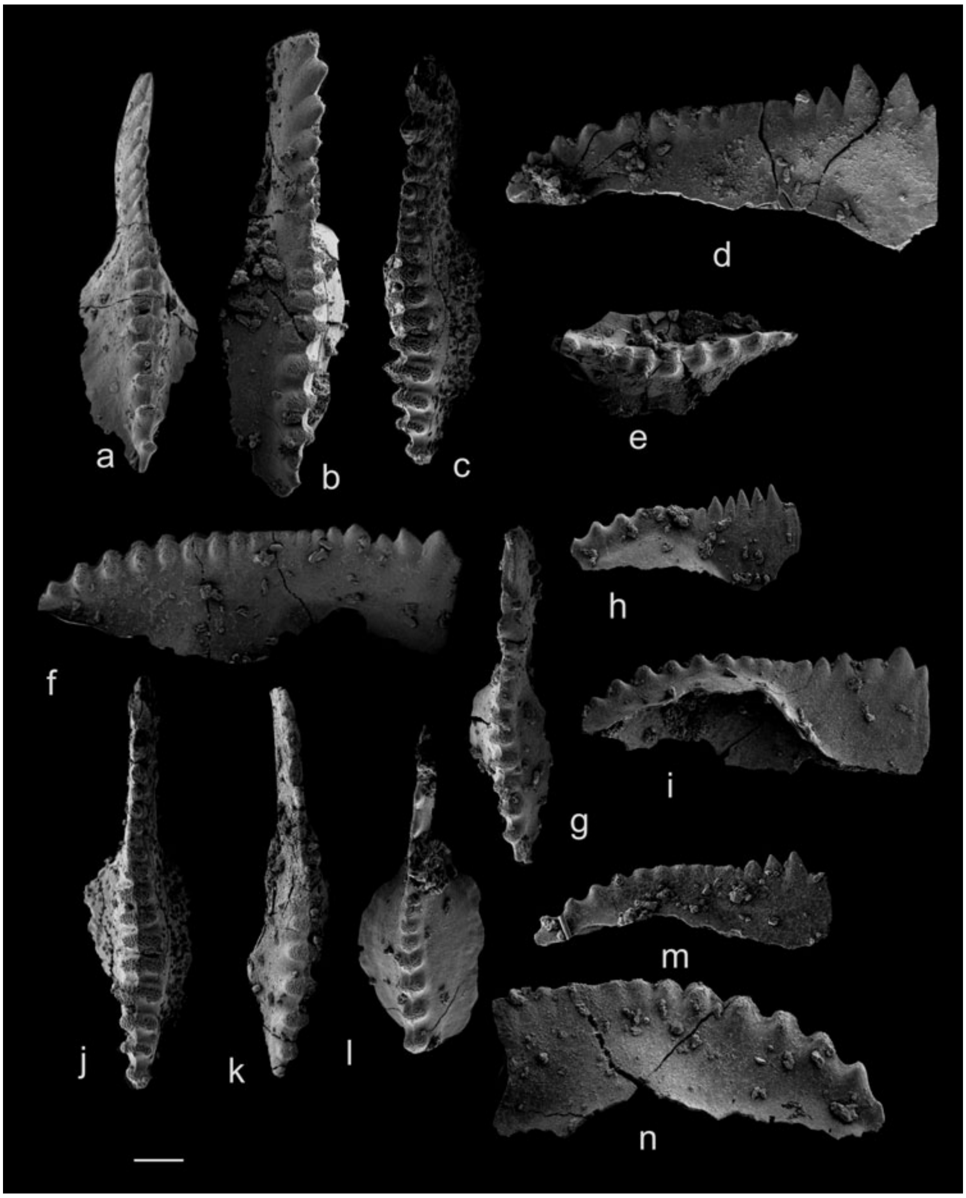

Figure 9. Conodonts from the E-Lert Formation. (a–n) Pa (P_1) elements of *Sweetognathus subsymmetricus* Wang, Ritter & Clark, 1987, all from sample EL-1101: (a) upper view, PRC 238, ×55; (b) oblique upper view, PRC 239, ×52; (c) oblique upper view, PRC 240, ×53; (d) lateral view, PRC 241, ×49; (e) upper view, PRC 242, ×87; (f) lateral view, PRC 243, ×45; (g) slightly oblique upper view, PRC 244, ×65; (h) lateral view, PRC 245, ×84; (i) oblique lateral-lower view, PRC 246, ×58; (j) upper view, PRC 247, ×54; (k) upper view, PRC 248, ×62; (l) slightly oblique upper view, PRC 249, ×62; (m) lateral view, PRC 250, ×61; (n) lateral view, PRC 251, ×58. Scale bar 100 μm.

Shivaella, *Carinaknightina*, *Polycope*, Aechminellidae? and Kirkbyiidae indet. (Figs 10–12). Among them, *Shivaella elertensis* Chitnarin *sp. nov.* is newly described (Figs 10, 11). The ostracode fauna is found in field sample EL-1103. Ostracodes and conodonts are absent from EL-1104 and EL-1105 (Fig. 4).

Class OSTRACODA Latreille, 1802
Order PALAEOCOPIDA Henningsmoen, 1953
Superfamily PARAPARCHITOIDEA Scott, 1959
Family PARAPARCHITIDAE Scott, 1959
Genus *Shivaella* Sohn, 1971

Type species. Shivaella suppetia Sohn, 1971

Shivaella elertensis Chitnarin *sp. nov.*
Figures 10a–g, 11

Etymology. From the E-Lert Formation.

Holotype. Complete carapace (Fig. 10a), SUT-12-036.

Paratypes. Complete carapace (Fig. 10b), SUT-12-037; complete carapace (Fig. 10c), SUT-12-038.

Material. 16 complete carapaces.

Type locality and horizon. 101° 43′ 35″ E, 17° 18′ 29″ N, Huai E-Lert Reservoir, Wang Saphung district, Loei province, northern Thailand. Upper Kungurian – Roadian. From field sample EL-1103.

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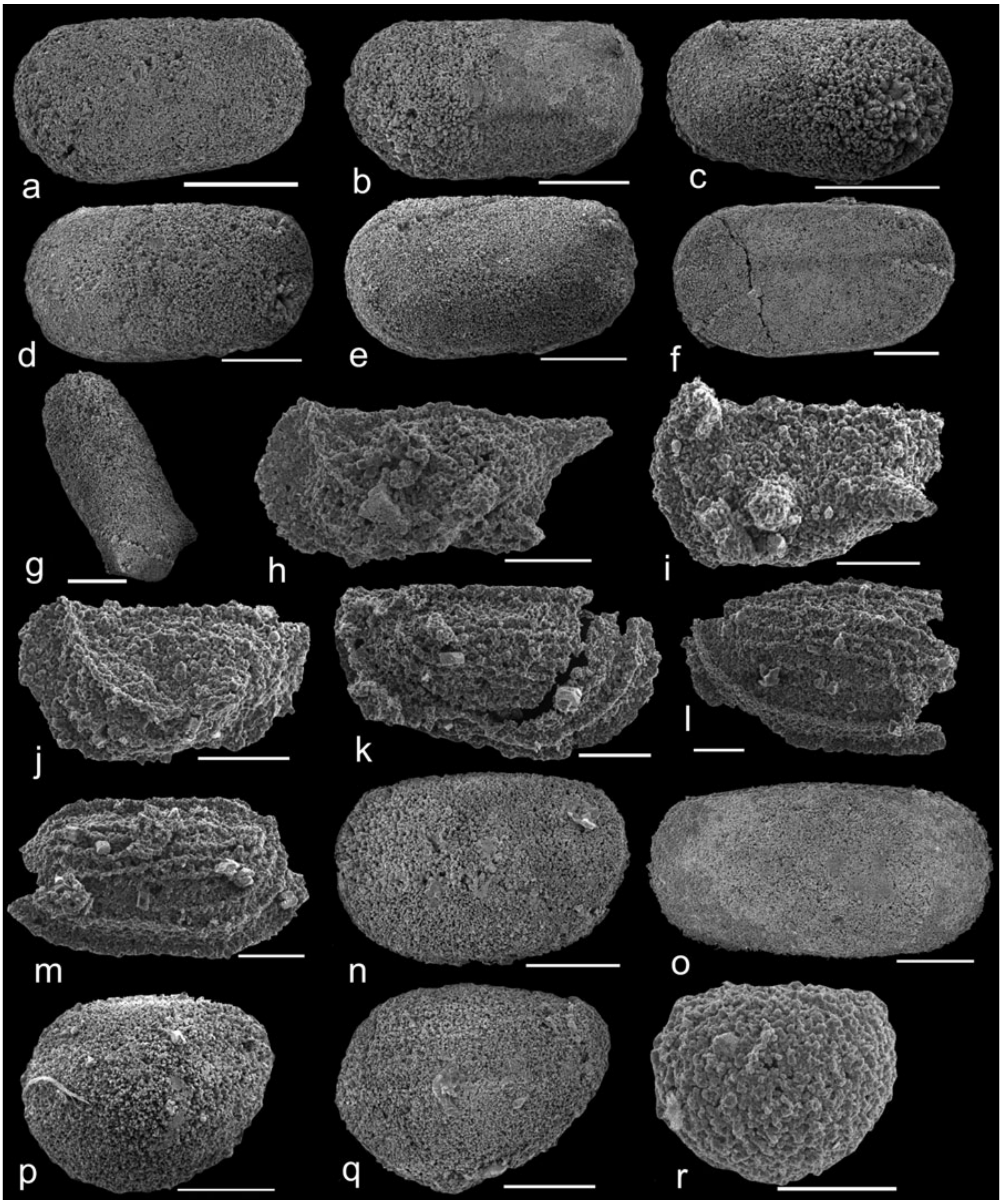

Figure 10. Ostracodes from the E-Lert Formation. All ostracode specimens are deposited in the Suranaree University of Technology collections (Nakhon Ratchasima, Thailand). (a–g) *Shivaella elertensis* Chitnarin *sp. nov.* (see Fig. 11): (a) holotype, left lateral view of the complete carapace, SUT-12-036; (b) paratype, left lateral view of the complete carapace, SUT-12-037; (c) paratype, right lateral view of the complete carapace, SUT-12-038; (d) left lateral view of the complete carapace, SUT-12-039; (e) left lateral view of the complete carapace, SUT-12-040; (f) left lateral view of the complete carapace, SUT-12-043; (g) dorsal view of the complete carapace, SUT-12-042; (h) *Paraberounella* sp., left lateral view of the complete carapace, SUT-12-052; (i) Aechminellidae? sp., left lateral view of the complete carapace, SUT-12-053; (j) Kirkbyidae indet. left lateral view of the complete carapace, SUT-12-054; (k–m) *Carinaknightina* sp. (k) left lateral view of the incomplete carapace, SUT-12-063; (l) left lateral view of the incomplete carapace, SUT-12-065; (m) left lateral view of the incomplete carapace, SUT-12-064; (n) *Paraparchites* sp.1, left lateral view of the complete carapace, SUT-12-072; (o) *Paraparchites* sp. 2, right lateral view of the complete carapace, SUT-12-058; (p, q) *Samarella* sp.; (p) left lateral view of the complete carapace, SUT-12-067; (q) left lateral view of the complete carapace, SUT-12-070; (r) *Shemonaella* sp., left lateral view of the complete carapace, SUT-12-073. Scale bars 100 μm.

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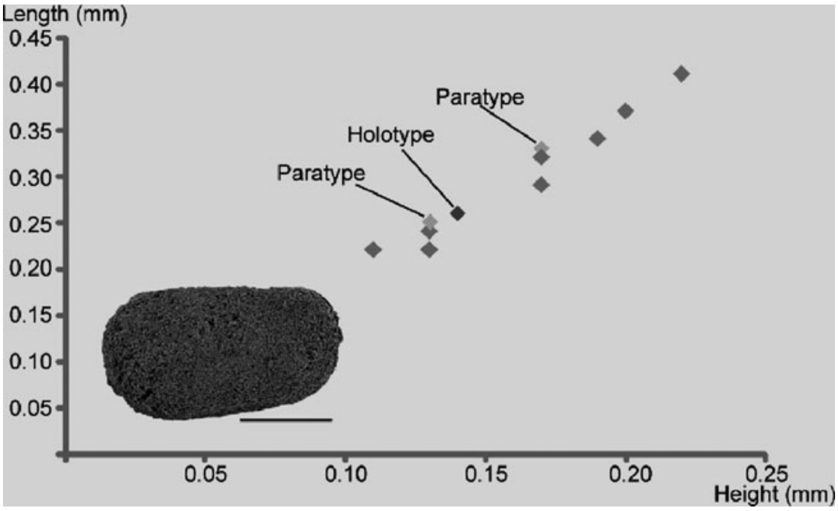

Figure 11. Relationship of height and length of *Shivaella elertensis* Chitnarin *sp. nov.*

Diagnosis. Species of *Shivaella* with elongate, subrectangular carapace, large and short posterodosal spines extruded below dorsal margin of both valves, $0.52<H/L<0.55$.

Measurements. Height $H = 0.11$–0.22, length $L = 0.22$–0.41 mm.

Description. Carapace subrectangular, slightly preplete in lateral view; dorsal border straight and long; anterior border with large radius of curvature, maximum convexity located at mid-height; ventral border straight and long; posterior border with large radius of curvature, maximum convexity located at or just above mid-height; anterior border larger than posterior border in juveniles, posterior and anterior borders almost of the same size in adult specimens; anterior cardinal angle 145–155 degrees, posterior cardinal angle 140–150 degrees; short and large posterior spines extruded below dorsal margin of both valves; carapace slightly compressed laterally on the free margin; oval carapace with distinct posterior spines in dorsal view; carapace smooth.

Remarks. The newly described *Shivaella elertensis* has a smooth carapace without sulcus which suggests the family Paraparchitidae, and the presence of dorsoposterior spines on both valves fits the diagnosis of the genus (Sohn, 1971). Although the subrectangular carapace is not commonly found in this genus it discriminates this species from *Shivaella* sp. described from the Pennsylvanian–Cisuralian succession of Austria and *S.* cf. *brazoensis* (Coryell & Sample, 1932) from the Lopingian succession of Greece (Crasqin–Soleau & Baud, 1998). The carapace is slightly preplete in juveniles and more rectangular in adult specimens. The spines of *S. elertensis* are distinctively large and short, located in the postero-dorsal part of the valves and pointing to the back.

Genus *Paraparchites* Ulrich & Bassler, 1906

Type species. Paraparchites humerous Ulrich & Bassler, 1906.

Paraparchites sp. 1
Figure 10n
Paraparchites sp. 2
Figure 10o
Genus *Shemonaella* Sohn, 1971

Type species. Shemonaella dutroi Sohn, 1971.
Shemonaella sp.
Figure 10r
Genus *Samarella* Polenova, 1952

Type species. Samarella crassa Polenova, 1952.
Samarella sp.
Figure 10p, q
Superfamily KIRKBYOIDEA Ulrich & Bassler, 1906
Family KIRKBYIDAE Ulrich & Bassler, 1906
Genus *Carinaknightina* Sohn, 1970

Type species. Carinaknightina carinata Sohn, 1970.
Carinaknightina sp.
Figure 10k–m
Kirkbyidae indet.
Figure 10j

Remarks. This specimen resembles *Nemoceratina* sp. 2 sensu Bless (1987) which is found in the Cisuralian succession of Timor.

Family AECHMINELLIDAE Sohn, 1961
Aechminellidae? sp.
Figure 10i
Suborder BEYRICHICOPINA Scott, 1961
Superfamily OEPILELLOIDEA Jaanusson, 1957
Family APARCHITIDAE Jones, 1901
Genus *Cyathus* Roth & Skinner, 1930

Type species. Cyathus ulrichi Roth & Skinner, 1930

Cyathus caperata Guan (Guan *et al.* 1978)
Figure 12s, t

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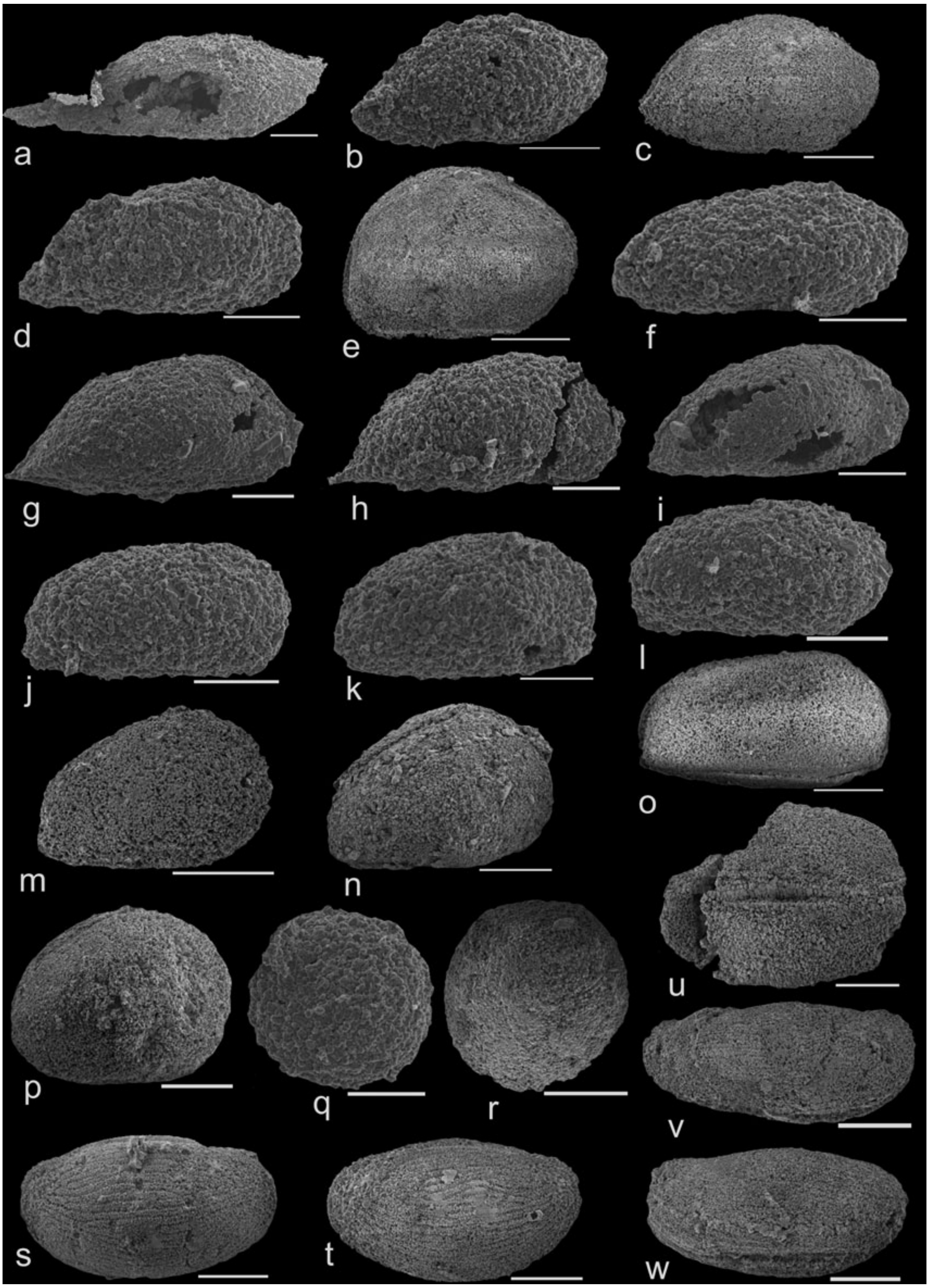

Figure 12. Ostracodes from the E-Lert Formation. All ostracode specimens are deposited in the Suranaree University of Technology Collections (Nakhon Ratchasima, Thailand). (a) *Bairdia* sp. 1, right lateral view of the complete carapace, SUT-12-001; (b) *B.* sp. 2, right lateral view of the complete carapace, SUT-12-002; (c) *B.* sp. 3, right lateral view of the complete carapace, SUT-12-003; (d) *B.* sp. 4, right lateral view of the complete carapace, SUT-12-004; (e) *Cryptobairdia* sp., right lateral view of the complete carapace, SUT-12-005; (f) *Bairdiacypris?* sp., right lateral view of the complete carapace, SUT-12-006; (g–i) *Spinocypris* sp.: (g) right lateral view of the complete carapace, SUT-12-007; (h) right lateral view of the complete carapace, SUT-12-008; (i) right lateral view of the incomplete carapace, SUT-12-010; (j–l) *Pseudobythocypris* sp.; (j) right lateral view of the complete carapace, SUT-12-011; (k) right lateral view of the complete carapace, SUT-12-012; (l) right lateral view of the complete carapace, SUT-12-013; (m, n) *Baschkirina* sp. (m) right lateral view of the complete carapace, SUT-12-014; (n) right lateral view of the complete carapace, SUT-12-015; (o) *Microcheilinella* sp., right lateral view of the complete carapace, SUT-12-019; (p) *Basslerella* sp., right lateral view of the complete carapace, SUT-12-018; (q, r) *Polycope* sp. (q) left lateral view of the complete carapace, SUT-12-033; (r) left lateral view of the complete carapace, SUT-12-032; (s, t) *Cyathus caperata* Guan (Guan *et al.* 1978); (s) left lateral view of the complete carapace, SUT-12-021; (t) left lateral view of the complete carapace, SUT-12-022; (u–w) *Cyathus elliptica* (Shi & Chen, 1987); (u) dorsal view of the complete carapace, SUT-12-031; (v) right lateral view of the complete carapace, SUT-12-029; (w) left lateral view of the complete carapace, SUT-12-030. Scale bars 100 μm.

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1978 *Sinocoelonella caperata* Guan in Guan *et al.* 1978, p. 149, plate 37, fig. 17; plate 38, fig. 1.

1986 *Cyathus caperata* (Guan); Chen & Bao, 1986, p. 111, plate 4, fig. 3.

1987 *Cyathus caperata* (Guan); Shi & Chen, 1987, p. 32, plate 10, figs 10–18.

2007 *Cyathus caperata* (Guan in Guan *et al.* 1978); Yuan *et al.* 2007, plate 1, fig. 15.

2010 *Cyathus caperata* (Guan in Guan *et al.* 1978); Crasquin *et al.* 2010, p. 332, fig. 3A–D.

2012 *Cyathus caperata* (Guan in Guan *et al.* 1978); Chitnarin *et al.* 2012, p. 806, fig. 4A, B, D–E.

Remarks. *Cyathus caperata* has been reported from the Cisuralian succession of China (Guan *et al.* 1978; Chen & Bao, 1986), the Cisuralian–Guadalupian succession of central Thailand (Chitnarin *et al.* 2012) and in the Lopingian succession of China (Shi & Chen, 1987; Yuan *et al.* 2007; Crasquin *et al.* 2010).

Cyathus elliptica Shi in Shi & Chen, 1987
Figure 12u–w

1987 *Cyathus elliptica* Shi in Shi & Chen, 1987, p. 32, plate 10, figs 20–23; plate 17, figs 5–6.

2010 *Cyathus elliptica* Shi in Shi & Chen, 1987; Crasquin *et al.* 2010, p. 334, fig. 3E–H.

2012 *Cyathus elliptica* Shi in Shi & Chen, 1987: Chitnarin *et al.* 2012, p. 810, fig. 4C, F, G, J.

Remarks. C. elliptica has been reported from the Cisuralian–Guadalupian succession of central Thailand (Chitnarin *et al.* 2012) and the Lopingian Permian succession of China (Shi & Chen, 1987; Crasquin *et al.* 2010). E-Lert Formation specimens are small for the species.

Order PODOCOPIDA Müller, 1894
Suborder PODOCOPINA Sars, 1866
Superfamily BAIRDIOIDEA Sars, 1888
Family BAIRDIIDAE Sars, 1888
Genus *Bairdia* McCoy, 1844

Type species. *Bairdia curtus* McCoy, 1844.

Bairdia sp.1
Figure 12a
Bairdia sp. 2
Figure 12b
Bairdia sp. 3
Figure 12c
Bairdia sp. 4
Figure 12d
Genus *Cryptobairdia* Sohn, 1960

Type species. *Cryptobairdia ventricosa* Roth & Skinner, 1930

Cryptobairdia sp.
Figure 12e
Genus *Bairdiacypris* Bradfield, 1935

Type species. *Bairdiacypris deloi* Bradfield, 1935.

Bairdiacypris? sp.
Figure 12f
Genus *Spinocypris* Kozur, 1971

Type species. Spinocypris vulgaris Kozur, 1971

Spinocypris sp.
Figure 12g, h, i

Remarks. Spinocypris has been reported from the uppermost Permian succession of Saudi Arabia and China (Crasquin–Soleau, Vaslet & Le Nindre, 2005; Crasquin, Carcione & Martini, 2008; Forel, 2012) and from the Triassic succession of Hungary, Romania, Tibet and Turkey (Monostori, 1994; Crasquin–Soleau & Gradinaru, 1996; Kozur *et al.* 2000; Crasquin–Soleau *et al.* 2006; Forel & Crasquin, 2011). This is the first report of the genus in the late Kungurian or Roadian.

Family BAIRDIOCYPRIDIDAE Shaver, 1961
Genus *Baschkirina* Rozdestvenskaja, 1959

Type species. Baschkirina memorabilis Rozdestvenskaja, 1959

Baschkirina sp.
Figure 12m, n
Family PACHYDOMELLIDAE Berdan & Sohn, 1961
Genus *Microcheilinella* Geis, 1933

Type species. Microcheilus distortus Geis, 1932.

Microcheilinella sp.
Figure 12o
Family CYTHERIDEIDAE Sars, 1922–1928
Genus *Basslerella* Kellett, 1935

Type species. Basslerella crassa Kellett, 1935

Basslerella sp.
Figure 12p
Family BEROUNELLIDAE Sohn & Berdan, 1960
Genus *Paraberounella* Blumenstengel, 1965

Type species. *Paraberounella lobella* Blumenstengel, 1965.

Paraberounella sp.
Figure 10h

Remarks. *Paraberounella* is known from Guadalupian–Lopingian deep-water facies in Sicily, Italy (Kozur, 1991; Crasquin, Carcione & Martini, 2008) and south China (Yuan *et al*. 2007).

Order MYODOCOPIDA Sars, 1866
Suborder CLADOCOPINA Sars, 1866
Family POLYCOPIDAE Sars, 1866
Genus *Polycope* Sars, 1866

Type species. *Polycope orbicularis* Sars, 1866.

Polycope sp.
Figure 12q, r

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3.c. Radiolarians

Class ACTINOPODA
Subclass RADIOLARIA Müller, 1858
Superorder POLYCYSTIDA Ehrenberg, 1838, emend. Riedel, 1967
Order ALBAILLELLARIA Deflandre, 1953, emend. Holdsworth, 1969
Family ALBAILLELLIDAE Deflandre, 1952, emend. Holdsworth, 1977

Genus *Albaillella* Deflandre, 1952; emend. Holdsworth, 1966; emend. Ormiston & Lane, 1976

Type species.Albaillella paradoxa Deflandre, 1952

Albaillella asymmetrica Ishiga & Imoto, 1980
Figure 13a–h

1980 *Albaillella* sp. B. Ishiga & Imoto, 1980, plate 5, figs 6–10.

1982 *Albaillella asymmetrica* Ishiga & Imoto in Ishiga, Kito & Imoto, 1982, plate 3, figs 3–11.

1984 *Albaillella asymmetrica* Ishiga & Imoto, 1980; Ishiga & Suzuki, 1984, plate 1, figs 9, 10, 12–15.

1986 *Albaillella asymmetrica* Ishiga & Imoto, 1980; Ishiga, Watase & Naka, 1986, plate 1, figs 9–15.

1992 *Albaillella asymmetrica* Ishiga & Imoto, 1980; Blome & Reed, 1992, figs 9.1–9.5.

1997 *Albaillella asymmetrica* Ishiga & Imoto, 1980; Miyamoto, Kuwazuru & Okimura, 1997, plate 2, figs 7–11.

1998 *Albaillella asymmetrica* Ishiga & Imoto, 1980; Xian & Zhang, 1998, plate 1, figs 8–11.

2010 *Albaillella asymmetrica* Ishiga & Imoto, 1980; Zhang *et al.* 2010, fig. 5S, T.

Remarks. Our specimens show the main parts of the shell; the apical cone, pseudothorax and pseudoabdomen as described in Ishiga, Kito & Imoto, 1982. The apical cone curves slightly toward the ventral side and is distally tapered into a spine. It has a flattened pseudothorax with two asymmetrical wings and the pseudoabdomen is long, flattened and traversed by 7 or more horizontal bands with a lattice–like framework.

Range. Cisuralian–Guadalupian (approximately Kungurian – lower Roadian).

Occurrence. Japan, west United States, south China and NE Thailand (sample no. EL-1004, EL-1005 from E-Lert section).

Albaillella sinuata Ishiga & Watase in Ishiga, Watase & Naka, 1986
Figure 13i–n

1982 *Albaillella* sp. D. Ishiga, Kito & Imoto, 1982, plate 1, figs 17, 18.

1984 *Albaillella* sp. D. Ishiga, Kito & Imoto, 1982; Ishiga & Suzuki, 1984, plate 1, figs 1–8, 11.

1986 *Albaillella sinuata* Ishiga & Watase in Ishiga, Watase & Naka, 1986, plate 1, figs 1–8.

1992 *Albaillella sinuata* Ishiga & Watase in Ishiga, Watase & Naka, 1986; Blome & Reed, 1992, plate 9, figs 6–9.

1994 *Albaillella sinuata* Ishiga & Watase in Ishiga, Watase & Naka, 1986; Wang, Cheng & Yang, 1994, plate 2, figs 13, 14.

1998 *Albaillella sinuata* Ishiga & Watase in Ishiga, Watase & Naka, 1986; Xian & Zhang, 1998, plate 1, figs 1–4.

2009 *Albaillella* sp. cf. *A. sinuata* Ishiga & Watase; Saesaengseerung *et al.* 2009, figs 7.18, 7.19.

2010 *Albaillella sinuata* Ishiga & Watase in Ishiga, Watase & Naka, 1986; Zhang *et al.* 2010, fig. 5R.

Remarks. The shell is conical with slightly oblique segments. Shell apex curves to the ventral side. Two rod-like wings extend horizontally from both dorsal and ventral sides and protrude vertically downwards in the lower wing.

Range. Kungurian – lowermost Roadian.

Occurrence. Japan, western North America, China, east and NE Thailand (sample no. EL-1004, EL-1005 from E-Lert section).

Family FOLLICUCULLIDAE Ormiston & Babcock, 1979
Genus *Pseudoalbaillella* Holdsworth & Jones, 1980

Type species. *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980

Pseudoalbaillella scalprata Holdsworth & Jones, 1980, Morphotype *postscalprata* Ishiga, 1983
Figure 14t, u

1980 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980 morphotype *postscalprata* Ishiga, 1983, plate 2, figs 1–16.

1992 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980 morphotype *postscalprata* Ishiga, 1983; Blome & Reed, 1992, figs 10.13–10.17.

1997 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980 morphotype *postscalprata* Ishiga, 1983; Miyamoto, Kuwazuru & Okimura, 1997, plate 1, figs 4–6.

Remarks. This morphotype differs from *Ps. scalprata* m. *scalprata* by having a more rhombohedral pseudothorax and a longer pseudoabdomen than the latter.

Range. Cisuralian (middle–upper Wolfcampian).

Occurrence. Japan, west United States and NE Thailand (sample no. EL-1004, EL-1005 from the E-Lert section)

Pseudoalbaillella scalprata Holdsworth and Jones, 1980, Morphotype *scalprata* Ishiga, 1983
Figure 15c, i

1980 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980, p. 284, appendix fig. 1A, B.

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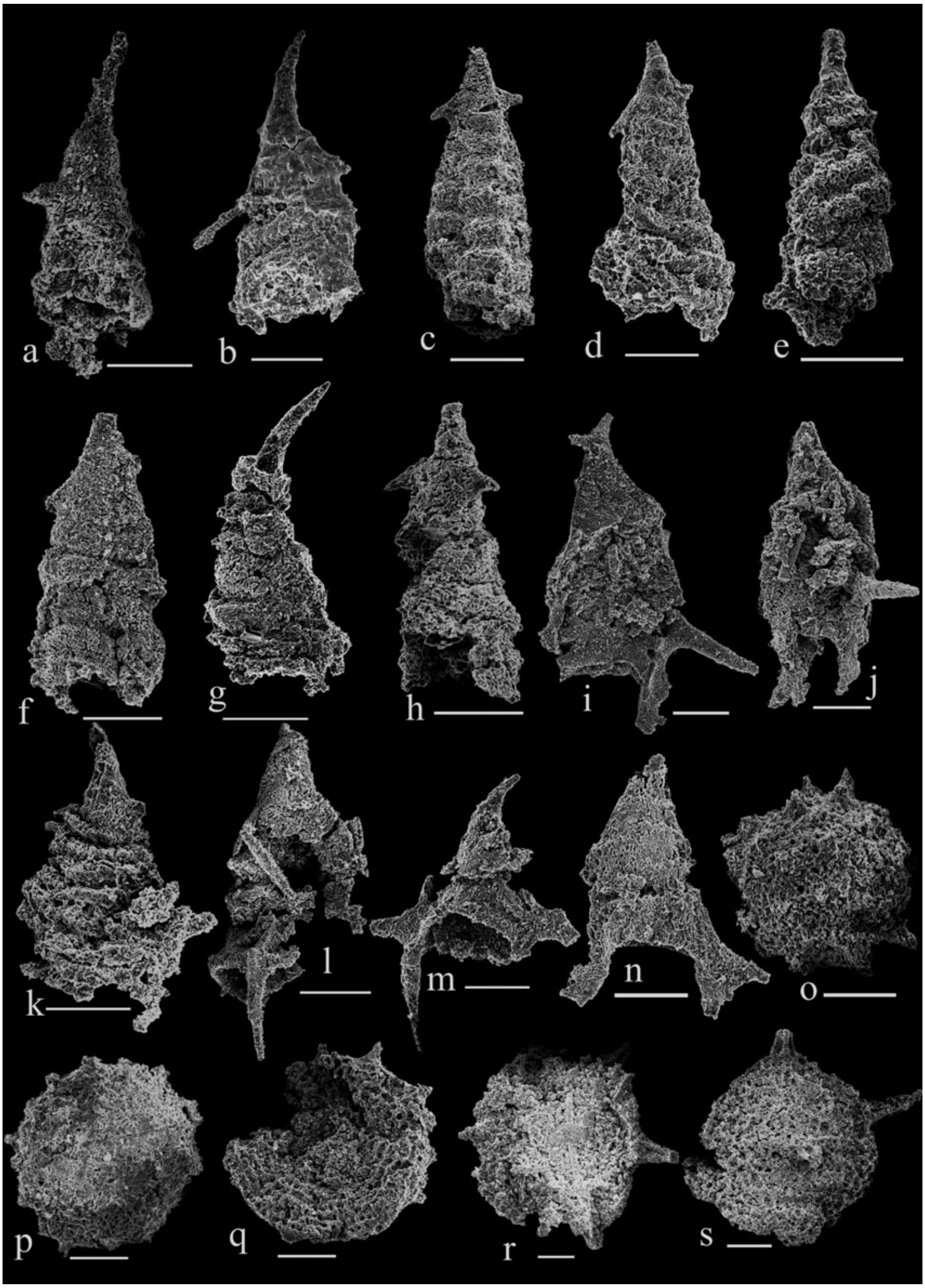

Figure 13. Radiolarians from the E-Lert Fm. (a–h) *Albaillella asymmetrica* Ishiga & Imoto, PRC 160–167; (i–n) *Albaillella sinuata* Ishiga & Watase, PRC 168–173; (o–s) *Copicyntra* spp., PRC 174–178. Scale bars 50 µm.

1980 *Pseudoalbaillella* sp. cf. *Ps. scalprata* Holdsworth & Jones 1980, plate 2, figs 4–8.

1982 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Ishiga, Kito & Imoto, 1982, plate 1, figs 11, 12;

1983 *Pseudoalbaillella scalprata* Holdsworth & Jones morphotype *scalprata*; Ishiga, 1983, plate 1, figs 1–18.

1984 *Pseudoalbaillella* sp. aff. *Ps. scalprata* Holdsworth & Jones; Ishiga *et al*. 1984, plate 1, figs 4–8.

1985 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Ishida, 1985, plate 1, figs 7–9.

1985 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Sheng & Wang, 1985, plate 2, figs 9–12.

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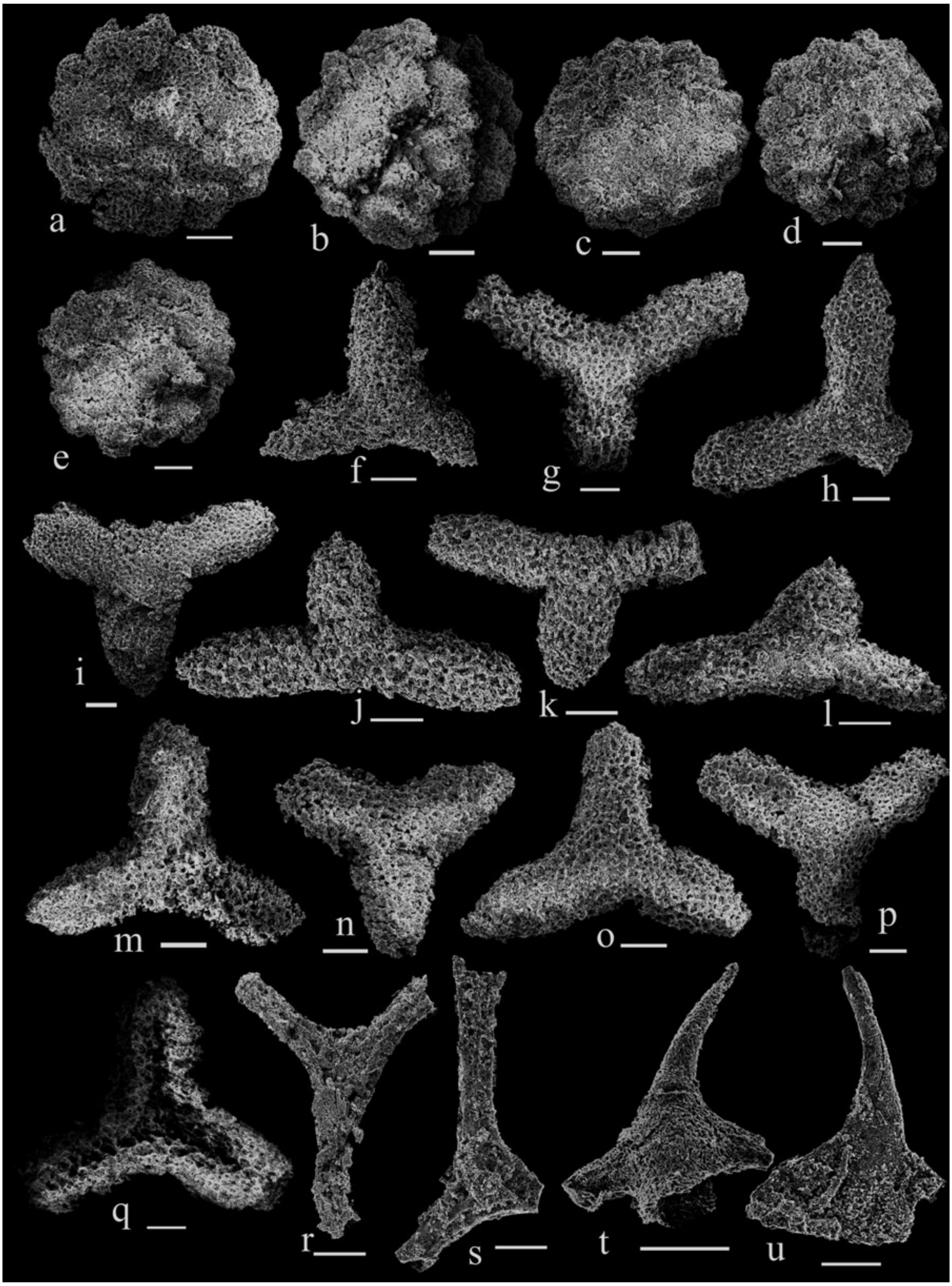

Figure 14. Radiolarians from the E-Lert Formation. (a–e) *Hegleria mamilla* (Sheng & Wang), PRC 179–183; (f–h) *Latentifustula patagilaterala* Nazarov & Ormiston, PRC 184–186; (i–l) *Latentifustula* sp. cf. *L. patagilaterala* Nazarov & Ormiston, PRC 187–190; (m–q) *Latentifustula crux* Nazarov & Ormiston, PRC 191–195; (r) *Latentifustula* sp. cf. *L. triacanthophora* Nazarov & Ormiston, PRC 196; (s) *Latentifustula* sp, PRC 197; (t, u) *Pseudoalbaillella scalprata* m. *postscalprata* Ishiga, PRC 198–199. Scale bars 50 μm.

1985 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Yoshida & Murata, 1985, plate 1, figs 8, 9.

1985 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Cornell & Simpson, 1985, plate 1, fig. 5.

1992 *Pseudoalbaillella scalprata* Holdsworth & Jones morphotype *scalprata*; Blome & Reed, 1992, figs 10.19–10.21.

1993 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Nazarov & Ormiston, 1993, plate 7, fig. 10.

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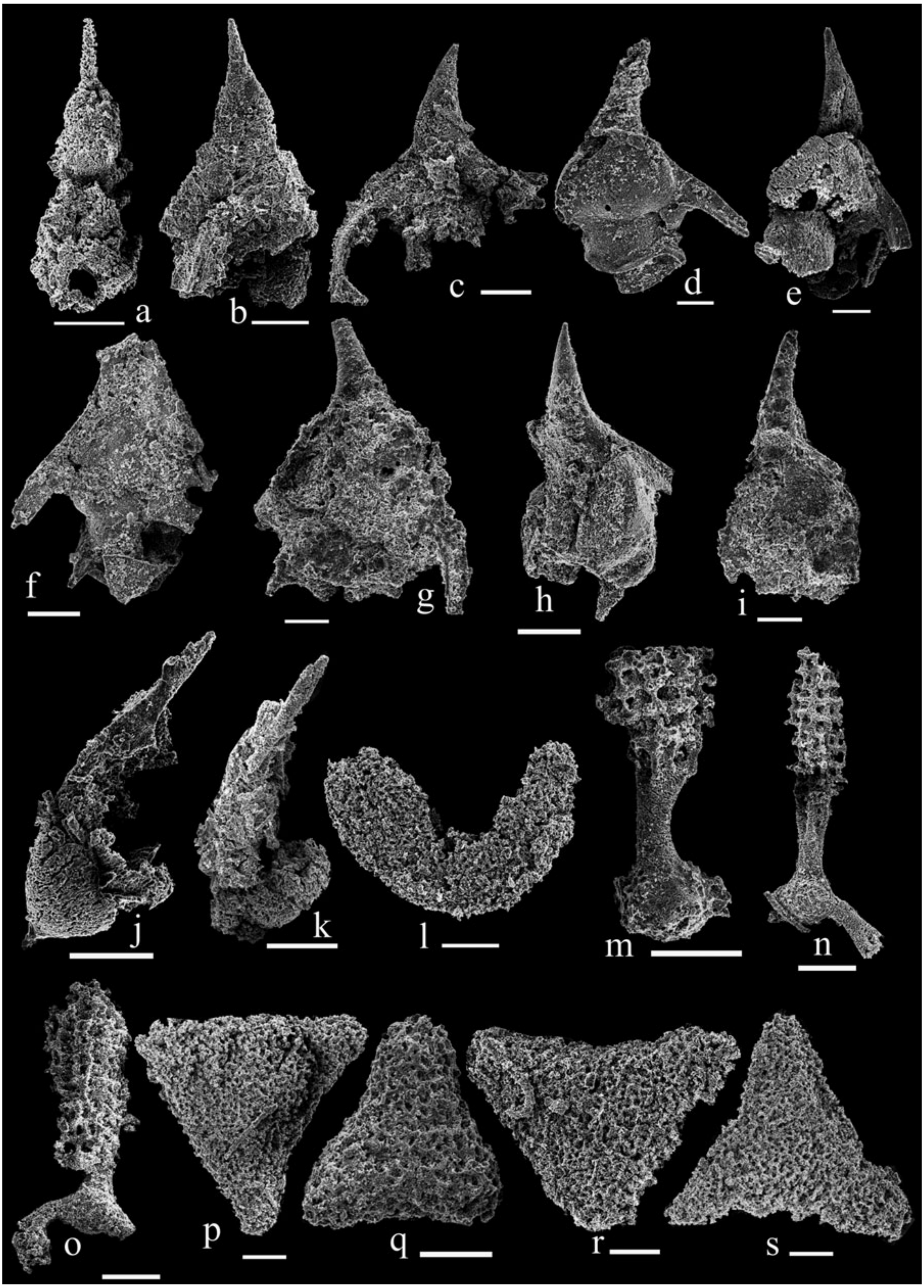

Figure 15. Radiolarians from the E-Lert Fm. (a–b) *Pseudoalbaillella* sp, PRC 200–201; (c–i) *Pseudoalbaillella scalprata* m. *scalprata* Ishiga, PRC 202–208; (j–l) *Pseudoalbaillella* sp. cf. *Ps. u-forma* m 1 (Ishiga *et al.*), PRC 209–211; (m–o) *Pseudotormentus kamigoriensis* De Wever & Caridroit, PRC 212–214; (p–s) *Ruzhencevispongus uralicus* Kozur, PRC 215–218. Scale bars 50 μm.

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1994 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Wang, Cheng & Yang, 1994, p. 182, plate 1, figs 20–22.

1996 *Pseudoalbaillella scalprata* Holdsworth & Jones morphotype *scalprata*; Spiller, 1996, plate 3, figs 6, 7.

1998 *Pseudoalbaillella scalprata* Holdsworth & Jones, 1980; Sashida *et al.* 1998, p. 13, figs 11–13.

2009 *Pseudoalbaillella scalprata* Holdsworth & Jones morphotype *scalprata*; Saesaengseerung *et al.* 2009, figs 7.28, 7.29.

2011 *Pseudoalbaillella scalprata* Holdsworth & Jones morphotype *scalprata*; Jasin & Harun, 2011, plate 4, fig. 4.

Remarks. The illustrated specimens of *Pseudoalbaillella scalprata* by Ishiga (1983) show a rather wide variation in the length of the apical horn and pseudoabdomen and the angle between the two shoulders. Our specimens clearly show the diagnostic features of this species in having a small and slightly curved apical horn. The pseudothorax is subglobular with two slightly flattened wings. A pseudoabdomen with two flaps extends downwards.

Range. Cisuralian (approximately middle–upper Wolfcampian).

Occurrence. Japan, west Texas, Oregon, China, peninsular Malaysia, north and east Thailand (eastern seaboard) and NE Thailand (Isarn region) (sample no. EL-1004, EL-1005 from E-Lert section).

Pseudoalbaillella sp.

Figure 15a, b

Remarks. The specimens are not well-preserved. The test consists of a relatively large cone with a rod-like apical cone. The pseudothorax is inflated and spherical in outline. The pseudoabdomen is inflated, long and cylindrical. There is a constriction between the pseudoabdomen and the pseudothorax.

Range. Upper Kungurian or lower Roadian.

Occurrence. NE Thailand (sample no. EL-1004, EL-1005 from E-Lert section).

Pseudoalbaillella sp. cf. *Ps. u-forma* Holdsworth & Jones, 1980, morphotype I (Ishiga *et al.* 1984)

Figure 15j, k, l

1980 *Pseudoalbaillella u-forma* Holdsworth & Jones, 1980, fig. 1C.

1980 *Pseudoalbaillella u-forma* Holdsworth & Jones, 1980; Ishiga & Imoto, 1980, plate 1, fig. 1.

1982 *Pseudoalbaillella* sp. aff. *Ps. u-forma;* Ishiga, 1982, plate 1, figs 18, 19.

1984 *Pseudoalbaillella u-forma* Holdsworth & Jones morphotype I; Ishiga *et al.* 1984, plate 1, figs 1–4.

2009 *Parafollicucullus u-formus* (Holdsworth & Jones) morphotype I; Saesaengseerung *et al.* 2009, figs 7.8, 7.9.

Remarks. The examined specimens are broken and poorly preserved. They resemble *Pseudoalbaillella u-forma* (Holdsworth & Jones) morphotype I, in having a slender apical cone, small pseudothorax and a U-shaped pseudoabdomen.

Range. Upper Kungurian – lower Roadian.

Occurrence. NE Thailand (sample no. EL-1005 from E-Lert section).

Order LATENTIFISTULARIA Caridroit, De Wever & Dumitrica, 1999

Superfamily RUZHENCEVISPONGACEA Kozur, 1980

Family LATENTIFISTULIDAE Nazarov & Ormiston, 1983

Genus *Latentifistula* Nazarov & Ormiston, 1983

Type species: *Latentifistula crux* Nazarov & Ormiston, 1983

Latentifistula crux Nazarov & Ormiston, 1983

Figure 14m–q

1983 *Latentifistula crux* Nazarov & Ormiston, 1983, plate 1, fig. 1.

1985 *Latentifistula crux* Nazarov & Ormiston, 1983; Nazarov & Ormiston, 1985, plate 3, fig. 6.

1992 *Latentifistula* sp. aff. *L. crux;* Blome & Reed, 1992, figs 13.2–13.5.

2006 *Latentifistula crux* Nazarov & Ormiston, 1983; Feng *et al.* 2006, figs 6.1, 6.2.

2009 *Latentifistula crux* Nazarov & Ormiston, 1983; Saesaengseerung *et al.* 2009, figs 8.1, 8.2.

Remarks. This species is distinguished from other species of this genus by its small size, spongy layer and short, thick rays.

Range. Lower Asselian (according to Nazarov & Ormiston, 1985) – Lopingian.

Occurrence. Urals, Oregon, Texas, south China, east and NE Thailand (sample no. EL-1004 to EL-1008 from E-Lert section).

Latentifistula patagilaterala Nazarov & Ormiston, 1985

Figure 14f, g, h

1985 *Latentifistula patagilaterala* Nazarov & Ormiston, 1985, plate 4, fig. 1.

1992 *Latentifistula patagilaterala* Nazarov & Ormiston, 1985; Blome & Reed, 1992, fig. 13.8.

1995 *Latentifistula patagilaterala* Nazarov & Ormiston, 1985; Wang & Qi, 1995, plate 4, figs 4–6.

1997 *Latentifistula patagilaterala* Nazarov & Ormiston, 1985; Jasin & Ali, 1997, plate 1, fig. 1.

2009 *Latentifistula patagilaterala* Nazarov & Ormiston, 1985; Saesaengseerung *et al.* 2009, fig. 8.4.

Remarks. This species differs from *Latentifistula crux* by being larger and by having triradiate, slender spongy arms. The arms are the same size and shape. The rays

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of the arms expand slightly from the point of junction and have a lanceolate terminus.

Range. Upper Kungurian.

Occurrence. Urals, Oregon, Texas, south China, Malaysia, east and NE Thailand (sample no. EL-1004 to EL-1008 from the E-Lert section).

Latentifistula sp.
Figure 14s

Remarks. The frame pattern of these specifically indeterminable specimens is characterized by having a latticed shell with pores arranged in radial lines on the arms. Although our specimens are incompletely preserved, they are tentatively included in the genus *Latentifistula* because of its diagnostic latticed shell.

Range. Cisuralian.

Occurrence. NE Thailand (sample no. EL-1003 to EL-1009 from the E-Lert section).

Latentifistula sp. cf. L. patagilaterala Nazarov & Ormiston, 1985
Figure 14i–l

Remarks. Several specimens were examined. These illustrated forms are characterized in having a coarse spongy shell with three long, slender, cylindrical arms. These specimens differ from *Latentifistula patagilaterala* by having unequal angles between the three arms. One straight arm is arranged perpendicular to the other two arms. Length and size of the specimens are variable.

Range. Cisuralian–Roadian.

Occurrence. NE Thailand (sample no. EL-1004 to EL-1006 from the E-Lert section).

Genus *Latentibifistula* Nazarov & Ormiston, 1983

Type species: *Latentibifistula triacanthophora* Nazarov & Ormiston, 1983

Latentibifistula sp. cf. *L. triacanthophora* Nazarov & Ormiston, 1983
Figure 14r

1983 *Latentibifistula triacanthophora* Nazarov & Ormiston, 1983, plate 1, figs 4, 5.

1985 *Latentibifistula triacanthophora* Nazarov & Ormiston, 1983; Nazarov & Ormiston, 1985, plate 3, figs 12–14.

1993 *Latentibifistula triacanthophora* Nazarov & Ormiston, 1983; Caridroit, 1993, plate 3, fig. 11.

1997 *Latentibifistula triacanthophora* Nazarov & Ormiston, 1983; Jasin & Ali, 1997, plate 2, figs 3, 4.

Remarks. Our specimens resemble those illustrated by Nazarov & Ormiston (1983, 1985) except that the narrow depression along the whole length of the arms is not visible and the outer spongy layer is not well preserved.

Range. Cisuralian–Roadian.

Occurrence. NE Thailand (sample no. EL-1004, EL-1005 from the E-Lert section).

Genus *Tetratormentum* Nazarov & Ormiston, 1985

Type species. *Tetratormentum narthecium* Nazarov & Ormiston, 1985

Tetratormentum? sp.
Figure 16m

Remarks. The examined specimens are tentatively assigned to *Tetratormentum* based on their diagnostic outline features. The outer spongy pyramid-like shell is rather large and distorted with conical terminal spines. The internal structure of the shell is not visible.

Range. Cisuralian–Roadian.

Occurrence. NE Thailand (sample no. EL-1005 from E-Lert section).

Family RUZHENCEVISPONGIDAE Kozur, 1980
Genus *Pseudotormentus* De Wever & Caridroit, 1984

Type species. *Pseudotormentus kamigoriensis* De Wever & Caridroit, 1984

Pseudotormentus kamigoriensis De Wever & Caridroit, 1984
Figure 15m–o

1984 *Pseudotormentus kamigoriensis* De Wever & Caridroit, 1984, plate 2, figs 1–7.

1984 *Nazarovispongus* (?) sp. A. Ishiga & Suzuki, 1984, plate 1, fig. 21.

1985 *Pseudotormentus kamigoriensis* De Wever & Caridroit, 1984; Ishiga, 1985, plate 2, figs 20, 21.

1986 *Pseudotormentus kamigoriensis* De Wever & Caridroit, 1984; Caridroit & De Wever 1986, plate 5, figs 7–11.

1986 *Pseudotormentus* cf. *P. kamigoriensis* Sashida & Tonishi, 1986, plate 4, figs 8, 9.

1986 *Pseudotormentus* sp. Ishiga, Watase & Naka, 1986, plate 3, figs 8, 9.

1987 *Nazarovella* sp. Nishimura & Ishiga, 1987, plate 4, figs 8–10.

1992 *Pseudotormentus kamigoriensis* De Wever & Caridroit, 1984; Blome & Reed, 1992, plate 12, figs 13–18, 21.

1993 *Latentibifistula kamigoriensis* Caridroit, 1993, plate 1, fig. 11.

1994 *Pseudotormentus kamigoriensis* De Wever & Caridroit, 1984; Wang, Cheng & Yang, 1994, plate 3, fig. 22.

2011 *Pseudotormentus kamigoriensis* De Wever & Caridroit, 1984; Nakae, 2011, figs 7.9–7.13.

Remarks. The main characteristics of this species are a Y-shaped arm structure and a slightly spherical central portion of the test. The length of the smooth proximal parts and the lattice pore arrangement of each arm are variable. All arms narrower distally and arm spines are present.

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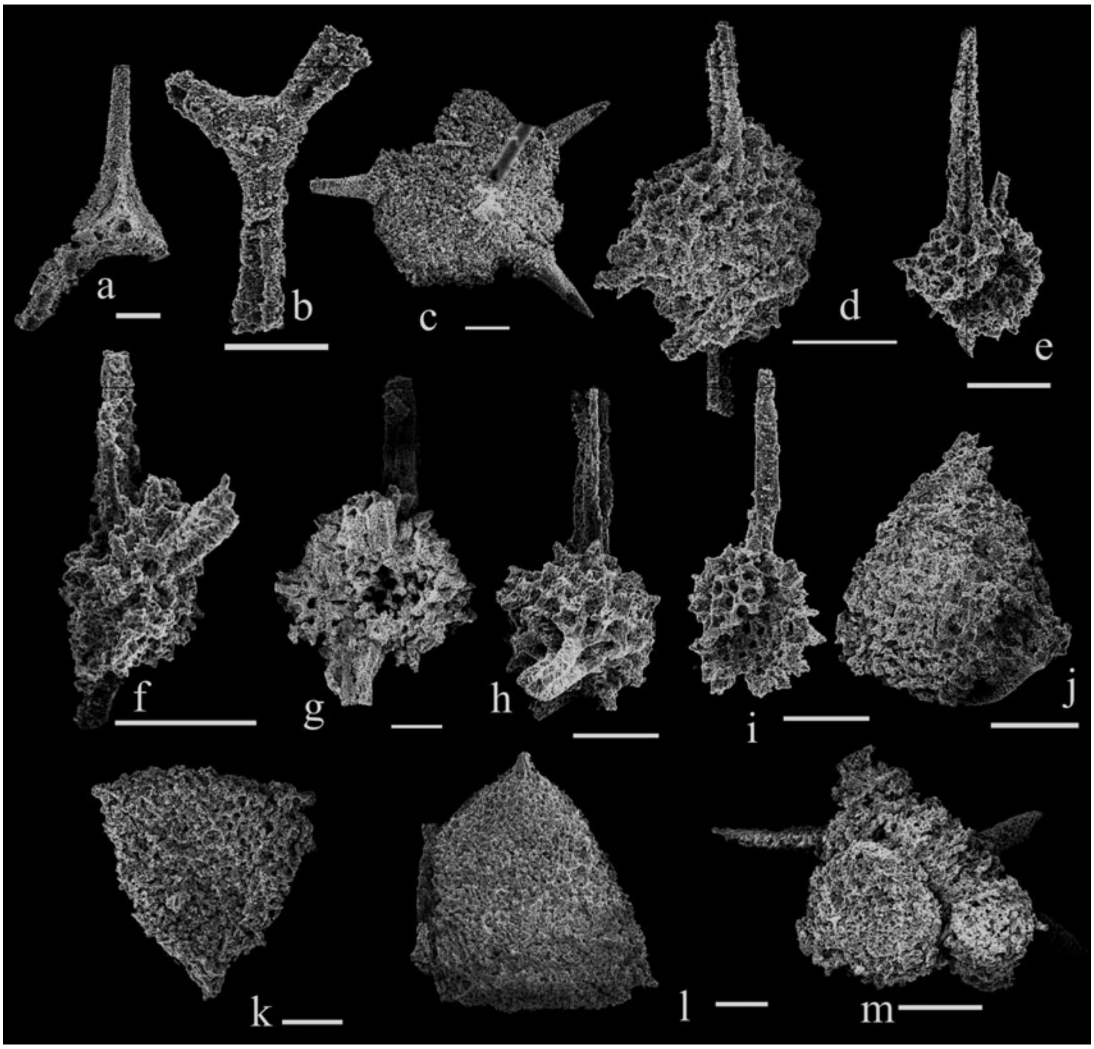

Figure 16. Radiolarians from the E-Lert Formation. (a, b) *Raciditor* spp. PRC 219–220; (c) Spumellaria gen et sp. indet., sp. A, PRC 221; (d–i) *Stigmosphaerostylus* sp. cf. *St. itsukaichiensis* (Sashida & Tonishi), PRC 222–227; (j–l) *Tormentum delicatum* Nazarov & Ormiston. PRC 228–231; (m) *Tetratormentum*? sp., PRC 231. Scale bars 50 µm.

Range. Guadalupian–Lopingian.

Occurrence. SW Japan, North America, south China, north and NE Thailand (sample no. EL-1004, EL-1005 from E-Lert section).

Genus *Ruzhencevispongus* Kozur, 1980
Type species.*Ruzhencevispongus uralicus* Kozur, 1980
Ruzhencevispongus uralicus Kozur, 1980
Figure 15p–s

1980 *Ruzhencevispongus uralicus* Kozur, 1980, plate 1, figs 1, 2.

1991 *Ruzhencevispongus uralicus* Kozur, 1980; Wang, 1991, plate 4, fig. 3.

1994 *Ruzhencevispongus uralicus* Kozur, 1980; Wang, Cheng & Yang, 1994, plate 3, fig. 19.

1997 *Ruzhencevispongus uralicus* Kozur, 1980; Jasin & Ali, 1997, plate 1, fig. 12.

1998 *Ruzhencevispongus uralicus* Kozur, 1980; Xian & Zhang, 1998, plate 4, figs 17–20.

2006 *Ruzhencevispongus uralicus* Kozur, 1980; Feng *et al.* 2006, figs 6.3–6.5.

Remarks. The specimens illustrated here can be compared with *Ruzhencevispongus uralicus* from the Cisuralian succession of the Urals in both outline and structure.

Range. Cisuralian (Kungurian according to Kozur, 1980) – Lopingian.

Occurrence. Urals, south China, Peninsular Malaysia and NE Thailand (sample no. EL-1004, EL-1005 from E-Lert section).

Genus *Tormentum* Nazarov & Ormiston, 1983
Type species.*Tormentum proteri* Nazarov & Ormiston, 1983
Tormentum delicatum Nazarov & Ormiston, 1985
Figure 16j–l

1985 *Tormentum delicatum* Nazarov & Ormiston, 1985, plate 5, figs 4, 5.

1997 *Tormentum delicatum* Nazarov & Ormiston, 1985; Jasin and Ali, 1997, plate 2, figs 11, 12.

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Remarks. The shell is inflated and subtriangular to triangular in outline. The outer surface is spongy with three short terminal spines. Our specimens are similar to those illustrated by Nazarov & Ormiston (1985).

Range. Upper Kungurian.

Occurrence. Urals, Peninsular Malaysia and NE Thailand (sample no. EL-1004, EL-1005 from the E-Lert section).

Family ORMISTONELLIDAE De Wever and Caridroit, 1984

Genus *Raciditor* Sugiyama, 2000

Type species. *Raciditor gracilis* (De Wever & Caridroit, 1984) = *Nazarovella gracilis* De Wever & Caridroit, 1984

Raciditor sp.

Figure 16a, b

Remarks. The specimens exhibit an inflated shell and four arms disposed tetrahedrally. The fourth arm is usually rotated and slightly perpendicular to the plane of the other arms. Our specimens resemble *Raciditor inflata* (Sashida & Tonishi) except that they show less expansion of the tetrahedron shell.

Range. Cisuralian–Roadian.

Occurrence. NE Thailand (sample no. EL-1004, EL-1005 from E-Lert section).

Order ENTACTINARIA Kozur & Mostler, 1982

Family ENTACTINIIDAE Riedel, 1967, emend. Nazarov, 1975

Genus *Stigmosphaerostylus* Rüst, 1892, emend. Foreman, 1963

Type species: *Stigmosphaerostylus notabilis* Rüst, 1892

Stigmosphaerostylus sp. cf. *St. itsukaichiensis* (Sashida & Tonishi, 1985)

Figure 16d, i

1985 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985, plate 1, figs 1–10.

1987 Unnamed entactinid, Nishimura & Ishiga, 1987, plate 4, figs 12, 13.

1990 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985; Ishiga, 1990, plate 1, fig. 1.

1990 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985; Tumanda, Sato & Sashida, 1990, plate 1, fig. 16.

1992 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985; Blome & Reed, 1992, figs 11.2–11.5.

1998 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985; Kuwahara & Yao, 1998, plate 2, fig. 59.

1998 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985; Feng *et al.* 1998, fig. 3c, d.

2000 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985; Sashida *et al.* 2000, fig. 7.14.

2008 *Stigmosphaerostylus itsukaichiensis* Kurihara & Kametaka, 2008, fig. 5-25.

2009 *Stigmosphaerostylus* sp. Saesaengseerung *et al.* 2009, figs 8.15, 8.17–8.19.

2011 *Stigmosphaerostylus* sp. cf. *S.itsukaichiensis* Nakae, 2011, figs 7.19–7.24.

2011 *Entactinia itsukaichiensis* Sashida & Tonishi, 1985; Jasin & Harun, 2011, plate 6, fig. 3.

Remarks. This species is characterized by possessing a small cortical shell with pores and needle-like spines at the vertices. Our specimens differ slightly from the type specimens in having slender, main spines.

Range. Cisuralian–Lopingian. This species has been reported from the Cisuralian succession of the Fukuji area, central Japan (Kurihara & Kametaka, 2008).

Occurrence. Japan, Peninsular Malaysia, west North America, south China, north and east Thailand (eastern seaboard) and NE Thailand (Isarn) (sample no. EL-1004 to EL-1008 from E-Lert section).

Genus *Hegleria* Nazarov & Ormiston, 1985

Hegleria mammila (Sheng & Wang, 1985)

Figure 14a–e

1985 *Hegleria mammifera* Nazarov & Ormiston, 1985, plate 6, figs 3–5.

1985 *Phaenicosphaera mammilla* Sheng & Wang, 1985, plate 3, figs 1–8.

1992 *Hegleria mammilla* (Sheng & Wang); Blome & Reed, 1992, plate 11, figs 10, 12, 13.

1994 *Hegleria mammilla* (Sheng & Wang); Wang & Li, 1994, plate 1, figs 22, 23.

1994 *Hegleria mammilla* (Sheng & Wang); Wang, Cheng & Yang, 1994, plate 2, figs 17, 18.

1997 *Hegleria mammilla* (Sheng & Wang); Sashida *et al.* 1997, figs 6.4, 6.5.

1998 *Phaenicosphaera mammilla* Sheng & Wang, 1985; Kozur & Krahl, 1987, fig. 7a.

1998 *Phaenicosphaera mammilla* Sheng & Wang, 1985; Xian & Zhang, 1998, plate 5, figs 18, 19.

2011 *Hegleria mammilla* (Sheng & Wang); Jasin & Harun, 2011, plate 6, fig. 4.

Remarks. Our specimens show the main characteristics of this species in having a spherical latticed cortical shell with numerous conical mammae on the surface and a bimodular shell.

Range. Guadalupian–Lopingian.

Occurrence. South China, west North America, Sicily, Peninsular Malaysia, east and NE Thailand (sample no. EL-1004, EL-1005 from E-Lert section).

Subfamily ASTROENTACTINIINAE Nazarov & Ormiston, 1985

Genus *Copicyntra* Nazarov & Ormiston, 1985

Type species.Copicyntra acilaxa Nazarov & Ormiston, 1985

Copicyntra sp.

Figure 13o–s

Remarks. The form illustrated here is rather common in our material. More than 20 specimens were examined by SEM and 5 of our specimens are illustrated. The

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test consists of several concentric spheres, and the outer shell has more than 6 subconical short spines. The pores on the shell are fine and subcircular in outline.

Range. Cisuralian.

Occurrence. NE Thailand (sample no. EL-1001 to EL-1009 from E-Lert section).

SPUMELLARIA incertae sedis
Spumellaria gen. et sp. indet., sp. A
Figure 16c

Remarks. This unnamed species is characterized by having a cortical shell with spongy layers of pore frame. It also has *c.* 4–6 short needle-like main spines on the shell. The internal structure of the shell is not visible due to poor preservation.

Range. Cisuralian–Roadian.

Occurrence. NE Thailand (sample no. EL-1005 from E-Lert section).

4. Biostratigraphy and correlations

4.a. Ammonoids

Ammonoids are present at two localities within the lower, dominantly mudstone–siltstone succession (Fig. 4) and consist of *Neopronorites* cf. *darvasicus*, *Metaperrinites ishibashii*, *Prostacheoceras* spp., *Popanoceras* cf. *sobolewskayanus*, *Bamyaniceras loiense*, *Sicanites* cf. *notabilis*, *Akmilleria electraensis* and *Agathiceras* sp. These belong to the upper Artinskian *Metaperrinites* Zone (Zhou & Liengjarern, 2004).

4.b. Fusulinids

The new fusulinid species *Laosella methikuli*, *L. parva* and *L.loeyensis* were described from calcareous shales in a presently unknown part of the type section at Huai E-Lert. On the basis of level of evolution, these were thought to be age equivalent to the Kungurian–Kazanian or to the Word Formation (Roadian – early Wordian) of Texas (Hamada, 1964; Pitkapaivan, 1965 p. 63). Ishibashi, Fujiyama & Nakornsri (1996) reported, but did not figure, *Parafusulina multiseptata*, *Monodiexodina* sp., *Chusenella* sp., *Schubertella* sp. and *Pseudodoliolina ozawai* from a limestone ‘olistolith’ within the E-Lert type section at Huai E-Lert and suggested an ‘early Middle Permian (Bolorian)’ age. Zhou & Liengjarern (2004, p. 317) stated that *Pseudodoliolina ozawai* at the E-lert reservoir locality ‘does provide evidence of Bolorian (Kungurian) age’. We have not as yet relocated these fusulinid localities although the *P. ozawai* locality is probably close to our collection locality (Fig. 4).

4.c. Radiolarian faunas and ages

The radiolarians from the upper shale/chert sequence are moderately preserved and indicate a Permian age. They are characterized by an abundance of Albaillellaria, Latentifistularia, Entactinaria and a few unidentifiable species. Twenty species of radiolarians are identified as follows:

Albaillella asymmetrica Ishiga & Imoto
Albaillella sinuata Ishiga & Watase
Pseudoalbaillella scalprata m. *scalprata* Ishiga
Pseudoalbaillella scalprata m. *postscalprata* Ishiga
Pseudoalbaillella sp.
Pseudoalbaillella sp. cf. *Ps. u-forma* m. I (Ishiga *et al.*)
Latentifistula crux Nazarov & Ormiston
Latentifistula patagilaterala Nazarov & Ormiston
Latentifistula sp.
Latentifistula sp. cf. L. patagilaterala Nazarov & Ormiston
Latentibifistula sp. cf. *L. triacanthophora* Nazarov & Ormiston
Tetratormentum ? sp.
Pseudotormentus kamigoriensis De Wever & Caridroit
Ruzhencevispongus uralicus Kozur
Tormentum delicatum Nazarov & Ormiston
Raciditor spp.
Stigmosphaerostylus sp. cf. *St. itsukaichiensis* (Sashida & Tonishi)
Hegleria mammilla (Sheng & Wang)
Copicyntra spp.
Spumellaria gen. et sp. indet., sp. A

This fauna is similar to those reported from the Cisuralian–Guadalupian succession of the Tamba district of Japan (Ishiga, 1982, 1986), the Fukuji area, central Japan (Kurihara & Kametaka, 2008), Oregon, USA (Blome & Reed, 1992), south China (Wang, Cheng & Yang, 1994; Xian & Zhang, 1998; Wang & Yang, 2011), west Texas (Cornell and Simpson, 1985), Cis-Ural (Kozur & Mostler, 1989), north and east Thailand (Sashida *et al.* 1998; Saesaengseerung *et al.* 2009), and Peninsular Malaysia (Jasin & Ali, 1997).

Although Permian radiolarian zonations have been erected, for instance in south China and Japan, it is only recently that reliably identified and useful conodonts have been found associated with zonal radiolarians that allow direct correlation with the standard Permian stages and zones (e.g. Yao, Yao & Kuwahara, 2001; Nestell *et al.* 2006; Wu & Feng, 2008; Zhang *et al.* 2010; Nishikane *et al.* 2011; Tsuyashi *et al.* 2013). Many important radiolarian faunas were described from tectonically complicated sequences such as a mélange belt in Oregon (Blome & Reed, 1992) and from olistostromes within the extensive accretionary complex of Japan (Ishiga, 1982, 1986) where superpositional and successional relationships are difficult or impossible to establish. Some radiolarian species

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that were thought to be stratigraphically restricted were found to be long ranging (Blome & Reed, 1992). Previous correlations between radiolarian zones and standard platform sequences were tenuous or misleading. We have therefore plotted (Fig. 17) the range of E-Lert radiolarians against zonations in south China and Japan and with formations in the Delaware Basin of Texas where there is conodont and other faunal evidence for correlation with the standard Permian ages/stages which have been defined on the basis of conodonts (Henderson, Davydov & Wardlaw, 2012).

Among those plotted, the most abundant and important radiolarian species for age determination are *Albaillella asymmetrica* Ishiga and Imoto, *Albaillella sinuata* Ishiga & Watase and *Pseudoalbaillella scalprata* m. *scalprata* Ishiga (Fig. 17).

Pseudoalbaillella scalprata was first described from Alaska, USA by Holdsworth & Jones (1980). Ishiga (1983) divided this species into three well-known morphotypes (*scalprata*, *postscalprata* and *rhombothoracata*) based mainly on variations of the pseudothorax, pseudoabdomen and wing-pit. Ishiga (1986, 1990) defined the first occurrence of *Pseudoalbaillella scalprata* morphotype *scalprata* in the upper part of *Pseudoalbaillella lomentaria* assemblage Zone, which correlates with the upper Artinskian succession (Fig. 17). The co-occurrence of *Albaillella asymmetrica*, *Pseudoalbaillella scalprata* m. *scalprata* and *Pseudoalbaillella scalprata* m. *postscalprata* indicates the *Pseudoalbaillella scalprata* m. *rhombothoracata* assemblage Zone which is correlated with the lower Kungurian succession. However, the *Pseudobaillella rhombothoracata* Zone is correlated with the upper Kungurian succession by Kozur (2003, fig. 1). *P. scalprata* is found in the *P. globosa* Zone in the cool-water cherty section at Dachongling, Guangxi, south China associated with conodonts identified as the Roadian *Jinogondolella nankingensis*, and ranges up to the upper Wordian *P.bella* Zone (Zhang *et al.* 2010) showing that this is a long-ranging species (Fig. 17).

In Guangxii *Albaillella sinuata* and *A. asymmetrica* occur in the underlying *A. foremanae* Zone of latest Kungurian age but not in the overlying Roadian *P. globosa* Zone. This restricted upper Kungurian range for these two species in the *A. sinuata* Zone and correlates is repeated elsewhere in south China and in Japan (Fig. 17). A limited extension of the range of both *A. asymmetrica* and *A. sinuata* into the basal part of the Roadian *P. globosa* Zone is, however, recorded in Japan and China by Ishiga (1986) and by Wang & Yang (2011).

Hegleria mammilla (Sheng & Wang) ranges from the upper Kungurian to the upper Capitanian succession in south China and *Pseudotormentus kamigoriensis* De Wever & Caridroit from the base of the Roadian stage to the Lopingian stage (Fig. 17).

Tormentum delicatum Nazarov & Ormiston and *Latentifistula patagilaterala* Nazarov & Ormiston appear to have restricted stratigraphic ranges; they were initially described from and are abundant in the Bone Spring Formation of the Delaware Basin, West Texas (Nazarov & Ormiston, 1985). The Bone Spring Formation is correlated with the upper Kungurian succession on the basis of conodonts (Kozur, 1998, table 1; Henderson & Mei, 2003, fig. 5; Henderson, Davydov & Wardlaw, 2012, fig. 24.3). However, Kozur & Mostler (1995 p. 114) consider that the radiolarians described by Cornell & Simpson (1985) and by Nazarov & Ormiston (1985) were not collected from the Bone Spring Formation but from the overlying Roadian Cutoff Formation. Using the ratified definition of Roadian, the lower 60 % or so of the Cutoff Formation is placed in the upper Kungurian succession and the upper 40 % in the Roadian (Henderson & Mei, 2003 fig. 5; Henderson, Davydov & Wardlaw, 2012, fig. 24.3).

The Bone Spring Formation of Cornell & Simpson (1985) is the type locality for *Albaillella foremanae* which gives its name to the upper Kungurian *A. foremanae* Zone in south China (Fig. 17) although the species *A. foremanae* continues into the Roadian *P. globosa* Zone (Zhang *et al.* 2010). Zhang *et al.* (2010) note that there is a striking decline in diversity and abundance of *Albaillella* in the *P. globosa* Zone; the abundance of *Albaillella* in the E-Lert fauna and the absence of characteristic *P. globosa* species suggests a pre-*P. globosa* (pre-Roadian) age for the E-Lert fauna. Our E-Lert radiolarian fauna does not include species typical of Kozur's (2003, fig. 2) various Guadalupian *Parafollicucullus* zones.

Other common radiolarian species from E-Lert are *Latentifistula crux* Nazarov and Ormiston and *Ruzhencevispongus uralicus* Kozur. These species were first reported from the Cisuralian succession of the Urals (Kozur, 1980; Nazarov & Ormiston, 1985); they have since been described in Guadalupian and Lopingian successions and so add little to the age determination of the E-Lert fauna. *R. uralicus* first appears in the Kungurian succession, but cannot be used for correlation beyond the Cis–Urals (Kozur, 2003).

The abundance of *Albaillella*, the absence of typical *P. globosa* (Roadian) and Wordian species and the stratigraphically restricted *Albaillella sinuata*, *A asymmetricus*, *Tormentum delicatum* and *Latentifistula patagilerata*, along with the longer-ranging *Hegleria mammilla* and *Pseudotormentus kamigoriensis*, all suggest a latest Kungurian, or possibly an early Roadian, age for the E-Lert radiolarian fauna.

4.d. Age of the conodont assemblage

Although the radiolarian fauna suggests correlation with the upper Kungurian to possibly lowest Roadian succession, correlations and identifications of conodonts close to the Cisuralian–Guadalupian (Kungurian–Roadian) boundary are highly controversial (Kozur, 1994, 1995, 1998, 2004; Henderson, 2001; Kozur *et al.* 2001*a*; Henderson & Mei, 2003; Leven, Reimers & Kozur, 2007; Shen *et al.* 2013). The base of the Roadian (and Guadalupian) is defined as the FAD of the first serrated gondolellids which belong to

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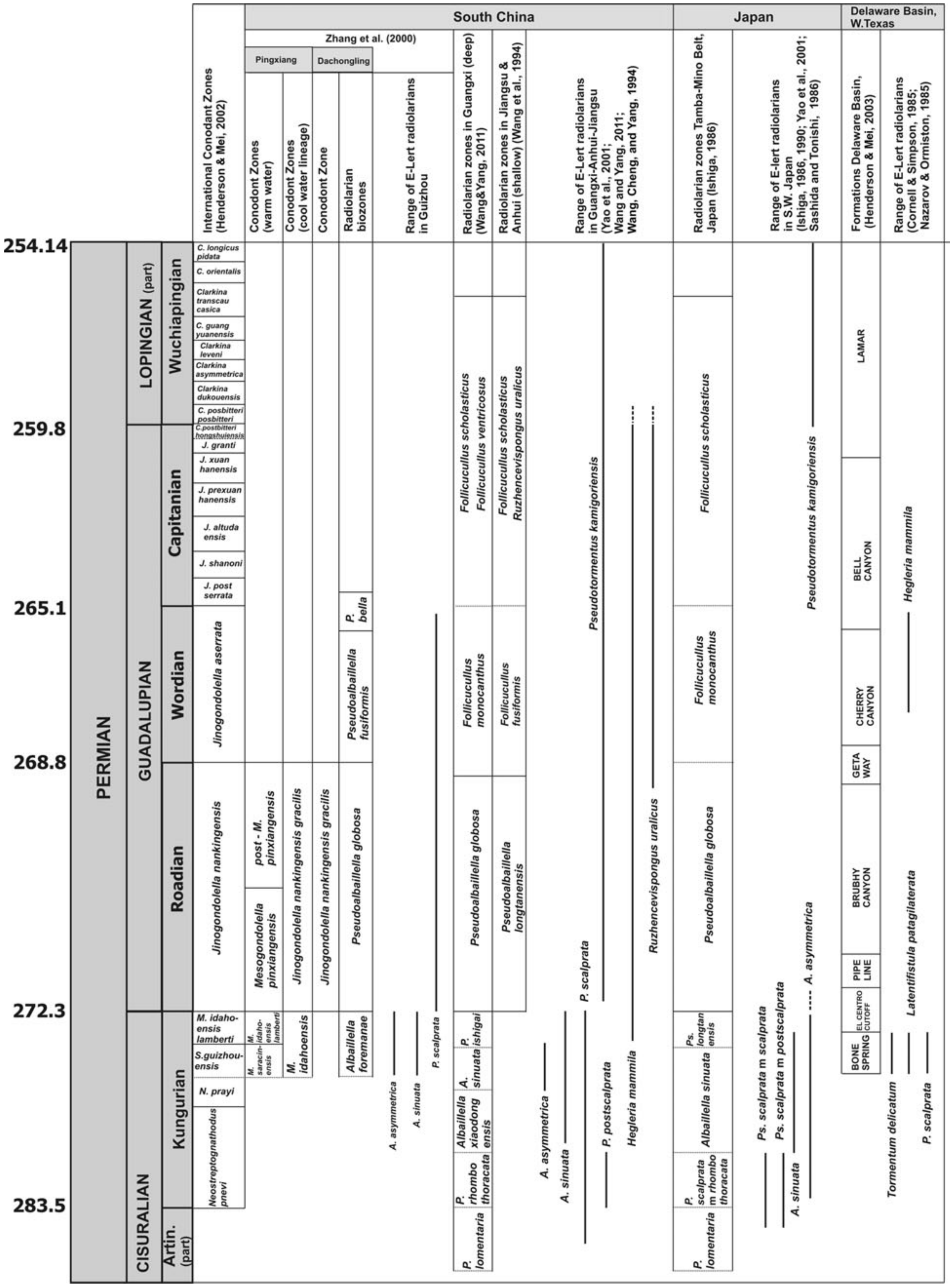

Figure 17. Correlation chart for part of the Permian showing range of selected E-Lert radiolarian species in south China, Japan and in the Delaware Basin, west Texas.

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the species *Jinogondolella nankingensis* which ranges through the Roadian succession. This is followed by *J. aserrata* which defines the base of and ranges through the Wordian succession. However, it is probable that the appearance of serrated conodonts (i.e. *Jinogondolella*) was diachronous (Henderson & Mei, 2003) and that in several places such as Sicily and south and north China the Roadian is characterized by mainly non-serrated conodonts. The identification of gondolellids is challenging. For instance *Mesogondolella idahoensis lamberti* identified by very experienced Permian conodont experts Mei & Henderson (2002*a*, *b*) from the Rustaq area in Oman are regarded as *Jinogondolella aserrata* by very experienced Permian conodont specialists Kozur & Wardlaw (2010).

Two models exist for correlating successions around the Kungurian–Roadian boundary. In one model, faunas containing *Mesogondollella siciliensis* and *Sweetognathus subsymmetricus* (as in south China, Oman and in Sicily) are correlated with the Roadian–Wordian or with the Wordian based on the co-occurrence of ammonoids (particularly *Waagenoceras*) and fusulinids (Kozur *et al.* 2001*b*; Kozur, 1993*a*, 2004; Kozur & Wardlaw, 2010). In this model, *M. siciliensis* is not found in the stratotype or nearby sections of west Texas. In the second model, *M. siciliensis* is regarded as occurring in the upper Kungurian succession in Oman, Sicily and China (Mei & Henderson, 2001, 2002*a*) and as ranging through the upper Kungurian succession of Texas with *M. zsuzsannae* in the Texas Kungurian being regarded as a junior synonym of *M. siciliensis* (Henderson, 2001; Mei & Henderson, 2001, 2002*a*; Henderson & Mei, 2003). However, Kozur & Wardlaw (2010) have shown that *M. siciliensis* occurs with both the Wordian *Jinogondolella aserrata* and a *Waagenoceras* fauna in Oman. They report a middle Roadian – Wordian range of *M. siciliensis*, as *M. siciliensis* is reported from the probable upper Kungurian – upper Roadian stage of Guangxi (Zhang *et al.* 2010) and from the middle Chihsian *M. gujioensis* Zone through the upper Chihsian *M. idahoensis* (sensu lato) Zone of the Nashui Section in Guizhou, south China (Wang, 1994). If the Texan species *M. zsuzsannae* is indeed a junior synonym of *M. siciliensis*, then a maximum possible range of *M. siciliensis* would be upper Kungurian – Wordian. In summary, *M. siciliensis* either ranges from the upper Kungurian to the Roadian succession (Henderson & Mei, 2003) or from the middle Roadian – Wordian stage (Kozur & Wardlaw, 2010), or has a maximum combined range of upper Kungurian – Wordian. As discussed above, some of our Pa specimens assigned to *M. siciliensis* are similar in platform outline and, in having a high blade and small cusp, to some *M. idahoensis lamberti* specimens from Oman assigned to the Wordian *Jinogondolella aserrata* by Kozur & Wardlaw (2010). A Wordian age for the E-Lert section cannot yet be ruled out.

Hindeodus gulloides occurs in the uppermost bed of the Road Canyon Formation and in the Glass Mountains of Texas (Kozur and Mostler, 1995; Kozur *et al.* 2001*b*); it is therefore Roadian in age. Kozur (1998, p. 207) states that *H. gulloides* is not present in any well-dated pre-Roadian section. Kozur *et al.* (2001*a*, *b*) also mention, but do not illustrate, its presence in the Luodian section in south China associated with Kubergandinian (either lower Roadian or middle Kungurian; Henderson & Mei, 2003, fig. 4; Kozur, 2003, fig. 3) fusulinids.

In south China, *Sweetognathus subsymmetricus* is found in Member II of the Chihsia Formation of Guangxi (Shen *et al.* 2007) up to the *M. idahoensis* Zone of the uppermost Chisian in Guizhou (Wang, 1994) and into the lowest Roadian in Guangxi (Zhang *et al.* 2010). Mei, Henderson & Wardlaw (2002) and Henderson & Mei (2003) show *S. subsymmetricus* ranging through much of the Kungurian and Roadian successions in the Luodian section of Guizhou and Zhang *et al.* (2010) record it in the lower Roadian stage of Guangxi. Mei & Henderson (2001) show *S. subsymmetricus* ranging to the uppermost Wordian succession.

Pseudohindeodus oertlii ranges through the Bolorian succession (upper Artinskian – lower Kungurian or upper Kungurian) of the Pamirs (Henderson & Mei, 2003, fig. 6; Kozur, 2003), through the lower Roadian succession of Guangxi (Zhang *et al.* 2010) and through the Roadian and Wordian successions of Sicily (Kozur 1993*a*).

Four of the E-Lert conodont species (*P.oertlii*, *S.subsymmetricus*, *M.siciliensis* and *H.gulloides*) are also found in the Roadian–Wordian succession of Sicily and in the lower Roadian succession of Guangxi (Kozur 1993*a*; Zhang *et al.* 2010).

4.e. Combined biostratigraphy

The lower siltstone mudstone succession is at least in part upper Artinskian on the basis of well-studied ammonoids (Zhou & Liengjarern, 2004).

The conodont fauna comes from turbiditic limestones so some specimens may be reworked. When combined with the age of the overlying radiolarian fauna, an age of latest Kungurian – earliest Roadian is likely but the Roadian age of *Hindeodus gulloides* and the middle Roadian – Wordian age range of *Mesogondolella siciliensis* (following Kozur & Wardlaw, 2010) supports a Roadian age. We therefore place our microfossil assemblages within the age range late Kungurian – Roadian, but a Wordian age cannot be excluded.

5. Palaeoecology and palaeoenvironments

5.a. Radiolarian palaeoecology

The radiolarians from the upper shale/chert sequence are characterized by an abundance of Albaillellaria, Latentifistularia and Entactinaria. On the basis of studies in the Delaware Basin of west Texas, where palaeobathymetry can be calculated with confidence, Kozur (1993*b*) and Meng in Yuan *et al.* (2007) suggest that samples dominated by Copicyntrinae, Entactinaria and

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Albaillellaria indicate palaeodepths of <50 m, 50–500 m and >500 m, respectively. At E-Lert we therefore appear to have a mixing of relatively shallow- and deeper-water radiolarians but a palaeodepth close to 500 m seems likely.

5.b. Ostracode palaeoecology

Late Palaeozoic marine ostracodes are now relatively well known from many continents and have been recovered from very-shallow-water to very-deep-water sedimentary rocks (e.g. Chen, 1958; Sohn, 1971; Gründel & Kozur, 1975; Kozur, 1985*a*, *b*, 1991; Shi & Chen, 1987, 2002; Fohere, 1997; Crasquin–Soleau & Baud, 1998; Crasquin–Soleau *et al.* 1999, 2005; Yuan *et al.* 2007; Crasquin *et al.* 2010).

Chitnarin *et al.* (2008, 2012) investigated several localities in central Thailand and described Cisuralian–Guadalupian ostracodes from the Pha Nok Khao and Khao Khwang carbonate platforms (see Section 1). This is the first study of ostracodes from a deep-water setting in the Permian succession of Thailand. The ostracodes belong to 3 orders, 4 superfamilies, 10 families, 16 genera and 23 species. As shown in Figure 18a, the most abundant superfamily is Bairdioidea including Bairdiidae (genera *Bairdia*, *Cryptobairdia*, *Bairdiacypris?*, *Spinocypris*, *Baschkirina*, *Pseudobythocypris*), Bairdiocyprididae (genus *Baschkirina*), Pachydomellidae (genus *Microcheilinella*) and Berounellidae (genus *Paraberounella*), which constitute 47.82 % of the assemblage. The second-most abundant family is the Paraparchitidae (genera *Paraparchites*, *Samarella*, *Shemonaella* and *Shivaella*) constituting 21.74 %. The third-most abundant group is the Kirkbyoidea which includes Kirkbyidae (genus *Carinaknightina*), Kirkbyoidea indet. and Aechminellidae indet. which constitute 13.06 %. Two species of Aparchitidae (genus *Cyathus*) constitute 8.70 %. Cytherideidae (genus *Basslerella*) and Polycopidae (genus *Polycope*) are less diverse and constitute 4.34 %. Most of these genera have been reported from the central parts of Thailand (Chitnarin *et al.* 2008, 2012), except for *Pseudobythocypris*, *Paraberounella*, *Spinocypris*, *Shivaella* and *Carinaknightina* which are found for the first time in Thailand. The ostracodes recovered from the E-Lert Formation at the E-Lert reservoir locality are a benthic warm-water fauna (Crasquin–Soleau & Baud, 1998; Crasquin–Soleau *et al.* 1999).

Ostracode carapaces usually reflect the conditions of their seafloor habitats (Pokorny, 1978; Armstrong & Brasier, 2005). The palaeoecology of ostracodes has been analysed from the relationship of facies to the recovered fauna (Peterson & Kaesler, 1980; Costanzo & Kaesler, 1987; Melnyk & Maddock, 1988*a*, *b*; Crasquin–Soleau *et al.* 2006) and it is now well known that members of different ostracode families and/or superfamilies had specific ecological preferences which are summarized here. The Kirkbyoidea, Kloedenelloidea and Hollinellacea inhabited euryhaline environments on the inner part of a platform (internal platform). The Paraparchidoidea, Cytherididae and Cavellinoidea lived in shallow to very shallow, euryhaline environments on the intermediate platform. The Bairdioidea could live in shallow to deep, open carbonate environments with normal salinity and oxygenation on the outer part of the platform (external platform). The Polycopidae can be found in all palaeoenvironments. In deeper environments where oxygen content, light and temperature are low, palaeopsychrospheric species are dominant (Kozur, 1985*a*; Yuan *et al.* 2007).

The ostracode families found in this study can be grouped into four palaeoecological settings (Fig. 18b). The first setting is the internal platform (subtidal, euryhaline environment) which is occupied by Kirkbyoidea (13.64 %) (*Carinaknightina*, Kirkbyoidea indet., Aechminellidae indet.). The second setting is the intermediate platform (very shallow to shallow water, euryhaline environment) occupied by the Paraparchidoidea (genera *Shivaella, Paraparchites*, *Shemonaella*, *Samarella*) and Cytherididae (genus *Basslerella*) (36.36 %). The third setting is the external platform (open carbonate environment with normal salinity and oxygenation) occupied by most of the Bairdioidea (genera *Bairdia*, *Cryptobairdia*, *Bairdiacypris? Baschkirina*, *Pseudobythocypris*, *Microcheilinella*) (36.36 %). The fourth setting is the deeper environment down to abyssal plain which is occupied by elongate forms with delicate carapaces, commonly presenting well-developed spines such as *Bairdia* sp. 1, *Spinocypris* and Berounellidae (genus *Paraberounella*) (13.64 %). The ostracode assemblage comprises forms which lived on the continental shelf, from the inner to outer parts of the carbonate platform. Percentages for each palaeoecological setting are 36.36 % from the intermediate and external platforms and 13.64 % from the internal platform and the deep-water environment. The species identified as deep-water habitants are known from Italy and south China (Kozur, 1991; Yuan *et al.* 2007); however, the deep-water assemblage is not as diverse as found in previous studies. This may suggest that the depositional environment was not very deep, and the temperature was neither very low nor suitable for palaeopsychospheric species. According to the model of Lethiers & Raymond (1991), if the percentage of palaeopsychrospheric ostracodes is less than 50 % the environment of deposition is unlikely to be slope or abyssal plain; an upper slope environment is more likely. Kozur & Wardlaw (2010, p. 216) suggest that ‘palaeopsychrospheric ostracods indicate water depths below 100 m, if rare, and depths below 200–500 m if they are abundant’.

The presence of Kirkbyoidea suggests the inner part of the platform although Kloedenellid ostracodes, which are known to live in very shallow water in muddy substrates with variable conditions in a marginal marine environment, are absent. The Paraparchitidae and Aparchitidae have been recovered from limestones from several localities south of the studied section and are also found in shale-rich facies (Chitnarin *et al.* 2012).

Nearly all ostracode specimens are found with closed carapaces, indicating good preservation in a soft

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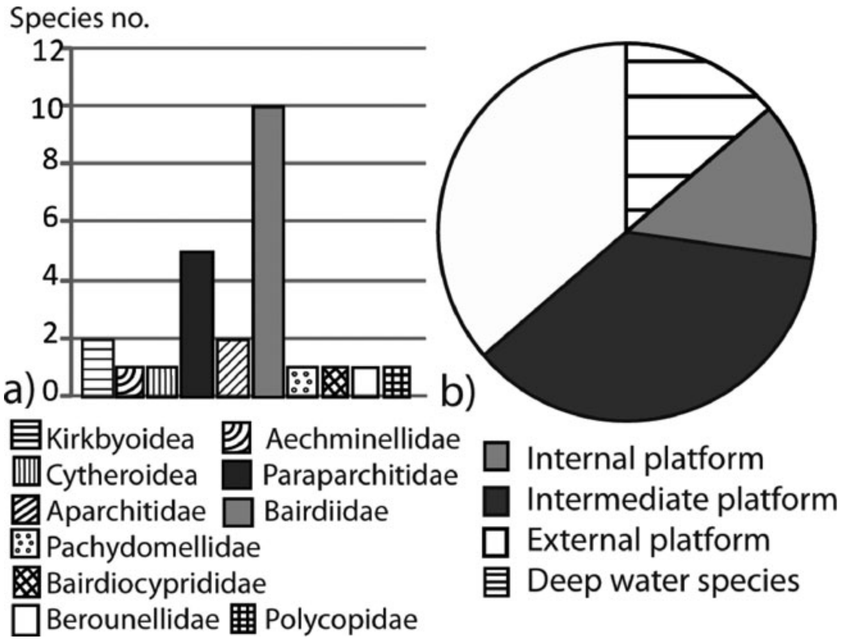

Figure 18. Ostracode assemblages of the E-Lert Formation: (a) number of species at family level and (b) pie chart showing the palaeoecological affinities of the ostracode families.

substrate and/or limited transport (Oertli, 1971). In thin-sections, ostracodes (almost always with closed carapaces) are dispersed through the carbonate turbidites. It is likely that many, if not most, ostracodes were transported a short distance from their original platform environments to be deposited in a slope environment of perhaps 100–200 m water depth.

5.c. Conodont palaeoecology

The conodont *M. siciliensis* obtained from the carbonate turbidites is regarded as a warm-water species by Henderson & Mei (2003) and Zhang *et al.* (2010), but is 'restricted to cool water facies' of the tropics in shallow pelagic deposits at water depths of less than 200 m by Kozur (1993*a*, p. 81). However, Crasquin, Carcione & Martini (2008) have found *M. siciliensis* in 80 % of their Permian samples from Sicily containing abundant palaeopsychrospheric ostracodes, but not in their shallow-water sample that lacks palaeopsychrospheric ostracodes. This may suggest that *M. siciliensis* could live at palaeodepths greater than 200 m. In contrast, in the temperature-based cline model of Henderson & Mei (2003) *M. siciliensis* has the diagnostic features of a warm-water species with a high and fused blade and a small cusp. However, *M. siciliensis* is common in deep-water deposits in Oman and Sicily, which makes the Henderson & Mei (2003) model unlikely. These doubts concerning the Henderson & Mei (2003) model are reinforced by Wardlaw's (2001, p. 24) observation of high-bladed *M. zsuzsannae* (= *M. siciliensis*?) and low-bladed *M. idahoensis* (sensu lato) in the same shallow shelf facies limestones in Texas.

5.d. Summary of palaeoenvironmental interpretation

At Huai E-Lert westwards-flowing carbonate turbidity currents deposited ostracodes, derived mainly from the outer parts of a tropical carbonate platform but also some from the internal platform, into a deep-water basin at depths of 200–300 m. Carbonate deposition ceased during latest Kungurian – Roadian time, allowing the possibly uninterrupted deposition of Albaillellaria-, Latentifistularia- and Entactinaria-dominated shales and cherts deposited at palaeodepths of probably *c.* 500 m.

6. Conclusions

In its lower part, the E-Lert Formation consists of shales containing an upper Sakmarian ammonoid fauna. The upper part contains carbonate turbidites containing a diverse ostracode fauna and a Tethyan *Mesogondolella siciliensis – Sweetognathus subsymmetricus* fauna of late Kungurian – Roadian (or even Wordian) age deposited in *c.* 200–300 m water depth. The carbonates are overlain conformably by siliceous shales and cherts containing a diverse late Kungurian – Roadian radiolarian assemblage deposited in *c.* 500 m water depth.

We and other workers (e.g. Metcalfe & Sone, 2008) have found that conodonts are rare in the Permian platform carbonates of Indochina and often require very large samples in order to acquire a useful fauna. This is partly due to high rates of deposition and the abundance of pelmatozoan, coralline and algal debris and fusulinids in subtidal environments. Since publication of the four pioneering monographs of J. Deprat (culminating in Deprat, 1915), the Carboniferous–Permian limestones of Indochina and many other Tethyan areas

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have been mainly dated using fusulinids and correlated with the Tethyan stages (Ueno & Charoentitirat, 2011). These stages have proved difficult to correlate to extra-Tethyan sequences in North America and Europe. In contrast to the platform carbonates, the E-Lert Formation and correlative deeper-water units in the Nam Duk Basin and its margins contain abundant conodont, fusulinid, ammonoid, ostracode and radiolarian faunas (Altermann *et al.* 1983; Zhou & Liengjarern, 2004). Collections from marginal localities such as the E-Lert Formation, containing both deep- and shallow-water faunas, will not only help in international stage correlations and the integration of different biozonations but also in regional correlations and palaeogeographic reconstructions of the economically important Carboniferous–Permian limestones throughout Indochina.

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