

Early Silurian Benthic Foraminifera from Saudi Arabia – including the oldest known multichambered litoiids

Michael A. Kaminski¹ and Pramudya R. D. Perdana^{1,2}

¹*Geosciences Department, College of Petroleum Engineering and Geosciences,
King Fahd University of Petroleum & Minerals, Dhahran, 31261, Saudi Arabia*

²*Current Address: Geological Engineering Department, Faculty of Exploration and Production Technology,
Pertamina University, Jakarta, 12220, Indonesia*
email: kaminski@kfupm.edu.sa; ORCID 0000-0002-7344-5874

ABSTRACT: A diverse assemblage of early Silurian agglutinated foraminifera is described from the transitional facies between the Qusaiba and Sharawra Formations of the Qalibah Group of Saudi Arabia. The agglutinated foraminiferal assemblage consists of 73 species belonging to 24 genera, and is found in dark graptolite-bearing claystone of Aeronian age. The assemblage is highly diverse compared with coeval early Silurian assemblages reported from Europe and North America. The assemblage is comprised mainly of species belonging to the monothalamid genera *Saccammina*, *Psammosphaera*, *Lagenammina*, *Thurammina*, *Thuraminoides*, *Amphitremoida*, *Bathysiphon*, *Rhabdammina*, and the tubothalamid genera *Hyperammina*, *Tolypammina* and *Turritellella*. The new species *Thuraminoides ellipsoidalis* n. sp. is described herein, but many of the species left in open nomenclature are also likely to be new. The assemblage also includes rare specimens belonging to the globothalamid (litoiid) genera *Ammobaculites* and *Simobaculites*. This new finding revises our understanding of the early evolution of the multichambered globothalamid foraminifera. Although the simple multichambered with rectilinear chamber arrangement are known from the Ordovician, our new findings show that the coiled globothalamids belonging to the order Litoiida are older than previously thought, and were already present in Gondwana by about 440 Ma.

Keywords: Foraminifera, Silurian, Qusaiba Shale, Saudi Arabia

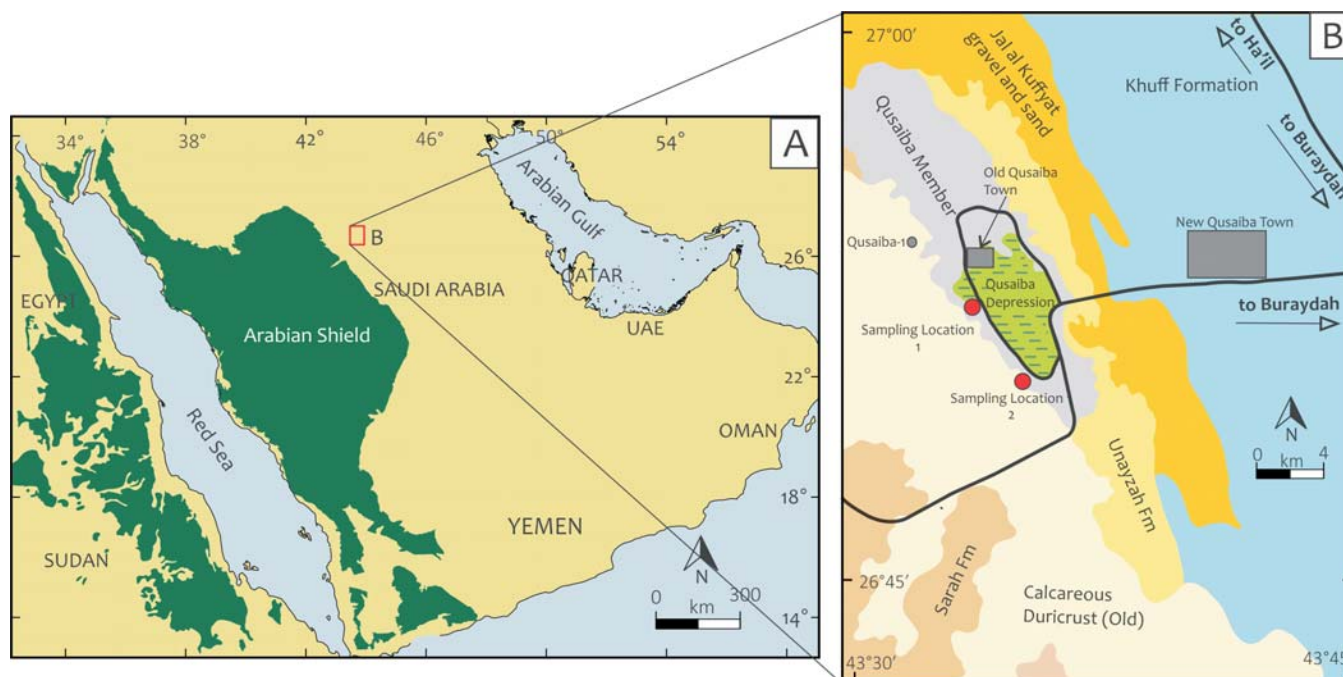
INTRODUCTION

During the early Silurian, Saudi Arabia was located on the coast of the southern Gondwana continent (Golonka et al. 2006). The melting of the Hirnantian continental ice cap resulted in a rapid sea level rise that resulted in the deposition of a lower Silurian succession of fine-grained graptolite-bearing shales that are rich in organic matter (Mahmoud et al. 1992). Lower Silurian sediments belonging to the Qalibah Group are well exposed in central Saudi Arabia, forming a prominent cuesta approximately 27 m high near the Village of Qusaiba (Abbas et al. 2017). The foraminiferal assemblage described in this study was recovered from the upper unit of the Qusaiba Shale Formation and in the shale interbeds within the lower part of the Sharawra Sandstone Formation (Kaminski and Perdana 2017a). Both lithological units are here regarded as having formation status in accordance with the current usage adopted by the Saudi Stratigraphic Committee in 2012.

Descriptive studies of Silurian foraminifera began with the pioneering works of Moreman (1930, 1933), Ireland (1939), Grubbs (1939), Stewart and Priddy (1941), and Dunn (1942) in North America. After the Second World War, additional descriptive studies in that region include those of Mound (1961; 1968), Browne and Schott (1963), McClellan (1966), McClellan (1973), Conkin and Conkin (1979), and Watkins et al. (1999). A review of North American Silurian foraminifera published by Conkin and Conkin (1982) listed a total of 36 species of monothalamids and tubothalamids from the early Silurian, and 62 species from the middle Silurian. The most

inclusive treatment of Silurian foraminifera from North American mid-continent was published by Mound (1968), who reported 82 species belonging to 31 genera. A synthesis of the Silurian foraminifera in the British Isles was given by Kircher and Brasier (1989). Morphologically simple agglutinated foraminifera were first recognized by Ireland (1958, 1967) in western England. Mabillard and Aldridge (1982) described and illustrated this early Silurian (Llandovery to Wenlock) fauna. Wenlockian foraminifera were also reported by Aldridge et al. (1979) from the Welsh Basin. Recently, a low-diversity assemblage of monothalamids and tubothalamids with North American affinities has been described from Silurian limestone from the Dingle Peninsula in western Ireland (Kaminski et al. 2016). In Australia (New South Wales), a sparse Silurian assemblage of foraminifera consisting of monothalamids was reported by Bell et al. (2000). Other than a taxonomic note by Kaminski and Perdana (2017b), there are no published reports of agglutinated foraminiferal assemblages from the Silurian of the Middle East.

Early Silurian foraminifera until now have been regarded to consist of simple single-chambered monothalamids and two-chambered tubothalamids such as *Hyperammina* and ammodiscids with a noncalcareous agglutinated wall. Although pseudo-multichambered agglutinated foraminifera first appeared in the mid-Ordovician (Kaminski et al. 2009), and the pseudo-multichambered genus *Lituotuba* is reported from the lower to middle Silurian (Conkin and Conkin 1982), the origin of multichambered coiled forms belonging to the Litoiida was not believed to have taken place until the Early Devonian at the earliest



TEXT-FIGURE 1

Studied sample locations in the Qassim District of Saudi Arabia (base map after Zalasiewicz et al. 2007). The location of the Qusaiba-1 core is also shown.

est (Holcová 2002). A published report of multichambered globothalamid agglutinated foraminifera from upper Cambrian sediments in Nova Scotia (Scott et al. 2003) remains speculative owing to problems with the geology and age assignments of the sampled locality, which is now no longer accessible. New discoveries of early Silurian foraminifera from the Qusaiba Shale in Saudi Arabia (Kaminski and Perdana 2017a,b) that include the genus *Ammobaculites* now point to an earlier origin of the multichambered lituolid foraminifera than the estimate currently accepted by molecular biologists (Pawlowski et al. 2003). The purpose of this study is to document the foraminifera recovered from the Qusaiba Shale outcrop sections from the Qassim District of Saudi Arabia and investigate their paleoecological and paleobiogeographical significance.

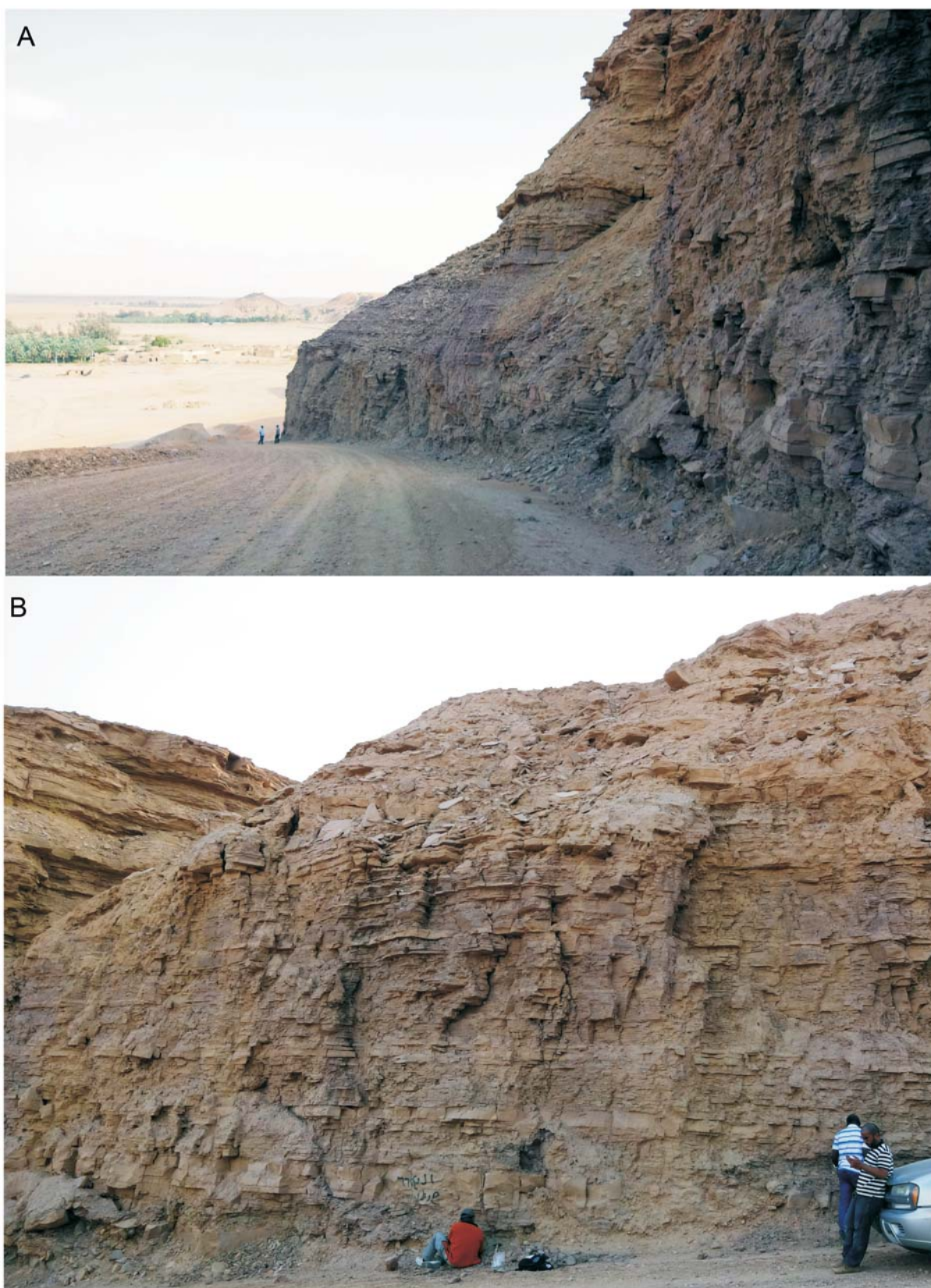
GEOLOGIC SETTING

The Qalibah Group of central Saudi Arabia is subdivided into the Qusaiba Shale Formation and the Sharawra Sandstone Formation (Mahmoud et al. 1992; Al-Laboun 2009). The two formations are exposed in old Qusaiba Village in the Qassim District of Saudi Arabia (text-fig. 1), where they form a cuesta that is as much as 27 m high. The Qusaiba Shale Formation predominantly comprises laminated shale and mudstone with thin interbeds of siltstone and sandstone. This unit is pyritic, rich in organic matter, and in the studied section contains graptolite assemblages consisting of 14 species (Zalasiewicz et al. 2007). The amount of detrital sand and mica gradually increases towards its upper part, at the transition to the overlying Sharawra Formation (Abbas et al. 2017). The high amount of organic matter in the lower part of the Qusaiba Shale produces gamma ray values higher than 150 API, and it is widely known as the Qusaiba “hot shale” (Mahmoud et al. 1992; Cole et al. 1994;

Lüning et al. 2000). This hot shale is usually 9–31 m thick, laminated, and is considered to be the main hydrocarbon source rock of the Paleozoic Petroleum System in Saudi Arabia and North Africa (Jones and Stump 1999; Lüning et al. 2000).

The Sharawra Sandstone Formation conformably overlies the Qusaiba Shale Formation with a gradational contact, and mostly consists of sandstone, siltstone, and minor shale interbeds rich in mica (Abbas et al. 2017). In the studied outcrop in Old Qusaiba Village, the formation is found at the top of the cuesta and varies in thickness from 17 to 27 m along a distance of a few kilometers. In the reference section between the towns of Tayma and Al Qalibah, the thickness of the Qalibah Group is approximately 499 m, with 256 m of the Qusaiba Shale Formation and 243 m of the Sharawra Sandstone Formation (Mahmoud et al. 1992). From a regional point of view, the Lower Silurian Qalibah Group exhibits a progradational succession that is interpreted as deposition along a broad continental shelf during the transgression caused by the melting of the Hirnantian ice cap. However, the late Silurian hiatus in the uppermost part of the succession is thought to be a result of uplift associated with the Caledonian Orogeny (Mahmoud et al. 1992).

Foraminifera-bearing samples were recovered from silty shale of the upper part of the Qusaiba Shale, which is interpreted as having been deposited in an offshore to lower shoreface paleoenvironment (Abbas et al. 2017). In the transitional facies near the contact between the Qusaiba Shale and Sharawra Sandstone, interbedded thinly bedded sandstone shows signs of bioturbation, indicating that oxygenated conditions existed at the sea floor. We therefore focused our efforts on sampling this transitional lithofacies in the uppermost part of the Qusaiba



TEXT-FIGURE 2

A. Section 1 sampled in this study, view toward the east. The Old Qusaiba Village is in the middle distance. Samples were collected at 1 m intervals along the road at the base of the road-cut. B. Close-up view of the lithological transition between the uppermost Qusaiba Shale and the Sharawra Formation, view toward the south. The base of the Sharawra Formation is placed at the lowermost sandstone bed.

TABLE 1
Taxonomic assignments of the recovered foraminifera.

ORDER	FAMILY	GENUS	SPECIES
ASTRORRHIZIDA	RHABDAMMINIDAE	<i>Rhabdammina</i>	<i>Rhabdammina trifurcata</i>
	BATHYSIPHONIDAE	<i>Bathysiphon</i>	<i>Bathysiphon</i> sp. 1
			<i>Bathysiphon</i> sp. 2
			<i>Bathysiphon</i> sp. 3
	HIPPOCREPINELLIDAE	<i>Amphitremoida</i>	<i>Amphitremoida citroniforma</i>
			<i>Amphitremoida eisenacki</i>
			<i>Amphitremoida</i> sp. 1
			<i>Amphitremoida</i> sp. 2
	STEGNAMMINIDAE	<i>Blastammina</i>	<i>Blastammina vulgaris</i>
		<i>Ceratammina</i>	<i>Ceratammina cornucopia</i>
			<i>Ceratammina</i> sp. 1
		<i>Raibosammina</i>	<i>Ceratammina</i> sp. 2
			<i>Raibosammina aspera</i>
		<i>Stegnammina</i>	<i>Stegnammina contorta</i>
			<i>Stegnammina elongata</i>
			<i>Stegnammina</i> sp. 1
			<i>Stegnammina</i> sp. 2
			<i>Stegnammina</i> sp. 3
			<i>Stegnammina</i> sp. 4
		<i>Thuramminoides</i>	<i>Thuramminoides ellipsoidal</i>
			<i>Thuramminoides plummerae</i>
			<i>Thuramminoides sphaeroidalis</i>
	HEMISPHAERAMMINIDAE	<i>Hemisphaerammina</i>	<i>Hemisphaerammina casteri</i>
			<i>Hemisphaerammina</i> sp. 1
			<i>Hemisphaerammina</i> sp. 2
	SACCAMMINIDAE	<i>Lagenammina</i>	<i>Hemisphaerammina</i> sp. 3
			<i>Lagenammina</i>
			<i>aff.cumberlandiae</i>
			<i>Lagenammina ligula</i>
			<i>Lagenammina silnica</i>
		<i>Saccammina</i>	<i>Lagenammina</i> sp. 1
			<i>Lagenammina</i> sp. 2
			<i>Saccammina aspera</i>
			<i>Saccammina</i> sp. 1
			<i>Saccammina galinae</i>
		<i>Thurammina</i>	<i>Saccammina</i>
			<i>Thurammina arcuata</i>
			<i>Thurammina holcovae</i>
			<i>Thurammina papillata</i>
			<i>Thurammina pentagona</i>
			<i>Thurammina(?)</i> sp. 1
			<i>Psammosphaera cava</i>

Shale (corresponding to the “Gray shale facies” of Hayton et al. 2017) with the aim of recovering foraminiferal assemblages. As a continental shelf deposit, the absence of carbonate deposition in the Qalibah Group is likely a consequence of the high latitude position of this part of Gondwana during the early Silurian (Golonka et al. 2006). Furthermore, a high rate of sediment supply represented by the thick progradational clastic sequence also inhibited the generation of carbonate buildup (Mahmoud et al. 1992).

The age of the Qusaiba Shale has been determined as early Rhuddanian to early Telychian based on the study of graptolites recovered from boreholes (Williams et al. 2016). Eleven graptolite zones are present in the Qusaiba Shale recovered from boreholes, providing an excellent correlation to the graptolite zonations of the United Kingdom and the Czech Republic. Graptolites studied from the nearby Qusaiba-1 core (drilled on top of the crest of the cuesta about one kilometer from our sampled sections) are of Aeronian age (*Lituigraptus*

TABLE 1
Continued.

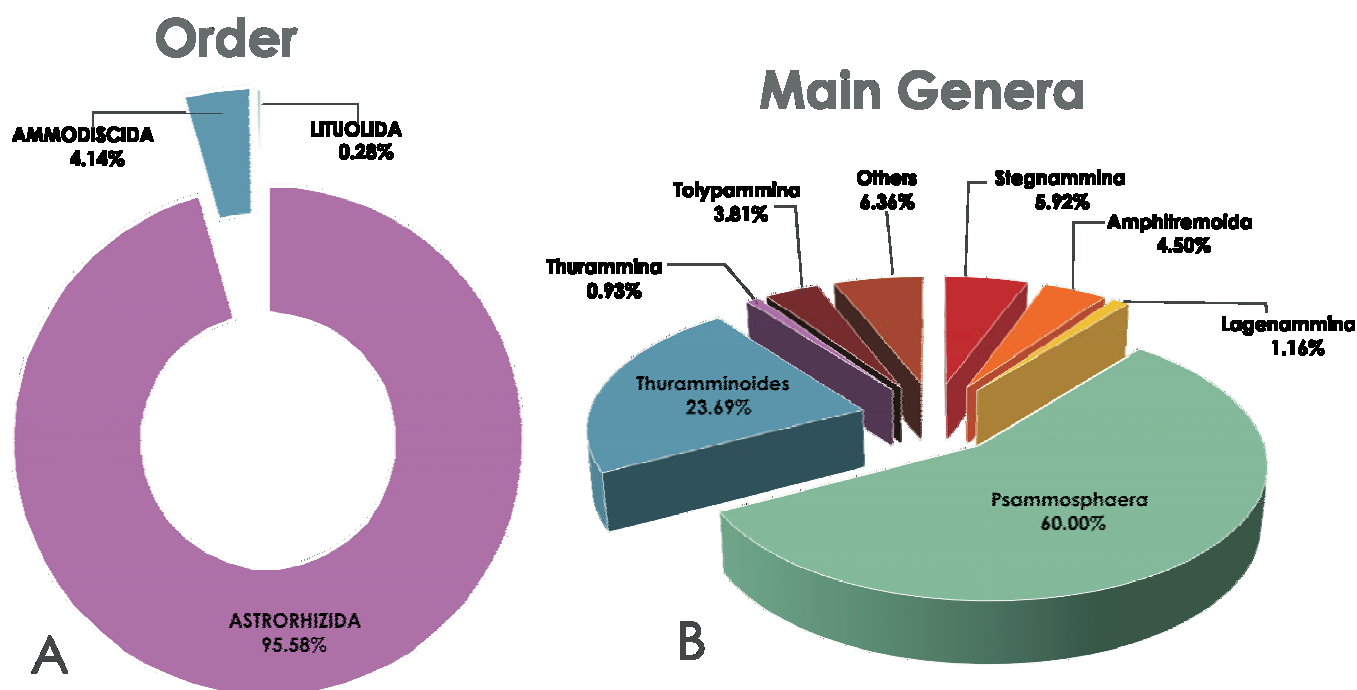
ORDER	FAMILY	GENUS	SPECIES	
AMMODISCIDA	PSAMMOSPHAERIDAE	<i>Psammosphaera</i>	<i>Psammosphaera</i> sp. 1	
			<i>Psammosphaera</i> (?) sp. 1	
			<i>Psammosphaera</i> (?) sp. 2	
			<i>Psammosphaera</i> (?) sp. 3	
			<i>Sorosphaera bicella</i>	
		<i>Sorosphaera</i>	<i>Sorosphaera tricella</i>	
			<i>Webbinella</i> sp. 1	
	LACUSTRINELLIDAE	<i>Webbinelloidea</i>	<i>Kechenotiske expansa</i>	
	HIPPOCREPINIDAE	<i>Kechenotiske</i>	<i>Hyperammina sinuosa</i>	
	HYPERAMMINIDAE	<i>Hyperammina</i>	<i>Hyperammina</i> sp. 1	
			<i>Hyperammina</i> sp. 2	
			<i>Ammovertella</i> sp. 1	
		<i>Ammovertella</i>	<i>Ammovertella</i> sp. 1	
			<i>Ammovertella</i> sp. 2	
			<i>Ammovertella</i> sp. 3	
			<i>Ammovertella</i> (?) sp. 4	
			<i>Tolypammina aihemerensis</i>	
			<i>Tolypammina</i> cf. <i>bulbosa</i>	
			<i>Tolypammina</i> howchini	
		AMMODISCIDAE	<i>Tolypammina</i>	<i>Tolypammina</i> aff. <i>jacobschapelensis</i>
				<i>Tolypammina</i> aff. <i>serpens</i>
				<i>Tolypammina</i> aff. <i>tornella</i>
	<i>Tolypammina</i> cf. <i>tortuosa</i>			
	<i>Tolypammina</i> sp. 1			
	<i>Tolypammina</i> sp. 2			
	<i>Tolypammina</i> sp. 3			
	<i>Tolypammina</i> sp. 4			
	<i>Tolypammina</i> sp. 5			
<i>Turritellella</i>	<i>Turritellella</i> sp. 1			
LITUOLIDA	LITUOLIDAE	<i>Ammobaculites</i>	<i>Ammobaculites qusaibaensis</i>	
		<i>Simobaculites</i>	<i>Simobaculites</i> sp. 1	
	?HORMOSINIDAE	Incertae sedis	Incertae sedis	

convolutus zone) for the greater part of the Qusaiba Shale at this locality (Zalasiewicz et al. 2007), whereas the contact between the Qusaiba and Sharawra formations is correlated with the early Telychian based on chitinozoans (Miller and Melvin 2005). Our sampling of the outcrop exposure is limited to the uppermost 14 m of the Qusaiba Shale, belonging to the *L. convolutus* zone. The lower few meters of the cuesta is everywhere covered by fallen rubble, and is therefore not accessible.

METHODOLOGY

Two outcrop sections through the exposed part of the Qusaiba Shale and the overlying Sharawra Sandstone in the Qassim District, Saudi Arabia were selected for study (text-fig. 1). The lithology, chemostratigraphy and provenance of sediments exposed in these outcrop sections were described by Abbas et al. (2017). Samples were collected from the shale to silty shale of the upper part of the Qusaiba Shale and shale interbeds from the lower part of the Sharawra Sandstone. The first section (text-fig. 2), corresponding to Section 1 of Abbas et al. (2017),

is exposed along an unpaved road that leads up the face of the cuesta from the now largely abandoned Old Qusaiba Village (N 26° 51'35" E 43° 34'19"). This is our reference section, as it exposes 12 m of the Qusaiba Shale and provides the most complete section of the Sharawra Sandstone. The second section, corresponding to Section 2 of Abbas et al. (2017), is located about a kilometer to the south of the road outcrop (N 26° 50'2.8", E 43° 36'00"). Samples were collected at half-meter spacing from the upper 13 m of the Qusaiba Shale, whereas in the lower part of the Sharawra Sandstone the shale interbeds were sampled at irregular but more closely-spaced intervals. The shale samples were prepared from 400–500 grams of sediment to standardize recoverable foraminiferal residue, and washed under running water using a standard stainless steel 63 µm sieve, without any special chemical treatment. More than 300 foraminiferal specimens were picked from the >63 µm fraction from each sample, mounted onto cardboard microscope slides, and separated taxonomically. The specimens were photographed using a digital camera mounted on a Nikon-1500 stereo-microscope in the Geosciences



TEXT-FIGURE 3
Proportions of foraminiferal orders and genera in the studied samples.

Department at King Fahd University Petroleum & Minerals. The faunal slides and type specimens will be deposited in the collections of the European Micropalaeontological Reference Centre, Micropress Europe, located at the AGU University of Science & Technology in Kraków, Poland.

RESULTS AND DISCUSSION

Preservation

The recovered foraminifera generally exhibit moderate to good preservation, with several truncations encountered at the final and or initial stage of tubular and tubotalamamid forms. Delicate features of the monotalamid foraminifera, such as the test periphery, aperture(s), and protuberances, remain preserved, and only rare evidence of abrasion or erosion was seen. Our specimens also demonstrated no evidence of redeposition, which suggests the recoverable materials are preserved as autochthonous components in fine-grained sediments in an environment with low hydrodynamic energy.

Foraminiferal Assemblages

The studied early Silurian foraminiferal assemblages from the upper part of the Qusaiba Shale and lower part of Sharawra Sandstone consist exclusively of agglutinated foraminifera. No calcareous microfossils of any kind were found the sample residues. A total of 6315 foraminiferal specimens were recovered from our samples. The assemblage consists of a total of 73 species, classified as belonging to three orders, 13 families, and 24 genera (Table 1). In terms of species number, the foraminiferal

assemblages from the studied sections are more diverse than any previously described early Silurian assemblage.

The assemblages recovered from the upper part of the Qusaiba Shale and lower part of the Sharawra Sandstone are dominated by monothalamous forms of Astrorhizida, comprising 95.58% of the assemblage, followed by tubothalamids belonging to the Hippocrepinida and Ammodiscida (4.14%), and finally globothalamids consisting of Lituolida (0.28%) (text-fig. 3). Flattened and discoidal morphotypes of *Psammosphaera*(?) and *Thuraminoides* are the dominant genera. Other common genera include *Amphitremoida*, *Stegnammina*, *Lagenammina*, *Thurammina*, and *Tolypammina* (text-fig. 3). The multi-chambered lito-
lids occur as rare components in an assemblage consisting mostly of monothalamids.

The distributions of the common foraminiferal species in the upper part of the Qusaiba Shale and the lower part of the Sharawra Sandstone in the studied sections are shown in text-figures 4–5, and the quantitative species counts are given in the appendix (supplementary material). In the studied succession, a change is observed from a *Psammosphaera*-dominated assemblage in the upper part of the Qusaiba Shale to a less diversified assemblage with species of *Stegnammina* and *Amphitremoida* in the shaly interbeds within the lower part of the Sharawra Sandstone Formation. The lack of comparable foraminiferal studies in the Middle East and North Africa (Gondwana) means that additional sections need to be studied to assess the stratigraphic utility of the species from the studied locality.

TABLE 2

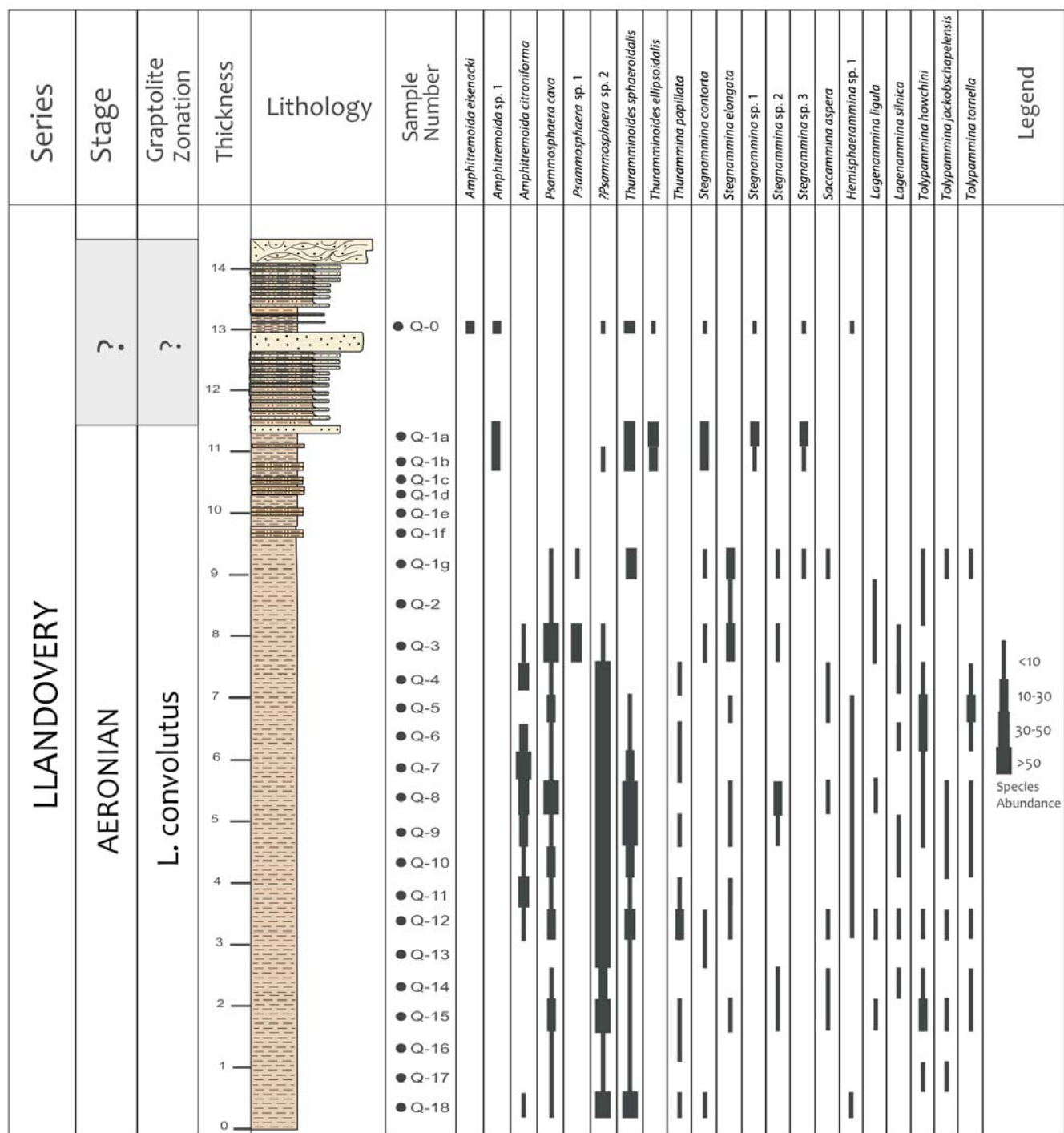
Comparison of the occurrence of agglutinated foraminiferal genera at studied Silurian localities in Australia, Bolivia, North America, Avalonia, Baltica, and Saudi Arabia.

Genus	Aus- tralia	Bolivia	Czech Republ.	Baltic Europe	North Amer.	Avalon.	Saudi Arabia
<i>Ammodiscus</i>					X	X	
<i>Ammolagena</i>				X			
<i>Ammosphaeroides</i>					X		
<i>Ammovolummina</i>			X				
<i>Amphitremoida</i>			X	X			X
<i>Anictosphaera</i>					X		
<i>Areniconulus</i>				X	X		
<i>Arenosiphon</i>				X	X		
<i>Aschemonella</i>					X		
<i>Atelikamera</i>					X	X	
<i>Bathysiphon</i>				X	X		X
<i>Bifurcammina</i>					X		
<i>Blastammina</i>				X			X
<i>Ceratammina</i>						X	X
<i>Colonammina</i>					X		
<i>Crithionina</i>					X		
<i>Gastroammina</i>					X		
<i>Glomospira</i>		X	X		X		
<i>Glomospirella</i>			X				
<i>Hemisphaerammina</i>					X		X
<i>Hyperammina</i>	X	X	X	X	X	X	X
<i>Kechenotiske</i>							X
<i>Lagenammina</i>		X	X		X	X	X
<i>Lituotuba</i>	X				X		
<i>Marsipella</i>					X		
<i>Ordovicina</i>				X	X		
<i>Oryctoderma</i>					X		
<i>Protonina</i>					X		
<i>Psammophax</i>					X		
<i>Psammospaera</i>	X	X	X	X	X	X	X
<i>Pseudastorhiza</i>				X			
<i>Raibosammina</i>					X		
<i>Rhabdammina</i>	X				X		X
<i>Saccammina</i>			X		X	X	X
<i>Saccamminita</i>							X
<i>Serpenulina</i>			X				
<i>Sorosphaera</i>	X		X	X	X	X	X
<i>Stegnammina</i>				X	X	X	X
<i>Stomosphaera</i>						X	
<i>Storthosphaera</i>						X	
<i>Thekammina</i>					X		
<i>Tholosina</i>		X			X	X	
<i>Thurammina</i>	X	X	X	X	X	X	X
<i>Tolypammina</i>	X	X			X	X	X
<i>Turritellella</i>					X		X
<i>Webbinelloidea</i>		X	X		X	X	X
<i>Thuraminoides</i>	X		X				
<i>Reophax</i>					X		??
<i>Ammobaculites</i>							X
<i>Simobaculites</i>							X

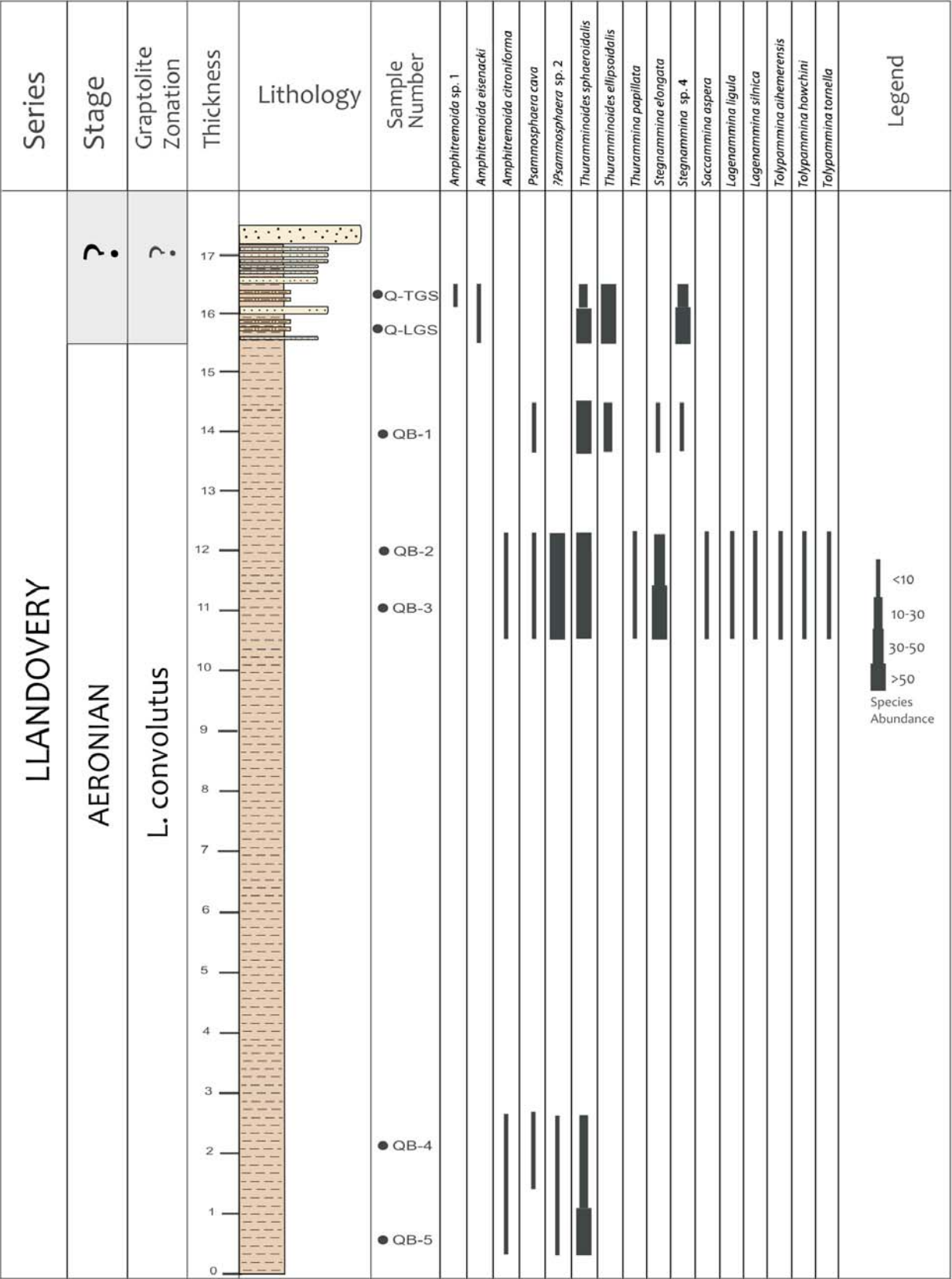
Paleoecology

Until the present study, Silurian agglutinated foraminifera have mostly been recovered from carbonate rocks (McClellan 1966; McClellan 1973; Watkins et al. 1999), often in acid residues of samples that were processed for conodonts or other fossils. The published record of the Silurian is therefore biased towards carbonate environments. However, clastic environments that have a low rate of sediment flux also constitute a favorable habitat for agglutinated benthic foraminifera, as shown by numerous studies of the Cretaceous to Paleogene “flysch-type” faunas (Gradstein and Berggren 1981). The Silurian foraminifera re-

covered from the Qalibah Group lived in a muddy to silty substrate in a clastic marine environment on a high-latitude shelf of southern Gondwana. The Qusaiba Shale Formation was deposited during the transgression that resulted from the melting of continental ice after the Late Ordovician (Ashgillian) glacial period (Al-Laboun 2009). The Sharawra Sandstone Formation rests conformably on the thick transgressive shale sequence. The pro-deltaic to delta front Sharawra Formation deposits mark the termination of a major transgressive period (Abbas et al. 2017). The Sharawra Formation exhibits a series of transgressive and regressive cycles, with the thin shale interbeds representing



TEXT-FIGURE 4
Chronostratigraphy, lithological column, studied samples, and common foraminifera in section 1.



TEXT-FIGURE 5
Chronostratigraphy, lithological column, studied samples, and common foraminifera in section 2.

small-scale transgressive events occurring between the regressive sandy intervals (Abbas et al. 2017).

The agglutinated foraminifera in the Qassim Region of Saudi Arabia inhabited an offshore to lower shoreface environment. Conditions at the sea floor varied from anoxic during the deposition of the Qusaiba ‘hot shale’ to dysoxic in the grey shale that is exposed in outcrop. The diversity of the assemblages also varies from those environments, including taxa occurring in diversified assemblages only (deeper water, low-energy environment), such as *Amphitremoida citroniforma*, *Tolypammina*, *Turritella*, *Thurammina*, *Sorosphaera*, *Stegnammina elongata*, and *Hemisphaerammina*. Taxa from the lower shoreface environment (higher hydrodynamic energy) include *Hyperammina rockfordensis*, *Amphitremoida eisenacki*, *Amphitremoida* sp. 1, *Thuramminoides ellipsoidalis* n.sp., and *Stegnammina* sp. 1. However, many taxa are commonly present across a range of paleoenvironments, such as *Thuramminoides sphaeroidalis*, *Stegnammina*, *Psammosphaera cava*, *Bathysiphon*, *Hyperammina*, *Saccammina*, and *Lagenammina*.

Paleobiogeography of Silurian Foraminifera

A comparison of the paleogeographical distribution of Aeronian agglutinated foraminifera from Saudi Arabia and other areas is carried out in an attempt to delineate faunal provinces. The previously studied regions include the Gondwanan continents, i.e., Australia (Bell et al. 2000), Bolivia (Gagnier et al. 1996), the peri-Gondwanan terranes, i.e., the Czech Republic (Holcová 2002), the Laurentian continent i.e., the mid-continent of North America (Moreman 1930; Grubbs 1939; Stewart and Priddy 1941; Dunn 1942; Ireland 1966; McClellan 1966; Mound 1968; Conkin and Conkin 1982; Watkins et al. 1999), Avalonia (Aldridge et al. 1979; Mabillard and Aldridge 1982; Kircher and Brasier 1989; Kaminski et al. 2016, and Baltica (Eisenack 1938, 1954, 1969) (text-fig. 6). The spatial distribution of foraminifera during the Silurian was compiled to infer the relationship between paleolatitude and possible paleoenvironments that favor particular foraminiferal associations (Table 2). The comparison of the foraminifera is only applied to the genus level, since only limited comparative studies have been conducted for Silurian foraminifera. A more comprehensive synthetic study needs to be carried out to map faunal provinces at the species level.

More than 20 genera of the early Silurian foraminifera found in Saudi Arabia exhibit a global distribution. These taxa can be classified as cosmopolitan, and are represented mainly by *Thuramminoides*, *Psammosphaera*, *Lagenammina*, *Thurammina*, *Saccammina*, *Sorosphaera*, *Hyperammina*, and *Webbinoidea*. Generally speaking, we recognize two faunal provinces. The Austral (Gondwanan) province consists of monothalamid foraminifera with rare tubothalamids and globothalamids. The ‘classical’ Laurentian faunas described from the midwestern states of the USA were located in the southern subtropical province affected by the southeasterly trade winds during the early Silurian (Zaleha 2018). The subtropical faunal province (Laurentia and Avalonia) contains abundant monothalamids and tubothalamids but lacks globothalamids. According to Conkin and Conkin (1982), the earliest North American litoiids are not found until the early Mississippian. Early Silurian assemblages from western Ireland are numerically dominated by ammodiscids (*Rectoammodiscus*) with subdominant hyperamminids (Kaminski et al. 2016). Likewise the early Silurian assemblage from the Welsh

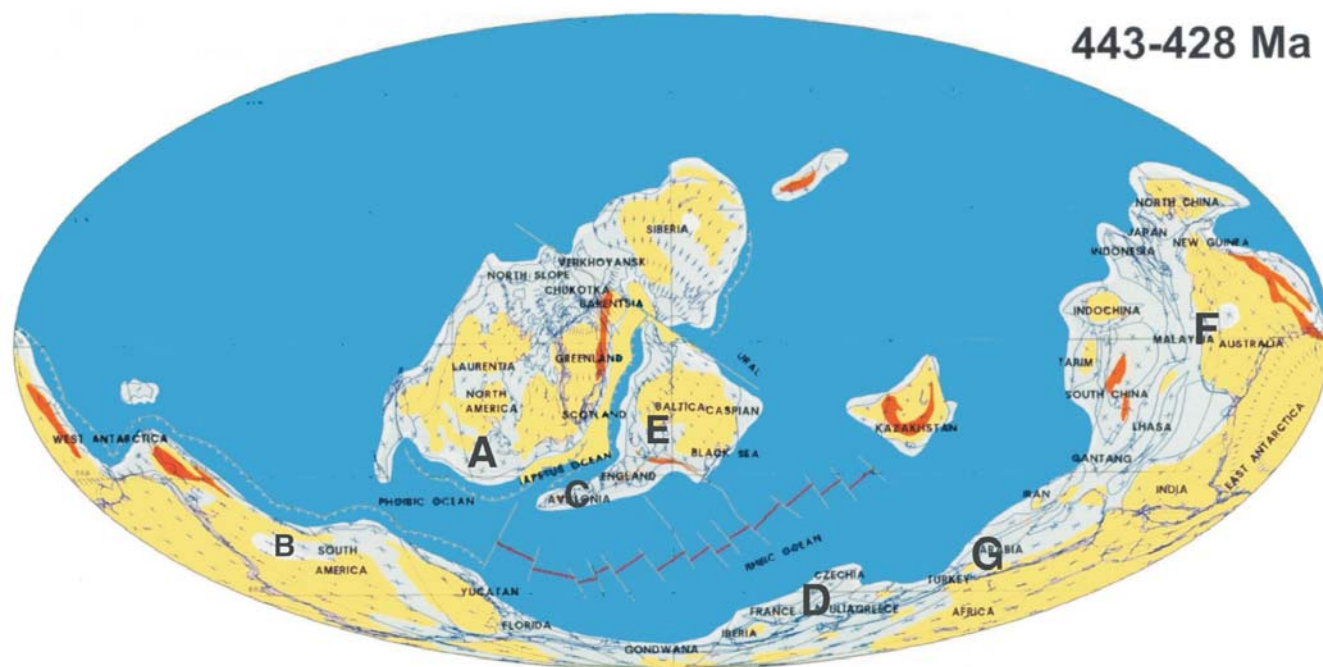
borderlands and English West Midlands is reported to be a diverse *Ammodiscus* assemblage (Kircher and Brazier 1989). A number of taxa that were thought to be cosmopolitan, i.e., *Ammodiscus*, *Rectoammodiscus*, *Glomospira*, *Lituotuba* and *Tholosina*, which are common in various parts of North America (Conkin and Conkin 1982) and NW Europe (Mabillard and Aldridge 1982; Kaminski et al. 2016), have not been found in Saudi Arabia.

An early origin for the multichambered globothalamids

The fossil record of agglutinated foraminifera dates back certainly to the early Cambrian, with some reports extending further back to the Ediacarian (Gaucher and Sprechmann 1999; McIlroy et al. 2001; Kaminski et al. 2010), or possibly even to the Cryogenian (Bosak et al. 2011). The earliest known agglutinated forms that may be tentatively ascribed to the foraminifera are the Cryogenian vase-shaped microfossils. In a recent review of these microfossils by Morais et al. (2017), these forms were compared with modern arcellinid testate amoebae. By modifying the projecting apertural neck into a second tubular chamber, such vase-shaped forms may have evolved into rectilinear tubothalamids (*Platysolenites* and *Spirosolenites*), which are present in the early Cambrian of Norway (Føyn and Glaessner 1979). By the middle Cambrian, additional morphologies have been reported from Sardinia by Cherchi and Schroeder (1985), such as round and hemispherical forms (*Psammosphaera* and *Hemisphaerammina*) and tubular forms including *Hyperammina*. Foraminifera are usually rare in Lower Paleozoic rocks and are mostly reported from acid residue of samples studied for non-calcareous microfossils. The mean standing diversity of agglutinated foraminifera grew slowly but steadily during the early Phanerozoic from the Cambrian to the Ordovician, reaching a stable plateau of around 50 genera in the mid-Silurian (Kaminski et al. 2010).

The first appearance of multichambered foraminifera remains problematic, and depends upon how a multichambered foraminifer is best defined. A pseudo-multichambered foraminifer has primitive chambers formed by simple constrictions of the test wall. The wall itself is continuous between chambers, just as the outer casing of a string of sausages represents one continuous sheath. The first pseudo-multichambered form is reported to be the genus *Ammolagena* from the lower part of the Middle Ordovician (Eisenack 1954; Kaminski et al. 2009). The genus *Lituotuba* is listed by Conkin and Conkin (1982) from the early Silurian of North America – this form has an undivided chamber in its early stage with pseudochambers in its later stage, and therefore is now classified as a tubothalamid (Kaminski 2014). An agglutinated foraminifer displaying sausage-like constrictions (i.e., *Subreophax*) has been illustrated from the upper Silurian (upper Pridolian) of Sardinia by Gnoli and Serpagli (1984, pl. 1, figs. 10, 15), and more recently the genus *Subreophax* has been reported from the upper Ordovician (Katian age) Ra’an Shale Member of the Qassim Formation in Saudi Arabia (Kaminski et al. 2019).

The first agglutinated foraminifer with true overlapping chambers was widely regarded to be the genus *Reophax*. The oldest report of the genus is the Late Ordovician (Sandbian) species *Reophax blackriveranus* described by Gutschick (1986) from the Mifflin Formation of Illinois (USA). The presence of *Reophax* in the Upper Ordovician was recently confirmed by Kaminski et al. (2019) in their study of the Ra’an Shale in Saudi Arabia. Mound (1968) reported a species of *Reophax* from the



TEXT-FIGURE 6

Paleogeographical position of previously studied Early Silurian foraminiferal assemblages. A. Central United States (Moreman 1930; Dunn 1942); B. Bolivia (Gagnier et al. 1996); C. Western Ireland (Kaminski et al. 2016); D. Czech Republic (Holcová 2002); E. Baltic Region (Eisenack 1954); F. Western Australia (Bell et al. 2000); G. this study.

Silurian Salamonie Dolomite of Indiana that was misidentified as *Reophax elongatus* Grzybowski.

According to Conkin and Conkin (1982), the oldest coiled multichambered lituolid is the genus *Oxinosia* (type species *O. botrys* Gutschick, Wiener and Young 1961), reported from the Mississippian (Kinderhookian) Sappington Limestone in Montana by Gutschick (1962). This taxon is an attached form like *Ammolagena*, but the second chamber embraces and overlaps the neck of the previous one. However, its origin is still uncertain. According to Conkin et al. (1965) and Conkin and Conkin (1982), the species “*Oxinosia ligula*” (= *Saccammina ligula* Gutschick, Wiener and Young 1961), begins with a single-chambered “form A” in the upper part of the Middle Devonian, the multichambered “form B” begins with a poorly developed two-chambered form in the Tioughniogan (=Givetian), and multichambered forms of “*O. ligula* form B” are present in the Upper Devonian Louisiana Limestone and in the Lower Mississippian (Kinderhookian). However, Loeblich and Tappan (1987) did not uphold the synonymy of *Saccammina ligula* with the type species *Oxinosia botrys*, and reported the origin of *Oxinosia* in the Upper Devonian. We regard *Saccammina ligula* as belonging in the genus *Lagenammina*.

The earliest coiled multichambered globothalamids belonging to the genera *Ammobaculites* and *Trochammina* were reported by Conkin and Conkin (1982) as ranging from the Early Mississippian (Kinderhookian). There is a report of a species of *Haplophragmoides* from the Lower Devonian Rabbit Hill Formation of Nevada (McClellan 1973), but the species is poorly

illustrated and based on a single specimen, and is therefore questionable. A more recent study by Holcová (2002) recorded the occurrence of three species belonging to the genus *Ammobaculites* in the Lower Devonian in the Czech Republic, which at the time was a Gondwanan terraine. Two unnamed species were found in the Dvorce-Prokop Limestone of Pragian age. Another species identified by Holcová as *Ammobaculites* aff. *leptos* from the Dalejian (= upper Emsian) Třebotov Limestone is most similar to our specimens of *Ammobaculites* from the Qusaiba Shale. Our finding of *Ammobaculites* in the Qusaiba Shale pushes back the known origin of the lituolid foraminifera by more than 40 m.y. to the early Silurian (Aeronian). This new date of 440 Ma for the origin of multichambered foraminifera is 90 million years older than the age adopted by Pawlowski et al. (2003, fig. 1) in their phylogenetic tree of the foraminifera based on partial small subunit rRNA gene sequences. This evolutionary event apparently took place on the shelf of Gondwana rather than in the subtropics.

SYSTEMATIC PALEONTOLOGY

The higher systematics of the agglutinated foraminifera utilized in this study are taken from the updated classification of Kaminski (2014). We use the terminology for the three groups of foraminifera (monothalamids, tubothalamids, and globothalamids) defined by Pawlowski et al. (2013), at the level of a subclass, whereas the taxonomy of agglutinated foraminiferal genera and species is based to a large extent on the classic papers of Moreman (1930, 1933), Ireland (1939), Grubbs (1939), Stewart and Priddy (1941), and Dunn (1942), as well as the taxonomic monographs of Conkin (1961), McClellan (1966), Loeblich and

Tappan (1987), and Holcová (2002). New taxa from the Qusaiba Shale were described by Kaminski and Perdana (2017b). The data matrix with the abundance species in each sample is given in the Supplementary Materials. All the species listed below were recovered from the Qusaiba Shale outcrop near Qusaiba old Village, Qassim District, Saudi Arabia.

Class FORAMINIFERA d'Orbigny 1826
Subclass MONOTHALAMANA Pawlowski, Holzmann and Tyszká 2013
Order ASTORRHIZIDA Lankester 1885
Suborder ASTORRHIZINA Lankester 1885
Family RHABDAMMINIDAE Brady 1884
Genus *Rhabdammina* M. Sars in Carpenter 1869

Rhabdammina trifurcata Moreman 1933
Plate 1, figure A

Rhabdammina trifurcata MOREMAN 1933, p. 394, pl. 47, figs. 1, 2. – KAMINSKI et al. 2019, p. 28, pl. 1, figs 1-2.

Material: Five specimens from three samples (Appendix 1).

Dimensions: Width 156–236 µm, length 250–437 µm.

Remarks: Some of our specimens may exhibit different diameter of the arms. They sometimes possess one larger arm, and two smaller arms of similar diameter.

Stratigraphic range: Late Ordovician (Moreman 1933) to Silurian (Bell et al. 2000).

Geographic distribution: This species was first recovered from the Upper Ordovician (Katian) Viola Formation of Oklahoma, USA (Moreman 1933), from the Upper Ordovician (Katian) Ra'an Shale Member of the Qassim District in Saudi Arabia, and from the Silurian of New South Wales, Australia (Bell et al. 2000).

Family BATHYSIPHONIDAE Avnimelech 1952
Genus *Bathysiphon* Sars 1872
Type species. *Bathysiphon filiformis* G.O. and M. Sars 1872

***Bathysiphon* sp. 1**
Plate 1, figures B–C

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 26 specimens from eight samples (Appendix 1).

Dimensions: Length 156.3–212.5 µm, width 43.75–187.5 µm

Description: Test monothalamous, tubular, elongate, with slightly smaller diameter at the initial stage and constant toward the end. Wall composed of fine siliceous particles. Aperture at the open ends of the tube.

Remarks: All of our specimens are broken fragments.

?*Bathysiphon* sp. 2
Plate 1, figure D

Type horizon: lower Silurian (Aeronian), Qusaiba Formation.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: A single specimen from sample Q1G.

Dimensions: Length 430 µm, width 218.75 µm.

Description: Test free, elongate, monothalamous, with constant diameter. Wall thick, made of fine quartz grains. Aperture at the open ends of the tube.

Remarks: Our specimen is broken, and therefore the generic determination is tentative. This form is rare in the middle part of the studied succession.

***Bathysiphon* sp. 3**
Plate 1, figures E–F

Type horizon: Lower Silurian (Aeronian), Qusaiba Formation.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Nine specimens from five samples (Appendix 1).

Dimensions: Length 156.3–656.3 µm, width 120–218.7 µm.

Description: Test free, tubular unbranching form, with constant diameter, Wall thin, composed of finely agglutinated particles, with a mottled surface. Aperture at the open ends of the tube.

Remarks: Specimens consist of broken fragments, due to the fragile nature of the *Bathysiphon* test. Individual tests vary in size.

Family HIPPOCREPINELLIDAE Loeblich and Tappan 1984
Genus *Amphitremoida* Eisenack 1938, emend. Nestell and Tolmacheva 2004

Type species. *Amphitremoida citroniforma* Eisenack 1938

Amphitremoida citroniforma Eisenack 1938
Plate 1, figures G–I

Amphitremoida citroniforma EISENACK 1938, p. 235, pl. 15, figs. 27–28; pl. 16, fig. 12. – EISENACK 1954, p. 55, pl. 3, figs. 14–16; pl. 4, figs. 12–13. – EISENACK 1969, p. 30, figs 19, 38–41, 44. – RIEGRAF and NIEMEYER 1996, p. 30, figs 19, 38–41, 44. – KAMINSKI et al. 2019, p. 30, pl. 1, fig. 6.

Material: 242 specimens from 13 samples (Appendix 1).

Dimensions: Length 156–218 µm, width 125–281 µm.

Remarks: Some of our specimens compare well to the description of Eisenack (1938). Deformed specimens may have a median depression oriented to the long axis of the test. *Amphitremoida citroniforma* is one of the most common foraminifera recovered from the middle part of the studied succession.

Stratigraphic range: Middle Ordovician (Darriwilian) (Riegraf and Niemeyer 1996) to early Silurian (Aeronian) (this study).

Geographic distribution: This species was first recovered from glacial boulders found on the Samland Peninsula, in the former East Prussia (Eisenack 1938). Eisenack (1954) erected a neotype for *Amphitremoida citroniforma* and corrected its reported age. The neotype is from a glacial pebble from the Ordovician “Baltic limestone”, which according to Nestell and

Tolmacheva (2004) is equivalent to the Lyckholm Formation (upper Caradoc to lower Ashgill) of Estonia. Riegraf and Niemeyer (1996) reported the species from the Plettenberger Bänderschiefer (*Didymograptus bifidus* zone) of northwestern Germany.

Amphitremoida eisenacki Conkin and Conkin 1964
Plate 1, figures J-N

Amphitremoida eisenacki CONKIN and CONKIN 1964, p. 7, pl. 12, figs. 8-10.

Material: 39 specimens from three samples collected from the top of the studied sections (Appendix 1).

Dimensions: Length 169–487 µm, width 125–287 µm.

Description: Test free, fusiform, compressed laterally, possessing two apertures located at both ends, wall thin, made up of medium to coarse quartz grains creating a rough surface.

Remarks: Compared to the specimens described by Conkin and Conkin (1964, pl. 1, figs. 8-10) from the Devonian Louisiana Limestone, our specimens can be broader across the middle part of the chamber. Some specimens are asymmetrical, and/or may exhibit truncation at one or both apertural ends. Wall composed of medium to coarse agglutinated particles. The species was only found in the Sharawra Formation.

Stratigraphic range: early Silurian (Aeronian) (this study) to Late Devonian (Conkin and Conkin 1964).

Geographic distribution: Originally described from the Upper Devonian Louisiana Limestone of Missouri (Conkin and Conkin 1964).

***Amphitremoida* sp. 1**
Plate 1, figures O-P

Type horizon: Lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 22 specimens (Appendix 1).

Dimensions: Length 150–212.5 µm, width 106–125 µm.

Description: Test free, fusiform to oval in outline, flattened, comprised of a single chamber with two rounded apertures situated at the opposite ends of the test. Apertures are located on short necks and surrounded by a low collar. Test wall composed of rough siliciclastic grains, color pale rusty white.

Remarks: The features distinguishing this species from *Amphitremoida eisenacki* Conkin and Conkin 1964, are the more compressed test with distinctly rounded apertures. It differs from *Thurammina foerstei* Dunn 1942 in its more spindle shaped outline, and thick wall consisting of medium-grained agglutinated particles.

***Amphitremoida* sp. 2**
Plate 1, figure Q

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: A single specimen from sample Q1A.

Dimensions: Length 309.2 µm, width 125 µm.

Description: Test monothalamous, elongate and slender, slightly tapering at both ends; test somewhat bent at the center, possessing two apertures situated at each end of the tapering part. Wall agglutinated, with smooth surface, consists of fine siliceous particles.

Remarks: The shape of the test resembles that of *Bathysiphon* and *Stegnammina*.

Suborder SACCAMMININA Lankester 1885

Family STEGNAMMINIDAE Moreman 1930

Genus *Blastammina* Eisenack 1932

Type species. *Blastammina polymorpha* Eisenack 1932

Blastammina vulgaris Bykova 1961
Plate 1, figures R-T

Blastammina vulgaris BYKOVA 1961, p. 21–22, pl. 1, figs 1–5.

Material: Four specimens from sample Q4.

Dimensions: Length 237–278 µm, width 156–194 µm.

Remarks: These specimens do not have a visible aperture(s), and most closely resemble *Blastammina vulgaris* described by Bykova (1961).

Stratigraphic range: Late Ordovician (Caradocian) (Bykova 1961) to Silurian (Aeronian) (this study).

Geographic distribution: First described from the Caradocian of north Kazakhstan by Bykova (1961).

Genus *Ceratammina* Ireland 1939

Type species. *Ceratammina cornucopia* Ireland 1939

Ceratammina cornucopia Ireland 1939

Plate 2, figures A–B

Ceratammina cornucopia IRELAND 1939, p. 196, pl. A, figs. 31–32.

Material: Eight specimens from seven samples (Appendix 1).

Dimensions: Length 219–781 µm, width 163–262 µm.

Remarks: Our specimens closely agree with the holotype described by Ireland (1939).

Stratigraphic range: Silurian (Aeronian) (this study) to Early Mississippian (Conkin and Conkin 1982).

Geographic distribution: This species is reported from North America (Ireland 1939; Mound 1968; McClellan 1973; Conkin and Conkin 1982).

***Ceratammina* sp. 1**
Plate 2, figure C

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: One specimen from sample Q8.

Dimensions: Length 300 µm, width 212 µm.

Description: Test free, monothalamous, chamber size increasing gradually at the initial end, and abruptly broader and crooked at about 1/3 the length to the end of the chamber; aperture not recognized; wall made of fine agglutinated grains.

Remarks: Our specimen is placed in the genus *Ceratammina* in accordance to its shape, which best resembles *Ceratammina cornucopia*, but it differs in having an abrupt bend, and in the larger size of the terminal stage.

***Ceratammina* sp. 2**

Plate 2, figures D-E

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Three specimens from three samples (Appendix 1).

Dimensions: Length 350–687.5 µm, diameter 175–350 µm.

Description: Test free, elongate, with undivided chamber, uniform test size, somewhat bent, exhibiting a nipple like shape in the initial portion of the test. Aperture terminal, indistinct, plugged with sediment. Wall thick, constructed of medium to coarse siliciclastic particles.

Remarks: This species is similar to *Ceratammina cornucopia* Ireland 1939, which differs in having a nipple like shape in the initial portion of the test.

Genus *Raibosammina* Moreman 1930

Type species. *Raibosammina mica* Moreman 1930

***Raibosammina aspera* Moreman 1930**

Plate 2, figure F

Raibosammina aspera MOREMAN 1930, p. 50, pl. 6, figs 13–15.

Material: Two specimens from two samples, Q3 and Q8

Dimensions: Length 275–313 µm, width 125–150 µm.

Remarks: Our specimens compare well to the holotype illustrated by Moreman (1930), but differ in possessing a smoother wall surface.

Stratigraphic range: Late Ordovician (Moreman 1930) to early Silurian (this study).

Geographic distribution: This species was reported from the Viola Limestone of Oklahoma (USA) (Moreman 1930).

Genus *Stegnammina* Moreman 1930

Type species. *Stegnammina cylindrica* Moreman 1930

***Stegnammina contorta* McClellan 1966**

Plate 2, figures G-H

Stegnammina contorta McCLELLAN 1966, p. 476, pl. 36, fig. 17a, b; pl. 40, fig. 17a, b.

Material: 52 specimens from ten samples (Appendix 1).

Dimensions: Length 462.5–580 µm, width 112.5–162.5 µm.

Remarks: Our specimens conform well to the types of McClellan (1966).

Stratigraphic range: early Silurian (Aeronian) (this study) to Middle Silurian (Homerian) (McClellan 1966).

Geographic distribution: This species was first described from the Waldron Shale of Indiana (USA) (McClellan 1966).

***Stegnammina elongata* Ireland 1939**

Plate 2, figures I-K

Stegnammina elongata IRELAND 1939, p. 194, pl. A, fig. 17

Material: 113 specimens from 12 samples (Appendix 1).

Dimensions: Length 375–475 µm, width 162.5–250 µm.

Remarks: The specimen illustrated by Ireland (1939) is identical to ours. Some of our specimens are somewhat curved.

Stratigraphic range: early Silurian (Aeronian) (this study) to Early Devonian (Lochkovian) (Ireland 1939).

Geographic distribution: This species was originally reported from the Lower Devonian Haragan Shale of Oklahoma (USA) (Ireland 1939).

***Stegnammina* sp. 1**

Plate 2, figures L-N

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 34 specimens from five samples (Appendix 1)

Dimensions: Length 212.5–625 µm, width 94–125 µm.

Description: Test free, monothalamous, tubular, with constant dimensions, slightly bent at the terminal stage. Test slightly compressed, test wall constructed of medium to coarse siliceous particles.

Remarks: These specimens resemble *Stegnammina contorta* Moreman, but differ in having a more compressed test.

***Stegnammina* sp. 2**

Plate 2, figure O

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: One specimen from sample Q7.

Dimensions: Length 337.5 µm, width 187.5 µm.

Description: Test free, monothalamous, rhomboid in outline, laterally compressed; aperture not visible; wall agglutinated, constructed by fine quartz particles.

Remarks: This specimen is placed into *Stegnammina* because of its shape and the lack of a distinct aperture, which distinguishes it from the single aperture observed in *Saccammina* and *Lagenammina*.

***Stegnammina* sp. 3**

Plate 2, figure P

Type horizon: Lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 31 specimens from six samples (Appendix 1).

Dimensions: Length 281–500 µm, width 156–250 µm.

Description: Test free, monothalamous, elongate chamber constant to tapering at both ends; no aperture present, constructed of fine grain siliceous material.

Remarks: The distinguishing feature of this species is the ratio between the length and width of the test of about 2:1.

***Stegnammina* sp. 4**

Plate 2, figure Q

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 130 specimens from six samples (Appendix 1).

Dimensions: Length 162.5–400 µm, width 93–119 µm.

Description: Test free, monothalamous, elongate, slightly flattened, somewhat tapering on one side, showing depression in center of the test parallel to the long axis, apparently thicker at the periphery of the test; no aperture visible; agglutinated wall of medium to coarse particles creating a rough surface.

Remarks: This species is probably a member of the genus *Stegnammina* due to its elongate shape and the absence of an aperture, and its characteristic flattened test.

Genus *Thuramminoides* Plummer 1945, emend. Conkin 1961

Type species. *Thuramminoides sphaeroidalis* Plummer 1945

Thuramminoides sphaeroidalis Plummer 1945, emend. Conkin 1961

Plate 3, figures A–B, E

Thuramminoides sphaeroidalis PLUMMER 1945, p. 218, pl. 15, figs. 4–10. – CONKIN 1961, p. 243, pl. 17, figs 1–10; pl. 18, figs 1–4. – CONKIN et al. 1963, p. 221, pl. 1, figs 16–17. – CONKIN et al. 1968, p. 168, pl. 1, figs 16–17. – HOLCOVÁ 2002, p. 89, pl. 1, figs 1, 2, 4, 6; pl. 2, figs 6, 8, 14; pl. 3, fig. 14; pl. 7, fig. 1; pl. 8, figs 12–15; pl. 9, figs 1, 15–16; pl. 10, fig. 7; pl. 12, fig. 3; pl. 13, fig 5; pl. 14, figs 8–11. – KAMINSKI et al. 2019, p. 31, pl. 1, fig. 10; pl. 2, fig. 1.

Thuramina sphaeroidalis (Plummer 1945). – RIEGRAF and NIEMEYER 1996, p. 26, figs 4–6, 8–11, 14–15, 20–23, 25–31, 45, 58–60, 63.

Material: 1345 specimens from 26 samples (Appendix 1).

Dimensions: Diameter 112.5–787.5 µm.

Remarks: Plummer (1945) originally described *Thuramminoides sphaeroidalis* as possessing a labyrinthic interior, but Conkin (1961) reported that this is not the case. In his emendation of the species based on a study of topotypes from the Pennsylvanian of Texas, Conkin observed that instead, the specimens are hollow and surrounded by a thick test that possesses an inner “centripetal tubular structure”. The tubes may or may not pierce the surface of the test. Conkin transferred the genus from the Saccamminidae to the Astrorhizidae. In this study we follow the classification of Kaminski (2014), and place the genus in the Stegamininae.

In the studied material, *Thuramminoides sphaeroidalis* is the second most abundant taxon, and is commonly present in almost all samples.

Stratigraphic range: early Cambrian (Culver 1991) to Permian (Conkin et al. 1968).

Geographic distribution: This species has been widely reported from West Africa (Culver 1991), North America (Conkin 1961; Conkin et al. 1963, 1968), Europe (Holcová 2002), and Australia (Bell et al. 2000; Dixon and Haig 2004). It is the most abundant species in the Upper Ordovician Ra'an Shale member of the Qassim District, Saudi Arabia (Kaminski et al. 2019).

Thuramminoides ellipsoidalis Kaminski and Perdana **n. sp.**

Plate 3, figures C, D

Thuramminoides sp. 1 KAMINSKI et al. 2019, p. 31, pl. 2, figs 1–2.

Etymology: from the ellipsoidal test shape.

Type material: Holotype (pl. 3, fig. C): deposited in the collections of the European Micropalaeontological Reference Centre, Micropress Europe.

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 214 specimens from six samples (Appendix 1).

Dimensions: Length 162.5–275 µm, width 55–93 µm.

Description: Test free, unilocular, ellipsoidal, with a flattened test depressed in the center and thickened at the peripheral margin. No aperture observed. Wall constructed of medium to coarse grains.

Remarks: This species is assigned to the genus *Thuramminoides* due to its flattened test, depressed in the center and thickened at the periphery. It differs from *Thuramminoides sphaeroidalis* in its generally smaller dimensions and possessing an ellipsoidal test. The diagnostic feature of this species is the ratio of the width and length of the test, which is 1:3.

Stratigraphic range: Upper Ordovician (Katian) Ra'an Shale Member of Saudi Arabia (Kaminski et al. 2019) to Lower Silurian (this study).

Thuramminoides plummerae Kaminski and Perdana 2017

Plate 3, figure F

Thuramminoides plummerae KAMINSKI and PERDANA 2017b, p. 62, pl. 1, figs 17–18. pars. 1945 *Thuramminoides sphaeroidalis* sp. nov. PLUMMER 1945, p. 218, pl. 15, fig. 8.

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 24 specimens from three samples (Appendix 1).

Dimensions: Diameter 187.5–600 µm.

Description: Test free, spheroidal and strongly compressed, bearing several protuberances protruding from the periphery.

Remarks: These specimens are similar to one of the paratypes of *Thuraminoides sphaeroidalis* Plummer 1945 (pl. 15, fig. 8), which is here assigned to this species due to the distinctive protuberances at the margin of the test.

Family HEMISPHAERAMMINIDAE Loeblich and Tappan 1961, emend. Mikhalevich 1995

Genus *Hemisphaerammina* Loeblich and Tappan 1957

Type species. *Hemisphaerammina batalleri* Loeblich and Tappan 1957

Hemisphaerammina casteri McClellan 1966

Plate 3, figure N

Hemisphaerammina casteri McCLELLAN 1966, p. 486, pl. 38, figs. 1a, b; pl. 42, figs 1a, b.

Materials: Three specimens from sample Q6.

Dimensions: Maximum diameter 237.5–262.5 µm, minimum diameter 162.4–187.5 µm.

Remarks: Our specimens conform well to the type specimens illustrated by McClellan (1966).

Stratigraphic range: early Silurian (Aeronian) (this study) to middle Silurian (Homerian) (McClellan 1966).

Geographic distribution: This species was first reported from the Waldron Shale of Indiana (USA) (McClellan 1966).

***Hemisphaerammina* sp. 1**

Plate 3, figures G-K

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim Region, Saudi Arabia.

Material: 18 specimens from 11 samples (Appendix 1).

Dimensions: Diameter 112.5–237.5 µm.

Description: Test monothalamous, of planoconvex shape, aperture not observed; wall thin, constructed of fine to medium grains.

Remarks: Compared with *Hemisphaerammina cecillalickeri* Conkin and Conkin 1981, our specimens have thinner wall and more planoconvex test. In addition, some of our specimens have a flange.

***Hemisphaerammina* sp. 2**

Plate 3, figure L

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Materials: One specimen from sample Q2.

Dimensions: Length 150 µm, width 100 µm.

Description: Test attached, monothalamous, planoconvex in shape, somewhat acute at the edges of the chamber, no aperture apparent. Wall agglutinated, constructed of fine to medium particles.

Remarks: Compared with *Hemisphaerammina batalleri* Loeblich and Tappan 1957 and *Hemisphaerammina casteri* McClellan 1966, our specimen is more hemispherical in outline and acute at the edges.

***Hemisphaerammina* sp. 3**

Plate 3, figure M

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: One specimen from sample Q8.

Dimensions: Length 206 µm, width 125 µm.

Description: Test or attached, monothalamous, planoconvex in shape, chamber constricted at the center, separate the blunt hemisphere from the bigger and slightly tapering one. No distinct aperture. Wall thin, made of fine to medium size siliceous particles.

Remarks: Our specimen resembles *Sorosphaera bicella* described by Dunn (1942), but it does not have exactly two separated chambers.

Family SACCAMMINIDAE Brady 1884

Genus *Lagenammina* Rhumbler 1911

Type species. *Lagenammina laguncula* Rhumbler 1911

Lagenammina* aff. *cumberlandiae (Conkin 1961)

Plate 4, figures A-B

aff. *Proteonina cumberlandiae* CONKIN 1961, p. 248, pl. 19, figs 1-3; pl. 26, figs 4,5; figs. 2,3.

aff. *Lagenammina cumberlandiae* (Conkin 1961). – McCLELLAN 1966, p. 477, pl. 36, fig. 19; pl. 40, fig. 19. – MABILLARD and ALDRIDGE 1982, p. 132, pl. 1, fig. 11.

Material: Three specimens from sample Q0.

Dimensions: Length 375–500 µm, width 212.5–262.5 µm.

Remarks: Our specimens have a shorter neck, are more compressed, and coarser wall texture compared with the holotype of *Lagenammina cumberlandiae* described by Conkin (1961).

Stratigraphic range: early Silurian (Aeronian) (this study) to Mississippian (Conkin 1961).

Geographic distribution: This species was first reported from the New Providence Formation of Kentucky, southern Indiana, and Ohio (USA) (Conkin 1961). McClellan (1966) and Mabillard and Aldridge (1982) also reported *Lagenammina cumberlandiae* from the Silurian of Indiana, and the Wenlock area, Shropshire England, respectively.

Lagenammina ligula (Gutschick, Weiner and Young 1961)

Plate 4, figures C–D

Saccammina ligula GUTSCHICK, WEINER and YOUNG 1961, p. 1207, pl. 150, figs 3, 6, 8, 11. – GUTSCHICK 1962, p. 1297, text-fig. 2a-c.

Material: 22 specimens from seven samples (Appendix 1).

Dimensions: Length 150–375 µm, width 112–281 µm.

Remarks: We follow McClellan (1966), who regarded that *Lagenammina* differs from *Saccammina* in having a pyriform shape and a neck. Compared with the specimens of Gutschick et al. (1961), some of our specimens have an ovoid to ellipsoidal shape, are laterally compressed, and possess a rough surface.

Stratigraphic range: early Silurian (Aeronian) (this study) to Mississippian (Gutschick 1962).

Geographic distribution: This species was reported previously from Oklahoma (Pontotoc County), the Sappington Formation of Montana, the Rockford Shale of southern Indiana, and the Chappel Limestone of central Texas (Gutschick 1962).

***Lagenammina silnica* Malec 1992**

Plate 4, figure E

Lagenammina silnica MALEC 1992, p. 280–281, pl. 1, figs 1, 4; pl. 2, figs 1-3; pl. 3, figs 5, 8.

Material: 24 specimens from nine samples (Appendix 1).

Dimensions: Length 300–337 µm, width 156–237 µm.

Remarks: Our specimens conform well to the description of the species by Malec (1992).

Stratigraphic range: early Silurian (Aeronian) (this study) to Early Devonian (Emsian) (Malec 1992).

Geographic distribution: This species was first described from the D browa borehole in southeastern Poland (Malec 1992).

***Lagenammina* sp. 1**

Plate 4, figure F

Type horizon: Lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 2 specimens from two samples (sample Q0 and Q12)

Dimensions: Length 375–562.5 µm, width 125–200 µm.

Description: Test free, monothalamous, elongate, consists of a single undivided chamber. The maximum width of the specimen is across the lower third of the chamber, which tapers toward the apertural end. The central part of the test is depressed. Aperture terminal, situated at the open end of the elongated chamber. Wall thin, composed of fine siliceous particles.

Remarks: This species is similar to the younger species *Saccammina scutella* Malec 1992 and *Lagenammina cumberlandiae*, but has distinct differences in having a depression and a smoother test constructed of fine-grained material.

***Lagenammina* sp. 2**

Plate 4, figure I

Type horizon: Lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Materials: Two specimens from sample Q0.

Dimensions: Length 200–218 µm, width 175–187.5 µm.

Description: Test free, monothalamous, spherical in shape with a short neck with a terminal aperture, test slightly compressed, composed of medium to coarse quartz particles.

Remarks: Our specimens have finer wall material and a more compressed test compared with *Lagenammina ampulacea* Crespin 1961 [pl. 66, figs 6–8] from the Devonian Virgin Hills Formation of Western Australia.

***Lagenammina* sp. 3**

Plate 4, figures K, L

Type horizon: Lower Silurian (Aeronian), Qusaiba shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Two specimens from sample Q8.

Dimensions: Length 400–487 µm, width 212.5–350 µm.

Description: Test free, monothalamous, elongated, laterally compressed, tapering toward the neck, with a terminal aperture situated at the end of a short neck. Wall thick, white in color, composed of fine siliciclastic particles.

Remarks: These specimens are placed in the genus *Lagenammina* because the chamber tapers toward the aperture, which is located at the end of a short collar-like neck.

Genus *Saccammina* Carpenter 1869

Type species. *Saccammina sphaerica* Brady 1871

***Saccammina aspera* Stewart and Priddy 1941**

Plate 4, figures G-H

Saccammina aspera STEWART and PRIDDY 1941, p. 372, pl. 54, fig. 13.

Materials: 43 specimens from nine samples (Appendix 1).

Dimensions: Length 225–262.5 µm, width 187.5–237.5 µm.

Remarks: This species is distinguished by its rounded-pentagonal outline and circular aperture on a short neck. Our specimens have a smoother test wall compared to the holotype of Stewart and Priddy (1941).

Stratigraphic range: early Silurian (Aeronian) (this study) to middle Silurian (Conkin and Conkin 1982).

Geographic distribution: Stewart and Priddy (1941) described the species from the lower Laurel Limestone of Indiana (USA).

***Saccammina* sp. 1**

Plate 4, figure J

Type horizon: Lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Materials: 12 specimens in two samples from the top of the studied section, Q0 and Q1B.

Dimensions: Diameter 214–412 µm.

Description: Test free, monothalamous, consists of spherical single chamber, shows lateral compression that makes the test flat-

tened, aperture terminal at the end of a short neck. Wall composed of medium to coarse siliciclastic grains.

Remarks: This species is close to *Saccammina moremani* (Ireland 1939, fig. A12) a Silurian taxon from the Chimney Hill Limestone of Oklahoma, but differs in its smaller dimensions and smaller aperture with a shorter neck.

Genus *Saccammina* Kaminski and Perdana 2017

Type species. *Saccammina galinae* Kaminski and Perdana 2017

Saccammina galinae Kaminski and Perdana 2017

Plate 5, figures A-D

Saccammina galinae sp. nov. KAMINSKI and PERDANA 2017b, p. 60, pl. 1, figs. 1–3. – KAMINSKI et al. 2019, p. 32, pl. 2, fig. 4.

Material: Three specimens from sample Q1G.

Dimensions: Length 312.5–375 µm, maximum width 112.5–156.25 µm.

Description: Test free, monothalamous, elongate, with a uniform undivided chamber, laterally compressed, tapering slightly at both ends. The ratio of width to length is approximately 1:3, with maximum width approximately in the central part of the test. Aperture a round opening at the end of a short apertural neck at one end of the test. Wall agglutinated, consists of fine quartz grains.

Remarks: The shape of the test resembles that of *Amphitremoida simelkuhensis* Nestell and Ghobadi Pour, from the Ordovician of Iran (Nestell et al. 2016), but it differs in possessing only a single aperture.

Stratigraphic range: Late Ordovician (Katian) (Kaminski et al. 2019) to early Silurian (Aeronian) (this study).

Geographic distribution: Until now, the species has only been found in the Qassim District of Saudi Arabia (Kaminski and Perdana 2017b; Kaminski et al. 2019).

Genus *Thurammina* Brady 1879

Type species. *Thurammina papillata* Brady 1879

Thurammina arcuata Moreman 1930

Plate 5, figure E

Thurammina arcuata MOREMAN 1930, p. 54, pl. 6, figs 2, 3. – HOLCOVÁ 2002, p. 96, pl. 16, fig. 11.

Materials: Ten specimens in five samples (Appendix 1).

Dimensions: Diameter 137.5–281.5 µm.

Remarks: Our specimens conform well to the holotype described by Moreman (1930), and specimens described by Holcová (2002).

Stratigraphic range: early Silurian (Aeronian) (this study) to Early Devonian (Dalejan = Emsian) (Holcová 2002).

Geographic distribution: First reported from the Chimney Hill Formation, Oklahoma, USA (Moreman 1930), and from the Trebotov Limestone of the Czech Republic (Holcová 2002).

Thurammina holcovae Kaminski and Perdana 2017

Plate 5, figure F

Thurammina holcovae KAMINSKI and PERDANA 2017b, p. 61, pl. 1, fig. 14.

Thurammina triradiata Gutschick and Treckman 1959. – HOLCOVÁ 2002, p. 97, text-fig. 15g, pl. 4, fig. 3, pl. 16, fig. 4.

Material: Seven specimens from five samples (Appendix 1).

Dimensions: Diameter 156–200 µm.

Description: Test free, rounded-triangular in outline, with three tapering neck-like projections situated at the corners of the triangle. Apertures circular, at the end of the projections. Wall finely agglutinated, translucent, with medium-size grains.

Remarks: These specimens differ from *Thurammina triradiata* Gutschick and Treckman 1959, emended by Conkin et al. (1968) in their more triangular outline, and having apertures situated at the apex of the triangle. Our specimens are most similar to the Devonian (Pragian) specimen illustrated by Holcová (2002) as *Thurammina triradiata*. Holcová's specimen has an inflated chamber, with short tubes serving as apertures located at each corner.

Stratigraphic range: Early Silurian (Aeronian) (this study) to Early Devonian (Pragian) (Holcová 2002).

Geographic distribution: Holcová (2002) reported the species from the Lower Devonian of the Czech Republic.

Thurammina papillata Brady 1879

Plate 5, figure G

Thurammina papillata BRADY 1879, p. 45, pl. 6, figs 4–8. – HOLCOVÁ 2002, p. 96, pl. 16, fig. 11.

Material: 33 specimens from eleven samples (Appendix 1).

Dimensions: Diameter 94–187.5 µm.

Remarks: Our specimens compare well with the specimens illustrated by Holcová (2002). However, our specimens have fewer protuberances than Holcová's plesiotype.

Stratigraphic range: Silurian to Recent.

Geographic distribution: Barrandian area, Czech Republic (Holcová 2002) and Saudi Arabia (this study).

Thurammina pentagona Kaminski and Perdana 2017

Plate 5, figures H-J

Thurammina pentagona KAMINSKI and PERDANA 2017b, p. 61, pl. 1, figs 8–9.

Material: Five specimens from three samples (Appendix 1).

Dimensions: Diameter 175–250 µm.

Description: Test free, monothalamous, rounded-pentagonal in outline, slightly inflated, with five small neck-like projections situated at the corners of the pentagon. Apertures circular, at the end of the projections. Wall finely agglutinated, translucent, with fine to medium-size grains.

Remarks: Our species most closely resembles *Thurammina hexagona* Dunn (1942), which differs in having an extra aper-

ture located at the periphery of the test and its hexagonal rather than pentagonal outline.

Stratigraphic range: lower Silurian (Aeronian) (this study).

Geographic distribution: Qassim District of Saudi Arabia.

***Thurammina(?)* sp. 1**

Plate 5, figure K

Type horizon: Lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: One specimen from sample Q4.

Dimensions: Length 212.5 μm , width 187.5 μm .

Description: Test free, monothalamous, compressed, a single chamber irregularly rounded-triangular in outline, apertures indistinct, wall composed of fine to medium siliceous grains.

Remarks: This specimen is tentatively placed in the genus *Thurammina* because of its shape.

Family PSAMMOSPHAERIDAE Haeckel 1894

Genus *Psammosphaera* Schulze 1875

Type species. *Psammosphaera fusca* Schulze 1875

***Psammosphaera cava* Moreman 1930**

Plate 5, figure N

Psammosphaera cava MOREMAN 1930, p. 48, pl. 6, fig. 12. – IRELAND 1939, p. 371, pl. 54, figs 8, 9. – DUNN 1942, p. 322, pl. 42, fig. 6. – IRELAND 1966, p. 225, pl. 1, fig. 16. – MOUND 1968, p. 74, pl. 5, figs 13–15. – WATKINS et al. 1999, p. 543, fig. 5: 8–9. – KAMINSKI et al. 2016, p. 118, pl. 1, figs 9–12. – KAMINSKI et al. 2019, p. 32, pl. 2, fig. 5.

Material: 299 specimens from 22 samples (Appendix 1).

Dimensions: Diameter 110–120 μm .

Remarks: Our specimens conform well to those described by Ireland (1939). However, our specimens have a smaller test diameter.

Stratigraphic range: Late Ordovician (Mound 1968) to Late Pennsylvanian (Conkin and Conkin 1982).

Geographic distribution: First described from the Silurian of Oklahoma (USA) by Moreman (1930); it has also been reported from the Upper Ordovician (Katian) of Saudi Arabia (Kaminski et al. 2019), the Silurian of England (Mabillard and Aldridge 1982), Ireland (Kaminski et al. 2016), Sardinia (Gnoli and Serpagli 1984), Australia (Bell et al. 2000), the Lower–Middle Devonian of the Czech Republic (Holcová 2004), and the Upper Devonian of central Poland (Olempska 1983). Conkin and Conkin (1982) reported a questionable occurrence of *P. cava(?)* from the Upper Pennsylvanian.

***Psammosphaera* sp. 1**

Plate 5, figure O

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Materials: 34 specimens from two samples (Q1G and QQ3).

Dimensions: Length 125–187.5 μm , width 62–5–100 μm .

Description: Test free, nearly fusiform single chamber, no aperture visible, the ratio between length and width about 2; wall smooth composed of fine siliceous particles, white in color.

Remarks: These specimens are most similar in outline to a specimen from the Salamonie Dolomite of Indiana identified by Mound (1968, pl. 5, fig. 20) as *Psammosphaera pusilla* Parr, but our specimens are more elongated and have a more finely agglutinated wall.

***Psammosphaera(?)* sp. 2**

Plate 5, figure L

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 3428 specimens from 23 samples (Fig. 3) (Appendix 1).

Dimensions: Diameter 93.8–375 μm .

Description: Test free, monothalamous, discoidal, depressed in the center, and thicker at the periphery; no distinct aperture; wall thin, translucent, composed of fine siliceous grains.

Remarks: This species differs from *Psammosphaera cava* in having a discoidal form, and from *Thuramminoides* in possessing a thin, translucent wall. This species is the most common foraminiferal species recovered from the studied sections.

***Psammosphaera(?)* sp. 3**

Plate 5, figure M

Type horizon: Lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Nine specimens from four samples (Appendix 1).

Dimensions: Diameter 112.5–375 μm .

Description: Test free, monothalamous, triangular to sub-triangular in outline, having a flange; wall thin, translucent, fairly smooth, constructed of minute siliceous particles.

Remarks: This species differs from *Psammosphaera?* sp. 2, in having a rounded-triangular outline, but the nature of the test wall is identical.

Genus *Sorosphaera* Brady 1879

Type species. *Sorosphaera confusa* Brady 1879

***Sorosphaera bicella* Dunn 1942**

Plate 5, figure P

Sorosphaera bicella DUNN 1942, p. 325, pl. 42, figs 11–18. – McCLELLAN 1966, p. 472, pl. 37, figs 3–9; pl. 41, figs 7–9.

Materials: Three specimens from three samples (Appendix 1).

Dimensions: Length 300–337.5 μm , width 187.5–219 μm .

Remarks: Our specimens conform well to the specimens described by Dunn (1942).

Stratigraphic range: Silurian.

Geographic distribution: This species was first described from the Silurian Bainbridge Limestone of Genevieve County, Missouri and the Brassfield Limestone in Joliet, Illinois (USA) (Dunn 1942).

Sorosphaera tricella Moreman 1930

Plate 5, figure Q

Sorosphaera tricella MOREMAN 1930, p. 49, pl. 5, figs 12, 14. – McCLELLAN 1966, p. 472, pl. 37, fig. 10; pl. 41, fig. 10.

Material: One specimen from sample Q4.

Dimensions: Length 250 µm, width 187.5 µm.

Remarks: Our specimen compares well to specimens described by Moreman (1930), but it differs in having chambers of heterogeneous size, and in possessing a basal flange. The species apparently grew attached to the substrate.

Stratigraphic range: Silurian.

Geographic distribution: This species was described by Moreman (1930) from the Chimney Hill Formation, Arbuckle Mountain region, Oklahoma, USA. McClellan (1966) illustrated specimens from the Waldron Shale in Indiana and Kentucky.

Family LACUSTRINELLIDAE Mikhalevich 1995

Genus *Webbinelloidea* G.A. Stewart and Lampe 1947

Type species. *Webbinelloidea similis* G.A. Stewart and Lampe 1947

***Webbinelloidea?* sp. 1**

Plate 6, figures A-B

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Two specimens from sample Q8.

Dimensions: Length 150–175 µm, width 93 µm.

Description: Test attached, monothalamous, consisting of three pseudochambers, ovoid in outline; aperture absent; wall surface smooth, consisting of medium to fine siliciclastic grains.

Remarks: Our specimens differ from the type species in having “hemi-ovoid” rather than hemispherical chambers.

Subclass TUBOTHALAMANA Pawlowski, Holzmann and Tyszk 2013

Order AMMODISCIDA Mikhalevich 1980

Suborder HIPPOCREPININA Saidova 1981

Family HIPPOCREPINIDAE Rhumbler 1895

Genus *Kechenotiske* Loeblich and Tappan 1984

Type species. *Hyperamminoides expansus* Plummer 1945

Kechenotiske* cf. *expansa (Plummer 1945)

Plate 6, figures C-D

cf. *Hyperamminoides expansus* PLUMMER 1945, p. 223, pl. 16, figs 1–6.

cf. *Kechenotiske expansa* (Plummer 1945). – HAIG and MORY 2016, p. 71, figs. 5v, w.

Material: Two specimens from sample Q12.

Dimensions: Length 312.5–437.5 µm, width 250–344 µm.

Remarks: Our specimens are nearly identical to *Kechenotiske expansa*, illustrated by Haig and Mory (2016). Unfortunately our specimens are broken and the proloculi are missing.

PLATE 1

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

A *Rhabdammina trifurcata* Moreman 1933, Sample Q9

B-C *Bathysiphon* sp. 1, Sample Q2

D *Bathysiphon* sp. 2, Sample Q3

E-F *Bathysiphon* sp. 3, Sample Q4

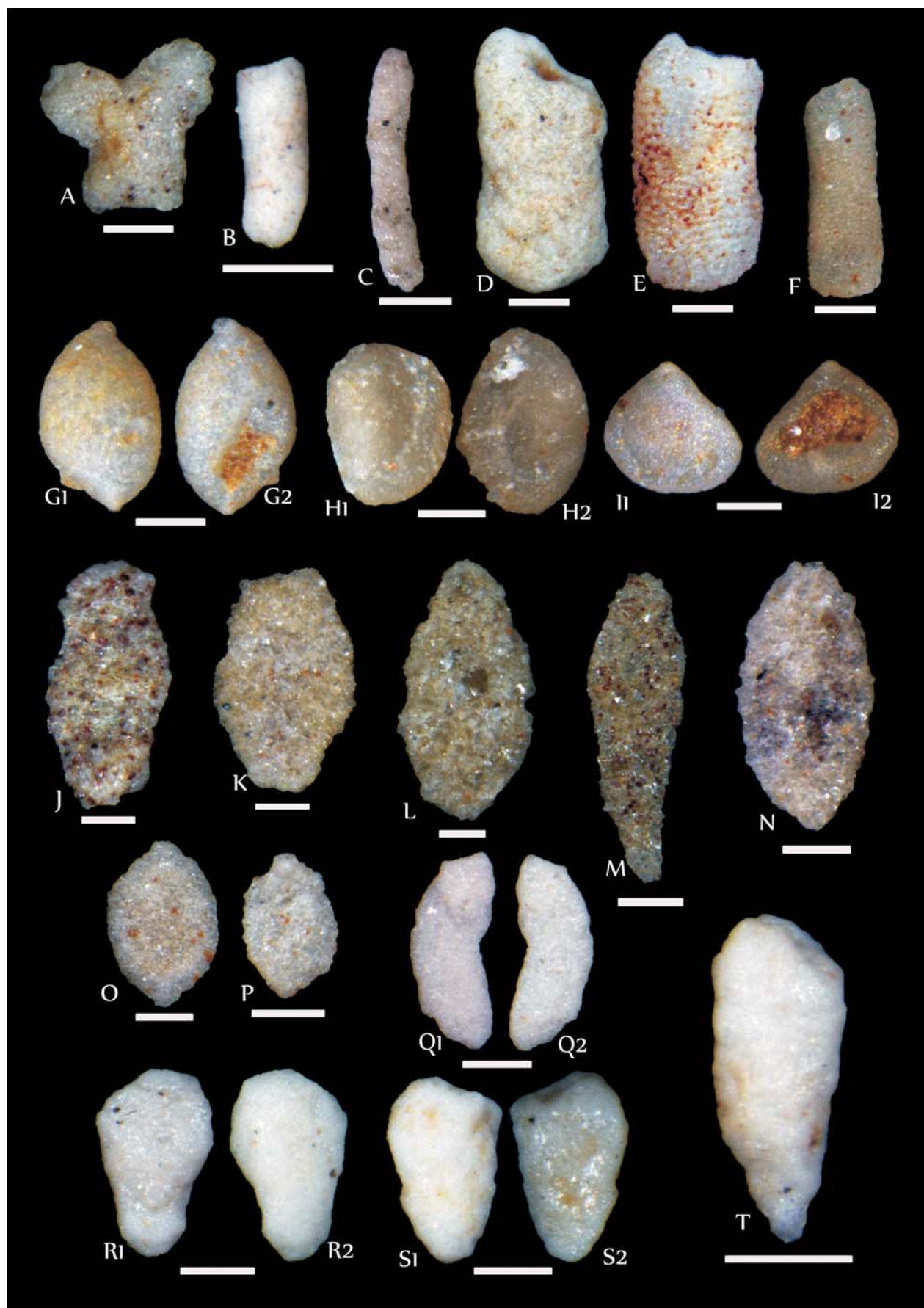
G-I *Amphitremoida citroniforma* Eisenack 1954, Sample Q7

J-N *Amphitremoida eisenacki* Conkin and Conkin 1964, Sample Q0

O-P *Amphitremoida* sp. 1, Sample Q0

Q *Amphitremoida* sp. 2, Sample Q10

R-T *Blastammina vulgaris* Bykova 1961, Sample Q4



Stratigraphic range: Loeblich and Tappan (1987) reported the stratigraphic range of the genus as Late Carboniferous to Early Cretaceous (Neocomian). Kaminski et al. (2019) reported an unnamed species of *Kechenotiske* in the Upper Ordovician (Katian) Ra'an Shale of Saudi Arabia, thereby extending its known range.

Geographic distribution: This species was first reported from the Upper Carboniferous Smithwick Formation, Algerita, Texas, USA (Plummer 1945), and was later found in the Bulgadoo Shale, Baker Formation (Crespin 1958; Haig and Mory 2016) of Western Australia. We report *Kechenotiske* from the Upper Ordovician to lower Silurian of Saudi Arabia.

Family HYPERAMMINIDAE Eimer and Fickert 1899

Genus *Hyperammina* Brady 1878

Type species. *Hyperammina elongata* Brady 1878

Hyperammina sinuosa Kaminski and Perdana 2017

Plate 6, figures E-G

Hyperammina sinuosa KAMINSKI and PERDANA, 2017b, p. 62, pl. 1, figs 4–6.

Material: Four specimens from sample Q1G.

Dimensions: Length 275–437 µm, width 100–112 µm across the tubular chamber.

Description: Test free, tubothalamous, elongate, with a rounded proloculus and an undivided short and bent or meandering tubular second chamber. Proloculus may be slightly wider than the tubular chamber. Aperture terminal, situated at the open end of the tube. Wall thin, constructed of medium to coarse siliceous particles.

Remarks: The species is characterized by its globular proloculus, which is visible in immersion, and its short tubular chamber which may be bent or slightly meandering. The speci-

mens are laterally compressed. Our species differs from the Ordovician species *Hyperammina minuta* Moreman 1930 in possessing a thinner and more coarsely agglutinated wall, and short tubular chamber.

Stratigraphic range: early Silurian (Aeronian) (this study).

Geographic distribution: Saudi Arabia.

***Hyperammina* sp. 1**

Plate 6, figure H

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: A single specimen from sample Q0.

Dimensions: Length 437.5 µm, width 125 µm, proloculus 162.5 µm in diameter.

Description: Test free, tubothalamous, elongate, slightly compressed, with oval and large proloculus followed by slightly tapering second chamber; wall medium- to coarse-grained.

Remarks: Our specimen is broken at the apertural end. It is more coarsely agglutinated than any of the Silurian specimens of *Hyperammina* illustrated by McClellan (1973) or Holcová (2002).

***Hyperammina* sp. 2**

Plate 6, figure I

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: A single specimen from sample Q8.

PLATE 2

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

A-B *Ceratamina cornucopia* Ireland 1939, Sample Q4

C *Ceratamina* sp. 1, Sample Q4

D-E *Ceratamina* sp. 2, Sample Q4

F *Raibosammina aspera* Moreman 1930, Sample Q3

G-H *Stegnammina contorta* McClellan 1966, Sample Q0

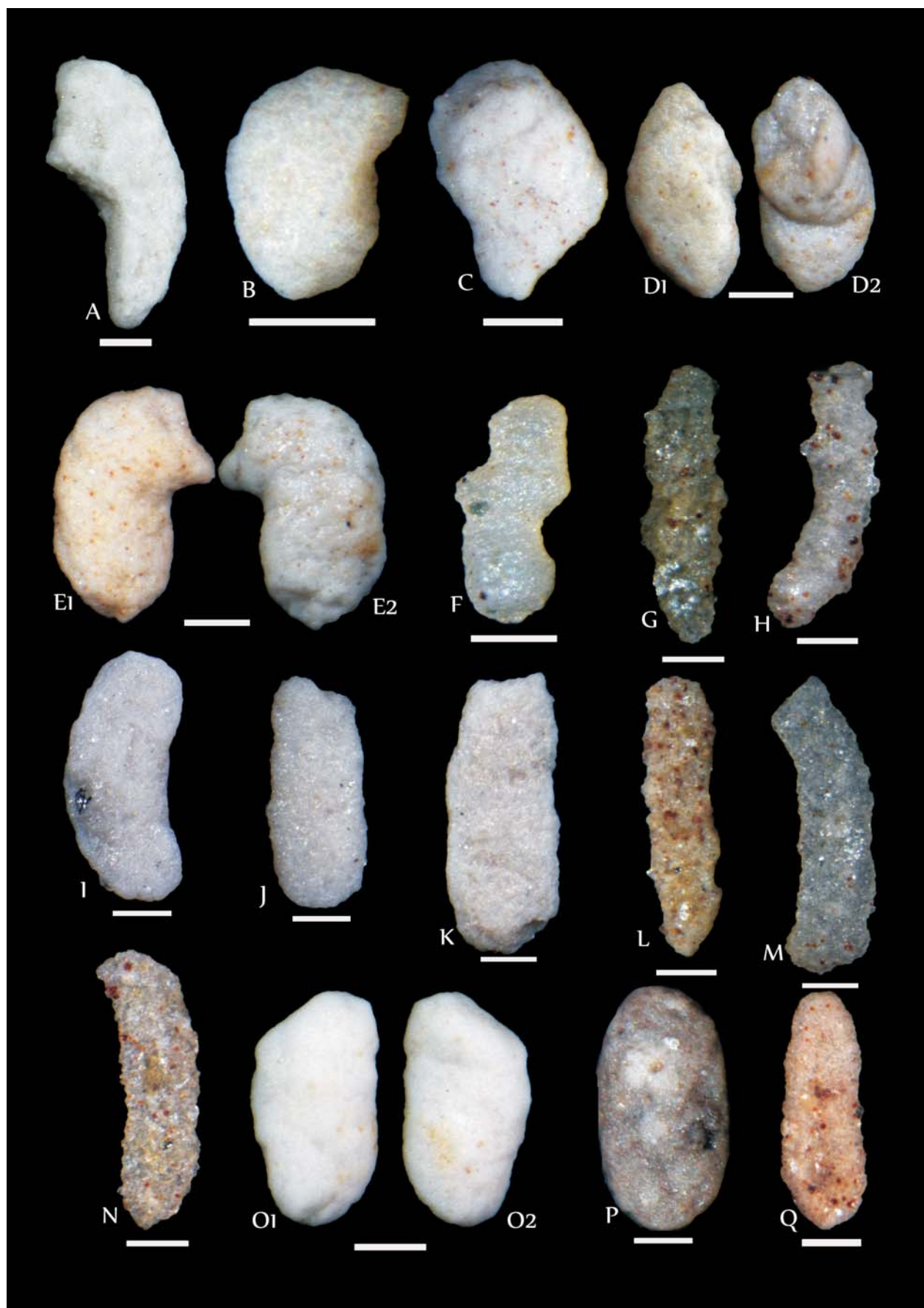
I-K *Stegnammina elongata* Ireland 1939, Sample Q1

L-N *Stegnammina* sp. 1, Sample Q0

O *Stegnammina* sp. 2, Sample Q2

P *Stegnammina* sp. 3, Sample Q8

Q *Stegnammina* sp. 4, Sample Q0



Dimensions: Length 350 µm, width 63 µm, proloculus 75 µm in diameter

Description: Test free, tubothalamous, elongate, slightly bent in the central part, then straightens out. The distal part enlarges in slowly in diameter. Proloculus subglobular. Aperture terminal, a round opening, at the distal end of the tubular chamber. Wall constructed of medium to fine quartz grains.

Remarks: Only a single specimen was found in the studied samples.

Suborder AMMODISCINA Mikhalevich 1980

Family AMMODISCIDAE Reuss 1862

Genus *Ammovertella* Cushman 1928

Type species. Ammodiscus (Psammophis) inversus Schellwien 1898

***Ammovertella* sp. 1**

Plate 6, figure J

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim Region, Saudi Arabia.

Material: One specimen from sample Q4.

Dimensions: Length 612 µm, width 450 µm, proloculus 163 µm in diameter.

Description: Test attached, tubothalamous, proloculus not visible; second chamber compressed, and tightly winding, back and forth, forming a low trochospiral cone. Aperture not visible. Wall composed of fine to medium particles.

Remarks: Only a single specimen from the Qusaiba Shale.

***Ammovertella* sp. 2**

Plate 6, figure K

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim Region, Saudi Arabia.

Material: Two specimens from sample Q6

Dimensions: Length 218 µm, width 150 µm (plesiotype).

Description: Test attached, tubothalamous, consisting of a proloculus, and tubular second chamber winding irregularly around the proloculus in a single plane, proloculus and second chamber separated by a constriction. Tubular chamber increases in diameter gradually toward the distal end.

Remarks: These specimens are classified as *Ammovertella* due to the fact that they wind in a single plane. These specimens were recovered from the middle part of the studied section.

***Ammovertella* sp. 3**

Plate 6, figure L

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District Saudi Arabia.

Material: 12 specimens from five samples (Appendix 1).

Dimensions: Length 237.5–310 µm, diameter 100–110 µm.

Description: Test attached, tubothalamous, with a spherical proloculus continued by a tubular second chamber winding sinusously in one plane, proloculus and second chamber have con-

PLATE 3

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

A,B,E *Thuramminoides sphaeroidalis* Plummer 1945, Sample Q9

C,D *Thuramminoides ellipsoidalis* Kaminski and Perdana, n. sp., Sample Q0. C, Holotype; D, Paratype

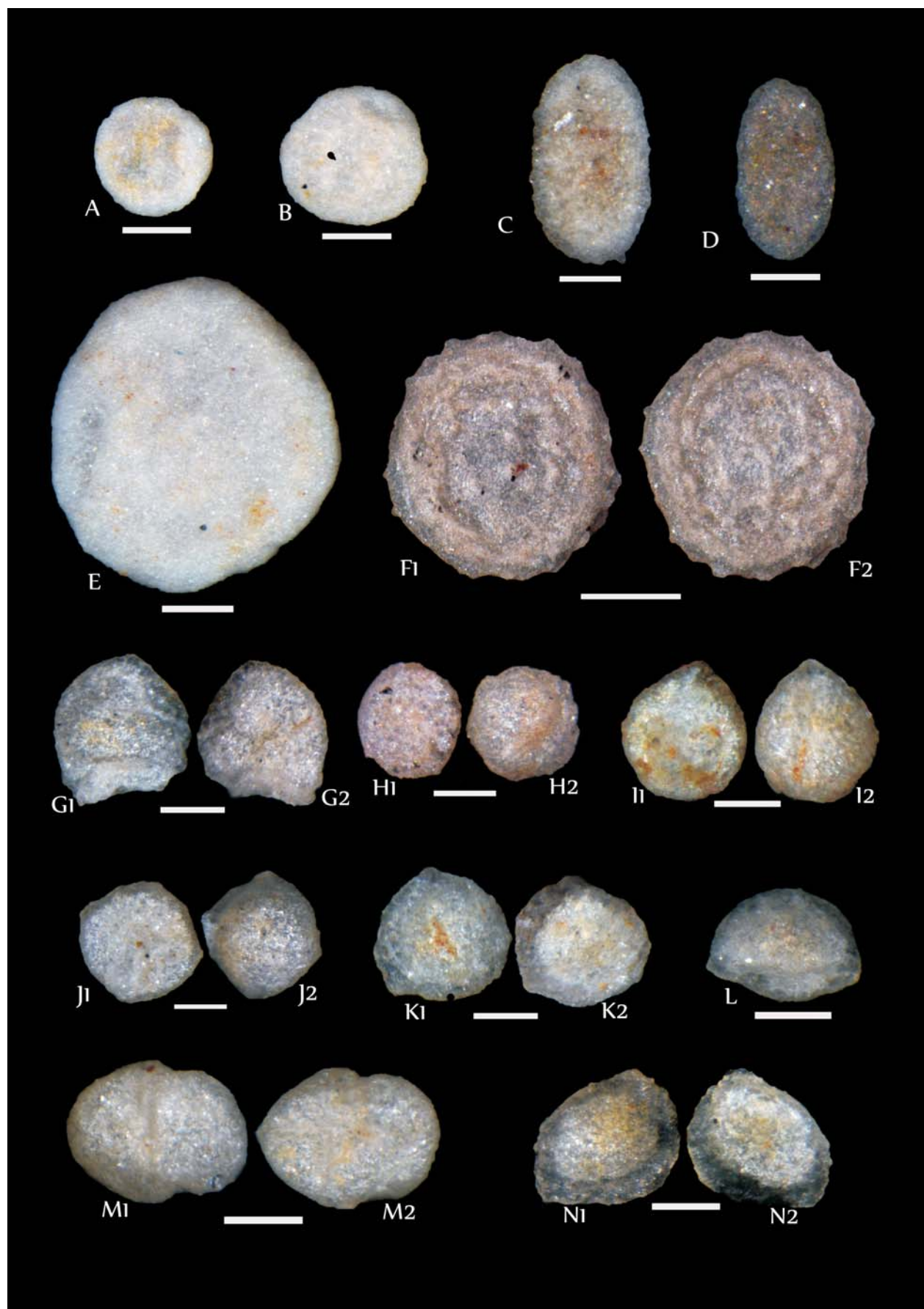
F *Thuramminoides plummerae* Kaminski and Perdana 2017, paratype, Sample Q10

G-K *Hemisphaerammina* sp. 1. G. Sample Q0. H-K. Sample Q6

L *Hemisphaerammina* sp. 2, Sample Q2

M *Hemisphaerammina* sp. 3, Sample Q9

N *Hemisphaeramminaasteri* McClellan 1966, Sample Q6



stant size. Aperture located at the open end of the tube. Wall constructed of fine to medium quartz grains.

Remarks: These broken specimens were recovered from the middle part of the shale succession.

***Ammovertella(?)* sp. 4**

Plate 6, figure M

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: A single specimen from sample Q4.

Dimensions: Test length 312 μm , width 210 μm , second chamber width 87 μm .

Description: Test attached, tubothalamous, fusiform in outline, consisting of undivided bent tubular second chamber that winds irregularly. Wall smooth, made of agglutinated material.

Remarks: This specimen superficially resembles *Lagenammina* in outline but in immersion, the winding second chamber is visible. The chamber is initially zigzag as in *Ammovertella*, but the terminal part forms a trochospiral whorl. For this reason we tentatively assign it to *Ammovertella*.

Genus *Tolypammina* Rhumbler 1895

Type species. *Hyperammina vagans* Brady 1879

Tolypammina aheimerensis Said and Eissa 1969

Plate 6, figure N, Plate 7, figure A

Tolypammina aheimerensis SAID and EISSA 1969, p. 359, pl. 3, figs 8–11.

Material: 23 specimens from five samples (Appendix 1).

Dimensions: Length 274–694 μm , width 112.5–187.5 μm .

Remarks: Proloculus and aperture in our specimens cannot be recognized since they were broken as a result of taphonomic processes. Nevertheless, we consider these specimens as *Tolypammina aheimerensis* due to the uncoiled twisting and the presence of some constrictions on the second chamber.

Stratigraphic range: Silurian (Aeronian) (this study) to Late Pennsylvanian (Said and Eissa 1969).

Geographic distribution: Said and Eissa (1969) first described this species from shales of the Upper Pennsylvanian Abu Darag Formation in Egypt.

Tolypammina* cf. *bulbosa (Gutschick and Treckman 1959), emend. Conkin and Conkin 1964
Plate 7, figure B

Ammovertella bulbosa GUTSCHICK and TRECKMAN 1959, p. 247, pl. 37, figs 4, 5, 8, 9.

Tolypammina bulbosa (Gutschick and Treckman 1959). – CONKIN and CONKIN 1964, p. 92, pl. 13, figs. 12–17. – HOLCOVÁ 2002, p. 106, pl. 17, figs. 11–12.

Material: Twelve specimens from five samples (Appendix 1).

Dimensions: Length 350–437.5 μm , width 156–187.5 μm .

Remarks: Our specimens are broken with a short second chamber, but are most similar to the specimen illustrated by Holcová (2002, pl. 17 fig. 11) in the shape of the proloculus. Holcová's specimens have longer second chamber that varies in diameter along its length.

Stratigraphic range: Silurian (Aeronian) (this study) to Early Mississippian (Gutschick and Treckman 1959).

PLATE 4

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 μm .

A,B *Lagenammina* aff. *cumberlandiae* (Conkin 1961), Sample Q0

C,D *Lagenammina ligula* (Gutschick, Weiner and Young 1961). C. Sample Q12, D. Sample Q2

E *Lagenammina silnica* Malec 1992, Sample Q4

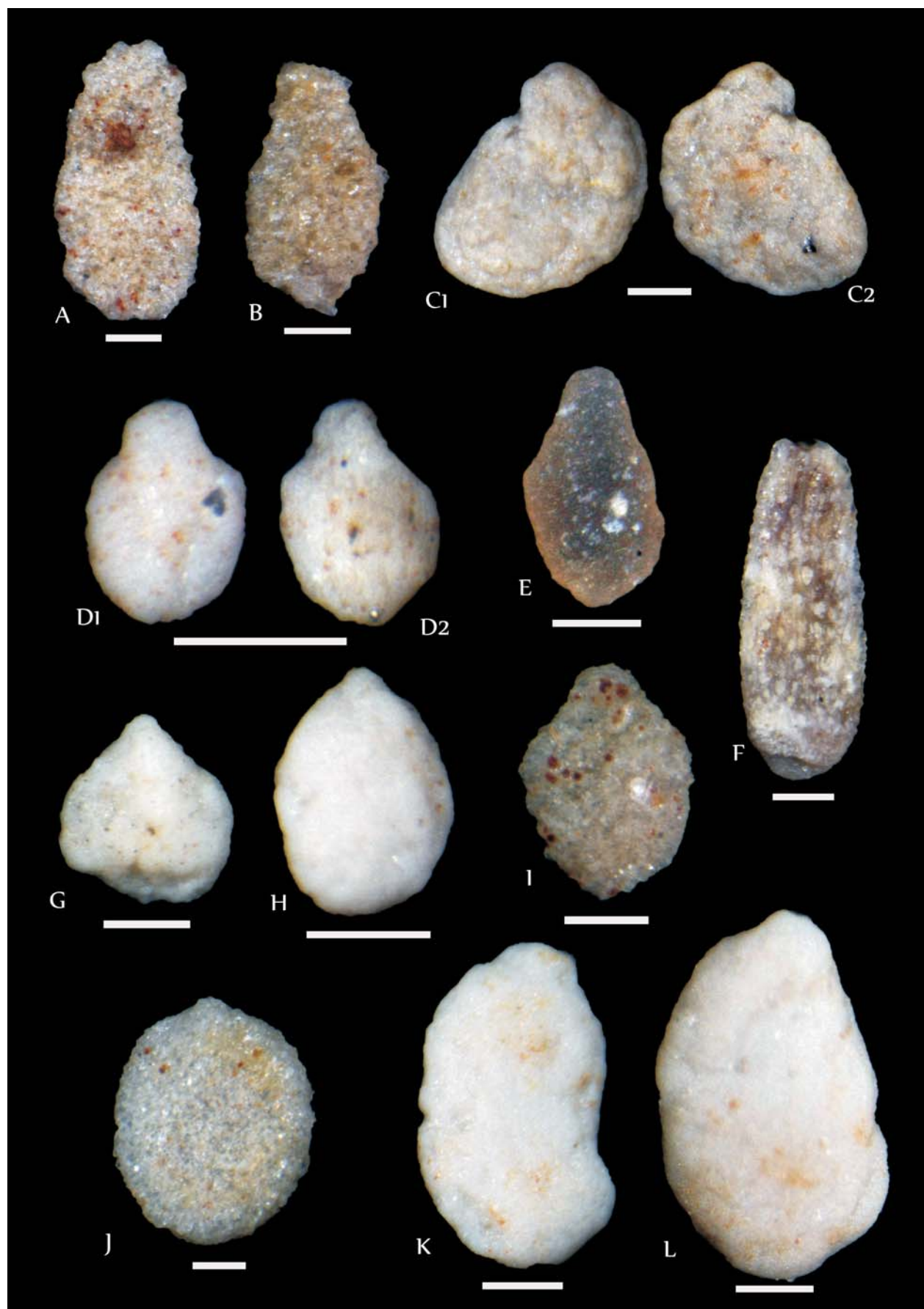
F *Lagenammina* sp. 1, Sample Q0

G,H *Saccammina aspera* Stewart and Priddy 1941, Sample Q4

I *Lagenammina* sp. 2, Sample Q0

J *Saccammina* sp. 1, Sample Q0

K,L *Lagenammina* sp. 3, Sample Q8



Geographic distribution: This species is reported from the Devonian to Lower Mississippian of the North American mid-continent (Gutschick and Treckman 1959; Conkin and Conkin 1964), and from the Devonian of the Barrandian area of the Czech Republic (Holcová 2002).

Tolypammina howchini (Ludbrook 1967)

Plate 7, figures C–F

Ammovertella howchini LUDBROOK 1967, p. 80, pl. 4, figs. 6–8.

Material: 79 specimens from 14 samples (Appendix 1).

Dimensions: Length 237.5–350 µm, width 125–150 µm.

Remarks: Based on the *Tolypammina* and *Ammovertella* definition proposed by Conkin (1961), we transfer *Ammovertella howchini* Ludbrook 1967 to the genus *Tolypammina*. We also place all the tolypamminids that have a second chamber winding as an irregular zigzag in this species. The zigzags of the chamber double back on themselves, causing the outline to appear lobate. Our specimens are smaller than the type specimens illustrated by Ludbrook (1967).

Stratigraphic range: Silurian (Aeronian) to early Permian (Ludbrook 1967).

Geographic distribution: This species was originally reported from South Australia (Ludbrook 1967).

Tolypammina* aff. *jacobschapelensis Conkin 1961

Plate 7, figures G–H

Tolypammina jacobschapelensis CONKIN 1961, p. 303, text-fig. 23; pl. 22, figs 16–21; pl. 27, fig. 5.

Material: 18 specimens from seven samples (Appendix 1).

Dimensions: Length 487.5–535 µm, width 250–300 µm, Proloculus length 312–375 µm, width 250–300 µm.

Remarks: Our specimens differ from typical *Tolypammina jacobschapelensis* in having a short tubular portion and a larger oval proloculus, whereas the proloculus of *T. jacobschapelensis* has a pointed tip. The winding mode is not apparent as a result of truncation.

Stratigraphic range: Silurian (Aeronian) to Carboniferous (Mississippian) (Conkin 1961).

Geographic distribution: This species was first described from the Rockford Limestone and Chapel Shale in Jacobs Chapel, Indiana (Conkin 1961).

Tolypammina* aff. *serpens Ireland 1956

Plate 7, figure I

aff. *Tolypammina serpens* IRELAND 1956, p. 851, text-fig. 5, 3–5

Material: Two specimens from two samples, Q3 and Q9.

Dimensions: Length 281–312.5 µm, width 87.5–100 µm.

Remarks: Compared with the holotype of Ireland (1956), our specimens do not display intense coiling surrounding the proloculus.

Stratigraphic range: Silurian (Aeronian) (this study) to Carboniferous (Pennsylvanian) (Ireland 1956)

Geographic distribution: Ireland (1956) first described this species from the Upper Pennsylvanian Topeka, Burlingame, Wakarusa, Reading, and Dover Limestones of Kansas.

PLATE 5

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

A–D *Saccamminita galinae* Kaminski and Perdana 2017, Sample Q12

E *Thurammina arcuata* Moreman 1930, Sample OQV

F *Thurammina holcovae* Kaminski and Perdana 2017, Sample Q7

G *Thurammina papillata* Brady 1879, Sample Q9

H–J *Thurammina pentagona* Kaminski and Perdana 2017, Sample Q11

K *Thurammina* (?) sp. 1, Sample Q0

L *Psammosphaera* (?) sp. 2, Sample Q6

M *Psammosphaera* (?) sp. 3, Sample Q6

N *Psammosphaera cava* Moreman 1930, Sample Q2

O *Psammosphaera* sp. 1, Sample Q3

P *Sorosphaera bicella* Dunn 1942, Sample Q6

Q *Sorosphaera tricella* Moreman 1930, Sample Q4



Tolypammina* aff. *tornella (Ireland 1956)

Plate 7, figure J, Plate 8, figures A–C, E

aff. *Ammovertella tornella* IRELAND 1956, p. 855, text-fig. 5: 16–19.
Tolypammina aff. *tornella* Ireland. – HOLCOVÁ 2002, p. 105, pl. 4, fig. 11.

Material: 42 specimens from 12 samples (Appendix 1).

Dimensions: Length 250–475 µm, width 225–375 µm.

Remarks: The species *T. tornella* (Ireland) was described as coiling about an object such as a brachiopod spine. In the type specimens, the proloculus is followed by a tubular chamber that first winds in a zigzag manner along the spine, then coils about itself. Holcová (2002) noticed that the initial stage of *Tolypammina* aff. *tornella* is straight, and later the tube winds around itself in loose coils. Our specimens are less well-developed than Ireland's (1956) specimens, and are more similar to Holcová's (2002) specimens from the Early Devonian (Pragian) of the Czech Republic.

Stratigraphic range: Silurian (Aeronian), to Pennsylvanian (Ireland 1956).

Geographic distribution: This species has been previously reported from the Topeka Limestone in eastern Kansas (USA) (Ireland 1956), and from the Barrandian Area of the Czech Republic (Holcová 2002).

Tolypammina* cf. *tortuosa Dunn 1942

Plate 8, figure D

cf. *Tolypammina tortuosa* DUNN 1942, p. 341, pl. 44, figs 19–21, 32. – HOLCOVÁ 2002, p. 105, pl. 8, figs 7, 8.

Material: Six specimens from two samples, Q1G and Q4.

Dimensions: Length 282–312.5 µm, width 87.5–100 µm.

Remarks: Our specimens closely resemble those from Holcová (2002, pl. 8, fig. 7), but the preservation state of our specimens is poor, and the proloculus and winding second chamber are not clearly visible.

Stratigraphic range: Silurian (Aeronian) to Early Devonian (Pragian) (Holcová 2002).

Geographic distribution: First reported from the Mississippi Basin (Dunn 1942), and subsequently from the Barrandian area of the Czech Republic (Holcová 2002).

***Tolypammina* sp. 1**

Plate 8, figures F–H

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Nine specimens from six samples (Appendix 1).

Dimensions: Proloculus diameter 150 µm; second chamber length 205 µm and width 150 µm.

Description: Test free, consisting of a spherical proloculus followed by a slightly bent or straight second chamber. The diameter of the proloculus and the width of the tubular second chamber are about the same size; there is no indication of intense winding of the second chamber. Wall composed of fine to medium quartz grains.

Remarks: This specimen has some similarity to *Tolypammina* sp. 6 illustrated by Holcová (2002, pl. 4, fig. 1), but the similar

PLATE 6

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

A,B *Webbinelloidea?* sp. 1, Sample Q5

C,D *Kechenotiske* cf. *expansa* (Plummer 1945), Sample Q10

E–G *Hyperammina sinuosa* Kaminski and Perdana 2017, Sample Q12

H *Hyperammina* sp. 1, Sample Q0

I *Hyperammina* sp. 2, Sample Q8

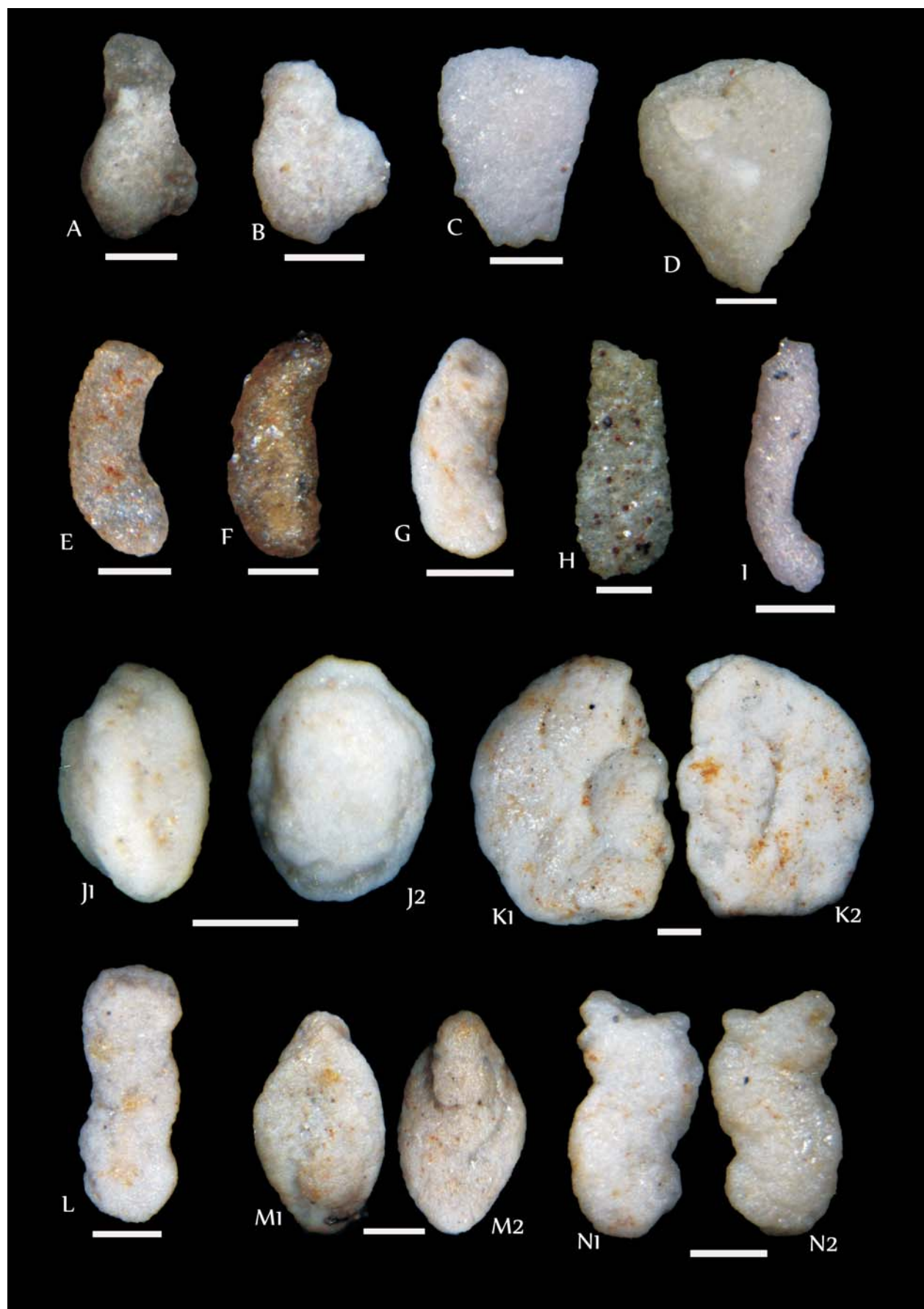
J *Ammovertella* sp. 1, Sample Q4

K *Ammovertella* sp. 2, Sample Q4

L *Ammovertella* sp. 3, Sample Q9

M *Ammovertella*(?) sp. 4, Sample Q12

N *Tolypammina aihemerensis* Said and Eissa 1969, Sample QB-2



diameter size of the proloculus and the width of the second chamber makes our specimen distinct. It also resembles the genus *Hyperammina*. However, because of the slightly twisted part between the proloculus and the initial stage of the second chamber, this species is better assigned to the genus *Tolypammina*.

***Tolypammina* sp. 2**

Plate 9, figs. A–F; Plate 10, figs. A–B

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 12 specimens from four samples (Appendix 1).

Dimensions: Proloculus diameter 163–363 µm; second chamber length 395–875 µm and width 240–463 µm.

Description: Test attached, consisting of a spherical to ovoid proloculus, and a tubular second chamber coiled about itself, crossing previous bends of the chamber in a glomospiral or quasi-milioline manner; second chamber flattened and compressed. Aperture not visible. Wall is thick, composed of fine to medium quartz grains of uniform dimensions.

Remarks: Some specimens show no proloculus, and the aperture is usually not visible. Some specimens display constrictions of the second chamber that may be growth lines. This species is one of the largest foraminifers found in the Qusaiba Shale in this study.

***Tolypammina* sp. 3**

Plate 10, fig. C

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: 10 specimens from four samples (Appendix 1).

Dimensions: Proloculus diameter 100–150 µm; second chamber length 200–275 µm, width 100–150 µm.

Description: Test attached, comprised of a spherical to hemispherical proloculus followed by a second coiled tubular chamber of constant diameter. The second chamber is attached to a foreign object; aperture probably at the open end of the tubular chamber, wall composed of fine-grained siliceous grains.

Remarks: This species resembles *Tolypammina* sp. 1, but is more tightly coiled. The figured specimen is attached to a tubular agglutinated foraminifer.

***Tolypammina* sp. 4**

Plate 10, fig. D

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Three specimens from three samples (Appendix 1).

Dimensions: Length 325–345 µm, width 112–125 µm.

Description: Test attached, consisting of a proloculus and a short undivided tubular second chamber of lesser diameter, which embraces along another foraminiferal specimen or other object; wall constructed of fine- to medium-grained siliceous particles.

Remarks: The figured specimen is attached to a tubular agglutinated foraminifer and consists mainly of a proloculus partially wrapped around its substrate.

***Tolypammina* sp. 5**

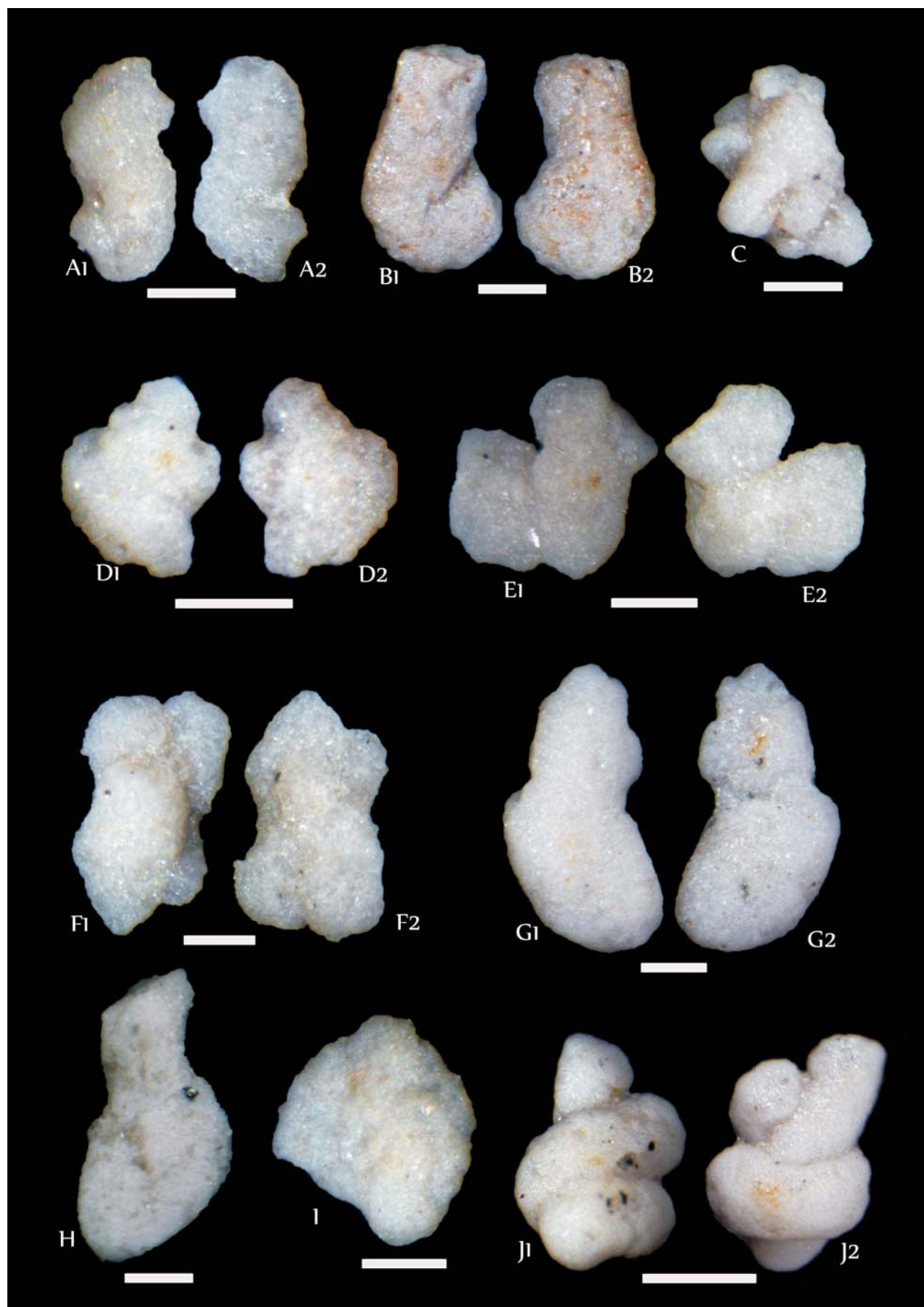
Plate 10, fig. E

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

PLATE 7

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

- | | |
|---|---|
| A <i>Tolypammina aihemerensis</i> Said and Eissa 1969, Sample Q10 | GH <i>Tolypammina</i> aff. <i>jacobschapelensis</i> Conkin 1961, Sample Q10 |
| B <i>Tolypammina</i> cf. <i>bulbosa</i> , Sample Q12 | I <i>Tolypammina</i> aff. <i>serpens</i> Ireland 1956, Sample Q6 |
| C–F <i>Tolypammina howchini</i> (Ludbrook 1967), Sample Q1G | J <i>Tolypammina</i> aff. <i>tornella</i> (Ireland 1956), Sample QB-3 |



Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Two specimens from sample Q4.

Dimensions: Length 393–587 µm, width 240–350 µm; proloculus: 187–200 in length, 112–125 µm in width.

Description: Test attached, consisting of a oval proloculus and an undivided tubular second chamber, which tightly winds back and forth in the initial stage, then wraps streptospirally around the early part of the test in the terminal stage. Aperture indistinct, presumably at the terminal end of the tube. Wall thick, smooth, composed of fine-grained siliciclastic particles, white in color.

Remarks: The specimens are thick walled and robust. Unlike *Tolypammina* sp. 2, the tubular second chamber does not increase in diameter in the terminal stage

Genus *Turritellella* Rhumbler 1905

Type species. *Trochammina shoneana* Siddall 1878

***Turritellella* sp. 1**

Plate 10, figs. F–G

Type horizon: lower Silurian (Aeronian), Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Six specimens from four samples (Appendix 1).

Dimensions: Length 280–320 µm, width 90–110 µm.

Description: Test free, with a tubular second chamber that is coiled trochospirally around a vertical axis. Proloculus not apparent due to poor preservation. Wall agglutinated of fine siliciclastic grains. Aperture a high interiomarginal opening that is umbilical in position.

Remarks: These specimens are placed into *Turritellella* due to their coiling mode, which is “extended” trochospiral, coiled

around a vertical axis. Our specimens differ from the type species *Turritellella schoneana* (Siddall 1878) in displaying coiling that is “stretched” or “extended”. Our specimens only possess a few whorls that are much extended, compared with the modern forms that may contain in excess of 18 low trochospiral whorls (see Brady 1884).

Stratigraphic range: Silurian (Aeronian).

Geographic distribution: Qassim District of Saudi Arabia (Kaminski and Perdana 2017b).

Subclass GLOBOTHALAMANA Pawlowski, Holzmann and Tyszk 2013

Order LITUOLIDA Lankester 1885

Suborder LITUOLINA Lankester 1885

Superfamily LITUOLOIDEA de Blainville 1827

Family LITUOLIDAE de Blainville 1827

Family LITUOLIDAE de Blainville 1827

Genus *Ammobaculites* Cushman 1910

Type species. *Spirolina agglutinans* d’Orbigny 1846

Ammobaculites qusaibaensis Kaminski and Perdana 2017

Plate 11, figs A–C

Ammobaculites qusaibaensis KAMINSKI and PERDANA, 2017b, p. 63, pl. 1, figs. 11–12.

Material: Three specimens from two samples, Q4 and Q12.

Dimensions: Length 218–350 µm, and 93.5–156 µm in diameter across the uncoiled part.

Description: Test free, small, elongate, initial portion close coiled, comprised of only four visible chambers, separated by straight radial sutures, with a depressed umbilicus; terminal part uncoiled and rectilinear, rounded in cross-section, comprised of three irregular, inflated chambers. Sutures in uniserial portion depressed. Wall medium to coarsely agglutinated. Aperture terminal, rounded, at the end of a broad and short neck.

PLATE 8

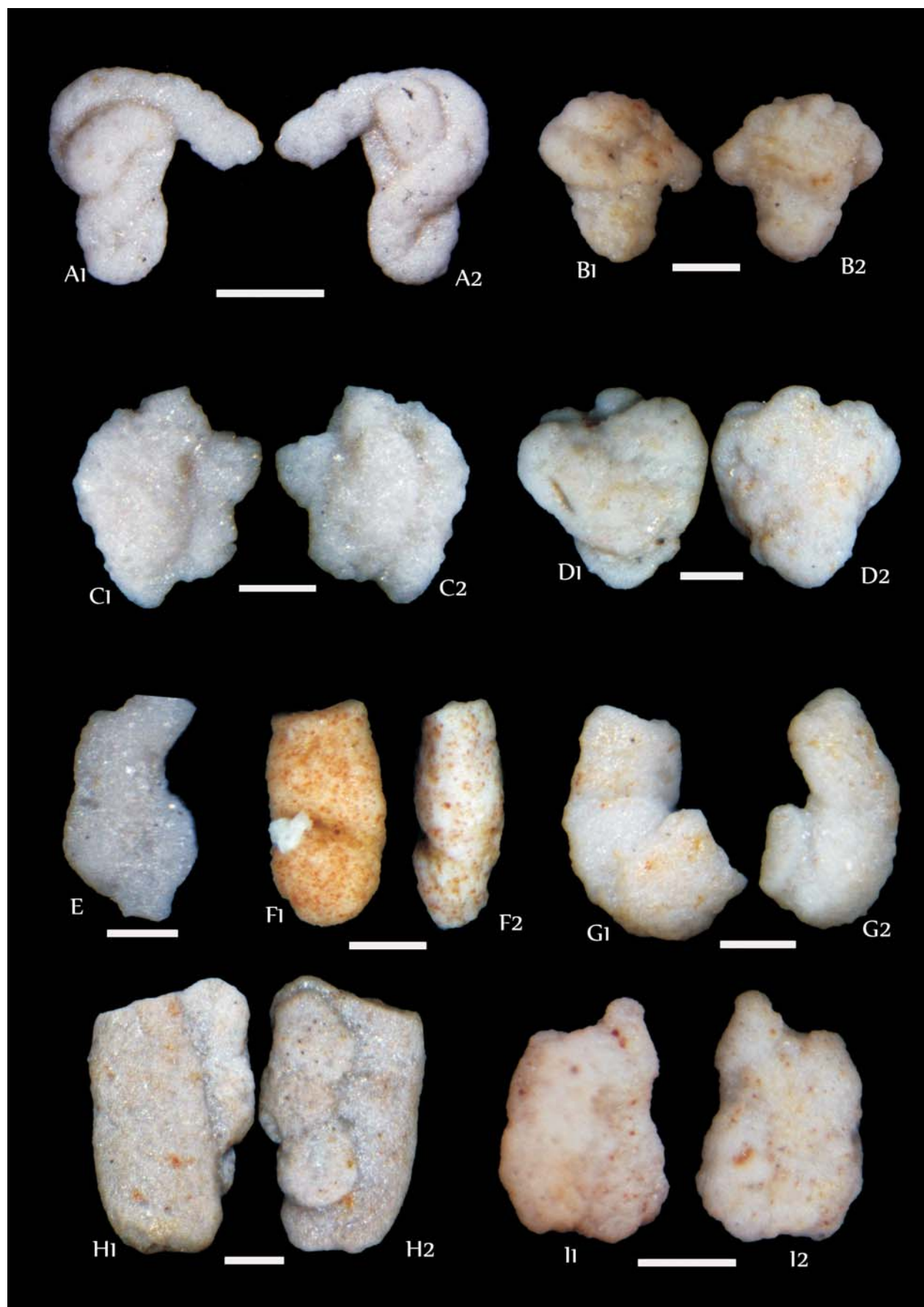
Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

A–C,E *Tolypammina* aff. *tornella* (Ireland 1956), A. sample QB-3, B. sample Q4, E. sample Q1G.

D *Tolypammina* cf. *tortuosa* Dunn 1942, sample Q6

F–H *Tolypammina* sp. 1. F. sample Q2, F, G. sample Q4

I *Simobaculites* sp. 1, sample Q4



Remarks: A small, somewhat irregular *Ammobaculites* species with few chambers. Compared with the Early Devonian specimens of *Ammobaculites* illustrated by Holcová (2002, pl. 6, fig. 5), our specimens have a smaller coiled portion and somewhat more inflated uniserial chambers. Holcová's specimen of "*Ammobaculites* sp. 1" has five chambers in the uniserial part, and the aperture is shifted toward the dorsal margin of the test as in the genus *Ammomarginulina*. The specimen illustrated by Holcová (2002, pl. 17, fig. 17) as *Ammobaculites* aff. *leptos* Gutschick and Treckman 1959 has a uniserial portion that is much narrower than the coiled portion.

Our finding of typical specimens of *Ammobaculites* in the Qusaiba Shale of Saudi Arabia pushes back the known stratigraphic range of the genus from the late Early Devonian (the Dalejan Třebotov Limestone of the Czech Republic) to the early Silurian (Aeronian).

Stratigraphic range: Silurian (Aeronian).

Geographic distribution: Qassim District of Saudi Arabia (Kaminski and Perdana 2017b).

Genus *Simobaculites* Loeblich and Tappan 1984
Type species. *Ammobaculites cuyleri* Tappan 1940

***Simobaculites* sp. 1**

Plate 8, fig. I; Plate 11, figs D–F

Simobaculites sp. 1 KAMINSKI and PERDANA 2017b, p. 63, pl. 1, figs. 15–16.

Type horizon: lower Silurian (Aeronian), uppermost part of the Qusaiba Shale.

Type locality: Old Qusaiba Village, Qassim District, Saudi Arabia.

Material: Three specimens from sample Q4.

Dimensions: Length 237–575 μm , and 112.5–200 μm in diameter across the uncoiled part.

Description: Test free, coiled in the initial stage, uncoiled tangentially [the uniserial chambers depart tangentially from the coiled part, rather than turning outward as in *Ammobaculites*] and rectilinear in the final uniserial portion. The initial coiled part is comprised of six to seven irregular rounded-triangular chambers in the final whorl, separated by straight, depressed, radial sutures, without a distinct coil suture, and a depressed umbilicus. Only a single whorl is visible. Uncoiled portion consists of three irregular chambers, broader than high, rounded to ellipsoidal in cross section, separated by depressed sutures. Wall consists of fine siliciclastic material. Aperture terminal, of ellipsoidal shape.

Remarks: Our specimens bear superficial resemblance to the Early Mississippian species *Ammobaculites* [actually *Simobaculites*] *leptos* Gutschick and Treckman 1959, which was regarded by Loeblich and Tappan (1987) to be the oldest known representative of the genus. However, the *Ammobaculites leptos* type specimens possess an undivided early portion and a later portion consisting of pseudochambers – these features are clearly visible in fig. 3 of Gutschick and Treckman (1959). The species therefore does not belong in the genus *Ammobaculites*, which has true (overlapping) chambers. Our specimens from the Qusaiba Shale have clearly defined sutures in the uncoiled part and therefore true chambers even though these are somewhat irregular.

Simobaculites differs from *Ammobaculites* in the strongly compressed test, evolute early coil, and in the later uniserial chambers being broad and flattened to ovoid rather than rounded in section. The discovery of *Simobaculites* in the Qusaiba Shale revises the known stratigraphic range of the genus, which was reported by Loeblich and Tappan (1987) to range upward from the Upper Pennsylvanian.

Stratigraphic range: Silurian (Aeronian).

PLATE 9

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 μm .

A–F *Tolypammina* sp. 2, Sample Q12



Geographic distribution: Qassim District of Saudi Arabia.

Family Incertae sedis (?Hormosinidae)

Genus *Incertae sedis*

Materials: Five specimens from two samples (Q4 and Q8).

Dimensions: Length 225–700 µm, width 150–375 µm.

Remarks: These are relatively large specimens that apparently have an adherent test, are nearly uniserial, consisting of up to three segments, which may be chambers or pseudochambers. The shape of the segments can be discoidal, *Thuramminoides sphaeroidalis* like, with a thick flange and slightly depressed central part. Wall is thick and finely agglutinated.

These specimens seem to be multichambered or pseudo-multichambered, and as such could be placed into the genus *Subreophax*, *Hormosina*, or even *Arthrodendron* due to the presence of nearly uniserial segments. However, the above genera are free-living forms and in this case the test appears to be adherent. Kaminski et al. (2019) reported the genera *Subreophax* and *Hormosina* from the Ordovician of Saudi Arabia.

Stratigraphic range: Silurian (Aeronian).

Geographic distribution: Qassim District of Saudi Arabia.

CONCLUSIONS

An early Silurian foraminiferal assemblage is documented from the Qusaiba Shale Formation and the lower part of the overlying Sharawra Sandstone Formation of the Qalibah Group in the type section at Old Qusaiba Village, Qassim Region of Saudi Arabia. The assemblage is highly diverse (consisting of at least 73 species) compared with Silurian assemblages reported from North America and Europe.

The assemblage is highly dominated by monothalamous and tubothalamid agglutinated foraminifera, which constitute >97% of the specimens. Unlike the North American and European early Silurian assemblages, the coiled tubothalamid genera such as diverse ammodiscids (i.e., *Ammovertella*, *Tolypammina*, *Turritelleva*) are rare (ca. 4% of the assemblage), and the tightly coiled forms (i.e., *Ammodiscus*, *Glomospira*, etc.) are absent, suggesting that the described assemblage belongs in a separate Austral (Gondwanan) bioprovince.

The assemblage from Saudi Arabia also contains rare globothalamids belonging to the genera *Ammobaculites* and *Simobaculites*. This finding constitutes the earliest known occurrence of multichambered foraminifera belonging to the order Lituolida, which revises the first evolutionary appearance of the multichambered globothalamids to an early Silurian (Aeronian) age or possibly even older.

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PLATE 10

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

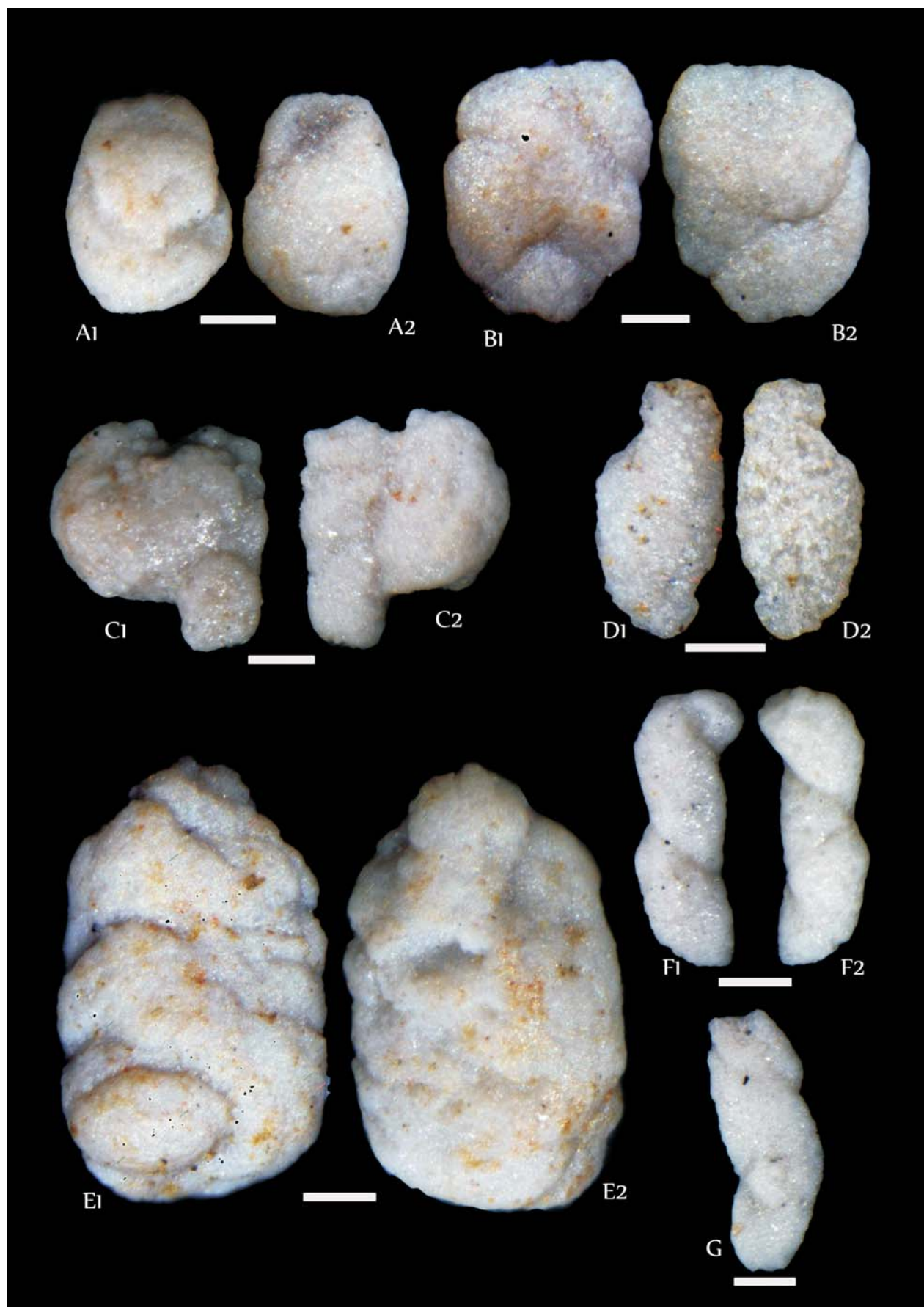
A,B *Tolypammina* sp. 2, sample Q6

C *Tolypammina* sp. 3, sample Q8

D *Tolypammina* sp. 4, sample Q5

E *Tolypammina* sp. 5, sample Q2

F,G *Turritelleva* sp. 1 sample Q6



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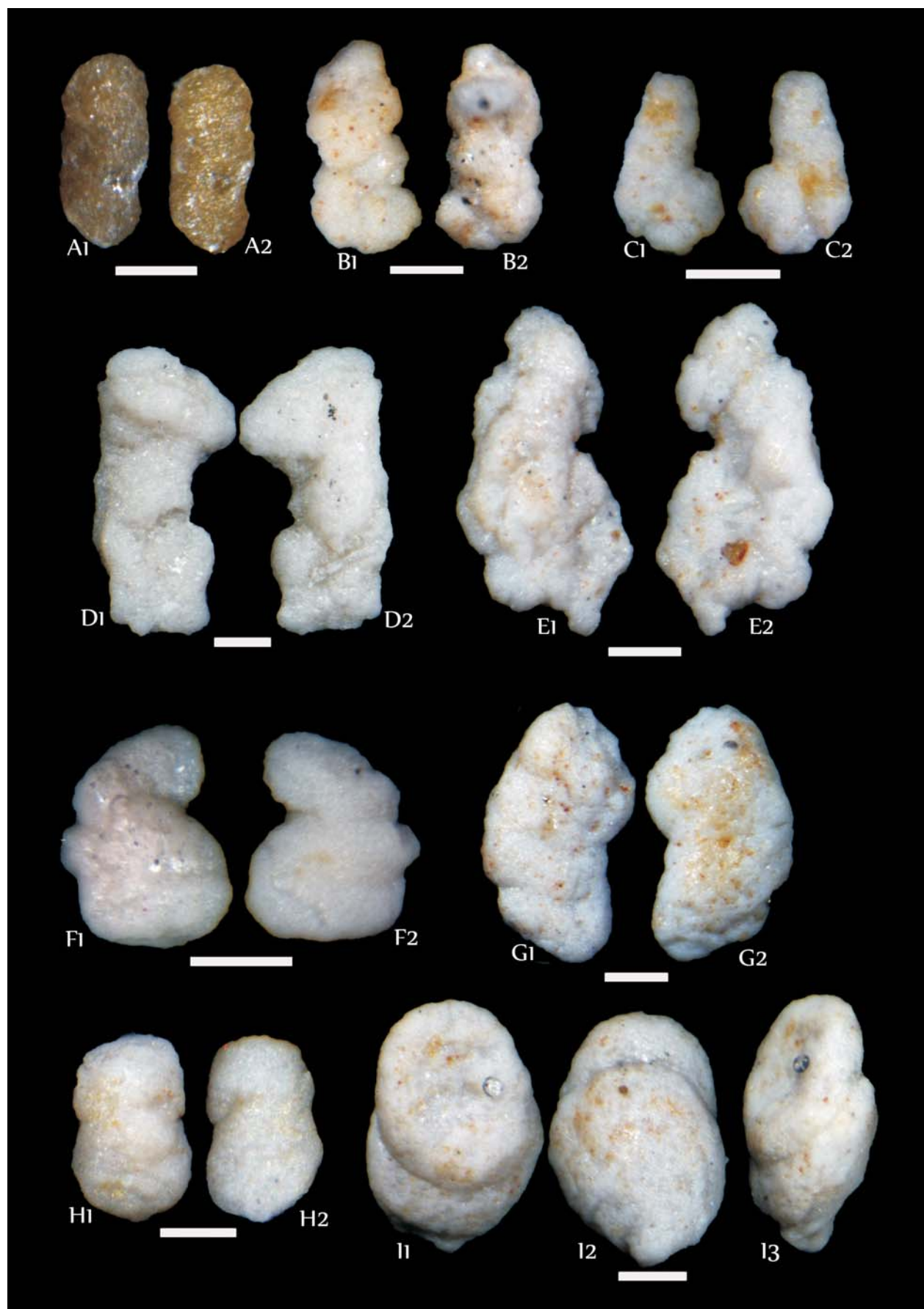
PLATE 11

Photomicrographs of agglutinated foraminifera from the lower Silurian Qusaiba Formation. Scale bars = 100 µm.

A–C *Ammobaculites qusaibaensis* Kaminski and Perdana 2017, sample Q4

D–F *Simobaculites* sp. 1, sample Q4

G–I ?hormosinid *Incertainae* sedis. F, G, sample Q4; H, I, sample Q12



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APPENDIX 1

Quantitative species counts from the studied sections.

Section 1

Compound		Amphitremoida				Psammospaera				Thuraminoides				hormosinid				Thuramina				Saccamina				Lagenamina				Saccaminina				Kechentaiske				Raibosamina				Stegnammina			
Sample	No	citroniforma	eisenacki	sp. 1	sp. 2	cava	sp. 1	sp. 2	sp. 3	sphaeroidalis	plummerae	ellipsoidalis	incertae sedis	arcuata	holocovae	papiliata	pentagona	sp. 1	aspera	sp. 1	aff. cumberlandiae	ligula	silinica	sp. 1	sp. 1	sp. 2	galinae	cf. expansa	aspera	contorta	elongata	sp. 1	sp. 2	sp. 3	sp. 4										
Q0	24	0	29	8	0	0	0	9	0	174	0	4	0	0	0	0	0	0	0	10	2	0	0	1	2	0	0	0	1	0	5	0	0	4											
Q1A	23	0	0	7	1	0	0	0	0	86	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	12	0	0	17											
Q1B	22	0	0	7	0	0	0	2	0	54	0	23	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	14	0	8	0	0	9											
Q1D	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0											
Q1E	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0											
Q1F	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0											
Q1G	18	0	0	0	0	10	3	0	0	31	0	0	1	0	0	0	0	0	9	0	0	0	0	0	0	0	3	0	0	1	16	0	0	9	0										
Q2	17	0	0	0	0	8	0	316	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0										
Q3	16	2	0	0	0	96	31	4	0	1	0	0	0	0	0	0	0	0	0	0	0	7	1	0	0	0	0	1	2	17	0	0	5	0											
Q4	15	43	0	0	0	11	0	196	0	0	0	0	4	0	1	1	0	1	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0										
Q5	14	0	0	0	0	24	0	269	0	11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0										
Q6	13	20	0	0	0	2	0	286	0	11	0	0	0	1	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0										
Q7	12	66	0	0	0	2	0	287	0	20	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0										
Q8	11	38	0	0	0	65	0	137	0	101	0	0	1	0	2	0	0	6	0	0	0	1	0	0	0	2	0	1	0	4	0	0	13	0											
Q9	10	11	0	0	0	3	0	215	2	174	20	0	0	3	1	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	1	0										
Q10	9	2	0	0	0	17	0	296	4	15	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0										
Q11	8	34	0	0	0	3	0	121	0	5	1	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0											
Q12	7	5	0	0	0	16	0	329	0	39	0	0	3	0	1	10	1	0	1	0	4	5	1	0	0	0	2	4	8	0	0	0	0	0											
Q13	6	0	0	0	0	0	0	221	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0											
Q14	5	0	0	0	0	5	0	24	0	7	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0										
Q15	4	0	0	0	0	11	0	274	1	4	0	0	0	0	0	3	0	2	0	0	2	0	0	0	0	0	0	0	0	4	0	0	1	0											
Q16	3	0	0	0	0	1	0	1	0	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
Q17	2	0	0	0	0	3	0	3	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
Q18	1	1	0	0	0	2	0	155	0	128	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0										
	TOTAL	222	29	22	1	279	34	3145	9	873	24	70	9	5	7	25	5	1	24	12	2	16	18	2	2	2	3	2	2	35	57	25		31	30										

Section 2

Compound		Amphitremaida								Psammospaera								Thuraminoides								hormosinid	Thuramina								Saccamina		Lagenamina								Saccaminina		Kechentoiske		Raibosamina		Stegnamina																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
Sample	No	citroniforma		eisenacki		sp. 1		sp. 2		cava		sp. 1		sp. 2		sp. 3		sphaeroidalis		plummerae		ellipsoidalis		insertae sedis		arcuata		holocavae		papillata		pentagona		sp. 1		aspera		sp. 1		aff. cumberlandiae		ligula		silinica		sp. 1		sp. 2		sp. 3		galinae		cf. expansa		aspera		contorta		elongata		sp. 1		sp. 2		sp. 3		sp. 4																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
Q-TGS	24	0	7	0	0	0	0	5	0	0	0	0	0	0	0	0	13	0	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TOTAL	242	39	22	1	299	34	3428	9	1345	24	214	9	10	7	33	5	1	43	12	2	22	24	22	2	2	3	2	2	52	113	34	0	31	130
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APPENDIX 1
Continued.

	<i>Blastamina</i>		<i>Bathysiphon</i>				<i>Rhabdammina</i>		<i>Ceratamina</i>					<i>Hemisphaerammina</i>			<i>Sorosphaera</i>		<i>Turritella</i>		<i>Ammobaculites</i>		<i>Sinobaculites</i>						Tolypammina												<i>Webbelloidea?</i>			
	<i>vulgaris</i>	sp. 1	sp. 2	sp. 3	sp. 1	sp. 2	<i>sinuosa</i>	<i>trifurcata</i>	<i>cornucopia</i>	sp. 1	sp. 2	<i>costeri</i>	sp. 1	sp. 2	sp. 3	<i>bicella</i>	<i>tricella</i>	sp. 1	<i>qusalbaensis</i>	sp. 1	sp. 1	sp. 2	sp. 3	sp. 4	<i>aithmerinis</i>	<i>cf. bulbosa</i>	<i>howchini</i>	<i>aff.jacobschapelensis</i>	<i>aff. serpens</i>	<i>aff. tornella</i>	<i>cf. tortuosa</i>	sp.1	sp. 2	sp. 3	sp. 4	sp. 5	sp. 1	Total						
	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	251					
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	177					
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119					
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
	0	1	1	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	5	0	3	3	0	0	0	0	0	0	0	111					
	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	335						
	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	3	0	0	0	0	0	0	0	173					
	4	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	3	3	4	1	0	3	1	0	2	8	0	0	3	3	0	0	0	0	0	2	0	263					
	0	0	0	0	0	0	0	0	1	0	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	3	10	0	0	12	0	2	0	5	0	0	0	346						
	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	1	0	1	0	1	0	2	1	0	0	2	14	0	0	1	0	1	0	2	0	0	0	334						
	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	318						
	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	9	0	0	0	0	1	0	0	2	354						
	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	2	0	0	2	6	1	1	2	0	1	1	0	0	0	0	444						
	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	0	0	0	0	0	0	344						
	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	138						
	0	3	0	2	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	0	1	0	1	7	0	1	0	0	452						
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	227						
	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	2	0	0	1	0	1	0	0	53					
	0	2	0	1	0	0	0	3	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	13	1	0	1	0	0	3	0	0	0	0	331						
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6						
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	2	0	0	0	0	17					
	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	292						
	4	10	1	9	2	1	4	4	8	1	3	3	16	1	1	2	1	5	3	5	1	2	6	1	5	12	73	18	2	35	6	9	12	10	3	2	2	5085						

[illegible]

4	26	1	9	2	1	4	5	8	1	3	3	16	1	1	2	1	6	3	5	1	2	12	1	23	12	79	18	2	42	6	9	12	10	3	2	2	6315
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