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PALEOBIOGEOGRAPHIC ANALYSIS OF YAHTASHIAN TO MIDIAN FUSULINACEAN FAUNAS OF THE SURMAQ FORMATION IN THE ABADEH REGION, CENTRAL IRAN

FUMIO KOBAYASHI[1] AND KEN-ICHI ISHII[2]

ABSTRACT

Fusulinaceans consisting of 56 species assignable to 30 genera are distinguished in the Surmaq Formation in the Abadeh region, central Iran. Based on the stratigraphic distribution of fusulinaceans, the Surmaq Formation is divisible into six biostratigraphic zones from lower to upper: *Darvasites ordinatus, Pseudofusulina quasifusuliniformis, Eopolydiexodina percica, Afghanella schencki, Neoschwagerina occidentalis,* and *Chusenella abichi.* Faunal composition and comparison between the Abadeh region, South West Asian, and Mediterranean Sea regions indicates that the first zone is Yahtashian in age, the second and third are definitely indeterminable, the fourth and fifth are Murgabian, and the last is Midian. Fusulinacean faunas of the *Pseudofusulina quasifusuliniformis, Eopolydiexodina persica,* and *Chusenella abichi* Zones are less diversified compared to the two intervening zones which have many neoschwagerinids and verbeekinids.

The Surmaq fusulinaceans, characterized by *Eopolydiexodina* and *Afghanella,* are one of the most widely represented Middle Permian faunas in the South West Asian and Mediterranean Sea regions, belonging to the western part of the Western Tethyan paleobiogeographic province. Murgabian and Midian faunas in this province differ from those of the eastern Tethyan Province in having only rare occurrences of *Colania* and *Lepidolina,* and from the Panthalassan Province in having *Afghanella* and *Sumatrina.* Permian carbonate deposition began in Yahtashian time throughout the Cimmerian terranes including the Abadeh region. Differences in fusulinacean faunal composition and species diversity in the Surmaq Formation are closely associated with differences in limestone lithologies. For example, the *Chusenella abichi* Zone is present mostly in lime-mudstone and wackestone that are partly dolomitized. These paleobiogeographic and lithologic chararacters have implications for the northward movement of this tectonic provenance, for the rift-drift-collision history of the western part of the Cimmerian Continent, and also for the evolution and extinction of fusulinaceans in Permian time.

INTRODUCTION

The Cimmerian Terrane is the tectonic collage of Gondwana-originated continental blocks and Triassic to Paleogene subduction-accretion complexes. In South West Asia, it is in contact with the northern Hercynian Terrane by the Paleotethyan suture zone and with the southern passive continental margin of Arabian and Indian blocks by the Neotethyan suture zone (Fig. 1). The Cimmerian continental block of Iran is divided into the Band e Bayan type Zone and the Helmend type Zone, each of which are western extensions of the Band e Bayan and the Helmend Zones of central Afghanistan (Fig. 1). Both zones are Proterozoic to Paleozoic terranes, and are thought to have been separated from each other by intracontinental rifting during Permo-Triassic time (Boulin, 1988). Geological and geophysical information from these terranes are important to the discussion about the tectonic evolution of the western part of the Cimmerian Continent, which is the second of several tectonic silvers that were rifted from Gondwana.

Permian and Triassic formations in the Abadeh region of central Iran are geotectonically part of the Helmend type Terrane, and are thought to represent platform sediments deposited on the Cimmerian Continent. The Permian formations, unconformably overlying non-marine Carboniferous beds, are composed mostly of fossiliferous bedded limestones with many fusulinacean foraminifers including neoschwagerinids, verbeekinids, and schwagerinids which are especially useful for biostratigraphic subdivision and paleobiogeographic reconstruction.

The main purpose of this paper is to discuss the late Early and Middle Permian fusulinacean faunas of the Surmaq Formation of the Abadeh region and their paleobiogeographic significance in relation to the tectonic development of the Tethyan terranes. After introducing the stratigraphy and limestone lithologies of the Surmaq Formation, the fusulinacean biostratigraphy is summarized based on reexamination of fusulinacean faunas and their stratigraphic distribution previously studied by Iranian-Japanese Research Group (1981).

All limestone samples of the Surmaq Formation used in this paper were collected in 1972 and 1975 by the joint research project organized by Iranian and Japanese geologists and paleontologists including one of us, K. Ishii. Some of fusulinaceans will be described systematically in a subsequent publication.

STRATIGRAPHY AND LIMESTONE LITHOLOGY OF THE SURMAQ FORMATION

Structural division and stratigraphy of Paleozoic and Mesozoic rocks in the Abadeh region were studied by Tarz (1969, 1974). In this region, the Permian is divided into the Surmaq, Abadeh, and Hambast Formations (Iranian-Japanese Research Group, 1981). These rocks attain about 1000 meters in total thickness without any conspicuous stratigraphic breaks, and consist mostly of bedded limestones several to several tens of centimeters thick. Bedded limestones are commonly argillaceous, and occasionally have

[1] Institute of Natural and Environmental Sciences, Himeji Institute of Technology, Sanda, Hyogo, 669-1546, Japan. E-mail: kobayasi@nat-museum.sanda.hyogo.jp
[2] Hayashibara Museum of Natural Sciences, Shimoishii-1, Okayama, 700-0907, Japan

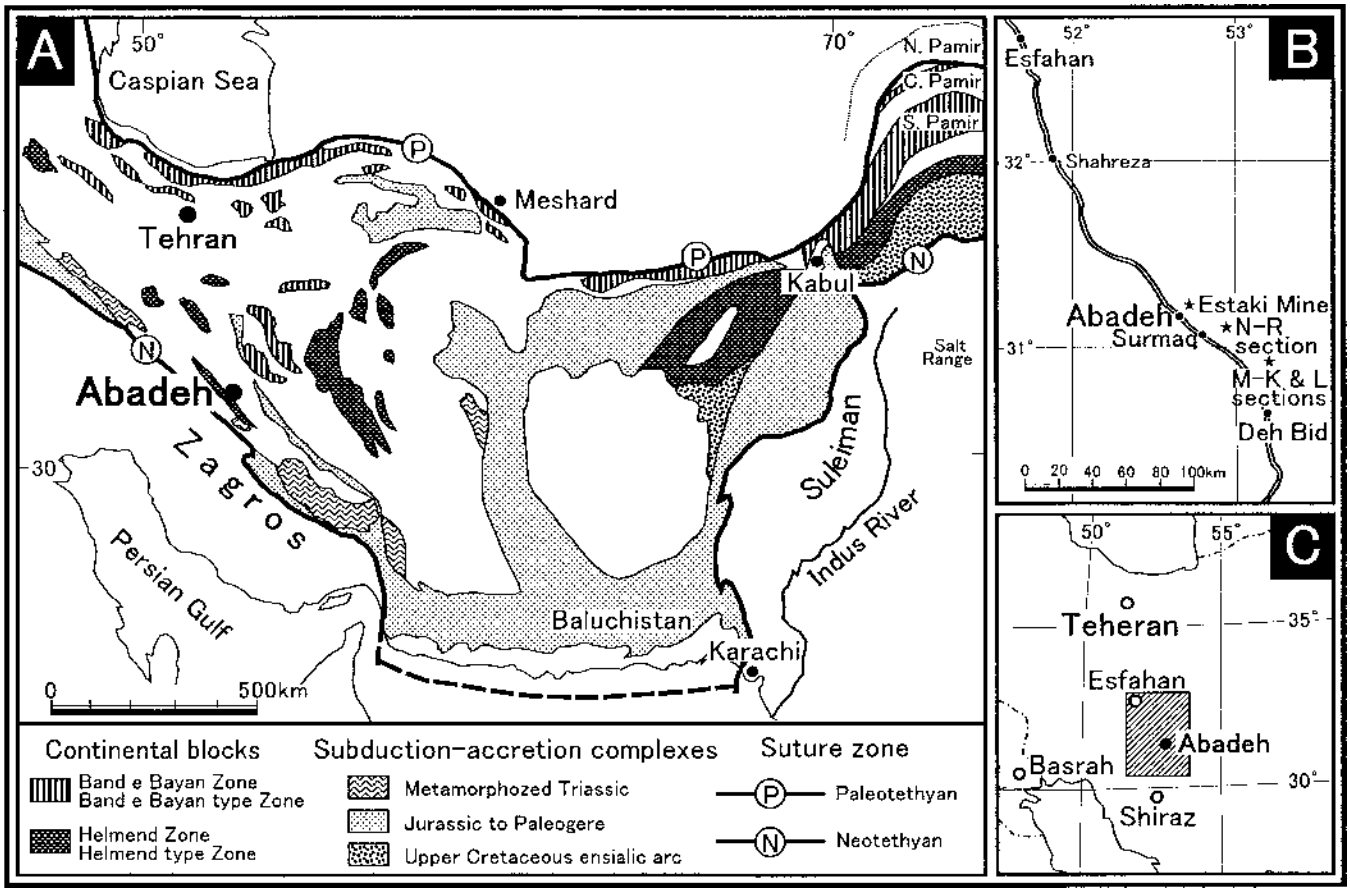


FIGURE 1. A: Geotectonic map of the Cimmerian Terrane in South West Asia (modified from Boulin, 1988). B: Location of columnar sections of N–R, M–K, and L sections of the Surmaq Formation, and Estaki Mine in the Abadeh region. C: Location of B.

interbeds of mudstone, chert and tuffacous rocks, and nodular to lenticular chert.

The Surmaq Formation, about 550 meters thick, is divided into three units (Fig. 2; Iranian-Japanese Research Group, 1981), and unconformably overlies the Carboniferous ''Sandstone Group'' (Tarz, 1969; 1974). Unit 1, about 390 meters thick, consists mostly of fossiliferous bedded limestone with thin interbeds of chert, mudstone, and tuffaceous rocks. Limestones are lime-mudstone, skeletal wackestone, and skeletal packstone. The fossils are dominated by algae, foraminifers and brachiopods, with subordinate gastropods and colonial corals, and accessary cephalopods. The lower part of Unit 1 that is referable to the *Pseudofusulina quasifusuliniformis* and *Eopolydiexodina persica* Zones consists of argillaceous limestones containing many skeletal fragments (Fig. 3-2). Fusulinaceans occur sporadically in these argillaceous limestones except for those with common *Eopolydiexodina* (Fig. 3-3). Neither verbeekinids nor neoschwagerinids are found in this part. Diversified fusulinaceans are especially abundant in the middle part of Unit 1 (Fig. 3-4–3-7). Limestones in the upper part of this unit are characterized by less fossiliferous lime-mudstone and wackestone with less diversified fusulinaceans (Fig. 3-8). Some of them are partially dolomitized (Fig. 3-9).

Unit 2, about 80 meters thick, conformably overlies Unit 1, and consists mostly of fine-grained, bedded limestone (Fig. 3-11) similar to the upper part of unit 1. Lithologies may exhibit some silicification, dolomitization, or recrystalization. Lenticular or nodular cherts are intercalated within limestones in the lower part of this unit. Thinly alternating beds of limestone and chert are well-developed in the upper part. Large-sized fusulinaceans are nearly absent in this unit except in the thin fusulinacean-algal packstone interbeds (Fig. 3-10).

Unit 3, about 80 meters thick, is composed mostly of black to dark gray fine-grained limestones. Three interbeds of chert are found in the lower part, and alternating beds of thickly and thinly bedded limestones are diagnostic of the middle and upper parts of this unit. Various kinds of fossils such as brachiopods, foraminifers, and bryozoans are contained. Fusulinaceans are rare and have low species diversity, as in unit 2. Limestone lithologies in unit 3 (Fig. 3-12) as well as in unit 2 are much more fine-grained and quite different from those in middle part of unit 1.

FUSULINACEAN STRATIGRAPHIC DISTRIBUTION AND CORRELATION

Three columnar sections are selected to exemplify the composition of fusulinacean faunas and their stratigraphic distribution in the Surmaq Formation (Fig. 2): most of unit 1 is well displayed in the M-K and N-R sections, and units 2 and 3 are well shown in the N-R section and L sections (Fig. 1; Iranian-Japanese Research Group, 1981). As a result

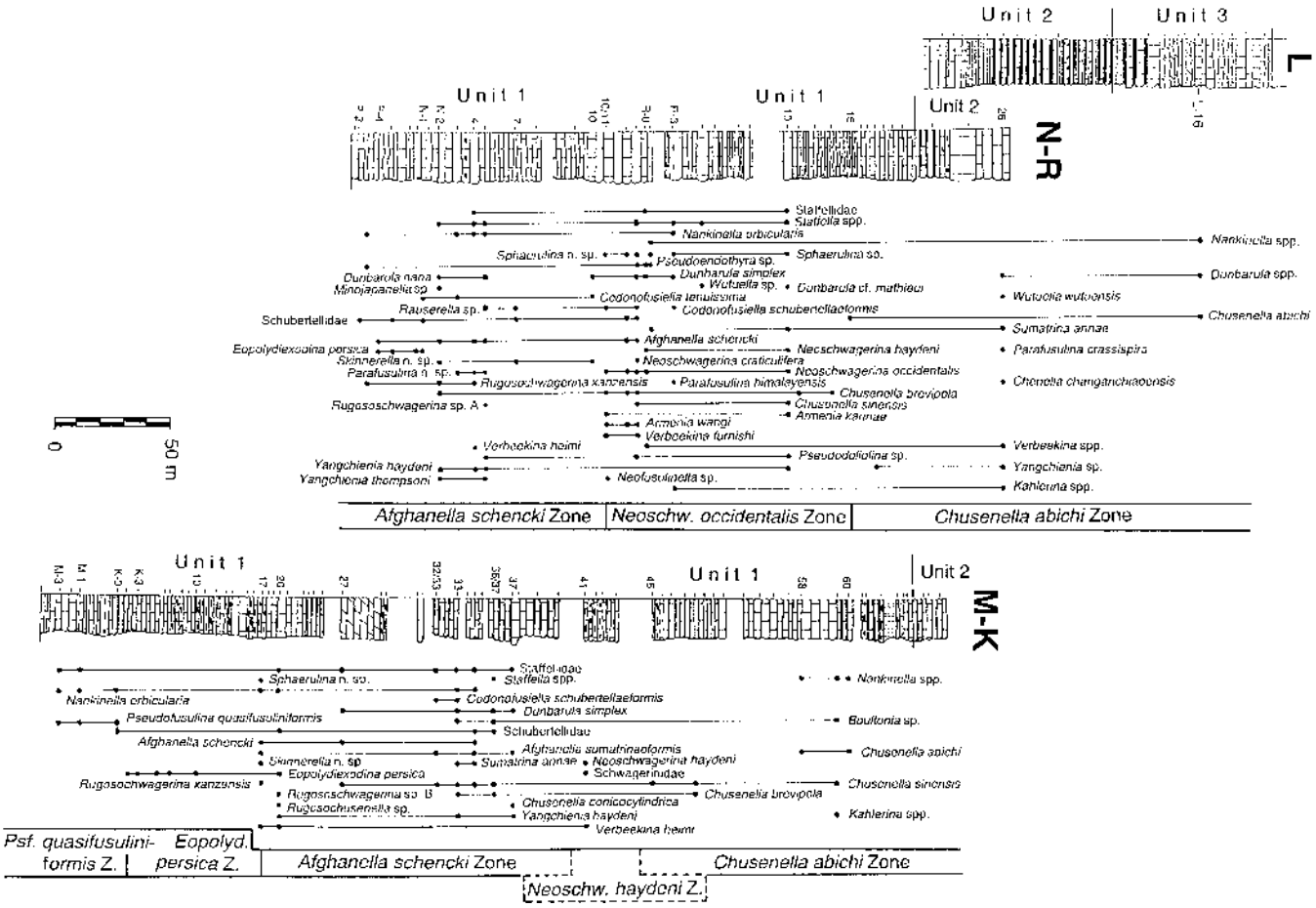


FIGURE 2. Stratigraphic distribution and biostratigraphic zonation of fusulinaceans in the Surmaq Formation. Columnar sections are based on Iranian-Japanese Research Group (1981) with slight modification.

of reexamination, 56 species referable to 30 genera have been discriminated (Table 1). Representatives are shown in Fig. 4 and Fig. 5.

Faunal composition and taxonomic diversity of fusulinaceans and their stratigraphic distribution in unit 1 differs considerably between the M-K and N-R sections (Fig. 2). Based mainly on the stratigraphic distribution of schwagerinids and neoschwagerinids, the Surmaq Formation is divisible biostratigraphically into six zones from lower to upper: *Darvasites ordinatus* Zone, *Pseudofusulina quasifusuliniformis* Zone, *Eopolydiexodina persica* Zone, *Afghanella schencki* Zone, *Neoschwagerina occidentalis* Zone, and *Chusenella abichi* Zone.

DARVASITES ORDINATUS ZONE

The *Darvasites ordinatus* Zone occurs in an isolated limestone succession of the alternating beds of thinly and thickly bedded limestone with thin intercalations of chert and shale at the Estaki Mine, 8 km northeast of Abadeh (Fig. 1), which is stratigraphically lower than the basal part of unit 1 in the M-K and N-R sections (Iranian-Japanese Research Group, 1981). These beds are rich in schwagerinids. Identified foraminifers are *Darvasites ordinatus, Chalaroschwagerina* cf. *mengi,* and *Pseudofusulina fusiformis,* along with *Pamirina leveni, Mesochubertella* sp., Schubertellidae gen. and sp. indet., *Geinitzina* sp., *Tetrataxis* sp., and palaeotextulariids.

The zonal index species and other schwagerinids are known from the Yahtashian to Bolorian of Southeast Pamir (Leven, 1967), Darvas (Kalmykova, 1967), and northern Afghanistan (Leven, 1997). *Pamirina leveni* is characteristic of the Yahtashian. Primitive *Misellina* such as *M. dyhrenfurthi* and *M. parvicostata,* which are typical of a Bolorian age, have not been recognized in the Surmaq Formation. Accordingly the D. ordinatus Zone is thought to be Yahtashian in age.

PSEUDOFUSULINA QUASIFUSULINIFORMIS ZONE

The *Pseudofusulina quasifusuliniformis* Zone contains the name-bearer but is devoid of other schwagerinids, verbeekinids, or neoschwagerinids. *Pseudofusulina quasifusuliniformis* was described from the Kubergandian (*Cancellina* Zone) of Southeast Pamir (Leven, 1967). *Nankinella orbicularia,* Schubertellidae gen. and sp. indet., *Pseudoglomospira* sp., *Globivalvulina* sp., *Pachyphloia* sp., *Neodiscus millioides,* and Palaeotextulariidae gen. and sp. indet. are also recognized in this zone. No reliable index taxa of Kubergandian or Bolorian age are distinguished from this zone so that detailed correlation and age determination are

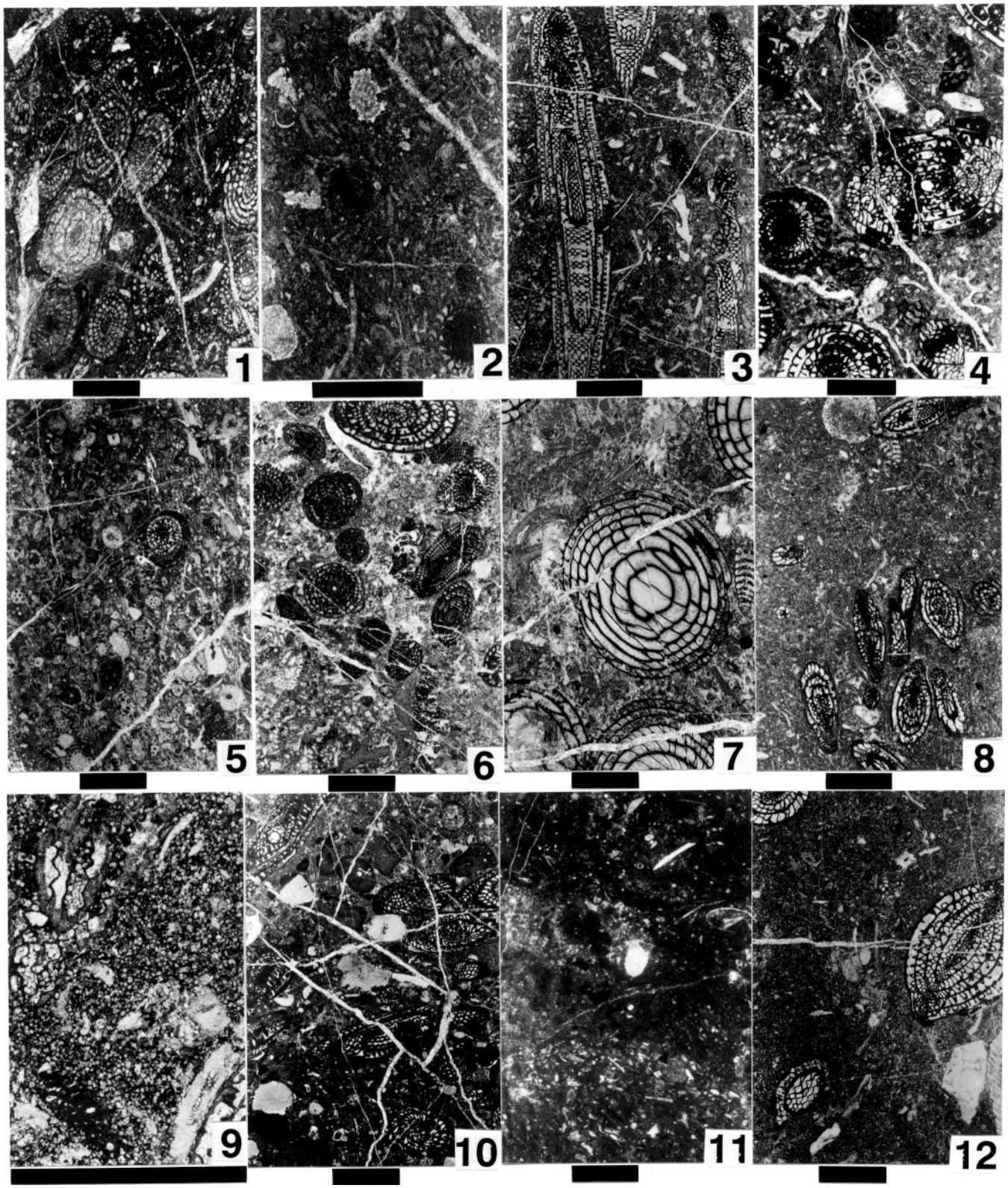


FIGURE 3. Photographs of limestone thin sections of the Surmaq Formation 1-7, 10: skeletal packstone, 1: Estaki Mine; 2: M-3; 3: N-1; 4: N-10; 5: P-4; 6: N-5; 7: K-41; 10: R-26; 8, 12: fusulinacean wackestone, 8: K-46; 12: L-16, 9: dolomitized fusulinacean wackestone; K-59, 11: lime-mudstone; K-67. Scale bar shows 3 mm.

TABLE 1. Fusulinacean faunal composition of the Surmaq Formation.

1. *Chenella changanchiaoensis* (Sheng and Wang)
2. *Pamirina leveni* Kobayashi
3. *Rauserella* sp.
4. *Boultonia* sp.
5. *Codonofusiella schubertellaeformis* Sheng
6. *Codonofusiella tenuissima* Sheng
7. *Dunbarula* cf. *mathieui* Ciry
8 *Dunbarula nana* Kochansky-Devide and Ramovs
9. *Dunbarula simplex* (Lange)
10. *Dunbarula* spp.
11. *Minojapanella* sp.
12. *Neofusulinella* sp.
13. *Wutuella wutuensis* (Kuo)
14. *Wutuella* sp.
15. *Yanghienia haydeni* Thompson
16. *Yanghienia thompsoni* Skinner and Wilde
17. *Yangchienia* sp.
18. Schubertellidae gen. and sp. indet.
19. *Chalaroschwagerina* cf. *mengi* (Chen)
20. *Chusenella abichi* (A. D. Miklukho-Maklay)
21. *Chusenella brevipola* (Chen)
22. *Chusenella conicocylinrica* Chen
23. *Chusenella sinensis* Sheng
24. *Darvasites ordinatus* (Chen)
25. *Eopolydiexodina persica* (Kahler)
26. *Rugosochusenella* sp.
27. *Rugosochwagerina xanzensis* Wang, Sheng and Zhang
28. *Rugososchwagerina* sp. A
29. *Rugososchwagerina* sp. B
30. *Parafusulina crassispira* Leven
31. *Parafusulina himalayensis* Ozawa and Gupta
32. *Parafusulina* n. sp.
33. *Pseudofusulina fusiformis* (Schellwien and Dyhrenfurth)
34. *Pseudofusulina quasifusuliniformis* Leven
35. *Skinnerella* n. sp.
36. Schwagerinidae gen. and sp. indet.
37. *Pseudodoliolina* sp.
38. *Armenia karinae* A. D. Miklukho-Maklay
39. *Armena wnagi* Sheng
40. *Verbeekina furnishi* Skinner and Wilde
41. *Verbeekina heimi* Thompson and Foster
42. *Verbeekina* spp.
43. *Neoschwagerina craticulifera* (Schwager)
44. *Neoschwagerina haydeni* Dutkevich
45. *Neoschwagerina occidentalis* Kochansky-Devide and Ramovs
46. *Afghanella schencki* Thompson
47. *Afghanella sumatrinaeformis* (Gubler)
48. *Sumatrina annae* Volz
49. *Kahlerina* sp.
50. *Pseudoendothyra* sp.
51. *Nankinella orbicularia* Lee
52. *Nankinella* spp.
53. *Sphaerulina* n. sp.
54. *Sphaerulina* sp.
55. *Staffella* spp.
56. Staffellidae gen. and sp. indet.

difficult. The *Pseudofusulina quasifusuliniformis* zone is overlain directly by the *Eopolydiexodina persica* Zone.

EOPOLYDIEXODINA PERSICA ZONE

In the M-K section, the *Eopolydiexodina persica* Zone occurs in thinly bedded limestone, 56 m thick, from K-2 to the horizon beneath K-17 in which *Afghanella schencki* first occurs. *Eopolydiexodina persica* ranges up to the lower part of the overlying *Afghanella schencki* Zone (Fig. 2). The basal part of this zone is not clearly defined in the N-R section. Foraminifers recognized in this part are, Schubertellidae gen. and sp. indet., *Staffella* spp., *Pseudoendothyra* sp., *Glomospira* sp., *Globivalvulina* sp., and *Neoendothyra* ? sp.

Eopolydiexodina ranges from the Kubergandian (*Cancellina* Zone) to the middle Murgabian (*Neoschwagerina craticulifera* Zone) according to Leven (1965). In South West Asia, *Eopolydiexodina* is widely distributed in Southeast Pamir (Leven, 1967), northern Afghanistan (Bamian Limestone) (Thompson, 1946; Leven, 1997), central Afghanistan (Lys and Lapparent, 1971), Iranian Baluchistan (Douglass, 1950), northern Iraq (Lloyd, 1963), Transcaucasus (Rozovskaya, 1965; 1975), Turkey (Erk, 1942; Kahler and Kahler, 1979), and Slovenia (Kochansky-Devidé, 1957). Close correlation and age determination of this zone are difficult, as with the underlying *Pseudofusulina quasifusuliniformis* Zone, because of the absence of neoschwagerinids and verbeekinids.

AFGHANELLA SCHENCKI ZONE

The base of the *Afghanella schencki* Zone is defined by the first occurrence of *Afghanella schencki* in the M-K section, and its top is at the first occurrence of *Neoschwagerina occidentalis* in the N-R section (Fig. 2). Foraminiferal species diversity increases markedly in this zone. Besides *Afghanella schencki*, this zone contains *Afghanella sumatrinaeformis, Sumatrina annae, Verbeekina heimi, Pseudodoliolina* sp., *Eopolydiexodina persica, Rugososchwagerina xanzensis, Skinnerella* n. sp., *Parafusulina* n. sp., *Chusenella sinensis,* and others (Fig. 2). In addition, more than 10 genera of non-fusulinacean foraminifers are also recognized in this zone.

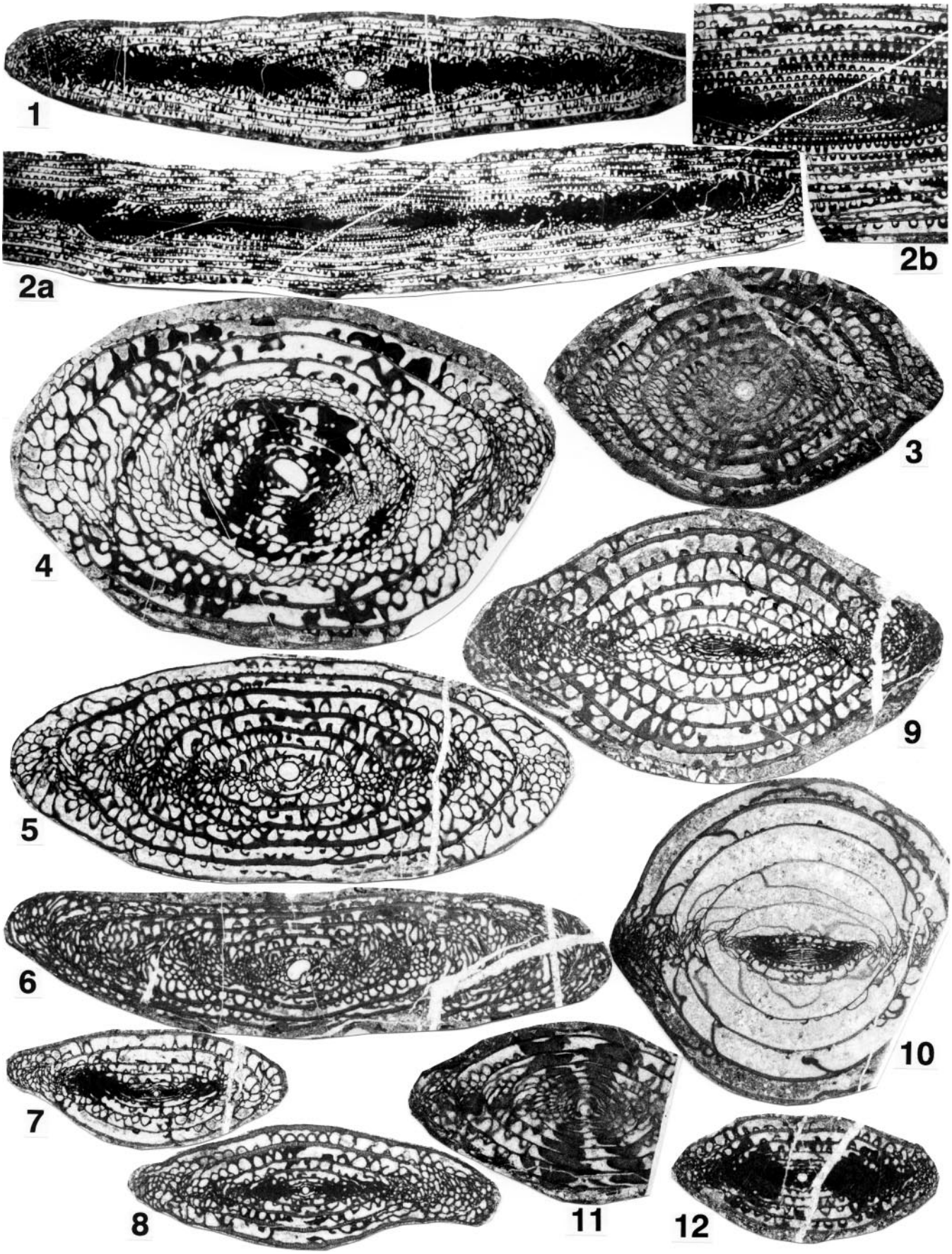
Eopolydiexodina persica ranges upwards into the lower part of this zone. According to Leven (1993a), late Kubergandian *Cancellina,* and early Murgabian *Presumatrina* and *Neoschwagerina* occur above the bed with abundant *Parafusulina* and *Skinnnerella* in the Surmaq Formation, however, we did not find these neoschwagerinids in our materials.

Afghanella schencki is widespread throughout the Tethyan regions in the Murgabian. Leven (1993b) considered it was an index species to the upper Murgabian based on the evolutionary trend of the Sumatrininae. In the Akiyoshi Limestone of Japan, the biostratigraphic range of *Afghanella schencki* is restricted to the *Afghanella schencki* Zone between the underlying *Neoschwagerina craticulifera* Zone and the overlying *Neoschwagerina haydeni* Zone (Ozawa and Kobayashi, 1990). We believe this zone is middle to late Murgabian in age.

NEOSCHWAGERINA OCCIDENTALIS ZONE

The *Neoschwagerina occidentalis* Zone, 105 m thick, extends from the bed N-10/11, where the zonal species first occurs, to the horizon beneath R-15, where *Chusenella abichi* first occurs in the N-R section (Fig. 2). In the M-K section, the occurrence of *Neoschwagerina* is restricted to bed K-41 where *N. haydeni* is associated with *Verbeekina heimi.* The 15 m thick limestone that includes K-41 is tentatively assigned to the *Neoschwagerina haydeni* Zone. Although the lower and upper boundaries of this zone in the M-K section are poorly defined biostratigraphically, bed 41 probably correlates with a part of the *Neoschwagerina occidentalis* Zone of the N-R section.

More fusulinacean and non-fusulinacean foraminifer taxa are distinguished in this zone than in the underlying *Afghanella schencki* Zone (Fig. 2). *Neoschwagerina occidentalis, N. haydeni, Sumatrina annae,* and others of this zone are well-known and widespread in South West Asia and Mediterranean Sea regions (e.g., Leven, 1967; 1997; Kochansky-Devidé and Ramovš, 1955). We consider this zone is late Murgabian in age, rather than early Midian, because this zone is characterized by evolved species of *Neoschwagerina* including the zonal species *N. occidentalis* and *N. haydeni,* but lacks species of *Yabeina* or other evolved forms of Lepidolininae and Sumatrininae which Leven (1980; 2001) uses to define the Midian Stage.



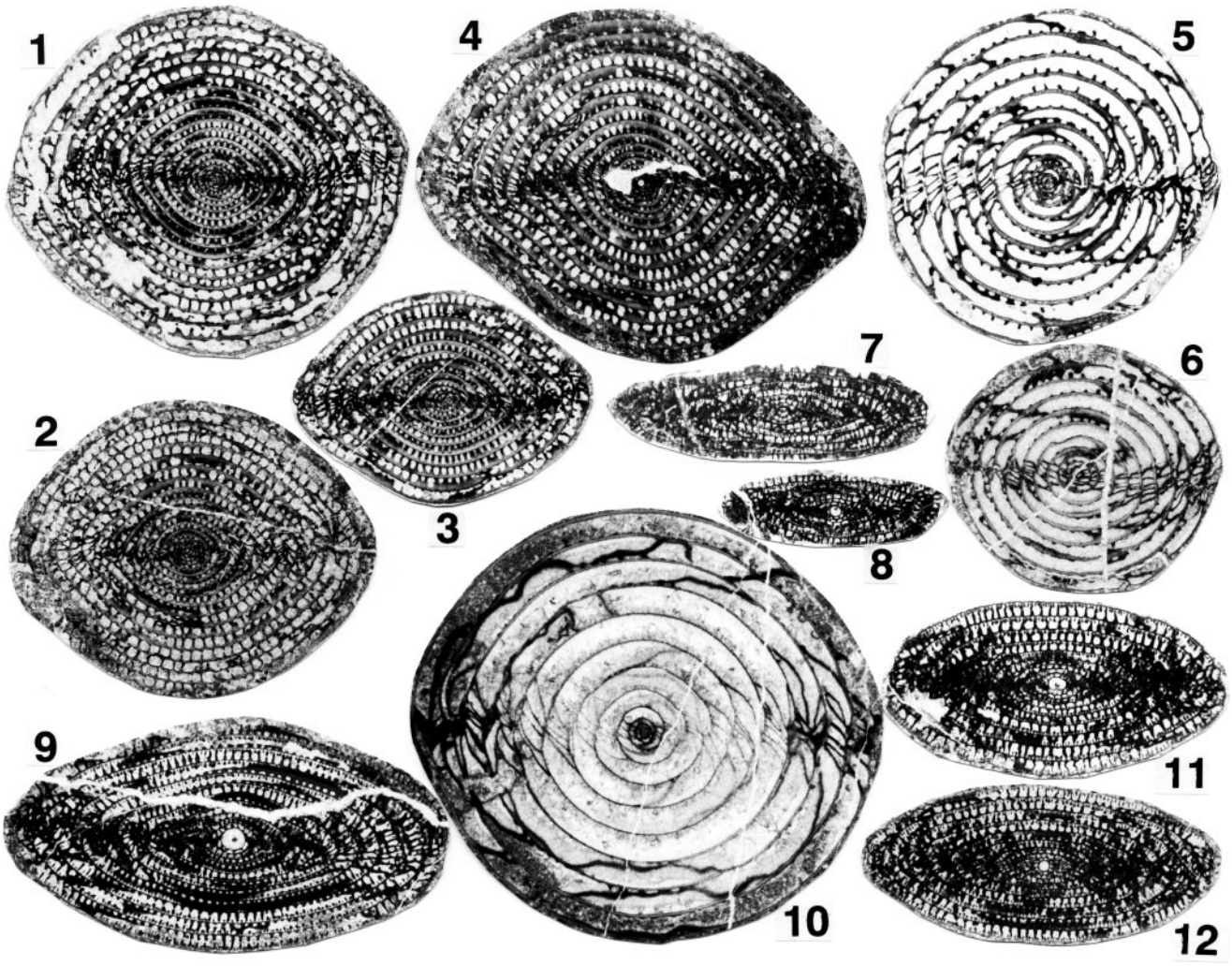


FIGURE 5. Representative fusulinaceans of the Surmaq Formation (Part 2) 1, 2: *Neoschwagerina occidentalis* Kochansky-Devide and Ramovs, 1: R-0; 2: N-10/11; 3: *Neoschwagerina craticulifera* (Schwager), N-12; 4: *Neoschwagerina haydeni* Dutkevich, K-41; 5: *Armenia wangi* Sheng, N-12; 6: *Armenia karinae* A. D. Miklukho-Maklay, N-10/11; 7, 8: *Sumatrina annae* Volz, R-10; 9: *Afghanella sumatrinaeformis* (Gubler), K-37; 10: *Verbeekina heimi* Thompson and Foster, K-17; 11, 12: *Afghanella schencki* Thompson, 11:N-5; 12: N-2. All: ×10.

CHUSENELLA ABICHI ZONE

The *Chusenella abichi* Zone forms the uppermost part of unit 1 (from bed R-15 to the top in the N-R section) and units 2 and 3. The base of this zone is defined by the first occurrence of *Chusenella abichi* in the N-R section where this zone is more than 170 m thick.

Biostratigraphic relationship between this zone and the tentatively designated *Neoschwagerina haydeni* Zone in the M-K section is uncertain. *Chusenella abichi*, *C. sinensis*, and *C. brevipola* are not found in the same collections with neoschwagerinids, verbeekinids, and other schwagerinids in this zone. Among neoschwagerinids, *Sumatrina annae* is exclusively known from this zone (Fig. 2). This species ranging downwards into the *Neoschwagerina occidentalis* Zone is associated with *Parafusulina crassispira*, *Wutuella wutuensis*, and *Chenella changanchiaoensis* in bed R-26. In the Surmaq Formation, these schwagerinid, schubertellid and ozawainellid species are restricted to this bed composed of fusulinacean-algal limestone. On the other hand, most of limestones of this zone consist of wackestone and lime-mudstone.

Chusenella abichi is the index species in the Midian of Trancaucasus (Rozovskaya, 1965; Kotlyar and others, 1989; Leven, 1998). *Wutuella wutuensis*, common in the upper part of the Maokou Limestone of South China (e.g., Sheng, 1963), is also known from Southeast Pamir (Leven, 1967)

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FIGURE 4. Representative fusulinaceans of the Surmaq Formation (Part 1) 1, 2: *Eopolydiexodina persica* (Kahler), N-1; 3: *Charlaroschwagerina* cf. *mengi* (Chen), Estaki Mine; 4: *Skinnerella* n. sp., K-17; 5: *Parafusulina* n. sp., N-4; 6: *Parafusulina crassispira* Leven, R-26; 7: *Chusenella brevipola* (Chen), R-11; 8: *Chusenella sinensis* Sheng, K-46; 9: *Chusenella abich* (A. D. Miklukho-Maklay), L-16; 10: *Rugososchwagerina xanzensis* Wang, Sheng, and Zhang, K-17; 11: *Darvasites ordinatus* (Chen), Estaki Mine; 12: *Pseudofusulina quasifusuliniformis* Leven, M-1. 1 and 2a: ×5, others: ×10.

and central Afghanistan (Leven, 1997). *Chenella changanchiaoensis* was originally described from the uppermost part of the Maokou Limestone in southern Jiangsu (Sheng, 1962). Based on these fusulinaceans, this zone is thought to be Midian in age.

FAUNAL ANALYSIS

Surmaq fusulinaceans are important to late Paleozoic biostratigraphic and paleobiogeographic studies of Cimmerian and southern Tethyan areas of south-central Asia. Early Permian rifting of the western part of the Cimmerian Continent from Gondwana and movements of the rifted fragments (terranes) northward into middle- to lower-latitudinal belts are suggested by paleomagnetic studies (Lottes and Rowley, 1990; Metcalfe, 1996), glacio-marine sediments, and cool-adapted biota (Nie and others, 1990; Ziegler, 1990). This tectonic event, or series of events, is also shown by a regional unconformity and sedimentary hiatus that lack marine Upper Carboniferous and Lower Permian (pre-Yahtashian) sediments on the Cimmerian terranes, including those in central Iran. The gradual change that started in the late Early Permian from fusulinacean faunas with low species diversity (i.e., older than the *Eopolydiexodina persica* fauna) to a marked increase in diversity and to mainly limestone deposition, further suggest progressive environmental changes in the Abadeh region from cool to warm temperature into subtropical climatic zones during the late Early to early Middle Permian time.

During the Permian, Surmaq fusulinaceans, which were warm to tropical shallow marine foraminifers, increased remarkably in faunal diversity. These changes were rapid, progressive changes in specific, generic, and family associations, particularly the expansions of phylogenetic lineages among the neoschwagerinids, schwagerinids, and verbeekinids. Along with these fusulinacean changes, other smaller foraminiferal lineages progressively appear in these strata. All of these changes are useful in interpreting the rapid paleogeographic displacement and tectonic development of these terranes which previously had had strong Gondwana affinities. By the beginning of the Late Permian, the ecological collapse and widespread extinction in most of the highly successful Middle Permian fusulinacean lineages provide considerable evidence about other major climatic and environmental changes which also were beginning to strongly affect these shallow, warm marine faunas.

FAUNAS OLDER THAN THE *EOPOLYDIEXODINA PERSICA* FAUNA

A global Yahtashian to Bolorian transgression is represented by limestones which unconformably lie on the Carboniferous or pre-Carboniferous clastic beds in the Cimmerian terranes. This trangressive event is also closely related to rapid evolution in several fusulinacean lineages (Ross and Ross, 1987; 1995, Leven, 1993a). Widespread faunas rich in *Pamirina* and *Misellina* which later evolved rapidly throughout Tethyan regions are associated with this event. Yahtashian fusulinacean faunas are variable from place to place and not easily defined faunistically when *Pamirina* is not found. *Pamirina leveni* occurs in association with *Darvasites ordinatus* at the Estaki Mine, however, *Misellina* has not been found in the Abadeh region. Foraminifer faunas of both the *Darvasites ordinatus* and the *Pseudofusulina quasifusuliniformis* Zone have low species diversity.

EOPOLYDIEXODINA PERSICA FAUNA

Eopolydiexodina persica is very characteristic of beds K-2 through K-20 in the lower part of the unit 1. *Eopolydiexodina* is common in the Cimmerian terranes of South West Asia and surrounding regions. Leven (1967) reports this genus from the Kubergandian and Murgabian of Southeast Pamir. It is also present in eastern Karakoram Himalaya (Gupta and Ozawa, 1985), central Afghanistan (Lys and Lapparent, 1971), Iranian Baluchistan (Douglass, 1950), central Zagros (Douglass, 1936; Sampo, 1969), northern Iraq (Lloyd, 1963), and Transcaucasus (Rozvskaya, 1965) which are all considered part of the Cimmerian Terrane of South West Asia.

The distribution of *Eopolydiexodina* also extends to North Pamir (Leven, 1965) and the Bamian zone of north Afghanistan (Thompson, 1946), both of which are assignable to the Hercynian terranes of South West Asia, and to the Kunlung Mountains (Da and Sun, 1983) between southern Qiangtang and northern Tarim. In these regions, carbonate deposition stopped by early Midian time. *Eopolydiexodiena* is also common in Mediterranean regions (Erk, 1942; Kochansky-Devide, 1957; Kahler and Kahler, 1979; Leven and Okay, 1996) and in Crimea (A. D. Mikluho-Maklay, 1957).

In comparison with the common occurrences of *Eopolydiexodina* in the faunas in these western Tethyan regions, *Eopolydiexodina* is almost absent in eastern Cimmerian terranes (Sibumasu) where well-developed Bolorian to Murgabian limestones contain many schwagerinids, verbeekinids, and neoschwagerinids. In South China, where carbonate sequences are nearly continuous throughout the Permian, *Eopolydiexodina* is only known from the Maokou Limestone in western Zhejiang (Sheng, 1962).

Eopolydiexodina is completely lacking in East Asia including Japan, and Far East Asia. Paleobiogeographically, South West Asian and Mediterranean Sea regions with dominant *Eopolydiexodina* are mostly assignable to the Western Tethyan Province (Fig. 6), which was distinguished through the faunal analysis of Murgabian and Midian fusulinaceans by Kobayashi (1997a).

AFGHANELLA SCHENCKI AND *NEOSCHWAGERINA OCCIDENTALIS* FAUNAS

Although no diagnostic index taxa of Bolorian to early Murgabian ages are found in our materials, many diverse fusulinaceans characterize the middle part of unit 1. Neoschwagerinids and verbeekinids first appear in the *Afghanella schencki* zone. The last occurrence of *Eopolydiexodina persica* extends to the lower part of this zone.

The *Afghanella schencki* zone is represented by *Afghanella schencki, A. sumatrinaeformis, Sumatrina annae, Armenia karinae, Verbeekina heimi, Skinnerella* n. sp., *Parafusulina* n. sp., *Rugosochwagerina xanzensis,* and others. In the *Neoschwagerina occidentalis* Zone in the N-R section, species diversity increases even more with *N. occiden-*

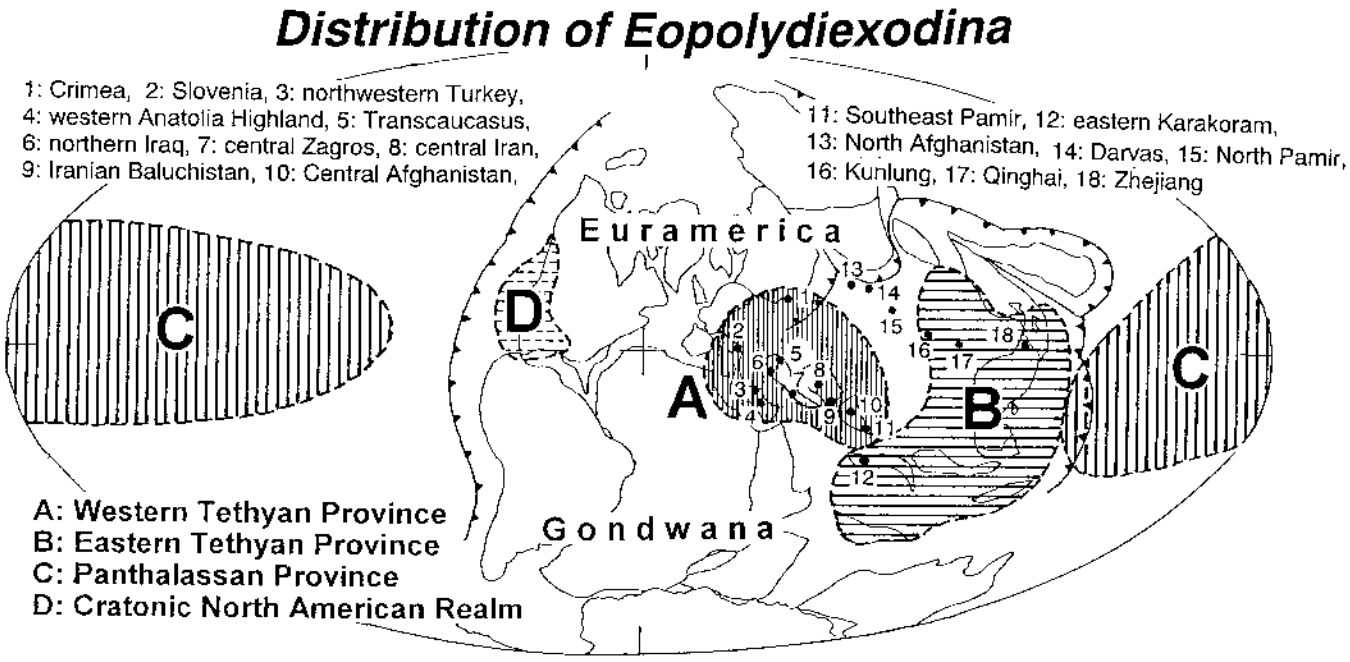

FIGURE 6. Distribution of *Eopolydiexodina* plotted on the fusulinacean paleobiogeographic map by Kobayashi (1997a)

talis, N. craticulifera, N. haydeni, Armenia wangi, A. karinae, Verbeekina furnishi and *V.* spp. first appear.

The higher species diversity in the middle to late Murgabian fusulinacean faunas and the dominance of verbeekinids and neoschwagerinids are thought to be related to the northward movement of western Cimmerian terranes, including the Abadeh region, into warmer water. Movement toward lower latitudes is suggested also by the floral change in the North Iran and Helmend terranes (Nie and others, 1990; Ziegler, 1990).

These Murgabian fusulinacean faunas are closely similar to those of other South West Asian and Mediterranean Sea regions and are paleobiogeographically assignable to the Western Tethyan Province (Kobayashi, 1997a). They have general similarities to those of the East Tethyan Province, however, *Colania,* which is characteristic of the East Tethys, is rare in the Western Tethys. ''*Colania altimurensis*'' from north Afghanistan (Leven, 1997) differs in many features from typical East to South East Asian *Colania,* such as *C. kwangsiana* and *C. douvillei,* which are characterized by having a large proloculus (e.g., Sheng, 1963; Ozawa, 1970b). It is uncertain that the specimen, identified as *Colania douvillei* by Hauser and others (2000) from northeastern Oman, is assignable to *Colania*. Murgabian faunas of both the Western and Eastern Tethyan Provinces are quite different from those of the Panthalassan Province which nearly lacks *Afghanella* and *Sumatrina* (Kobayashi, 1997a).

Fusulinacean faunal provincialism becomes evident and more easily distinguishable in the Tethyan regions toward the end of Middle Permian because of rapid and progressive evolution of neoschwagerinids and verbeekinids (Kobayashi, 1997a; 1999). Phyletic evolution and provincial evolution are shown clearly by an analysis of the ontogenetic development of shell characters and faunal composition in each of the faunal province.

The three Surmaq species of *Rugososchwagerina* are not like species of *Rugososchwagerina,* such as *R. yabei,* common in South West Asia and the Mediterranean region (e.g., Skinner and Wilde, 1966). One Surmaq species of *Rugososchwagerina* is identical with *R. xanzensis* described from South Xizang (Wang and others, 1981) which is referable to the Lhasa Terrane that lies between the Southeast Pamir and Sibumasu Terranes. Along with *Colania, Lepidolina* is rare in the Western Tethyan Province, and is known only from the Taurus Mountains, southern Turkey (personal communication from Dr. Demir Altiner). Two illustrated specimens, named ''*Lepidolina* ex. gr. *multiseptata*'' by Kotlyar and others (1989) from Southeast Pamir, are more reasonably assigned to *Yabeina* and *Sumatrina,* as indicated by Kobayashi (1999). Although *Lepidolina* is rarely found in the Chichibu faunas of the Panthalassan Province (Kobayashi, 1997b) or in the West Tethyan, it is the most diagnostic Midian neoschwagerinid genera of the Eastern Tethyan Province in South China, Sibumasu, Indochina, and the Akiyoshi of Japan, where *Colania* is dominant in the upper Murgabian (Kobayashi, 1997a).

CHUSENELLA ABICHI FAUNA

Fusulinaceans are rare and species diversity becomes poor in the *Chusenella abichi* Zone. The only neoshwagerinids and verbeekinids in the units 2 and 3 of the Surmaq Formation are in horizon R-26 (Fig. 2). Most of limestones in the *Chusenella abichi* Zone of the Surmaq Formation consist of lime-mudstone and wackestone containing skeletal fragments and common sponge spicules. These limestones are commonly dolomitized and silicified. Reefal limestones, which occurred in the underlying two zones, are not found. Low specific diversity of faunas along with an abrupt change of limestone facies in this zone indicate a change of sedimentary environment. Horizon R-26 is an unusual bed of fusulinacean algal packstone (Fig. 3-10) with *Sumatrina*

annae, Parafusulina crassispira, and others may be a flow bed which carried these fusulinaceans into the Abadeh basin in Midian time.

Chusenella abichi fauna in the Abadeh region and Transcaucasus (Rozovskaya, 1965; Leven, 1998) is considered to be contemporaneous with the Midian *Yabeina* fauna. In the Western Tethyan Province, the *Yabeina* fauna is more narrowly distributed than other Murgabian faunas, and is restricted to Southeast Pamir (Leven, 1967), Crimea (Tumanskaya, 1950), Tunisia (Skinner and Wilde, 1967), and Abadeh region and some localities in the Zagros Mountains (Baghbani, 1997). By the end of the Middle Permian (Midian), all neoschwagerinids, verbeekinids, and schwagerinids became extinct. In the Late Permian, faunal provincialism in the remaining fusulinacean families and in small foraminifers increased markedly from east to west throughout the Tethyan regions.

CONCLUSIONS

Although in the Eastern Tethyan regions, evolutionary lineages within the families Verbeekinidae and Neoschwagerinidae show distinct morphologic changes through the Middle Permian (e.g., Ozawa, 1970a), in the Western Tethyan regions these two families show considerably less distinct evolutionary changes perhaps because the lineages are less completely recorded. Yahtashian to Midian fusulinacean faunas of the Surmaq Formation are typical of the Western Tethyan faunal province. Most of these fusulinaceans belong to incomplete parts of lineages, or to different phylogenetic branches, than those typical of the Eastern Tethyan faunal province. Faunal provincialism in the intra-Western Tethyan faunal province increased through the Midian *Chusenella abichi* faunal zone.

Within the Surmaq Formation, faunal composition and species diversity were closely related to the environmental changes as shown by changes in limestone depositional lithologies that become less siliciclastic and more normal marine carbonate and, finally, into mixed siliceous (cherty) and dolomitic limestones through time. Overall, the changes in the succession of Surmaq fusulinacean faunas provide important biostratigraphic, evolutionary and paleobiogeographic evidence which greatly help to constrain the timing of the history of rift-drift-collision movements of the Cimmerian terranes that rifted from Gondwana's northeastern margin. These faunas show the effects of terrane motion from a cool climatic zone toward the tropical zone and they show a history of Late Paleozoic sealevel fluctuations, which were resulted from global climatic change, superimposed on the rapid tectonic movements of these Western Tethyan terranes.

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