ROCZNIK POLSKIEGO TOWARZYSTWA GEOLOGICZNEGO
ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DE POLOGNE

Tom (Volume) XXXIX — 1969 Zeszyt (Fascicule) 1—3 Kraków 1969

M. Y. SEROVA *

COMPARISON OF CHARACTERISTICS OF RZEHAKINIDAE IN THE CARPATHIAN REGION AND PACIFIC PROVINCE

М. Я. СЕРОВА

Сравнительная характеристика ржегакинид Карпатского региона и Тихоокеанской провинции

The Rzehakinidae form one of the most interesting, but poorly studied groups of the arenaceous Foraminifera. At the present, not only the origin of silica in the test wall (i.e. whether it is agglutinated or secretionary, primary or resulting from diagenetic replacement of a primarily calcareous test) is problematical but there is also the question, as to whether the type of coiling is of taxonomic importance for the group (Scott, 1961). Moreover, the problem concerning the position of Rzehakinidae in the scheme of phylogenetic development of protozoans is being solved in different ways.

In a previous paper (Serova, 1966), the present author tried to analyze the taxonomic importance of certain morphological features of representatives of the Rzehakinidae family.

The present paper deals with the stratigraphic importance and characteristics of Rzehakinidae assemblages in various basins of Late Cretaceous and Early Tertiary age. Attention is also drawn to the taxonomic importance of the type of coiling.

The discussion of these problems will be limited to a description of only two genera belonging to this family, *Rzehakina* and *Silicosigmoilina*, which are most interesting, very widespread and of considerable stratigraphic importance. These genera are well developed mainly in Upper Cretaceous and Lower Tertiary deposits.

Six species of the genus *Rzehakina* are most often encountered in recent literature: *Rzehakina epigona* (Rzehak), *R. inclusa* (Grzybowski), *R. fissistomata* (Grzybowski), found in the Carpathian Flysch basin, and *Rzehakina epigona lata* Cushman et Jarvis, *R. epigona minima* Cushman et Renz, *R. venezuelana* Hedberg, distinguished on the American continent. Most micropalaeontologists distinguish *Rzehakina epigona* or its variety *R. epigona lata* (on the American continent and in the most regions of the Pacific province). M. A. Glaessner (1937) and E. Hanzliková (1955) consider the variety „lata" and the species *R. inclusa* and *R. fissistomata* as junior synonyms of *R. epigona*. S. Geroch (1960), in his study on *Rzehakina* from the Silesian series of the Polish Flysch Carpathians, unlike the two

* Address: Dr M. Y. Serova, Geological Institute, Academy of Science ,USSR, Moscov W-17, Pyzhevskii 7.

previous authors, considers the possibility of retaining the *Rzehakina* forms distinguished by Grzybowski (1901), as independent specific taxons. Characteristic features, which served as a basis for distinguishing the species, mentioned above, are given below.

Rzehak (1895) gave a detailed description of *Rzehakina epigona*, genotype of the genus. In this description, there are no data on the range of variability of this species, namely about changes in length-width ratio of the test. This is supposed to result from distinction of the variety „lata", which differs from the typical form in a having wider, almost rounded form and a more compressed periphery (based on data by Cushman and Jarvis (1928), who described this variety from the Lizard Springs formation of Trinidad).

The data on principal dimensions (length, width, thickness) are absent in the first description of this variety. It should be mentioned that, while describing the new variety *R. epigona lata*, Cushman says that „...this variety is more rounded and much larger than the forms found in the Velasco shale of Mexico" (Cushman and Jarvis, 1928, p. 93), which were distinguished by him in 1927 as *Rzehakina epigona*.

In his later monograph on the Upper Cretaceous Foraminifera of the Gulf Coast and adjacent areas, Cushman (1946) included in the synonymy of *Rzehakina epigona lata* not only the forms of *Rzehakina epigona* from the Velasco shale mentioned above, but also forms from the same deposits of the Tampico region, described by White (1928). Cushman (1947) also assigned *Rzehakina* from the Santa Anita formation (Venezuela) to *R. epigona lata*.

The main reason for the distinction of the variety „lata" by Cushman was the relative width of the test. It would be interesting, therefore, to know the parametres of *Rzehakina* from various deposits assigned by Cushman to this variety. Unfortunately, almost all Cushman's papers contain no data on parameters, even in the description, of holotypes. Consequently, we were obliged to measure the forms figured. The results of these investigations are presented in Table 1.

Thus, at that time, Cushman considered relative width of the test as a decisive point for distinction of the „lata" variety, whereas in his monograph of 1946, he included in it not only the forms with a test wider than that of *R. epigona* (holotype of variety „lata"), but also forms with a similar degree of elongation, as well as forms more elongated than the holotype of *Rzehakina epigona*. In other words, all the *Rzehakina* found on the American continent, regardless of the degree of elongation of the test, were assigned by Cushman to *R. epigona* var. *lata*, whereas *R. epigona* was discarded.

The data cited seem to indicate that the degree of elongation („growth index" after E. Hanzliková, in Homola, Hanzliková, 1955; „growth index" after Scott, 1961) is an intraspecific feature and its change in various forms cannot serve as a basis for distinction of even a taxon of variety rank. However, this topic will be considered later.

Only two of the other specific taxons of the genus *Rzehakina*, will be considered: *R. inclusa* and *R. fissistomata*. These two species are known to have been distinguished first by Grzybowski (1901), on the basis of test structure, and were assigned to *Spiroloculina* (family Miliolidae). When describing them, that author paid attention to the

Table 1

Name of taxon Author, year \ Parameters	Length MM L	Width MM B	Thickness MM T	Degree of elongation L : B	Degree of flatn B : T
1	2	3	4	5	6
Rzehakina epigona /Rzehak, 1895/, holotype	0,6	-	-	1,5	2,9
Rzehakina epigona /Rzehak/ var. lata Cushman and Jarvis, 1928, holotype	-	-	-	1,35	3,7
Rzehakina epigona /Rzehak/ var. lata Cushman and Jarvis, 1932	-	-	-	1,35	3,7
Rzehakina epigona /Rzehak/ White, 1928	0,7	0,45	-	1,8	-
Rzehakina epigona /Rzehak/ Cushman, 1927	-	-	-	1,55	-
Rzehakina epigona /Rzehak/ var. lata Cushman, 1946, Fig. 1	-	-	-	1,43	2,9
Rzehakina epigona /Rzehak/ var. lata Cushman, 1946, Fig. 2	-	-	-	1,9	3
Rzehakina epigona /Rzehak/ var. lata Cushman, 1947	-	-	-	1,6	-

siliceous composition of the test of these „*Spiroloculina*". Later, on the basis of the composition of the wall and *Spiroloculina* type of coiling of chambers, they were assigned to *Rzehakina* genus. S. G e r o c h (1960), who studied these two species in detail, using topotypical material, considered them to be independent species, existing along with a typical species *Rzehakina epigona*. However, when describing *Rzehakina* from the Upper Cretaceous and Lower Palaeogene deposits of the Silesian series of the Western Carpathians, S. G e r o c h finds that all the three

species found here, *Rzehakina epigona* (Rzehak), *R. inclusa* (Grzybowski) and *R. fissistomata* (Grzybowski) have „...similar internal structure of the test differing in the external morphology" (S. Geroch, 1960, p. 132). According to the data given by S. Geroch, the main difference between the two latter species and the genotype of the genus *Rzehakina* is the lack of umbilici in the central part of lateral surfaces of tests of the *R. inclusa* species and the much more flattened test of *R. fissistomata,* as compared with the two previous species. „The arrangement of the chambers in the central coils is distinctly marked on the surface of broad umbilical depression of both sides of the test" (Geroch, 1960, p. 133), whereas chambers of *R. epigona* and *R. inclusa* are usually closed by lateral protuberances of the wall of later chambers or by non transparent matter of a supplementary skeleton.

Despite considerable similarity in the morphology of the tests of all three forms, in Geroch's opinion, it is possible for them to retain independent specific taxons, since the extreme forms *R. inclusa* and *R. fissistomata* „...are of stratigraphical importance in the Flysch of Silesian unit. The occurrence of *Rzehakina inclusa* is confined to the Lower Istebna Beds (Senonian), and *R. fissistomata* mainly occurs in the Ciężkowice Beds", (S. Geroch, 1960, p. 132). Unfortunately, Geroch did not give his opinion on the validity of *R. epigona lata* mentioned above.

M. A. Glaessner (1937) and E. Hanzlikovà (Homola, Hanzlikovà, 1955) studied very thoroughly the ranges of *Rzehakina epigona* (Rzehak) species and did not acknowledge the independence of the taxons *Rzehakina epigona lata* Cushman and Jarvis and *R. inclusa* (Grzybowski) but considered them to be junior synonyms of *R. epigona.* It should be emphasized, however, that E. Hanzlikovà, though accepting M. A. Glaessner's interpretation of *R. epigona,* considers this species most probably to include a group of species. In her opinion, the Maestrichtian-Palaeocene forms of *Rzehakina* of the Carpathian Flysch assigned to *Rzehakina* ex. gr. *epigona* (Rzehak) „differ from the specimen-forms from the typical Cretaceous groups by several, relatively marked features". These are:

„1) a broad, umbiliform, relatively shallow depression in the middle of the shell;

2) a visible winding, caused by the very thin walls of the initial whorls;

3) larger size; this character can be influenced by very different factors;

4) the moderately asymmetrical growth, and especially the asymmetrical winding of the last whorl (Homola, Hanzlikovà, 1955, p. 495).

The features of Maestrichtian-Palaeocene *Rzehakina,* mentioned by E. Hanzlikovà, correspond quite well to those of the species, characterized by Grzybowski (1901) and Geroch (1960) as *Rzehakina fissistomata,* the latter being typical for Maestrichtian-Palaeocene deposits.

When describing „specimen-form" in the *Rzehakina* ex gr. *epigona* group, Hanzlikovà tried to apply a method of growth indices (length-width ratio). In other words, she tried to present precisely and statistically the very feature, on which Cushman and Jarvis distinguished the variety *R. epigona lata.* On the basis of the data

obtained Hanzliková established that „The specimens found in sediments of a Palaeocene age (Beskydy Mts.) have a growth index (length to width) almost agreeing with that of the specimens from the Palaeocene of the Caucasus, which amounts to 1,5, where only the hundredths are different. The specimens found in sediments of Maestrichtian age... have values around 1,3" (Homola, Hanzliková, 1955, p. 495). Considering the growth-index to be of great importance, E. Hanzliková, however, believes that the data obtained are preliminary, since the material available is quantitatively insufficient. Furthermore, in her opinion, to establish the taxonomic rank of this feature, it is necessary to determine the variation in growth-index for the forms of various generation. According to Hanzliková, it is not possible to subdivide the Beskydian Rzehakinidae into species, until this work has been carried out. She provisionally assigns all these *Rzehakinidae* to one group *Rzehakina* ex. gr. *epigona*.

The method proposed by Hanzliková, for statistical treatment of features of Rzehakinidae of various generations, was used by G. Scott (1961), who published a rather detailed and interesting study of Rzehakinidae of New Zealand. He presented the results of statistical treatment of a large number of Rzehakinidae from the Upper Cretaceous and Lower Palaeogene deposits of New Zealand. The main aim of his work was to establish a definite opinion concerning morphological variability of local Rzehakinidae population and the study of possibilities of using this variability for stratigraphic interpretation. G. Scott approached this problem from the point of view of a biometric analysis of outer morphological features of Rzehakinidae; the size of proloculus, which can be easily measured in planispiral forms without investigating their sections, change in growth rate (length-width ratio) and the type of coiling of chambers. On the basis of many data on the main parameters and their statistical treatment, G. Scott distinguished four main Rzehakinidae groups, occurring in the Upper Cretaceous and Palaeocene deposits of New Zealand: the α, γ, β and δ forms. The α and γ forms represent mega-and microsphaerical generations, in which coiling of chambers takes place in one plane (spiroloculinic type of coiling) in all growth stages. The forms with size of proloculus exceeding 50 microns (50—75 microns) were assigned by G. Scott to the megasphaerical generation (α), while the forms having the proloculus below 50 microns in size were assigned to the microsphaerical one (γ).

The forms of group β and δ are micro- and megasphaerical generations of forms, in which coiling of successive pairs of chambers takes place in different planes (sigmoilinic type of coiling of chambers). In Scott's opinion, the growth ratios „a" for all forms studied are within the intraspecific rank.

Having analyzed the distribution in time of the groups distinguished, G. Scott points out that groups α and γ, differing only in parameters of proloculus, are widespread in the lower part of the Haumurian stage (Maestrichtian), where *Rzehakina* are better developed and more numerous than in the Raukumara series, where they appear for the first time. „Later Haumurian and Teurian samples reveal progressive attenuation in the shape of the microspheric generation together with rotation of planes of coiling of early chambers. The megalospheric generation throughout maintains stability in shape dimensions", (Scott, 1961,

abstract). In other words, the β forms, with sigmoilinic-type coiling of chambers, appear in the upper part of the Haumurian stage.

Rzehakinidae of the δ group (megaspheric species with a sigmoilinic type of arrangement of chambers) are found in these deposits much more rarely. All four groups are present in the deposits of Teurian age (Danian-Lower Palaeocene) and disappear in Dannevirke time (Palaeocene).

When describing genetic relations of the four Rzehakinidae groups distinguished, S c o t t is inclined to regard them rather as being cogenetic, assigning them to a single group, the *Rzehakina* group. However, the author does not exclude the possibility that β and δ forms, with a sigmoilinic arrangement of chambers, are micro- and megagenerations of an independent genetic group, which differs from the group represented by α and γ forms. In S c o t t ' s opinion, the extremely rare occurrence of δ forms in the East Basin of New Zealand, contrasted with the abundance of the β forms, is an argument against such an assumption.

S c o t t assigned all Rzehakinidae of New Zealand not only to one genus *Rzehakina,* but also to one species of this genus, *Rzehakina epigona* (R z e h a k), on the basis of the relative stability in growth index of the majority of forms studied. In this case, S c o t t emphasizes considerably greater variability in growth rate for representatives of the γ form as compared with the α form.

While evaluating the validity of the genus *Silicosigmoilina* C u s h m a n (1927), G. S c o t t indicates that the main difference in diagnoses of the genera *Rzehakina* and *Silicosigmoilina* is as follows: the former shows planispiral coiling of chambers, while the planes of coiling of the latter change progressively and only the last chambers are arranged in one plane. The difference in geometry of early chambers, however, in S c o t t's opinion is not a reliable criterion for a genetic classification of the Rzehakinidae. To confirm this point of view, S c o t t notes that in New Zealand the assemblages of planispiral Rzehakinidae and those displaying a tendency to change the coiling plane are found together in the Maestrichtian and Danian-Palaeocene deposits and cannot be separated.

Having analyzed the Californian *Rzehakina* fauna, described by M a l l o r y (1959), S m i t h (1957), I s r a e l s k y (1951) and other authors, S c o t t writes: „that in this country the microspheric (γ-group) of *Rzehakina* does show rotation of planes of coiling in upper Haumurian and Teurian populations; this being so, it would be quite unrealistic to assign the β and δ groups to *Silicosigmoilina*". The validity of this genus should be established „by careful study of the Californian faunas" (S c o t t, 1961, p. 36).

These are the essential conclusions of G. S c o t t, concerning Rzehakinidae and based on a statistical study of this problem. Practically all the considerable specific variability of Rzehakinidae (especially among representatives of the genus *Silicosigmoilina*) was grouped by him into one species, *Rzehakina epigona* R z e h a k. In this respect, he went even further than previous authors, not only eliminating species distinguished in the genus *Rzehakina,* but even denying the validity of the genus *Silicosigmoilina* C u s h m a n et C h u r c h. Consequently S c o t t considers the change in type of coiling of chambers to be the intraspecific variability, whereas in numerous Foraminifera groups, particularly Mi-

liolidae, representing the same structural type as Rzehakinida, this feature is considered to be at least of generic rank.

The Rzehakinidae being well represented in Cretaceous and Lower Tertiary deposits of the North-West part of the Pacific province (Sakhalin, Kamchatka, Koryak highland) attracted the attention of the present writer. But, in contrast with previous investigations the taxonomic importance of certain morphological features, which served as a basis for the classification of the Rzehakinidae, was approached in the present studies from a somewhat different point of view. In addition to the methods used previously for studying Rzehakinidae (immersion in transparent liquids; estimation of the degree of elongation — growth ratio, after G. S c o t t, 1961 [1]; the degree of flatness, by means of elementary statistics), thin sections were examined, to study the inner structures of Rzehakinidae.

The application of this method permitted examination of the types of coiling of chambers, their forms, the character of supplementary skeletal formations and the forms of sigmoid spiral in *Silicosigmoilina*. The study of these features, which is possible only in transverse cross-sections, made through the initial chamber of Rzehakinidae tests, permitted the establishment of new supplementary features in the generic and specific diagnoses of Rzehakinidae. The results of these studies, concerning mainly the representatives of the genus *Silicosigmoilina*, have been published in part (S e r o v a, 1966). In the present account, the methods of examination, described in the paper, cited above will not be considered. The reader will find here only the point of view of the present writer on evaluation of the taxonomic importance of certain features of Rzehakinidae, questioned by G. S c o t t.

First of all, the author does not agree with S c o t t as to his evaluation of the type of coiling of chambers of Rzehakinidae. This feature was inherited by Rzehakinidae from the Miliolidae family, which includes two genera: *Spiroculina* d ' O r b i g n y, 1926, with a planispiral arrangement of chambers, and *Sigmoilina* S c h l u m b e r g e r, 1887, which differs from the genus *Spiroloculina* in the arrangement of chambers along a sigmoid spiral. The arrangement of the coiling plane for all other genera of Miliolidae is known to be the main, diagnostic generic, feature. The common occurrence in one population of Rzehakinidae with sigmoilinic and convincing spiroculinic types of coiling cannot be held as a convincing criterion for uniting them into one species, as was suggested by S c o t t.

Moreover, it seems that the data presented by S c o t t, rather confirm than deny the existence of two generic categories, *Rzehakina* and *Silicosigmoilina* in Upper Cretaceous and Lower Palaeogene deposits of New Zealand. The presence of both micro- and macrogenerations in forms with a sigmoilinic arrangement of chambers (β and δ forms of Scott) is certainly an argument in favour of recognition of the genus *Silicosigmoilina*. The δ forms are more seldom found in the Eastern Basin of New Zealand, as compared with the β forms. This can be explained by a specific, ecological environment, allowing large-scale development of

[1] Editor's note: There is no close analogy between S e r o v a ' s degree of elongation and S c o t t's „growth ratio", since the latter is expressed as the ratio of standard deviations of length and width of a series of samples.

forms of the microspherical generation, as well as by the fact that the materials have not been studied thoroughly enough.

As to the growth ratio (length/width ratio), G. Scott's studies have distinctly shown, that this feature cannot be used for generic diagnosis, since wide and short forms can be found in *Silicosigmoilina* (in the holotype of species *Silicosigmoilina californica*, the length/ width ratio does not exceed 1,2), whereas relatively narrow and long forms were found in *Rzehakina* (*Rzehakina epigona* from the Velasco shale of Mexico, described by Cushman in 1927, length/width ratio is 1,9). Statistical treatment of the degree of flatness of tests (thicknees/width ratio) gives more promising results. The degree of flatness for the genus *Rzehakina* does not exeed 0,4 and is generally smaller. The degree of flatness for representatives of the genus *Silicosigmoilina* is always larger than 0,4, because the tests of *Silicosigmoilina* are always swollen in the central part, owing to a sigmoid arrangement of chambers.

As follows from these data, the genera *Rzehakina* and *Silicosigmoilina* are equally valid.

They are distinguished mainly by means of different types of coiling of chambers: *Rzehakina* displays spiroloculinic type of coiling and *Silicosigmoilina* a sigmoilinic one.

The material obtained by the present author, in a study of the *Rzehakina* fauna from the Upper Cretaceous and Lower Tertiary deposits of the North-West part of the Pacific province, permits the distinction of four species of *Rzehakina*, distributed within this time interval. These are *Rzehakina epigona* (Rzehak), *R. fissistomata* (Grzybowski), *R. inclusa* (Grzybowski) and the subspecies *R. epigona minima* Cushman et Renz, which latter must be regarded as an independent specific taxon. The supplementary features obtained for each species distinguished from a study of their internal structure and the structure of the wall in thin sections will be given below.

Before the examination of the internal structure, the specific identification of *Rzehakina* found in the present material was determined on the basis of those external morphological features, which were reported in the description of holotypes: supplementary data cited in the work of Geroch (1960) were considered for the first three species. After Geroch, forms displaying relatively elongated tests with a length/width ratio of not less than 1,5, as well as distinctly pronounced depressions (umbilici) in the central part of the lateral sides of the test, were assigned to the species *R. epigona*. Forms assigned to the species *Rzehakina inclusa* (Grzybowski) are characterized by approximately the same length/width ratio as for representatives of *R. epigona*, but they show somewhat smaller dimensions; and the sides of their tests are almost flat with a barely detectable concavity in the central part. Both in the first and in the second species chambers of the last whorl only are observed on the outer part of the test. Specimens assigned to the species *Rzehakina fissistomata* (Grzybowski) differ from the first two species in the considerably greater width of the test. The width of the test in some specimens is almost equal to the length (length/width ratio of specimens of this species ranges from 1 to 1,2—1,3, never reaching the value of 1,5). Moreover, they differ in uncomplete involution of chambers. Consequently the chambers of early whorls are always seen in the shallow broad umbilicus of the test.

Table 2 shows the main parameters and degree of elongation of the *Rzehakina* holotypes cited above.

Examination of Rzehakinidae in thin sections showed that the representatives of genus *Rzehakina* are characterized, (S e r o v a, 1966) by saddle-shaped or lump-shaped forms of outer contours of the chamber in cross-section, while lateral protuberances may reach almost the middle part of the test, closing partly or completely the chambers of previous whorls. The degree of involution of various *Rzehakina* species is different, providing supplementary data for diagnosis of the species.

The representatives of *R. inclusa* (G r z y b o w s k i) display small, rounded-triangular, inner cavities of chambers in cross-section, equidimensional in the direction of width and thickness of the test. The wall of the chamber is thin and lateral protuberances of the test wall reach the central part of the test, even slightly covering the wall of the opposite chamber. Because of complete involution of each pair of chambers, the chambers of the previous whorls are not seen on lateral surfaces. Since the lateral surfaces of the opposite chambers are in close contact or even slightly overlapping, there are no depression in the central part of the test of *R. inclusa* specimens.

Table 2

Name of species / Main parameters	Lenght MM	Degree of elongation length/width
Rzehakina epigona /Rzehak/	0,6	1,5
Rzehakina inclusa /Grzybowski/	0,9	1,6
Rzehakina fissistomata /Grzybowski/	0,7-1,2	1-1,3

The inner cavities of chambers of *R. epigona* species are oval in cross-section with long axis elongated in the direction of the thickness of the test.

The dimensions of chambers increase rather rapidly as added, so that the cross-section of each chamber of the subsequent whorl is almost twice as large as that of the chambers of the previous one. The wall of chambers is rather thin, the chambers being almost completely involuted. Lateral surfaces of the opposite chambers, however, do not adjoin each other at all, as in the case of *R. inclusa* species, forming a deep narrow umbilicus in the central part. This umbilicus in the specimens from the Far East was, as a rule, filled with the fine-grained glassy material of a supplementary skeleton.

Rzehakina fissistomata (G r z y b o w s k i) differs more distinctly from *R. epigona* in outer morphological features, because on lateral surfaces of this species the chambers of early whorls could be seen. Such a test structure is due to the form of the chambers, which are half involuted, as can be clearly seen in cross section. The cross-section is similar to that described for *R. epigona*: lateral protuberances of the wall

of chambers of *R. fissistomata* reach only the middle of the lateral surface, leaving the chambers of the previous whorls half open.

The differences mentioned above cannot result from a modification of the variability, because all the specimens studied had commensurable parameters of the proloculus, its size not exceeding 27—30 microns. According to the classification by Scott (1961), it is necessary to assign them to the form γ (microspherical generation with a planispiral arrangement of chambers).

Thus, as a result of studying *Rzehakina* in cross-section (thin sections and polished surfaces) new data were obtained. They confirmed the view put forward by Geroch on the specific rank of the taxons *R. epigona, R. inclusa* and *R. fissistomata.*

On the basis of the opinions cited above concerning the taxonomic rank of the degree of involution of chambers, the variety *Rzehakina epigona minima* Cushman et Renz should be given the rank of a species, because it is characterized (unlike the forms described above) by a complete evolution of chambers, so that the chambers of all whorls are always visible on the test surface.

R. minima Cushman et Renz species is rather similar to *R. venezuelana* Hedberg in terms of morphology of the test. They differ only in range of vertical distribution; *R. minima* is characteristic of Upper Cretaceous and Palaeocene deposits, whereas *R. venezuelana* was described by Hedberg (1937) from Neogene deposits (Carapita formation) of Venezuela. Since *Rzehakina* were not found in the north-western part of the Pacific province in deposits younger than Palaeocene in age, the present author cannot express her opinion on the validity of the species *R. venezuelana.*

R. epigona lata Cushman et Jarvis, as considered by Cushman (1946), is certainly composite and probably includes, three species of the genus distinguished on the European continent: *R. epigona, R. inclusa* and *R. fissistomata.* The present author shares the opinion of G. Scott, who indicated the necessity of a detailed study of the Californian Rzehakinidae fauna.

After a short review of the morphology of Rzehakinidae tests, geographical distribution and evaluation of the importance of this group for stratigraphic subdivision and correlation will be discussed. Available data on the distribution of this Foraminifera group in time and space are not numerous and sometimes incomplete. Since this problem was considered in general terms by Thalmann (1949), the data given in his paper will be not repeated here. Only new material on the distribution of this group in the Carpathians and Crimea-Caucasian region of the Atlantic province and in some areas of the Pacific province, where Rzehakinidae are best studied, will be discussed.

When analyzing the geographical and stratigraphical distribution of Rzehakinidae, it is necessary to emphasize that only the genus *Rzehakina* is present in the Upper Cretaceous and Palaeogene sediments of the Carpathian and Caucasian regions. There are no definite indications of the occurrence of *Silicosigmoilina.* Both genera are equally developed within this time interval in the Pacific province, with *Silicosigmoilina* prevailing in certain regions. It seems, however, that such limited distribution of *Silicosigmoilina* within the Pacific province does not correspond to the real distribution and may be due to the poor knowledge of this group on the European continent. The possibility is not excluded that

some authors could have taken *Silicosigmoilina* tests for *Rzehakina*, because *Rzehakina* and *Silicosigmoilina* have a flat spiral and are very similar. This opinion was confirmed by the discovery of *Silicosigmoilina* tests in the Cretaceous flysch deposits of the Carpathians (the collection of N. I. Maslakova). The present discussion will be limited to the published data.

The *Rzehakina* fauna in the Polish Flysch Carpathians was described by S. Geroch (1960), from the Silesian unit. It occurs in Flysch sediments, characterized by the wide development of arenaceous Foraminifera. The first *Rzehakina* assigned provisionally by Geroch to *Rzehakina epigona* (?) Rzehak were found by him in the upper part of the Godula Beds (horizon with *Hormosina ovulum* (Grzybowski) var. *gigantea* Geroch). In the lower Istebna Beds (Campanian-Maestrichtian), Geroch recognizes two species of *Rzehakina*, *R. epigona* (Rzehak) from the Godula Beds, and *R. inclusa* (Grzybowski), found only in the Istebna Beds. In Geroch's opinion, the latter may be considered as being an index species for Campanian-Maestrichtian deposits within the Carpathian region.

In the Upper Istebna Beds and Ciężkowice Beds of the Danian-Palaeocene age (horizon with *Nodellum velascoense* (Cushman), *Rzehakina fissistomata* (Grzybowski)), *Rzehakina epigona* (Rzehak.), *Hormosina ovulum* (Grzybowski), a new *Rzehakina* species appears. This is *R. fissistomata* (Grzybowski), the vertical distribution of which is Danian-Palaeocene in the Carpathian region.

According to the data presented by Geroch, *Rzehakina* does not pass into the upper (Eocene) part of the Silesian unit (Hieroglific Beds, Menilite Shales, Krosno Beds).

A similar feature of the vertical distribution of *Rzehakina* in flysch deposits of the Silesian Carpathians is given by E. Hanzlíková, who assigns all forms of *Rzehakina* to one group *Rzehakina* ex. gr. *epigona* (Rzehak).

Later on E. Hanzlíková (1965, p. 36) recognized the following *Rzehakina* species and gave their vertical distribution in the West Carpathians Flysch: *Rzehakina epigona lata* Cushman et Jarvis and *Rz. epigona* (Rzehak) — Maestrichtian-Danian; *R. minima* Cushman et Renz and *R. complanata* (Grzybowski) — Danian-Montian; *R. inclusa* (Grzybowski) — Montian-Landenian.

A scheme of vertical distribution of *Rzehakina* in Flysch deposits of the Eastern Carpathians, similar to that of S. Geroch, is presented by E. V. Miatluk (1950), N. V. Dabagian (Vialov, Dabagian, Kulchitskiy, 1960); Vialow, Dabagian, Zhurakovskiy (1967). The first *Rzehakina* described by Dabagian as *Rzehakina epigona* (Rzehak) and *R. inclusa* (Grzybowski) were collected by her from the deposits of fine- and middle-rythmical flysch of the Stryj series, exposed in the key section of the Cretaceous flysch on the Dnestr river, between Tereshov and Spas. These deposits overlie sandstones of Iamna type and are assigned by Dabagian to the uppermost Campanian. In the rocks of the sandy-clayey greenish-grey flysch (Danian-Palaeocene) of the upper part of the Stryj series, Dabagian recognized the species *Rzehakina fissistomata* (Grzybowski). E. V. Miatluk (1950) describes *R. epigona* from the middle (Maestrichtian) part of the Stryj series.

We have only poor data on the distribution of *Rzehakina* within the

Crimea-Caucasian area. M. A. Glaessner (1937) described *Rzehakina epigona* from Flysch deposits of the Ilsk area. He assigned them to the Goriaczi klucz horizon (Palaeocene), whereas N. N. Subbotina recognized this species in the flysch deposits of the inferior horizon (Danian-Lower Palaeocene). *R. epigona* was also found by I. Kacharava and M. Kacharava in Palaeocene clays, overlying marls, containing *Globorotalia conicotruncata* in the Adzhar-Trioletsk folded zone of Georgia.

Only two *Rzehakina* species are known from Trinidad: *R. epigona lata* Cushman et Jarvis, *R. epigona minima* Cushman et Renz. According to Beckmann (1960), both these species occur in the Naparima Hill formation (the upper part of which belongs to Lower Campanian) and in all the zones of Maestrichtian, Danian and Palaeocene, including the *Globorotalia velascoensis* zone. But are not known in the Eocene and younger deposits. Bolli (according to the data by Scott, 1961) determines more exactly the lower limit of the range of these two species and considers that *R. epigona minima* appears in the *Globotruncana fornicata* zone (Upper Santonian), while *R. epigona lata* occurs in the *Globotruncana stuarti* zone (Lower Campanian).

Thus, in the Upper Cretaceous and Palaeocene deposits of the Atlantic province only representatives of the genus *Rzehakina* were developed. There is no published data on the occurrence there of the genus *Silicosigmoilina*.

Within the Pacific province, the morphology and stratigraphic distribution of Rzehakinidae seem to have been most thoroughly studied in Japan and New Zealand. They have been described in numerous papers by Japanese geologists, but were best studied by Takayanagi (1960) and Ioshida (1963). Rzehakinidae forms with a sigmoilinic type of coiling of chambers appear first in the Upper Cretaceous deposits of Hokkaido Island. Takayanagi found *Silicosigmoilina* in the deposits of the Lower Gyliakian stage (Cenomanian) and described them as *Bramletteia ezoensis* Takayanagi. This species was traced by him along the section up to the deposits of the Lower Hetonian stage (lower part of the Maestrichtian) inclusively. Takayanagi assigned *Rzehakina* with a spiroculinic-arrangement of chambers to *Rzehakina epigona* Rzehak. They were observed only beginning from the deposits of the Upper Gyliakian stage (Turonian) and could be straced along the section up to the deposits of the Upper Urakai (Santonian). Thus on the basis of the data presented by Takayanagi, the vertical range of *Bramletteia ezoensis* Takayanagi in Hokkaido is Cenomanian-Maestrichtian, while that of *Rzehakina epigona* (Rzehak) is Turonian-Santonian.

In the south-eastern part of Hokkaido, in the deposits of the Nemuro group, assigned by Yoshida (1963) to Maestrichtian, only the following *Silicosigmoilina* species were found: *Silicosigmoilina futabaensis* Asano, *S. futabaensis tokachiensis* Yoshida, *S. kushiroensis* Yoshida, *S. akkesiensis* Yoshida.

Rzehakina is not observed in the deposits of the Nemuro groups. But in one of his earlier works, Yoshida (1958) recognized the species *Rzehakina epigona lata* in the deposits of the Kavarappu formation, which he correlated with the *Rzehakina-Spiroplectammina* zone, this species being considered to be the most typical form for these deposits.

However, despite the presence of representatives of *Rzehakina* genus in the Japanese complex of Upper Cretaceous and Palaeogene deposits

Silicosigmoilina still prevail markedly in the complexes, both in quantity and their systematic variability.

The distribution of Rzehakinidae in New Zealand has been mentioned already. On the basis of recent data, given by G. Scott (1961) and N. de B. Hornibrook (1968), Rzehakinidae appear in this region in the lowermost parts of the Raukumara series (Lower Senonian) and are traced upwards to the Lower Eocene, not passing into the Lower Eocene deposits. As was already mentioned, all the Rzehakinidae with a spiroloculinic and sigmoilinic types of coiling were assigned by Scott to one species, *Rzehakina epigona* (Rzehak). However, on the basis of his data, it may be said that Rzehakinidae with a spiroloculinic arrangement of chambers (α and γ forms, Scott, 1961) are traced within the whole time interval mentioned, from the Lower Senonian up to the Palaeocene. The forms with a sigmoilinic type of coiling (β and δ forms) appear only in the deposits of the Teurian stage (Danian-Lower Palaeocene) and are traced up to the upper boundary of the range of this group together with α and γ forms.

Thalmann (1949) gives the vertical range of Rzehakinidae on the American continent, determining it within the boundaries from Lower Senonian up to Palaeocene. The upper boundary of the range of *Silicosigmoilina californica* (after Mallory, 1959) is limited by the Narisian stage (Upper Eocene). *Rzehakina* from Lower Tertiary deposits of California are not determined by Mallory. However, as Scott states, certain Rzehakinidae cited in Mallory's paper as *Silicosigmoilina californica* should be assigned to genus Rzehakina.

The distribution of Rzehakina in the North-West part of the Pacific province will now be considered.

The first *Silicosigmoilina* here are very small, but with well pronounced morphological features. They were found in the Cogniacian-Santonian deposits (Barykov suite) of the eastern part of the Koryak highland, Ugolnaya Bay. O. Dmitrienko (oral information) provisionally assigned them to the species *Silicosigmoilina* ex. gr. *futabaensis* Asano.

There is no data as yet on the development of this group within the deposits of the Campanian stage, but in the Maestrichtian and Danian-Palaeocene deposits, both *Silicosigmoilina* and Rzehakina are well developed. In some rocks, they represent the total assemblage of microfauna. In the deposits of the Mainy-Kakiyne range section assigned to the uppermost parts of Maestrichtian, (southern part of the Koryak highland) the following species were found: *Rzehakina epigona* (Rzehak), *Rz. inclusa* Grzybowski, *Silicosigmoilina californica* Cushman et Church, *S. compacta* Serova. In the Danian-Paleocene deposits, the *Silicosigmoilina* assemblage was more diversified. In addition to the above Rzehakina species, *Silicosigmoilina mindalaformis* Serova and *S. futabaensis* Asano were also found. In the upper part of Upper Palaeocene (zone *Globigerina nana* — *Acarinina primitiva*) and younger deposits of the region investigated, *Rzehakina* are lacking, whereas *Silicosigmoilina* are found in Eocene deposits up to Upper Eocene.

At Sakhalin, in the stratotypic section of Upper Cretaceous deposits on the Naiba river, Rzehakinidae were found in Campanian — Maestrichtian deposits of the Krasnoiarsk formation and in Sinegory Beds of the Danian-Palaeocene age. In the lower part of the Krasnoiarsk formation, according to Vasilenko's data and the present writer's determinations (Serova, 1967), the following are present: *Rzehakina minima*

Cushman et Renz, *R. inclusa* (Grzybowski), *Silicosigmoilina futabaensis* Asano, *S. californica* Cushman and Church, *S. perplexa* (Izraelsky), *S. ezoensis* Takayanagi. In the upper Maestrichtian part of the section of the Krasnoiarsk formation, the Sinegory Beds contain *Rzehakina fissistomata* (Grzybowski) *R. epigona* (Rzehak), *Silicosigmoilina californica* Cushman et Church, *S. kushiroensis* Joshida, *S. elegantissima* Serova and *Silicomassilina sinegorica* Serova.

In the Eocene deposits of Sakhalin, as well as in the Koryak highland, only *Silicosigmoilina* were found.

On the basis of the above data on the morphology and systematics of the Rzehakinidae and their geographical and vertical distribution, the following conclusions may be drawn:

1) The main feature for distinction of genera in Rzehakinidae family, as well as in isomorphic Miliolidae family, is the type of coiling of chambers.

2) The degree of involution of chambers is one of specific features. In combination with other features it permits the distinction of *R. epigona, R. inclusa* and *R. fissistomata.*

3) Representatives of the genus *Rzehakina* are best developed within the Carpathian and Crimea-Caucasian regions of the Atlantic province, in the Upper Cretaceous and Lower Palaeogene deposits. *Silicosigmoilina* may also be present here. In the Upper Cretaceous and Palaeogene deposits of the Pacific province, both of these genera are present.

4) *Rzehakina* species have a narrower time range of occurrence. Involute forms of thise genera are developed in the Maestrichtian, Danian and Palaeocene. In the Pacific province, *Silicosigmoilina* appear in the Turonian stage (Japan: c.f. Takayanagi, 1960) and are traced in the section up to the Upper Eocene deposits.

5) Species of the genus *Rzehakina* are very valuable indicators of the age of rocks belonging to a certain facies type, owing to their narrow time ranges, the facies being, as a rule, characterized by an impoverished assemblage of arenaceous Foraminifera.

Acknowledgement

I am very grateful to Prof. Bieda, for his kind invitation to participate in the volume dedicated to the memory of Professor Grzybowski.

Geological Institute
Academy of Science, USSR

REFERENCES

Beckmann J. P. (1960), Distribution on benthonic Foraminifera at the Cretaceous-Tertiary boundary of Trinidad (West Indies). in *Intern. Geol. Congr.* part. V. *Proc.* sect. 5.

Cushman J. (1946), Upper Cretaceous Foraminifera of the Gulf Coastal region of the United States and adjacent Areas. *U.S. geol. Surv.* Prof. Paper 206.

Cushman J. (1947), A foraminiferal Fauna from the Santa Anita Formation of Venezuela. *Contr. Cushman Lab. Foram. Res.*, 23, pt. 1.

Cushman J., Jarvis P. (1928), Cretaceous Foraminifera from Trinidad. *Contr. Cushm. Lab. Foram. Res.* 4.

Geroch S. (1960), Zespoły mikrofauny z kredy i paleogenu serii śląskiej w Beskidzie śląskim. *Bull. Inst. Geol.* 153, 5.

Glaessner M.A. (1937), Die Foraminiferen der ältesten Tertiärschichten der Nordwest Kaukasus. *Probl. Paleont.*, 2—3.

Grzybowski J. (1901), Otwornice warstw inoceramowych okolicy Gorlic. *Rozpr. Wydz. mat.-przyr. Akad. Umiej.*, 41. Kraków.

Hanzlíková E. (1965), Stratigraphie der Kreide und des Paläogens der Flyschzone der Westkarpaten. *Geol. Sbornik* 16, 1. Bratislava.

Hedberg H.D. (1937), Foraminifera of the Middle Tertiary Carapita formation of North-Eastern Venezuela. *J. Paleont.*, 11.

Homola V., Hanzlíková E. (1955), Biotragrafické, tektonické a litologické studie na Tesinsku. *Sborn. Ústr. ust. geol.*, 21, 1954, *odd. paleontol.*

Hornibrook N. de B. (1958), New Zealand Upper Cretaceous and Tertiary foraminiferal zones and some overseas correlations. *Micropaleontology*, 4, nr 1.

Hornibrook N. de B. (1968), Handbook New Zealand Microfossil.

Israelsky M.C. (1951), Foraminifera of the Lodo formation Central California, General Introduction and Part I. Arenaceous Foraminifera. *Geol. Surv., Prof. Pap.* 240-A.

Kacharava I., Kacharava M. — Качарава И. и Качарава М. (1960), Датский ярус Грузии и его сопоставление с аналогичными отложениями средиземноморской провинции. Междунар. Геол. Конгр., XXI Сессия, Докл. Советских геологов.

Mallory V.S. (1959), Lower Tertiary Biostratigraphy of the California Coast Ranges. *Amer. Assoc. Petrol. Geol.*

Miatluk E.V. — Мятлюк Е.В. (1950), Стратиграфия флишевых осадков Северных Карпат в свете данных фауны фораминифер. Тр. ВНИГРИ, Нов. Сер., вып. 51, сб. IV.

Rzehak A. (1895), Über einige merkwürdige Foraminiferen aus österreichischem Tertiär. *Naturhist. Hofmuzeum, Wien, Ann.* 10.

Scott G.H. (1961), Contribution to the knowledge of Rzehakina Cushman (Foraminifera) in New Zealand. *N.Z. J. Geol. Geophys.* 4, 1.

Serova M.Y. — Серова М.Я. (1966), О таксономическом значении некоторых морфологических признаков представителей сем. Rzehakinidae и его систематическом положении. Вопр. Микропал. нр. 10.

Serova M.Y. (1967), The Zonal scale of the Paleogene deposits of the North-Western part of the Pacific province and their correlation to the Tethys deposits. Tertiary correlations and Climatic Change in the Pacific.

Smith B. (1957), Lower Tertiary Foraminifera from Contra Costa County California. *Univ. Calif. Publ. Geol. Sc.* 32, nr 3.

Subbotina N.N. —Субботина Н.Н. (1950), Микрофауна и стратиграфия Эльбурганского Горизонта Горячего Ключа. Микрофауна СССР, Сборник IV. Труды ВНИГРИ, нов. сер., вып. 51.

Takayanagi Y. (1960), Cretaceous Foraminifera from Hokkaido, Japan. *Sc. Rep. Tohoku Univ., Sendai, Japan, II Ser. Geol.*, 32, 1.

Thalman H.E. (1949), Regional-Stratigraphische Verbreitung der Foraminiferengattung *Rzehakina* Cushman, 1927. *Ecl. geol. Helv.* 42, 2.

Vialov O.S., Dabagian N.V., Kulchitskii J.O. — Вялов О.С., Дабагян Н.В., Кульчицкий Я.О. (1960), О границе между мелом и палеогеном в восточных Карпатах. Междунар. Геол. Конгр. XXI Сессия. Докл. Советских геологов.

Vialov O.S., Dabagian N.V., Zhurakovskii A.G. — Вялов О.С., Дабагян Н.В., Жураковский А.Г. (1967), Опис опорного разрізу крейдового флішу по р. Дністер між Тершевом та Спасом. Геол. Журнал 27, вып. 6.

White M. P. (1928), Some index Foraminifera of the Tampico Embayment Area of Mexico. Part. II. *J. Paleont.* 2. n. 3, 4.

Yoshida S. (1958), The Foraminiferal Fauna of the upper Cretaceous Hamanaka and Kiritappu formation of Eastern Hokkaido, *Japan. J. Hokkaido Gakugei Univ.* 9, 1.

Yoshida S. (1963), Upper Cretaceous Foraminifera from the Nemuro Group, eastern Hokkaido, *Japan. J. Hokkaido Gakugei Univ.*, 13, 2.

РЕЗЮМЕ

Приведенные в работе данные по морфологии и систематике ржегакинид и их географическому и вертикальному распространению позволяет сделать следующие выводы:

1. Тип навивания камер в сем. Rzehakinidae является основным признаком для выделения родов как и у изоморфного сем. Miliolidae.

2. К числу видовых относится признак степени объемлимости камер который в сочетании с другими признаками, позволяет различать виды: *R. epigona, R. inclusa, R. fissistomata, R. minima.*

3. В пределах Карпатского и Крымско-Кавказского регионов в верхнемеловых и нижнепалеогеновых отложениях преимущественное развитие имеют представители рода *Rzehakina,* хотя и не исключено присутствие здесь силикосигмоилин. В тихоокеанской провинции в верхнем мелу и палеогене присутствуют оба эти рода.

4. Ржегакины имеют более узкий возрастной интервал по сравнению с силикосигмоилинами. Инволютные формы этого рода развиты в кампане, маастрихте, дании и палеоцене. Силикосигмоилины в Тихоокеанской провинции появляются в туроне (Япония, Takayanagi, 1960) и прослеживаются в разрезе до верхнеэоценовых отложений включительно.

5. Виды рода *Rzehakina* благодаря узкому временному интервалу своего существования является весьма ценными индикаторами возраста пород определенного фациального типа, как правило, охарактеризованных обедненным комплексом агглютинирующих фораминифер.

В заключение я благодарю проф. Биеду за любезное приглашение принять участие в сборнике, посвященном памяти Гржибовского.