ABSTRACT: *The nomenclature of the foraminifera is overloaded with synonyms; the reasons for this situation are enumerated. The synonymy of* Nonion affine *(Reuss) is given as an illustration of this nomenclatorial confusion. This synonymy is the result of a study of types in the United States National Museum, Washington, D.C. Infraspecific categories, their concepts and usage, are discussed. The main purpose of this article is to call attention to the necessity for a greater respect for the basic laws of biology and for the International Rules of Zoological Nomenclature.*

Problems in taxonomy and nomenclature exemplified by Nonion affine (Reuss)

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SOURCES OF NOMENCLATORIAL CONFUSION

It is well known that, during recent decades, the nomenclature of the foraminifera has increased so enormously that it has become greatly overloaded with invalid names. This great increase of synonyms is a result of incorrect taxonomic determinations of specimens encountered by many students. These incorrect determinations are mainly due to the following four reasons:

1) Absence of literature: This is the most frequent cause of incorrect classification, especially in new laboratories situated far from good libraries. A very worthwhile step toward the elimination of this cause has been taken by B. F. Ellis and A. R. Messina in the publication of the CATALOGUE OF FORAMINIFERA. Unfortunately, due to its relatively great cost and the small number of copies issued, this catalogue is still unavailable in many places where foraminifera are studied.

2) Incomplete descriptions and poor figures, both leading to later misunderstanding of species. This handicap can best be overcome by examination of the original material of previous authors. The original material is certainly preferable to the descriptions and figures of even the most careful authors, but this material is usually even more difficult to obtain than the literature.

3) Disregard of the basic rules necessary for the erection of a new species or other taxonomic unit, namely, a sufficient number of individuals in a good state of preservation, and the possibility of comparing them with specimens of related species.

4) Ignoring the laws of theoretical biology. This is due to lack of comprehension of the species and subspecies concepts. Many Twentieth Century authors interpret these concepts very narrowly. Even minute details, such as ornamentation, size, and number of chambers, are sometimes considered sufficient reasons for the erection of new species.

Individual students can do little to overcome the first two of these difficulties. The last two, however, are completely within the control of all of us, and they must be considered with great attention. With regard to the lack of consideration of the basic rules that should be applied before the erection of a new species, sufficient has already been written, and repetition is unnecessary. An interesting paper dedicated to this problem was recently published by Hiltermann (1955). Little has been written, however, about the necessity of applying the laws of theoretical biology in our investigations of the foraminifera. I therefore take the liberty of reminding my colleagues of an earlier article on this subject published three years ago (Boltovskoy, 1954). The main purpose of that article was to bring to the attention of all students the necessity for stricter observance of the principal laws of biology relating to the species concept, the fundamental unit in biological science. I hoped at that time to stimulate an exchange of opinions which would be useful to all of us, "not only in the theoretical, but also in the practical field."

In spite of what I believed to be its timely appearance, that article aroused only slight interest. The

responses were few, and consisted only of some letters and a single article by Drooger (1954). The bulk of names continued and still continues to grow chaotically, causing more and more confusion in the work of students of the foraminifera. Even in those cases where invalid new names are not established, but only a list of identified species is given, taxonomic difficulties can be increased by the listing of synonyms. I am far from believing that all species have already been discovered and described, but I do assert that many "species" have been established on the basis of data and diagnostic features that do not meet the requirements of the zoological "species" concept.

These basic laws of the species and subspecies concept are as follows: All specimens referred to the same species should have transitional forms, but such forms should not exist between two different species. At the same time, transitional forms between two subspecies of a species can exist. Specimens of different species cannot, in general, interbreed; if interbreeding takes place, the offspring are not fertile. Specimens of two subspecies interbreed freely and have fertile descendents. As a result of this, two subspecies of a given species *cannot coexist* in the same region, as they will lose their characteristic features (by interbreeding). Two species of the same genus can certainly coexist, but it has long been observed by zoologists and botanists that related species avoid living together in the same region, or if they do, they select habitats with different ecologic conditions.

These basic laws, with some minor additions about which I wrote in the article mentioned above, cannot, I believe, be disputed by my colleagues. But there is one additional thesis, which is not accepted by many investigators, and this thesis often leads to confusion. This is the case of the category "varietas" (variety). Somewhat later in this article I shall discuss whether this category is or is not necessary in our work, but in any case we should obey the existing International Rules of Zoological Nomenclature. According to these Rules, the category "variety" has no validity, and therefore a name first appearing as "n. var." has no valid status and "defense." If an author describes a new variety and wishes to make it valid, he must consider this form as a new subspecies, and must transfer it to that category. But how can this be true if there are two, or even more, described "varieties" of a species existing in one area, when, according to the subspecies concept, this situation is impossible from a biological point of view?

The present article is an outgrowth of the ideas first expressed in the article written three years ago. At that time, the arguments against the increase in the number of invalid names were based solely upon theoretical considerations. I now wish to show practically, by one illustrative example, the large number of invalid names used for a single species, and the resulting and repeated errors of those working with foraminifera. The decision to write the present article arose from interesting discussions with Ruth Todd and other micropaleontologists, and from the study of collections in the United States during a visit to that country made possible by the generosity of the John Simon Guggenheim Memorial Foundation.

THE CASE OF NONION AFFINE (REUSS) AND ITS RELATIVES

While working with Recent South American material which I brought to the United States for comparison with collections in North American museums, I noted that specimens of one species of *Nonion* were identical with the type specimens of several species in the collections of the United States National Museum in Washington, D. C. Subsequent searches in this collection, as well as in the Cushman Collection, brought to light other identical forms with still different names. There was no alternative but to search through all of the rich material in these collections and the appropriate literature. In spite of the abundance of this material, the task of elucidating the synonymy of the many "different" species of this group was relatively easy, because of the primitive structure of the genus *Nonion*. I include here only the citations for which I had at my disposal the actual type specimens. It should be noted that, in the Cushman Collection, the term "plesiotype" is used for specimens that have been figured in some published work, but that, in the United States National Museum Collection, both "plesiotype" and "hypotype" have been used for such specimens.

I prefer to write this synonymy in the "classical" form which was used by Williamson, Brady, and Heron-Allen and Earland, and suggested by Rudolf Richter in his excellent book "Einführung in die Zoologische Nomenklatur" (1948). According to Richter, it is desirable to put the year of issue of the work first, then the name (citation with all supplementary words) of the form as it was written by the author in question, and finally the author, name of the journal, and other bibliographic data. After each citation I have added in brackets the geologic age, locality, character of the type material, and, if any existed, the catalogue number in the respective

collection. The resultant synonymy of *Nonion affine* (Reuss) is as follows:

Nonion affine (Reuss, 1851)

1851 *Nonionina affinis* m. – REUSS, Deutsch. Geol. Ges., Zeitschr., vol. 3, p. 72, pl. 5, fig. 32 [Oligocene, Germany; topotypes, Cushman Coll., no. 12196].

1880 *Nonionina formosa* n. sp. – SEGUENZA, R. Accad. Lincei, Atti, ser. 3, vol. 6, p. 63, pl. 7. fig. 6 [Tertiary, Italy; topotypes, Cushman Coll., no. 39919].

?1899 *Nonionina umbilicatula*, Montagu, sp., var. *depressula*, n. – SILVESTRI, Pont. Accad. Nuovi Lincei, Mem., vol. 15, p. 333, pl. 11, fig. 15 [Pliocene, Italy; specimens (topotypes?), Cushman Coll., no. 6782].

1926 *Nonionina umbilicatula* (Montagu). – CUSHMAN AND APPLIN, Amer. Assoc. Petr. Geol., Bull., vol. 10, no. 2, p. 182, pl. 10, figs. 14–15 [Eocene, U.S.A.; plesiotypes, Cushman Coll., no. 5427].

1929 *Nonion affinis* (Reuss). – CUSHMAN, Cushman Lab. Foram. Res., Contr., vol. 5, pt. 4, p. 89, pl. 13, fig. 24 [Miocene, Ecuador; plesiotypes, Cushman Coll., no. 14350].

1930 *Nonion planatum* Cushman and Thomas, n. sp. – CUSHMAN AND THOMAS, Jour. Pal., vol. 4, p. 37, pl. 3, fig. 5 [Eocene, U.S.A.; holotype, U. S. Nat. Mus. Coll., no. 371168].

1934 *Nonion pacifica* (Cushman). – CUSHMAN, Bishop Mus., Bull., no. 119, p. 120, pl. 4, fig. 7 [Pliocene, Fiji; plesiotype, Cushman Coll., no. 23921].

1936 *Nonion nicobarense* Cushman, n. sp. – CUSHMAN, Cushman Lab. Foram. Res., Contr., vol. 12, p. 67, pl. 12, fig. 9 [Pliocene, East Indies; holotype, Cushman Coll., no. 23325].

1936 *Nonion pompilioides* (Fichtel and Moll). – CUSHMAN, Geol. Soc. Amer., Bull., vol. 47, p. 422, pl. 2, fig. 10 [Tertiary, U.S.A.; plesiotypes, Cushman Coll., no. 22862].

1938 *Nonion affinis* (Reuss). – KLEINPELL, *Miocene stratigraphy of California*, p. 229, pl. 6, figs. 3, 7 [Miocene, U.S.A.; plesiotype, U.S. Nat. Mus. Coll., no. 497176].

1945 *Nonion pacificum* (Cushman). – CUSHMAN AND TODD, Cushman Lab. Foram. Res., Spec. Publ., no. 15, p. 36, pl. 5, fig. 26 [Miocene, Jamaica; plesiotype, Cushman Coll., no. 44404].

1948 *Nonion planatum* Cushman and Thomas. – CUSHMAN, Maryland, Dept. Geol. Min. and Water Res., Bull., no. 2, p. 232, pl. 18, fig. 1 [Eocene, U.S.A.; plesiotype, Cushman Coll., no. 61604].

1948 *Nonion* cf. *barleeanum* (Williamson). – PARKER, Harvard Coll., Mus. Comp. Zool., Bull., vol. 100, no. 2, p. 239, pl. 3, fig. 3 [Recent, North Atlantic Ocean, 142 meters; plesiotype, U. S. Nat. Mus. Coll., no. 28118].

1949 *Nonion nicobarense* Cushman. – BERMUDEZ, Cushman Lab. Foram. Res., Spec. Publ., no. 25, p. 116, pl. 11, fig. 20 [Miocene, Dominican Republic; plesiotype and other specimens, Cushman Coll., nos. 63436, 63397].

1949 *Nonion umbilicatulum* (Walker and Jacob). – SAID, Cushman Lab. Foram. Res., Spec. Publ., no. 26, p. 23, pl. 2, fig. 32 [Recent, Red Sea, 30–433 meters; plesiotype, Cushman Coll., no. 55626].

1952 *Nonion vicksburgense* Todd, n. sp. – TODD, U. S. Geol. Survey, Prof. Paper, no. 241, p. 22, pl. 3, fig. 21 [Oligocene, U.S.A.; holotype, Cushman Coll., no. 47652].

1952 *Nonion barleeanum* (Williamson). – CROUCH, Amer. Assoc. Petr. Geol., Bull., vol. 36, no. 5, p. 826, pl. 1, fig. 12 [Recent, North Pacific Ocean, 1025 fathoms; hypotype, U. S. Nat. Mus. Coll., no. 548405].

1953 *Nonion formosum* (Seguenza). – PHLEGER, PARKER AND PEIRSON, Swedish Deep-Sea Exped., Rept., vol. 7, fasc. 1, p. 30, pl. 6, fig. 5 [Recent, North Atlantic Ocean, 4480 meters (core); hypotype, U. S. Nat. Mus. Coll., no. 28113].

1954 *Nonion formosum* (Seguenza). – PARKER, Harvard Coll., Mus. Comp. Zool., Bull., vol. 111, no. 10, p. 506, pl. 6, fig. 3 [Recent, Gulf of Mexico, 117 meters; hypotype, U. S. Nat. Mus. Coll., no. 28114].

The differences between each of the forms described by these authors and what could be observed in a study of the actual specimens is noted below. In making these observations, I have been extremely cautious, placing species in synonymy only when convinced, beyond a possibility of doubt, of their specific identity.

1) *Nonionina affinis* Reuss, 1851: According to the description given by Reuss, this species has a coiled, involute, equally compressed test, composed of ten slightly curved chambers. Walls densely and finely perforate. Aperture short, crescentiform. Longer diameter 0.28–0.30 mm. The original figure supplements this description by demonstrating the rounded peripheral margin and the presence of the typical relatively small but deep umbilical cavity. The perforations are illustrated as closely spaced and rather coarse.

Examination of excellently preserved topotypes has confirmed the existence of these features and resulted in the description of others: a) The aperture has an indistinct enlargement in the central part of the base of the apertural face, and it extends on both sides as a fissure along the basal line; b) the sutures are limbate, but their width varies somewhat; furthermore, in general they are wider near the umbilicus, where they form a circle of varying size at the circumference, inside of which the umbilical cavity is situated. This cavity has a very remarkable character; it often has steep sides, and may be irregular in shape and of variable depth; sometimes it is almost totally covered by shell material. Two more small additions to the description may be mentioned: The number of chambers in the last whorl is ten to eleven, and the apertural face in some specimens has a very slight tendency toward a triangular form. The ratio between the longer diameter and the thickness of the test is $30:15 = 2$,

or somewhat more (2–2.3). This ratio (about 2) remains rather constant at all geologic horizons. According to the original figure it is greater than in the topotypes, but this is obviously in error, as among a large number of topotypes on many slides none was so compressed.

2) *Nonionina formosa* Seguenza, 1880: In erecting this form, Seguenza compared it with another species described by him at a somewhat earlier date (*Nonionina subcarinata* Seguenza, 1862), but from his description and figure the great similarity existing between *Nonion affine* and *Nonion formosum* is apparent. Comparison of topotypes confirmed this. The topotypes of Seguenza's species are slightly larger and are in a poor state of preservation, as they are filled with matrix. Nevertheless, they clearly show the same type of aperture (differing in the same way as Reuss' topotypes differ from Reuss' original figure), the same perforation, and the same umbilical cavity. The triangular character of the apertural face as shown by Seguenza is not present in all the specimens, and in reality is not as pronounced as represented by him. This feature does not exist as a difference between the species of Reuss described above and that of Seguenza. Probably the single difference that can be observed (and then only as a result of a determined effort to find *any* difference) is the insignificantly greater relative thickness of *Nonion formosum*, or in other words, the ratio between the greatest diameter and the thickness of the test, which is equal to 2 or slightly less. This difference in the specimens observed is inadequate even for subspecific separation. I have no hesitation, therefore, in considering this species of Seguenza as a synonym of *Nonion affine* (Reuss). The explanation of the error made by both Reuss and Seguenza in illustrating the aperture is probably as follows: It is well known that when a chamber is added to *Nonion*, the aperture of the previous chamber becomes enlarged by solution. Specimens with a missing or broken final chamber are often encountered, and very probably both authors drew such specimens. Their figures therefore represent specimens with an unusually large aperture.

3) *?Nonionina umbilicatula* (Montagu) var. *depressula* Silvestri, 1899: If Silvestri's original material or topotypes were available, I believe that this form would also prove to be *Nonion affine*, as Silvestri's description and figure appear to be identical with those of that species. Unfortunately, such type material does not exist in the United States. However, specimens are present in the Cushman Collection from the Pliocene of Castellarquato near Piacenza, Italy, which is situated some distance northwest of Silvestri's type locality, Coroncina, Province of Siena. These specimens are identified by Cushman as *Nonionina umbilicatula depressula* Silvestri. They are similar to the description and figure given by Silvestri, and identical with topotypes of *Nonion affine* except that the sutures of the final chambers are somewhat deeper than in the latter form. This single and minute difference certainly has no taxonomic value, but as these specimens are not true topotypes, an interrogation mark is placed before the citation.

4) *Nonionina umbilicatula* (Montagu) of Cushman and Applin (1926): Cushman and Applin's hypotype of this form is entirely identical with the topotypes of *Nonion affine* in the Cushman Collection.

5) *Nonion affinis* (Reuss) of Cushman (1929): Examination of this specimen permits no doubt as to its identity with *Nonion affine*.

6) *Nonion planatum* Cushman and Thomas, 1930: The authors compared this form with *Nonion umbilicatulum* on the basis of fossil material identified by other students, and stated that such identifications are always doubtful because that species was originally described as a Recent form. As their specimens were also fossil (Eocene), they wrote that it "... seems best to give our form a different name." The description and figure show its great similarity to *Nonion affine*. A comparison of the available material showed that they are identical in all features except that the topotypes of *Nonion affine* are somewhat larger (diameter 0.3 mm. as compared with 0.25 mm.).

7) *Nonion pacifica* (Cushman) of Cushman (1934): Originally, Cushman used this name, as *Nonionina umbilicatula* var. *pacifica*, in describing a form from shallow water off Samoa. He distinguished it from *Nonionina umbilicatula* by its more compressed test and the absence of limbation. I have compared the holotype of this form with *Nonion affine*, and I find that they are very similar. I refrained from considering it a synonym only because of my resolve to include in the synonymy none but forms concerning whose identity there is no question. It is very probably a local ecologic variant of *Nonion affine*. The close proximity of this form to *Nonion affine* is indicated by the fact that, after its elevation to specific rank by Cushman, some of his subsequent identifications of "*Nonion pacifica*" in reality refer to *Nonion affine*. The present citation is such an example. The hypotype from the Pliocene of Fiji mentioned above was compared with topotypes of *Nonion affine*, and I was unable to find the slightest difference between them.

8) *Nonion nicobarense* Cushman, 1936: This species represents an obviously erroneous determination. The founder compares it with *Nonion soldanii* (d'Orbigny), and writes that it has a "less prominent umbilical opening, larger number of chambers, and more compressed test." All of these features are correctly described, but they correspond exactly with the description of *Nonion affine*. A comparison of the specimens confirmed this, as not a single distinction could be found.

9) *Nonion pompilioides* (Fichtel and Moll) of Cushman (1936): The hypotype on the slide is labelled *Nonion pompilioides*. In publication this form was called "*Nonion pompilioides* (Fichtel and Moll) var." This specimen is identical with the topotypes of Reuss' species in the Cushman Collection.

10) *Nonion affinis* (Reuss) of Kleinpell (1938): Kleinpell's hypotype corresponds exactly with the topotypes of *Nonion affine*.

11) *Nonion pacificum* (Cushman) of Cushman and Todd (1945): The hypotype is similar in all respects to the topotypes of *Nonion affine*.

12) *Nonion planatum* Cushman and Thomas of Cushman (1948): Again in this case, the hypotype is identical with *Nonion affine*.

13) *Nonion* cf. *barleeanum* (Williamson) of Parker (1948): The hypotype is slightly larger (longer diameter 0.4 mm.) and probably somewhat thicker, and thus it is identical with the form encountered by Seguenza. But these are very unimportant characters, and because in all other features it is exactly similar to the topotypes of *Nonion affine*, I have no hesitation in considering it as belonging to that species.

14) *Nonion nicobarense* Cushman of Bermudez (1949): The hypotype differs in the somewhat greater thickness of the last two chambers and in having fewer chambers in the last whorl (only nine). These features represent a slight similarity to *Nonion pompilioides* (Fichtel and Moll), but other specimens from the same material of Bermudez and also labelled by him as *Nonion nicobarense* appear to be typical *Nonion affine*, although of somewhat larger size (longer diameter 0.35 mm.).

15) *Nonion umbilicatulum* (Walker and Jacob) of Said (1949): The hypotype is similar to typical *Nonion affine* except that it is somewhat larger, as is "*Nonion nicobarense*," cited above.

16) *Nonion vicksburgense* Todd, 1952: The author writes: "The species differs from *Nonion affine* (Reuss) in the less compressed test, the slightly fewer and less distinct chambers, and the irregular broken appearance of the umbilici as compared to the smoothly finished umbilicus in *Nonion affine*. It differs from *Nonion planatum* Cushman and Thomas in its larger size and irregular umbilici, and its slightly inflated later chambers." All of these insignificant differences are very difficult to see when one compares the holotypes of *Nonion vicksburgense* and *Nonion planatum* with only one topotype of *Nonion affine*; but when many specimens of each form are examined (paratypes of the former two and all of the topotypes of *Nonion affine*), we cannot separate them from each other. I feel certain that *Nonion vicksburgense* is a synonym.

17) *Nonion barleeanum* (Williamson) of Crouch (1952): Crouch's hypotype differs from topotypes of *Nonion affine* only in having thicker sutures and a "sutural ring" around the umbilical cavity. As stated above, this feature is not constant and varies considerably. Among the topotypes of *Nonion affine* there are some with the same character.

18) *Nonion formosum* (Seguenza) of Phleger, Parker and Peirson (1953), and *Nonion formosum* (Seguenza) of Parker (1954): The hypotypes of these two forms correspond exactly with the topotypes of *Nonion affine*. I have no hesitation in referring them to this species.

This recitation of cases may be rather tedious, but it is a necessary part of this article. It seems impossible to consider any of the cited minor differences as sufficient even for subspecific separation. Without doubt, these differences can all be included within the limits of natural variation of a single species, that is, all are of purely intraspecific character. Furthermore, we can even consider this species relatively quite constant in its morphologic features.

The arguments given above might have been more convincing had they been supported by statistical data such as measurements. When there are real differences between species, statistics are of great importance, but an attempt to apply them in this case seemed unnecessary, as the material listed obviously belongs to one species.

In spite of the very constant character of this species, six different "new species" were established for it and it was called by ten different names, all in the collections of one institution. I have no doubt that many more names could also be included if other collections throughout the world were revised. The collections of the United States National Museum are comparatively rich, but they represent

only a small part of all of the types described in all countries since the scientific study of foraminifera began. It is difficult to imagine how many "species" have been established throughout the world for other forms that are even more variable, such as, for example, species of *Cibicides* or *Discorbis*.

During the course of this revision, in addition to the forms which I have included above in the synonymy of *Nonion affine*, I also encountered many other types that are very similar to this species, which, after comparing the specimens, I place in two other lists of synonyms. The citations, together with data referring to age, locality and catalogue number, are given below, but they are not discussed as was done in the case of *Nonion affine* (Reuss). In order to save space, they are not presented in the usual style of synonymy, but are listed in paragraph form.

The first list of synonyms is as follows: *Nonion pompilioides* (Fichtel and Moll) [Pliocene, Coroncina, Italy; topotypes (and hypotype), Cushman Coll., no. 46452]; *Nonion soldanii* (d'Orbigny) [Tortonian, Nussdorf, Austria; topotypes, U. S. Nat. Mus. Coll., no. 549139]; *Nonion halkyardi* Cushman [Eocene, Biarritz, France; holotype and paratypes; Cushman Coll., nos. 23224–23225]; *Nonion agrestum* Cushman and Stevenson [Miocene, Ecuador; holotype and paratypes, Cushman Coll., nos. 57741–57742]. The main difference between *Nonion pompilioides* and *Nonion affine* is the increase in the width of the last three to five chambers and the somewhat coarser perforation in *Nonion pompilioides*.

The second list of synonyms is as follows: *Nonion barleeanum* (Williamson) var. *inflata* van Voorthuysen [Pliocene, Netherlands; U. S. Nat. Mus. Coll., no. 549138 (two years later this name was changed by its author to *Anomalinoides barleeanum* (Williamson) var. *zaandamae*)]; *Nonion barleeanum* (Williamson) [Recent, North Atlantic; hypotype, U.S. Nat. Mus. Coll., no. 28112]; *Nonion zaandamae* (van Voorthuysen) [Recent, North Atlantic; hypotypes, U. S. Nat. Mus. Coll., nos. 2027, 2028, 2816, 2817 (not 28115)]. All of these specimens, and especially the latter two, differ from *Nonion affine* in having thicker sutures and somewhat coarser but less dense perforation.

In reality, the forms in both lists of synonyms are very close to *Nonion affine*, but without a detailed study of the morphology of their tests as well as their habitat, it is difficult to judge this relationship. It is possible that they represent three subspecies of one species, the nominal subspecies of which, according to the Law of Priority, should have the name given by Fichtel and Moll. Thus we would have *Nonion pompilioides pompilioides* (Fichtel and Moll), *Nonion pompilioides affine* (Reuss), and *Nonion pompilioides zaandamae* (van Voorthuysen). But this is only supposition, and without further study I do not consider it possible to make any change in the synonymy of *Nonion affine* (Reuss) given above.

The well-known species *Nonion barleeanum* (Williamson) is also very close. I did not include it in the synonymy of *Nonion affine* (Reuss) or in that of the other forms only because I had neither the original material nor topotypes. There was also a very great temptation to call the form discussed above *Nonion umbilicatulum* (Walker and Jacob), as was done by Said (1949) (see the citation in the synonymy of *Nonion affine*). I do not consider this procedure correct, however. That name cannot be accepted because the figure given by its authors represents a test which is evidently not symmetrical on the two sides.

GENERAL CONCLUSIONS

We have seen how many synonyms were discovered by a revision of the types of one small group of Nonions. My placing many well-known and often used specific names in synonymy may arouse some distrust on the part of my colleagues. The present study was carried out with as much accuracy and impartiality as was possible, but if others disagree I can only suggest that they re-examine these types and make their own revisions. I believe that the results would not be very different. I had an opportunity to show all of the types of these synonyms of *Nonion affine* to Dr. A. R. Loeblich, and I requested him to verify them as thoroughly as possible. After studying them he came to the same conclusions, namely, that they all belong to the single species *Nonion affine*.

I shall not attempt to discuss here the reasons for each of the incorrect determinations cited above. The reader can judge for himself to which of the four causes listed at the beginning of this article these misidentifications should be ascribed. It appears that in the majority of cases the real reason was a "too narrow" interpretation of the species concept. I believe that a similar detailed revision of other material in the Cushman Collection and United States National Museum collection of foraminifera, as well as in other museums elsewhere in the world, would make it possible to suppress many other specific names as synonyms. It is a work of great importance and urgency, for how can we compare Recent faunas from different areas, or correlate fossil material, if our identifications and faunal lists are not correct?

In general, foraminifera are known as variable organisms. This appears to be true. Minor changes in ecological conditions can result in changes in the morphologic features of their tests. Loss of ornamentation, change in the character of the perforation, increase or diminution in the size of the whole test, and even (in a brackish-water environment) differences in the character and location of the aperture often originate in this way. It is my belief that such characters can sometimes, under certain conditions, become inheritable. I agree with Vinogradov (1952), who expressed this idea in describing the influence of trace elements on lower plants. But in spite of the fact that these differences are large, all of these variants are very often connected by transitional forms, indicating that they are of intraspecific character only.

I have observed this phenomenon rather often during the past eight years while studying the Recent foraminiferal fauna of many samples from the continental shelf from Cape Horn (lat. 56° S.) to Cabo Frio (lat. 23° S.). It is probable that if specimens of one of these variable species had been taken from the two extremes of this region, and if samples from the area between the extremes had not been seen, it would have been concluded that they belong to two different species. As more material becomes available for study, the true picture of intraspecific variation will become clearer.

On the other hand, some foraminiferal species are extremely constant, in spite of great differences in the ecological conditions of their habitats. We have already seen an example of such a very constant species in *Nonion affine*. It persisted through a long interval of geologic time, from the Eocene to the Recent, without change in any of its morphologic features, and it is now encountered in shallow water off Brazil, as well as in the greater depths of the Atlantic Ocean. Recent specimens compared with topotypes of Reuss' species do not show any differences except shade of color. Morphologically they are entirely identical.

I am deeply convinced that, in general, foraminiferal species are considerably more tolerant of changes in their environment and that their intraspecific variations are much wider than is usually admitted by the great majority of modern students of this group. In other words, what are now considered to be different species are in many cases actually only intraspecific variants, which are not sufficiently different even for subspecific separation. Because we have not yet found the intermediate forms, we have been obliged to consider them independent species and to give them different names. Subsequent studies, therefore, not only result in the discovery of new forms and an increase in the number of species, but also should result in the discovery of transitional forms and thus a decrease in the number of species.

PROBLEMS AND PROPOSALS CONCERNING TAXONOMIC UNITS

We now come to another problem. In the discussion of taxonomic units given above, we have considered the problem in the light of strict application of the International Rules of Zoological Nomenclature, but we have neglected practical considerations that are of primary importance in applied paleontology and zoology. If we name only specific and subspecific taxa, we shall not be able to refer to many small changes which, although not even of subspecific value, can be very useful in stratigraphic and ecologic applications. This means that taxonomic ranks lower than the subspecies are necessary in our work.

Many zoologists and paleontologists have made various proposals, used different categories, and expressed diverse opinions. Micropaleontologists have taken an extremely small part in these discussions, although (as I wrote in an earlier communication) for many reasons their opinions should be even more interesting and valuable than those of others.

I believe that in our work we can accept two units lower than the subspecies, namely, the "variety" (*varietas*) and the "form" (*forma*). Both of these units are to be interpreted as having no valid status and thus not in conflict with the existing International Rules of Zoological Nomenclature.

A subspecies should have well-defined features and more or less definite and restricted stratigraphic and zoogeographic distribution. A variety also has some (usually only a few) characters which result from the influence of the environment, but they are not as distinct, and the geographic or stratigraphic distribution of a variety is not well defined. As has been expressed very well by one paleontologist, the variety is a category which is useful at the beginning of a study, when the student is not yet able to recognize whether the form can be considered a subspecies or represents only a small local differentiation. Subsequent investigation with new data should resolve such a question. Under the present proposal, if a new name is given to the variety, its founder cannot lay claim to the Law of Priority. This means that if another worker describes it in more

detail as a subspecies, he may either suppress the name of the variety as a synonym, or he may accept the older name of the variety if he desires. Only the name applied to the subspecies has validity, however, and is protected by the Law of Priority.

This category is probably more useful to paleontologists than to zoologists. Those who work with Recent material can easily ignore the category "variety." But, as with all taxonomic units, its concept and usage should be the same both in paleontology and zoology, and certainly no differences in its application can exist. In other words, if a zoologist finds the varietal category useful, he should be able to use it in the same way as a paleontologist.

It is otherwise with the category "*forma.*" This category could be very useful in the work of paleontologists as well as in that of zoologists. This is the smallest category with so-called "directed variability," which is the opposite of "non-directed variability," or the individual variation shown by each specimen. A "*forma*" usually shows one unimportant but often clearly visible feature, which is not constant and can easily be lost. Furthermore, it has no definite region of distribution – its representatives are usually scattered. Both characteristics are equally important. The name of a "*forma*" should certainly be written without an author's name, and preferably as a clearly descriptive word, for instance: *glabra* (hairless, bald), *costata* (ribbed), *elongata* (elongate), *parva* (small), etc. The name should always be in the feminine gender.

In working with a fauna, especially with rich Recent material, we often see variability of form that should be considered under the category "forma." For example, in 1929 Cushman and Wickenden encountered specimens of *Bulimina patagonica* d'Orbigny (which usually has spines on the first half of its test) without these spines, and separated them as *Bulimina patagonica* var. *glabra.* In many places on the Patagonian shelf (the type locality of *Bulimina patagonica)*, I have found small populations or single specimens of the same form, which were either scattered among typical *Bulimina patagonica* or more or less isolated in very small areas. As a rule, their numbers increased in places with unfavorable ecological conditions. Certainly this change (loss of spines) does not fulfill the requirements for a subspecies or even for a variety concept, but the category *forma* is here quite apt. In no other way can this small difference within the species be expressed, although it has importance as evidence of impoverishment in the living conditions. Many other species lose or decrease their ornamentation under unfavorable ecological conditions.

And now let us summarize and make some practical suggestions. At present the nomenclature of the foraminifera is extremely overloaded with synonyms. The continuous increase in the number of invalid names may cause this branch of zoology (or paleontology) to lose its importance as a science and the foraminifera to lose their significance as stratigraphic guide fossils. We should now begin the "salvation" of our science, which may be done in two ways: 1) By cleaning our existing nomenclatural household; and 2) by being extremely careful in the publication of new names (new species or new subspecies).

In order to accomplish the first task, I would like to suggest that all students of foraminifera who have the opportunity should spend some time studying the collections of the United States National Museum in Washington, and, whenever possible, take time from their special studies for a revision of some published material (types). I refer to the United States National Museum because at present the richest depository of type material in the entire Western Hemisphere is concentrated there, and a revision based only on bibliographic data, without the types, has almost no value. The Eastern Hemisphere has its own centers of rich collections. To fulfill the second task, let us have much more respect for the laws of biology and the International Rules of Zoological Nomenclature.

REFERENCES

BOLTOVSKOY, E.
1954 – *The species and subspecies concepts in the classification of the foraminifera.* Micropaleontologist, vol. 8, no. 3, pp. 52–56.

DROOGER, C. W.
1954 – *Remarks on the species concept in paleontology.* Micropaleontologist, vol. 8, no. 4, pp. 23–26.

HILTERMANN, H.
1955 – *Zur Artfassung in der Paläontologie.* Roemeriana, vol. 1, pp. 385–392.

RICHTER, R.
1948 – *Einführung in die Zoologische Nomenklatur durch Erläuterung der Internationalen Regeln.* Ed. 2. Frankfurt am Main; Verlag Dr. Waldemar Kramer, 252 pp.

VINOGRADOV, A. P.
1952 – [*Fundamental principles of the distribution of trace elements among plants and environments.*] In: [*Trace elements in the lives of plants and animals*]. Akad. Nauk S.S.S.R., Sbornik, pp. 7–28.

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