CHAPTER 2

Classification of Foraminifera

Different workers including d'Orbigny (1826), Reuss (1861), Carpenter (1862), Jones (1876), Schwager (1877), Brady (1884), Galloway (1933), Chapman and Parr (1936), Glassner (1945), and Cushman (1940, 1943), have classified Foraminifera either on the basis of arrangement of chambers, or composition of wall, or morphological characters, etc. Some authors have greatly emphasised the importance of one or two such characters and based the entire classification on these while completely neglecting other equally important features.

Until about 1948, Cushman's classification was widely accepted by workers on Foraminifera. Cushman (op. cit.) based his classification on the morphological characters and phylogenetic and ontogenetic relationships. He considered the shape and nature of the test, arrangement of chambers, position and nature of the aperture, sutures, ornamentation, wall characters (not microstructure), etc., to be of high taxonomic value. But the main drawback in Cushman's classification is that he relied too much upon individual external features without taking into consideration the intra-specific and intra-generic range of variation. To cite one example, he maintains the validity of the genus Ammomarginulina. The only difference between Ammobaculites and Ammomarginulina is that while in the former the test is normal, in the latter the test is quite compressed. Detailed studies by various workers including the present author, clearly indicate that Ammomarginulina
is simply a compressed variant of *Ammobaculites* and that in most samples a complete gradation from one to the other may be found. As such, there is no ground for maintaining the genus *Ammomarginulina*. On similar grounds, the validity of many other genera can, and has been, questioned. Hence, Cushman's classification is on the whole not a balanced and natural one.

Wood's (1949) work on the microstructure of the test wall in Foraminifera, revolutionised the systematics of this order. He studied the test wall in polarized light and emphasized the value of its microstructure in classification. He suggested four main sub-divisions of the Foraminifera on the basis of microstructure of the test wall:

1) The Agglutinating Foraminifera,
2) The Forcellanea,
3) The Fusulinea, and
4) The Hyalina.

Since Wood's work (*op. cit.*), quite a good number of important changes have taken place in the taxonomic aspect of many genera and species of the Foraminifera. Different authors have attempted classification on modern lines and again some have greatly stressed the systematic value of one or two morphological features. Hay, *et al.* (1963), have studied ultramicrostructures in some selected foraminiferal tests with the help of phase-contrast and electron microscopes. However, such studies are still in the incipient stages and it is perhaps too early to say the extent to which such studies will help the systematists. The major drawback, if at all, with
such studies is that the proper equipment may not be available to all the workers.

Hayne (1952), made a comprehensive study of the family Lituolidae and made a number of taxonomic changes. However, he did not take into consideration all the important features in separating the different taxonomic units. He considered the mode of initial coiling in the Ammobaculites group to be of great systematic value and on this basis alone he (op. cit.) erected a new genus - Bulbobaculites - differing from Ammobaculites in the mode of initial coiling. Various workers have shown that the genus Bulbobaculites is invalid according to the International Rules of Zoological Nomenclature and the present work shows that it is invalid even on morphological grounds.

Haynes (1956), following Mood (op. cit.), laid great emphasis on the microstructure of the test wall in classification and on this basis erected a new genus - Protopelphidium - which is morphologically a Nonion but differs from it in having a radial wall microstructure.

Wood and Haynes (1957), described both radial and granular walled species of Cibicoides but did not consider the microstructure of wall alone to be the deciding factor in classification of Foraminifera. Cifelli (1962), has gone a step further in evaluating the value of wall structure in classifying Foraminifera. In his studies on the morphology and structure of Ammonia beccarii (Linne), he has shown that while the wall is finely perforate with radial microstructure, the septa are
imperforate and granular. He also did not consider the nature of the wall to be of great systematic value.

In recent years, Hofker (1951a, b.) has laid great stress on the microstructure, e.g., tooth-plate, pores, etc., in Foraminifera, and considers them to be of great taxonomic importance.

Smout (1954), proposed a classification of the superfamily Rotaliidea and took into consideration the evolutionary trends and various microstructures including laminae, septa, canal system, pillars, chambers, etc. In his classification, the Nonionidae is characterised by the perforate, granular wall, single septa, and the absence of canals, while the Elphidiidae has radial wall, double septa, and a canal system.

Loeblich and Tappan (1961a), proposed a suprageneric classification of the Rhizopoda and have employed different criteria for separating different taxonomic units. In their classification, while the superfamilies are differentiated on the grounds of wall structure and composition, the families are separated on the basis of arrangement of chambers, nature of the aperture, and on ontogenetic and phylogenetic relationships. The subfamilies are separated on the basis of aperture, chamber, septa, wall, and trends in development. Recently, minor modifications have been suggested in this classification by the authors themselves (1962).

Our knowledge of the biology of living foraminifers is quite meagre and, perhaps because of lack of proper laboratory
facilities, sufficient importance has not been attached to this aspect by the systematists. Bhatia (1956), questioned the validity of giving generic names for forms representing gerontic stages of Cibicides. He suggested a detailed and careful study of the living species of the genus Cibicides in order to confirm this view. Following Bhatia's suggestions (op. cit.), Nyholm (1961), worked on the laboratory cultures of Cibicides lobatulus and showed that Cyclocibicides, Annulocibicides, Rectocibicides, and allied genera are nothing but the morphological variants in the life of Cibicides lobatulus and that the distinction between them is only artificial and un-natural. This shows that studies on the living foraminifers, wherever possible, must be taken into consideration in order to make the classification more natural and convincing.

Pokorny (1963), while dealing with the systematic part of the Foraminifera, has taken into account nearly all the modern lines of investigation including composition and structure of the wall, pores, nature of chambers and aperture, phylogenetic and ontogenetic relationships, etc. However, he does not take into account the tooth-plate and other microstructure. His classification is more advanced and up-to-date than any of the earlier ones and, therefore, it has been followed in the case of arenaceous and porcellaneous groups of Foraminifera included in the present work.

For the perforate species of Foraminifera, the re-classification proposed by Reiss (1963), has been followed
in the present study. Balss (op. cit.) made a detailed study of the perforate Foraminifera and proposed a classification which is essentially a 'horizontal' one. He does not consider any one individual character eg. wall structure or tooth-plate, etc., to be of high taxonomic value. Instead, he considers the criteria for separating different groups by synchronising these characters with the other persistent ones. However, in certain cases, where he emphasised the importance of individual feature in dividing various taxa, he takes into account the persistence, evolutionary trends, modifications, etc., of such characters.

In his classification (1963, 1963), a basic distinction between lamellar and non-lamellar Foraminifera has been made. He (1963), has grouped the perforate Foraminifera into five superfamilies - Nodosariidea, Buliminidea, Monolamellidea, Bilamellidea, and Rotaliidea. Beiss attaches considerable importance to the microstructure in Foraminifera and takes into consideration wall structure, pores, nature of chambers, aperture, tooth-plate, canal system, etc., besides phylogenetic relationships, in classifying the perforate Foraminifera. In a way, he based his classification on nearly all the observable characters and synchronised them with one another, thus making it more balanced, logistic, and natural than any other classification proposed so far. It is because of these considerations that his classification of perforate Foraminifera has been followed in the present study.

In the following pages, the arenaceous and porcellaneous genera have been arranged according to Pokorny's (1963) classification, while the perforate forms are arranged according to
the re-classification proposed by Reiss (1963). The different species within a single genus, however, are arranged alphabetically.

The following new species are described:

A. *Raghvapuram Shalesi*

1. *Haplophragmoides bani*
2. *Ammobaculites cespinae*
3. *Ammobaculites boeki*
4. *Ammobaculites indicus*
5. *Ammobaculites rachavpuramensis*
6. *Ammobaculites sabnii*

B. *Infra-Trappian Beds:*

7. *Pseudopolymorhina devarapalleensis*
8. *Planulina bhatiai*

C. *Inter-Trappian Beds:*

9. *Protelphidium adamsi*
10. *Protelphidium dudukuruensis*
11. *Monion kindi*
12. *Discorbia toddae*

The holotypes and a few paratypes of the new species have been deposited in the museum of the Geology Department, Panjab University, Chandigarh, and their references are designated by PUOD Cat. no. in the text. It is the intention of the author to deposit, at a later date, a few paratypes of the new species in the museum of the Geological Survey of India at Calcutta.
The synonymies are reduced to a minimum and arranged chronologically indicating only important shifts in generic names. Further, in order to avoid repetition, the word *et. syn.* follows those references in which complete or satisfactory synonymies have already appeared.

In view of the fact that considerable variation is shown by foraminifers, especially the arenaceous forms, great emphasis has been laid in the present study at working out the range of variation shown by different species. Likewise, dimorphism is also considered to be an important feature and, wherever possible, the dimorphic generations are described and illustrated.

**Laboratory Procedure and Techniques:**

The usual procedure of crushing the sample, boiling in detergents and screening through a set of sieves has been followed in the present work. In the case of the Tertiary samples, the carbon-tetrachloride flotation method was used for concentrating the microfossils. The microfossils were picked with the help of a fine sable-hair brush and arranged in squared slides for identification and study.

In recent years, a great deal of emphasis has been laid on the structure of wall in calcareous foraminifera and therefore it was considered necessary in the present work also to study this in detail. The techniques described by Wood (1963) have been followed. The specimens were cleaned, immersed in absolute alcohol to remove the moisture, and were placed in xylene contained in a glass slide with a central cavity.
The immersed specimen was viewed under crossed nicols. The isogyres in the radially built wall were best seen at the periphery by rotating the stage of microscope. In the keeled forms, the dark brushes are clearly seen at the periphery. However, in forms having globular chambers, e.g., Vaginulina, Fissurina, etc., the black cross can be well seen in the centre of the chambers. In the case of granular forms, e.g., Monion etc., the periphery remains illuminated throughout the rotation of the stage. On crushing the specimens in xylene, the fragments do not give satisfactory results regarding the nature of the wall. In the present study, where no conclusive results were obtained by the above mentioned methods, thin sections had to be prepared.

In order to study the internal structure (including the proloculus) of the arenaceous foraminifers the specimens were first thoroughly cleaned and then kept immersed for about two days in xylene contained in a glass cavity slab. The cavity slab was then placed on the stage of a stereoscopic binocular microscope. The reflecting mirror was so adjusted that a contrast is developed between the specimen and the xylene. The natural light was found more suitable than the artificial. However, in some cases where this method was not found suitable, thin sections were prepared in order to study the internal structure and size of proloculus, etc.

The pores in the wall of foraminifera were studied by immersing the specimen in xylene for about two days in order to remove the air bubbles in the specimen and then crushing them.
in Canada balsam under a cover slip (Wood, personal communication, 1964).

In order to make the surface feature distinct, specimens were stained following the silver nitrate method described by Levinson (1951).