VII. THE CORRELATION OF ROCKS BY MEANS OF MICROSCOPIC FOSSILS

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To successfully carry on geological work in any area it is recognized that a knowledge of the succession of the rock formation is necessary. This process of matching up the rocks as to age in various parts of a region, or those of one region with those of another region, or those of one country with those of another country is called correlation of formations or of members of formations.

In such correlation the use of megascopic fossils long has been recognized, though different species vary greatly in their value as an aid to correlation. Thus one species, of the larger forms of Leptaena rhomboidalis, lived for many millions of years or through a good part of four great geologic periods, so if we were to depend on this fossil alone we could say that the strata containing it belong to the Ordovician, Sliurian, Devonian or Mississippian. Another form, Meristella arcuata, which also is common in the Haragan marl of the Arbuckle region, is limited to the very basal formation of the Devonian there and in New York and in New Brunswick, and thus it is recognized as a good horizon marker.

Accordingly, the age of a formation sometimes may be told by the identification of a single species, but more commonly several fossils constituting a fauna are studied. In the study of faunas it is found that some are very definitely limited to a formation, while others are transitional in character. Thus the application of the principles of correlation at times involves many problems, and this particularly is true in an area where the rock structures are complex.

The principles used in the case of megascopic forms can largely be applied in the use of microscopic forms, with the added difficulty in handling the latter because many of them are exceedingly small. With reference to the study of microscopic forms, many species of foriminifera were illustrated and described many years ago, but at that time the work was done wholly from a scientific standpoint, with little idea that a time was coming when they would be used extensively in correlation and that the publications containing them would be in great demand.

However, this has happened, so that now most of the larger oil companies are including in their laboratories a department of micro-paleontology. To illustrate how recently interest in these forms has been aroused and their practical value recognized, at a meeting of the American Association of Petroleum Geologists a little over two years ago, at Shreveport, Louisiana, an opinion was expressed by one of the leading Tertiary paleontologists to the effect that he doubted whether they ever would become of importance in accurately locating horizons in deep wells. His statement was answered by Miss Richards, now Mrs. Paul Applin, consulting geologist for the Rio Bravo Company, who replied that such correlation by means of these forms already had been accomplished over large areas in Texas. In Mexico their use has developed by leaps and bounds.

In this connection the testimony of Dr. Joseph A. Cushman, recognized as the foremost authority in America on foraminifera, will be of interest. In one of the publications of the Smithsonian Institution, "An Introduction to the Morphology and Classification of the Foraminifera," he gives this testimony: "The economic use of the foraminifera is perhaps one of the best examples of the application of purely scientific work to economic uses. Until recent years their study has been a matter of pure science, and their interest confined, except in a general way to zoologists, to a small group of workers. In the last few years, however, they have assumed an importance in economic work. ** Especially in connection with the petroleum industry they have great present and future possibilities. In the drilling of wells most fossils are so broken up that they become unrecognizable in the samples. The foraminifera, however, are usually of such minute size and are in such quantities that enough of them escape the destructive force of drilling so that they form a recognizable part in the well samples themselves. By close study of the section through which a well is drilled, it becomes possible to recognize various zones which may be found again in adjacent wells. By such study subsurface maps may be made, which show the geologic features of the underground structures. By this means it is possible to control the placing of additional wells in a field with greater or less certainty of increase in production. When the age of the strata is not definitely known, a well may be abandoned before it actually reaches a producing horizon, or may pass through such a horizon for a considerable distance without its being recognized. In either case a considerable loss results. The knowledge that might have been obtained from the borings is also lost. In many oil fields it is necessary to shut off underground water, and these water horizons may be recognized by a study of the forminifera. This again is a great economic use of these small fossils."

J. J. Galloway, of Columbia University, in an article in the Bulletin of The American Association of Petroleum Geologists, Vol. X, No. 6, p. 567, states that on the whole, foraminifera are just as reliable as mollusca or any other marine forms, for correlation, and that this applies to the smaller forms as well as larger ones.

Corroborating testimony to the same effect is being received from former students now in the employ of large oil companies. One of these, A. C. Wright, in a letter of April 29, 1924, said: "The most common foraminifera belongs to the genus Cristillaria which also was common in the Midway shales I sent you. The Cretaceous Cristillaria may be recognized from the Midway forms on close examination by the fact that the Cretaceous forms have a thin wide keel, while the Midway forms have a narrow rounded keel." Another former student, Harold Vanderpool, now working in Louisiana, writes as follows, in a letter of October 4, 1926, which shows the importance of these forms in that states. He writes: "Much of the field work ,as well as the sub-surface correlations, is almost solely dependent upon diagnostic "forams," and for this reason they are closely studied, and constitute an important phase of the work down here."

As has been noted previously, the reason for the use of microscopic forms is that very few megascopic forms are preserved in well cuttings, while the microscopic forms are not destroyed by the drilling processes. They are particularly abundant and more easily secured from the shales of the Mesozoic and the unconsolidated clays of the Tertiary, but they occur in many formations of the Paleozoic in sufficient numbers to be of value, and rather recently large numbers of them have been studied and described from thin sections of what is considered to be early Paleozoic cherts from Gaspe.

The method of securing these tiny forms from the outcropping rocks is to soften them by soaking and then concentrating by washing, drying and the use of sieves of fine meshes. Well cuttings are treated in much the same way, though at times these are sufficiently fine so they can be concentrated without soaking. Besides these methods, heavy solutions have been used to some extent, and magnetic methods have been attempted for forms replaced by iron.

The concentrated material then is placed on a slide under the microscope, and the forms picked out with a fine red sable brush, to the dampened end of which the tiny forms adhere.

These are then placed in a small bottle on which is placed a gummed label for permanent record, or they are transferred to a glass slide for study. Various kinds of slides are used. At first glass slides with one or more concave depresions were used. In these the microscopic forms were placed with a cover glass fastened above them by means of gummed labels. Then a label is placed on either or both ends of the slide to record name, locality, and horizon. This type of slide has been used extensively, but because of the concave surface on which the fossils rest, the focus must be constantly changed as different forms are studied, and not infrequently some of the small forms get wedged in the thin space around the edge of the concavity against the glass cover. Moreover, if many forms are placed together in a single slide it is difficult at times to separate the individual ones and isolate them for study on the concave surface.

To obviate the difficulties involved in using slides with a concave depression, a thicker slide wth a somewhat deeper well with vertical sides and horizontal bottom has been used to some extent.

However, pasteboard slides are being used more extensively than glass at the present time. These are made with one, two, three, five, or more depresseions, with either a black or white background, depending on the nature of the fossils to be studeid. If the fossils are dark and opaque they may be seen best on a light background, but if they are hyaline and transparent, they show up better on a dark background. The slides are made by punching holes in one piece of cardboard and to this piece fastening either a black or white piece of the same size, then covering the depressions with cover glasses, depending on hte number of depressions in a slide.

At the University of Chicago a method has been devised by which the pasteboard slide containing the fossils is slipped into a slot composed of a pasteboard strip below and a glass slide 1 x 3 inches above, the latter serving as a cover glass. This methods admits of the easy removal of fossils, or the changing of them at any time. Other persons use still other methods. Mr. P. V. Roundy, of the United States Geological Survey, uses a shallow tray for the study of fossils ,and by a mechanical device moves the tray across the stage of the microscope so that all the area of the bottom of the tray is covered by the field of the objective. When not in use the fossils are kept in labelled bottles.

While the microscopic forms include not only the foraminifera, but also ostracodes, diatoms, radiolaria, and some gastropods and pelecypods, the foraminiferal group is by far the most abundant and important. These vary in size from microscopic forms about 1/10,000 of an inch in diameter up to large forms several inches across. The hard tests of foraminifera very greatly. A few types of forms enclose themselves in a test made of sand grains or other foreign material cemented together, some have opaque porcellanous tests, while those of others are transparent and hyaline. As to the composition of the tests, in a few forms it is arenaceous, due to the cementing together of sand grains, in a few the test is chitinous or horny, but in most forms it is composed of calcium carbonate.

All Foraminifera are unicellular. However, some of the forms that secrete tests are unilocular or monathalamous, consisting of a single chamber, but others are very complex multilocular or polythalamous with numerous chambers. In the sectioning and study of some polythalamous types, it has been discovered that there is a great variation in the sizes of the primordial, or first chamber. Also, from this study these seems to be some evidence that as a rule, forms with a microsphere, or tiny primordial chamber, develop and become relatively large, while those with a megasphere or large primordial chamber small or medium sized forms. Indeed, in a few cases both megaspheric and microspheric forms occur in the same species.

As to the methods of identification it may be said that the different forms vary greatly in size, shape and markings. The group of foraminifera commonly is divided into ten families, twenty five subfamilies and one hundred and seventy nine genera. Nearly every genus includes numerous species, the number of which is being increased rapidly by the discovery and naming of new species. Presently slides will be shown which will illustrate various methods of organization of the tests of foraminifera, some of the variations in a single genus, and some of the methods of study to identify species. However, before showing these slides I wish to speak briefly of several other groups of microscopic fossils.

First, the ostracodes will be mentioned. These are crustacean arthropoda which secrete chitinous or calcareous bivalve shells varying in size from less than a fortieth of an inch in length up to three fourths of an inch or more. These are similar to pelecypod shells, but differ from them in generally being much smaller, in having the valves more unequal, in the absence of concentric growth lines, and in the presence of an exterior protuberance representing the eye spot. Ostracodes live in fresh, brackish, and marine waters, and they have been abundant since the early Paleozoic. Some of the larger forms were so numerous in the Ordovician of the Arbuckle Mountains that they make up a considerable part of some of the thin beds in the upper part of the Arbuckle and the lower part of the Simpson formations. Frequently the subsurface of some of the limestones literally is coated with the shells of ostracodes.

In studying the basal part of the Glenn formation of early Pennsylvanian age east of the Criner Hills, Mr. James Waters found that ostracodes were among the most numerous of the microscopic fossils. Many ostracodes have been described and illustrated in early geological literature. In the "Scientific Transactions of the Royal Dublin Society" there is a small monograph on "The Carboniferous Ostracodes of Ireland," and Ulrich and Bassler have written a paper on the Paleozoic ostracodes in one family in this country.

Numerous other types of fossils are microscopic. Many tiny gastropods occur in both low and high spired types. Another Molluscan group, the scaphopods, has many tiny forms in the shape of curved, tooth-like shells open at both ends. In some formations spines of pustulose brachiopods occur, and in some spines and plates of sea-urchins and crinoids are abundant, and many fragments of various types of shells occur as well as the teeth of some annulate worms. In cherts the radiolaria are common, and in many of the Tertiary formations tiny siliceous diatomaceous plants are found in almost incredible numbers. Diatoms are particularly abundant, and make up a large part of the thick formations in the Miocene of California, where they are thought by some to have had much to do with the origin of oil in some of the California fields.

In this brief review only an inkling has been given of the great field which is being opened in the study of microscopic fossils, and its very practical application in the correlation of formations, chiefly in the application of surface and sub-surface geology to the great petroleum industry. This industry is deeply indebted to the United States Geological Survey, The United States National Museum and other national agencies for the valuable collections made. Through these agencies there has been accumulated the great mass of fossils and recent material containing foraminifera which through its study has become of great economic value, and which makes the foraminifera one of the greatest assets of the geologist in economic work.