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Collection and Preparation of Conodonts Through Mass Production Techniques

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COLLECTION AND PREPARATION OF CONODONTS THROUGH MASS PRODUCTION TECHNIQUES

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ABSTRACT

The nature of conodonts, their use for correlation, and their occurrence in the Paleozoic rocks of Illinois are discussed. A threefold plan for collecting conodonts is outlined and recommendations for the size, number, and stratigraphic spacing of samples are presented.

Techniques for separating conodonts from limestone, shale, and dolomite are discussed in detail. A flow chart for the mass production processing of quantities of conodont-bearing rock is given.

INTRODUCTION

Conodonts are minute toothlike microfossils that may be cone, bar, blade, or platform shaped and are composed of concentric layers or longitudinal fibrous bundles of calcium metaphosphate. They range in size from less than 0.1 mm to more than 4.0 mm. Unaltered, the fossils are translucent amber-brown and have a waxy luster; altered, they range in color from translucent gray through opaque white and gray to opaque black.

The biologic affinities of conodonts are unknown (Rhodes, 1954; Müller, 1956a), but their internal structure, shape, and composition suggest that they may be hard parts of soft-bodied primitive vertebrates. The fossils are distributed so widely in marine Paleozoic rocks (Collinson, Rexroad, & Scott, 1959) and are so independent of facies that they almost certainly represent pelagic—probably nektonic—organisms. Because they are highly resistant to chemical weathering, conodonts commonly are concentrated in the residuum from rocks that originally contained them and may be found reworked into younger sediments and admixed with younger faunas.

Where conodonts have received careful study they are exceedingly useful as geologic age indicators. Their value arises from the fact that the conodont-

bearing organism evolved rapidly during much of the Paleozoic Era and new forms were dispersed so swiftly that most marine formations contain at least several distinctive faunas that are restricted to relatively short intervals of geologic time. In addition the fossil remains are so abundant and widely distributed that regional and stratigraphic variability of species can be determined precisely and faunal sequences reconstructed to form the basis for unusually accurate biostratigraphic zonations. The only serious obstacle to unlimited use of conodonts for Paleozoic correlation is the fact that inexpensive mass production techniques are known by relatively few workers. This report describes the conodont collecting and processing procedures through mass production techniques used by the Illinois State Geological Survey during the past eight years. The collecting procedures were developed by the author with the help of Carl B. Rexroad and Alan J. Scott. The processing routines were developed jointly with these two colleagues, but there also have been significant contributions by several student assistants who have actually operated the laboratory in recent years. Most of the techniques are not new but represent adaptation of widely known methods.

OCCURRENCE OF CONODONTS

Conodonts are rarely seen in the field, although some early workers (Ulrich & Bassler, 1926; Huddle, 1934) made collections using a hand lens. Where conodonts are visible to the naked eye, they are in most cases exceedingly abundant and occur on bedding planes or as thin layers. On bedding surfaces of black shale they, or their molds, appear as shiny black objects or, if oxidized, as tiny white figures against the dark background. In lighter colored rocks conodonts appear as dark irregular grains that reflect light from their broken surfaces.

In general practice, rocks believed to contain conodonts are collected and returned to the laboratory where they are disaggregated and the conodonts removed. Thus the collector must know in advance where conodonts are likely to be found and formulate a plan for sampling the area and stratigraphic interval to be studied.

Two erroneous beliefs about the occurrence of conodonts are widely held. First, that they occur most commonly in shale and, second, that they occur most abundantly in black shale. As will be seen in the following discussion, neither is true.

Conodonts may be found in fair abundance in almost any normal marine rock, ranging in age from late Cambrian through middle Triassic, that can be disaggregated successfully without destroying the fossils. Nearly all limestones, dolomites, and shales (generally excluding black shales) respond to petroleum solvent or acid digestion (Beckman, 1952, 1958; Müller, 1956b; Bischoff & Ziegler, 1957; Thursch, 1958; Collinson, Rexroad, & Scott, 1959; Hass, 1962) and in most cases permit the processing of quantities of material in relatively few hours. Calcareous and argillaceous sandstones are amenable to the same techniques but with somewhat lower numerical yields of specimens. At present no practical mass technique is known for the disaggregation of black shales without destruction of the contained conodonts.

Abundance of Conodonts

During the past several years the paleontological staff of the Survey has processed many thousands of samples containing conodonts and for the last five years has kept records of the amounts and kinds of rocks processed and the numbers of conodonts recovered. Based mainly on samples from Silurian, Devonian, and Mississippian rocks of the central United States but also representing several hundred samples from western and eastern United States as well as southwestern Canada, these figures show that significant numbers occurred in more than half of all samples examined.

Limestone

Of the rock types processed, limestones have been the most reliable and productive. For example, more than 85 percent of all limestone samples of late Mississippian age have yielded at least 10 conodonts per kilogram and several beds yielded more than 100 per kilo. Of 70 consecutive samples recently taken from a 140-foot Middle Devonian outcrop, all yielded conodonts and more than 75 percent produced over 15 conodonts per kilogram. Several samples contained more than 100 per kilogram. More than 5000 specimens came from this average section. Probably the greatest abundance of conodonts ever reported from limestone is that published by Bischoff & Ziegler (1957, p. 13) who found a concentration in excess of 20,000 specimens per kilo in a limestone lens in the lower Cheiloceras-Stufe of Germany.

There are notable exceptions to the reliable productivity of limestones. Some fine-grained limestones, such as the Upper Devonian Louisiana Limestone of the Mississippi Valley, appear to represent a rapid chemical precipitate and average less than 5 conodonts per kilogram. Oolitic limestones may or may not contain identifiable conodonts because specimens commonly are rounded and unidentifiable.

Shale

Shales are generally excellent sources for faunas and frequently produce spectacular abundances. Yields exceeding 1000 specimens per kilogram are known in Illinois, but occurrences in general are sporadic and beds containing great numbers are interspaced with intervals carrying relatively few or none. In overall aspect shales do not yield as consistently as limestones, nor is the average yield as high. Because of ease of processing and because shales have for many years been considered the primary source of conodonts, enormous quantities have been processed, with the result that more conodonts have been collected from gray, green, buff, or brown shales than from any other kind of rock.

Red shales produce significant numbers of specimens where they represent marine sediments, as in the Fern Glen Formation of Missouri, but where the shales represent nonmarine or brackish-water sediments, as in the red beds of the Chesterian Series, no conodonts are found.

Black shales have long been considered excellent sources of conodonts; actually, they are among the poorest. Their low productivity is due to the lack of a satisfactory mass technique for separating conodonts from them. Their high

reputation arose from the fact that the well known faunas described by Ulrich & Bassler (1926), Huddle (1934), and Branson & Mehl (1934), were reputed to have come from such lithologies. However, the former two faunas were found on bedding planes of black shale and the latter (Grassy Creek) came mainly from greenish gray shale.

Dolomite

Although fewer samples of dolomite than limestone have been processed, several hundred samples from the Silurian, Devonian, and Mississippian indicate that conodonts are somewhat less regularly distributed than in limestone and occur less abundantly than in either limestone or shale. The apparent difference may be owing to processing difficulties inasmuch as dolomite is less soluble than limestone and residues are commonly clogged with dolomite rhombs that may be difficult to separate cleanly in heavy liquids. Nevertheless, conodonts are common in dolomites and frequently are found in abundances greater than 50 specimens per kilogram.

In summary, one can say that limestone represents the most favorable rock type for the collection of conodonts. Distribution is more regular than in other rock types and the average number of specimens contained is higher. Faunas from limestones are in general superior because of better preservation, less breakage, and cleaner specimens. Most shales are more easily disaggregated than limestones, and some beds produce prodigious collections. However, distribution is uneven and the overall average of specimens per kilogram is lower than for limestones. Sandstones and siltstones produce faunas, but sporadically, in relatively low number.

The stratigraphic distribution of conodonts and the relation of occurrence to lithology indicate that the conodont-bearing animal was almost continuously present and uniformly abundant in Paleozoic and early Mesozoic seas and the rate of sediment deposition was apparently the most important factor governing present day occurrence. Sea bottom environment seems to have been a negligible factor.

Conodont Collecting

Modern collecting and processing techniques make practical the recovery of abundant faunas from continuous or nearly continuous consecutive samples from the greater part of the Paleozoic. As a result collections from unrelated short stratigraphic intervals or isolated outcrops can no longer be considered adequate for taxonomic or biostratigraphic determinations. Exceptions, of course, are collections made for the purpose of obtaining comparative specimens or for relating isolated sections to longer sequences.

The availability of large and correlated collections suggests that conodont taxa should be considered deficient unless related in time to ancestor, descendant, and contemporary variants; biostratigraphic zones, correlations, and age determinations should be considered less than certain unless sequences of faunas above and below the units in question are known. Knowledge of the sequence of faunas is vitally important, inasmuch as elements comprising the fauna from any particular horizon represent only increments of numerous phylogenetic lineages

and must be related to major portions of these lineages to be useful biostratigraphically. Many a fauna described as representing a specific stratigraphic unit actually represents only one of many intergrading faunas and may be quite unlike faunas from other stratigraphic horizons in the same unit.

For the above reasons, any study other than for collection of comparative material should be based on a predetermined orderly and comprehensive sampling scheme that will give adequate geographic as well as stratigraphic coverage and give assurance that the information secured is not only as comprehensive as possible but can be duplicated by subsequent workers as well. So many realms of conodont occurrence remain unstudied that preoccupation with short sequences, incompletely known faunas, and isolated faunas serves only to dilute and delay progress toward adequate knowledge of conodont biostratigraphy and the paleogeographic refinement it will bring.

A PLAN FOR COLLECTING CONODONTS

A routine for collecting conodont samples has been developed by the author and colleagues and has been used for several years. It is offered here as a practical approach to systematic conodont collecting and consists of three operations:

(1) Reconnaissance.—Continuous channel sampling of the largest and best exposed sections available consistent with good geographic spacing.
(2) Selective recollections.—Recollection of zones of especial abundance to gain comprehensive knowledge of relatively complete faunas.
(3) Bulk recollection.—Recollection of large quantities of material in parts of the section where faunas are of particular significance.

Reconnaissance

Distribution of collecting localities

In reconnaissance, emphasis is placed on careful collecting of samples from a few of the longest, best exposed, and most nearly complete sections available. More important than uniform geographic spacing is adequate representation of all facies, members, or formations of the stratigraphic interval under study. The best sections in which each stratigraphic unit is exposed should be sampled to serve as references for subsequent work. After the faunal sequences of these reference sections are well known, need for additional localities becomes apparent and zones where conodonts are lacking or stratigraphic units are missing will suggest locations for additional sampling.

Distribution of samples

The length of stratigraphic section to be studied, the capacity of facilities available for processing samples, and the amount of time available for collecting and processing determine the sampling pattern that will be most useful in any given study.

Where the geologic column is relatively short, as in central United States, sections seldom exceed 200 or 300 feet and continuous channel sampling is recommended. Our techniques are such that large quantities of material can be handled even in laboratories of modest size and 100 or 200 samples, totaling 200 to 400 pounds, per reference section are not excessive.

Where the geologic column is long and sections may be several thousand feet thick, 100 or 200 samples must be distributed so that maximum information can be derived. If the section is composed mainly of limestone, conodonts should be uniformly distributed throughout the section and collection of uniformly spaced composite channel samples should give optimum results. In sandstone, shale, or siltstone sequences, conodonts are irregularly distributed, and samples should be concentrated above and below formational or member contacts or where special problems exist. For example, if 100 samples are the maximum that can be handled efficiently and there are 5 formational boundaries in a 1000-foot section, 10 composite channel samples both above and below each formational boundary should give optimum practical coverage.

Of special importance in the collection of reconnaissance samples is the accurate geographic and stratigraphic location of all samples. Where possible, the outcrop or core should be marked permanently. If the sample is from soft sediments, a survey stake will serve as a reference point. The ability to re-collect precisely any particular sample is imperative.

Sample interval

Reconnaissance samples should be of the channel type in which every inch of the sample interval is represented. Where natural beds are less than 5 feet thick each sample may represent a single bed or any part of it. Where beds are thicker, or bedding is not significant, as in shale sections, $2\frac{1}{2}$- to 5-foot intervals may be utilized. In special cases 10-foot intervals are useful, but in such samples the strong possibility exists that faunas of significantly different aspect and age will be intermixed.

Size of sample

Extensive experience in collecting samples for conodonts has shown that a 2-kilogram sample is eminently satisfactory for both biostratigraphic and taxonomic studies. A 7 x 12-inch cloth sample bag will hold slightly more than 2 kilograms. Collecting from middle Paleozoic rocks has demonstrated that this size of sample will contain, on the average, 10 to 20 conodonts in more than half of all samples. Such numbers are generally adequate both for reconnaissance and for age determinations where the faunal sequence is already well known. Experience has shown that a 2-kilogram sample gives an 89 percent level of confidence that at least one conodont will be encountered if concentrations are in excess of one specimen per kilogram. This degree of confidence enables the collector to remove from consideration zones of low concentration and thereby to devote further efforts to zones of promise or to compute the amount of material that must be collected in order to get significant numbers of specimens from zones of low occurrence.

Selective Recollecting

After reconnaissance samples have been processed and zones of low, common, and abundant occurrence have been outlined, it is recommended that zones of abundance be resampled. This is done in order to expand the collections to a point where they are fairly representative of the entire fauna. The percentage of the total fauna represented by various genera and species then can be determined reliably, along with the intraspecific variability of the more important species. The operation also verifies by repetition results of the original collection.

Samples for recollecting are of the standard 2-kilogram size and are commonly taken at 6-inch or shorter intervals in the zones of abundance. Such distribution determines the variation of occurrence within the zone and pinpoints the horizons of highest occurrence. Such high-occurrence beds may later be invaluable for detailed taxonomic studies.

Bulk Recollecting

Commonly, after a sequence of conodont faunas is fairly well known, some stratigraphic or taxonomic problem will remain that must be solved in order to complete the study. In most cases the solution will be found in a part of the section where conodont occurrences are very low. It is then necessary to collect and process quantities of material. Several times it has been necessary to collect and process 400 or 500 pounds of material from a single bed in order to resolve a stratigraphic problem.

Collection of Subsurface Samples

Cores

Cores often represent irreplaceable material and should, therefore, be subdivided into the smallest practical sample intervals. A 250-gram sample is suggested as the smallest unit that can be processed efficiently in a mass production operation. In a 3-inch bioclastic limestone core, this would represent approximately $\frac{1}{2}$-inch intervals. Such short intervals have been used successfully in our laboratory.

If the core is of the order of 100 feet long, 1- or 2-foot sample intervals are practical. It must be kept in mind, however, that samples can be combined after processing but never again subdivided stratigraphically once the core is exhausted.

Well samples

The normal size of sample taken at the well for microscopic study is too small for conodont studies, and it is necessary for the conodont worker to make special collections at the well site. Because well cuttings are generally finer than samples crushed for processing of conodonts, approximately twice as much material must be collected per stratigraphic unit as would be used for a similar

outcrop study. Approximately 4000 grams per sample should represent the practical minimum to be collected at the well and all material that will pass through a 24-mesh sieve should be eliminated from the sample before processing.

Contamination

Because of the unusual durability of conodonts, special measures must be taken to guard against contamination. Sample bags should not be reused. Tools such as picks, trowels, and shovels should be cleaned before each sample is taken and sample bags must be sealed tightly and inspected for rips or punctures. Whenever there is the slightest possibility of contamination, samples should be discarded.

In collecting from outcrops it is wise to take the lowest samples first and work uphill, cleaning the sample site carefully before sampling. Because conodonts characteristically accumulate in weathered material, great care should be taken to secure samples from fresh exposures. Contamination is to be anticipated particularly on shale slopes where slope wash and slump are active. Often it is necessary to dig the slope back 2 or 3 feet. Flat areas at the base of shale slopes should be avoided. Reworked material there may be difficult to recognize and the possibility of its occurrence is high.

MASS PRODUCTION TECHNIQUES FOR SEPARATION OF CONODONTS FROM LIMESTONE, DOLOMITE, SHALE AND CALCAREOUS SANDSTONE

A microfossil processing laboratory has been in continuous operation at the Illinois State Geological Survey since 1955. Over the years a number of refinements have been added to well known and widely used methods so that large quantities of rock can be processed quickly with little investment of labor, equipment, and money. The refinements represent the accumulation of ideas brought forth by the research and technical assistants who have operated the laboratory. Foremost among them are Alan J. Scott, Carl B. Rexroad, Robert Townsend, James Hamilton, R. William Orr, and Romayne Ziroli.

A flow chart of laboratory procedure is presented (fig. 1) and the steps are discussed separately.

Crushing of Samples

The standard size of field sample used for collecting conodonts weighs 2 kilograms. In the laboratory, indurated samples are crushed in an 8-inch jaw crusher to a maximum size of 25 mm, then recrushed in a 3-inch jaw crusher to a maximum of 18 mm (the size mode is near 1 cm). Samples to be placed in acid are next dry sieved, whereas shale samples are placed directly in Stoddard solvent.

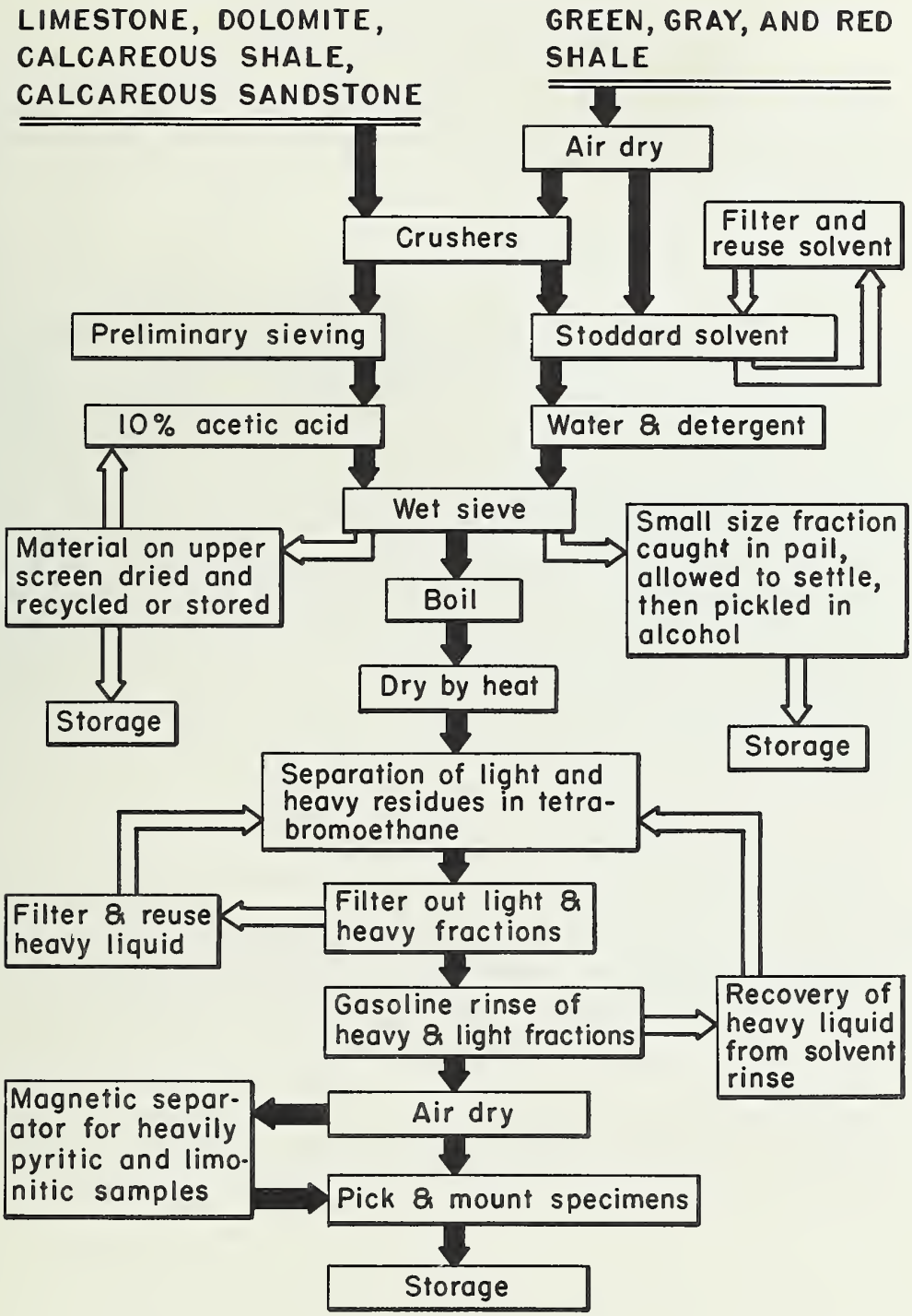

Fig. 1 - Sequence of laboratory procedures used for disaggregating sedimentary rocks and separating conodonts from them.

Preliminary Dry Sieving of Limestone, Dolomite, Calcareous Shale, and Calcareous Sandstone

The time and quantity of acid required to dissolve or disaggregate calcareous samples in acid is reduced greatly by dry sieving, through a 24-mesh screen, particles generally too small to contain significant numbers of identifiable specimens. Material not passing the sieve is retained for acidation.

Use of Stoddard Solvent

Noncalcareous shales and mudstones are air dried before being placed in 10-quart galvanized metal pails and covered with Stoddard solvent. Low volatility, flammability, and faint odor makes Stoddard superior to either gasoline or kerosene. Many similar solvents are on the market under various trade names.

After being covered with solvent, samples should be agitated so that trapped air is released. Samples should soak at least 2 hours, although 6 to 8 hours may be required for many samples. A simple test indicates whether or not the sample is thoroughly soaked. Place a piece of shale in water. If it turns several shades lighter and forms a sludge it is ready to be removed from the solvent. Then decant the solvent and cover the sample with water. The use of a small amount of detergent and hot water speeds the sludging. The sample soaks until it is reduced to sludge and samples that do not disaggregate within 2 or 3 hours should be dried and recycled. Black or very dark gray shales generally do not respond to this process and we have been unable to discover a mass production method satisfactory for disaggregation of such shales.

Acidizing of Calcareous Samples

Calcareous samples that have been crushed and dry sieved are placed in 8- or 10-quart polyethylene pails. No more than 500 grams of sample should be spread on the bottom of the bucket and 8 quarts of 10 percent glacial acetic acid added. Generally 8 quarts will dissolve 400 to 450 grams of relatively pure limestone. Concentrations up to 14 percent can be used without serious etching of specimens. However, 10 percent will dissolve 400 grams of sample in a 12- to 24-hour period with no etching of specimens. Figure 2 illustrates solution rates for several different kinds of rock. Because dolomite dissolves slowly in acetic acid, monochloroacetic acid may be preferable (Beckman, 1952) where large quantities of dolomite are to be processed. When the pH of the acetic acid solution remains relatively constant for several hours the sample is ready for sieving.

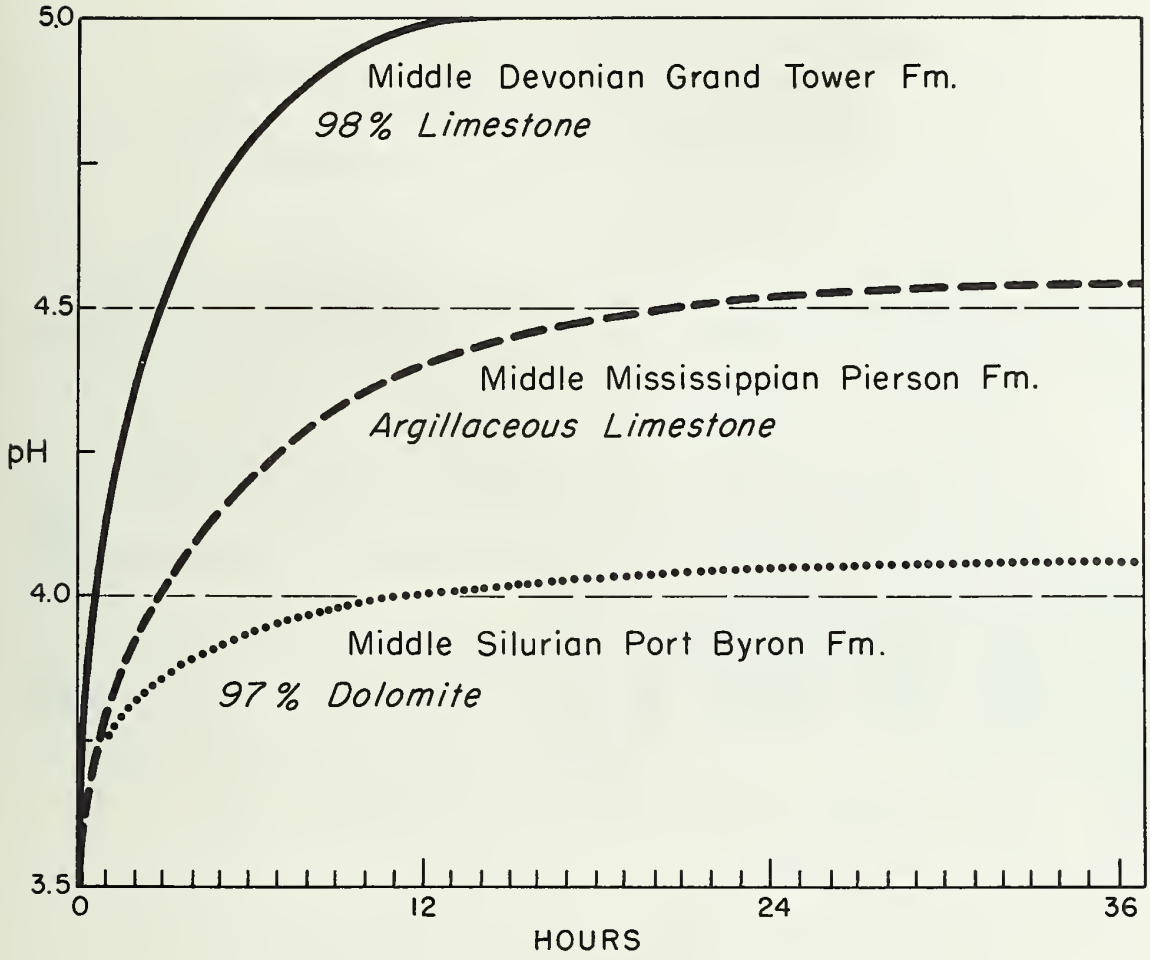

Fig. 2 - Relative solution rates of pure limestone, argillaceous limestone, and dolomite in 10% acetic acid solution at approximately 75° F; 500 grams of crushed rock in 8 quarts of acid solution were used for the tests.

It can be seen from figure 2 that the solution rate for most rocks will have dropped to a low level between 12 and 24 hours after solution has begun. As a general rule, if the sample does not effervesce when the pail is tapped, action has virtually ceased and the sample is ready for sieving. Maximum efficiency in solution of carbonates may be obtained by use of several dozen pails. Thus a number of dissolved samples are ready for sieving each day and new samples are placed in the pails they release.

Where acid buckets are stored on open racks (fig. 3) and personnel must work in the same room, it is advantageous to cover buckets with sheets of polyethylene film held in place by rubber bands made from strip rubber, such as are used on model airplanes. Under such conditions, a large window fan offers adequate ventilation.

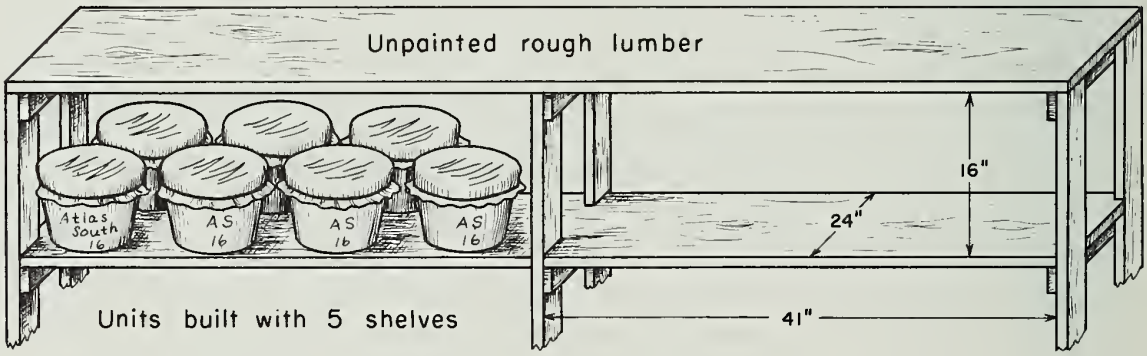

Fig. 3 - Pails covered with polyethylene film and stored on racks during solution of samples. Sample identification numbers are marked on pails with grease pencil.

Wet Sieving of Disaggregated Samples and Residues

After dissolution or disaggregation is complete both acid residues and solvent sludges are washed through 2 sieves using tap water and a small hose. The top sieve is of 16-mesh size and the lower 100-mesh. If residues may contain cone-shaped conodonts, a 200-mesh lower sieve is used in place of the 100-mesh.

Commonly the portion of the residue that passes the lower screen is washed directly into the sink and discarded. However, when chitinozoans, hystrichosphaerids, spores, or pollen are to be preserved, a simple rack is used to support the sieves over a pail (fig. 4) and the small size fraction is retained for examination.

In the wet sieving process, conodonts, along with other insoluble material, are caught on the lower screen where they are thoroughly rinsed with a fine spray

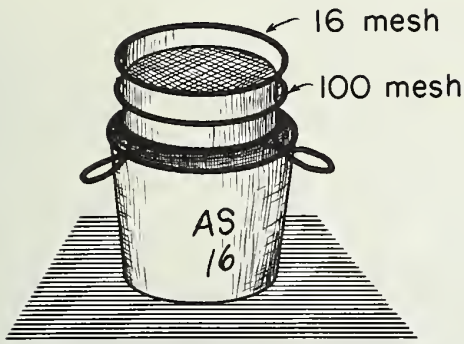

Fig. 4 - Sieves on rack over pail used for catching fine material washed through 100 mesh sieve. Such fine material commonly contains chitinozoans, hystrichosphaerids, and spores or pollen.

and then washed into a saucepan for boiling. Material on the upper screen is recycled, stored, or discarded as the situation demands.

In order to remove clay-sized material, all residues are boiled in a slightly alkaline solution for 1 to 6 hours during which the water is periodically decanted. The settling rate of conodonts in water (fig. 5) requires that the residue in a quart saucepan should settle 10 to 15 seconds between decantings. Residue in a 10-quart pail should settle 30 to 40 seconds. After decanting, the sample is reboiled until the water remains relatively clear. The sample is then dried on a hot plate. Electric plates avoid the danger of an open flame in a laboratory using flammable solvents.

Samples containing specimens that did not boil clean may be treated by a sonic cleaner. Such devices are especially well adapted for cleaning of individual specimens or very small samples.

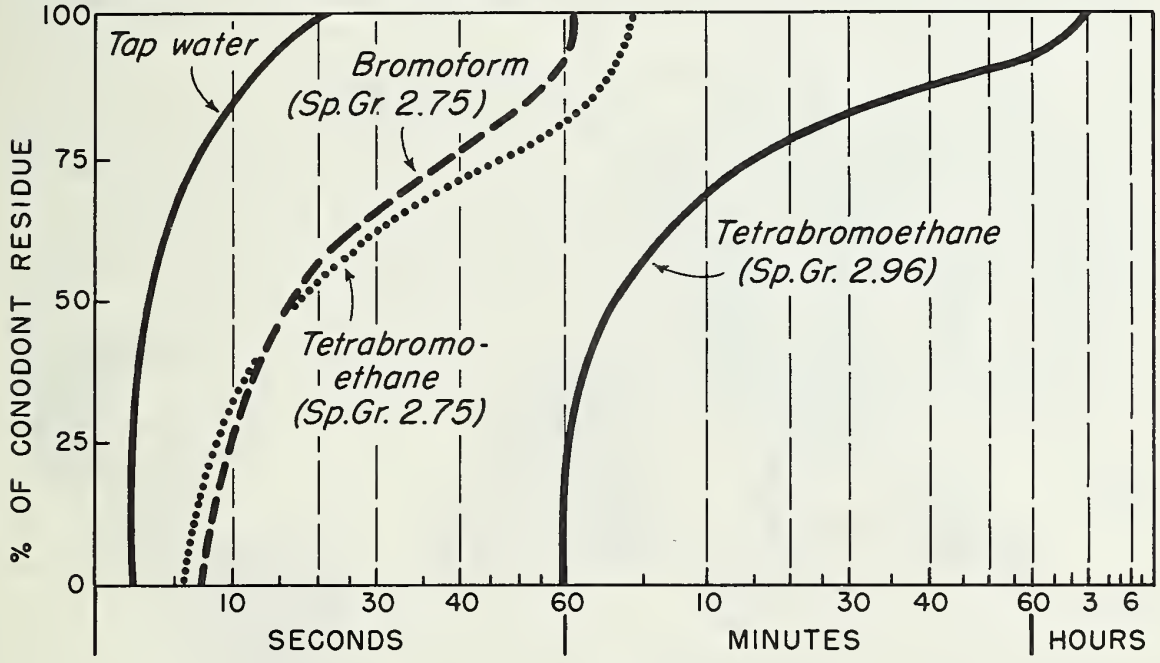

Fig. 5 - Settling times for conodont residues in a 15 cm column of liquid at 75° F. The percentage scale on the left indicates the percent of total residue that has settled to bottom. Thus an entire residue would have settled to bottom in 16 seconds in a pan of tap water 15 cm deep. The residues used to construct the diagram were of Upper Devonian age and consisted mainly of palmate-shaped platform and narrow bar-shaped specimens.

Separation of Conodonts by Heavy Liquids

After the residues are dry and have cooled, they are ready to be separated into light and heavy fractions in a heavy liquid. Conodonts, which are part of the heavy fraction, are separated from the remainder of the residue by use of tetrabromoethane (acetylene tetrabromide). Bromoform (specific gravity 2.6 to 2.8) performs nearly as well but tetrabromoethane is preferable because of its higher specific gravity (2.89), low toxicity, low volatility, and relatively inoffensive odor. Bromoform is both volatile and toxic. In addition, recovery and restoration of diluted tetrabromoethane is simpler than restoration of diluted bromoform.

A 12-unit battery of 6-inch diameter funnels with half-inch diameter clear polyethylene tubing attached to the throat (fig. 6) is used. Depending on the size of the residue, the funnels are 1/4 to 3/4 filled with tetrabromoethane and the residue stirred into the liquid.

Total settling times for conodonts vary with the specific gravity of the liquid used. The specific gravity of conodonts ranges between 2.84 and 3.10 (Ellison, 1944) and the specific gravity of pure tetrabromoethane is 2.89. Thus an exceptionally clean separation can be made with nearly pure tetrabromoethane, although frequent periodic stirring and a settling period of at least 2 hours are required because of the similar gravities of the liquid and specimens. The settling times of conodonts in tetrabromoethane and bromoform are shown in figure 5. In our laboratory whenever pure tetrabromoethane is used a settling time of 12 to 15

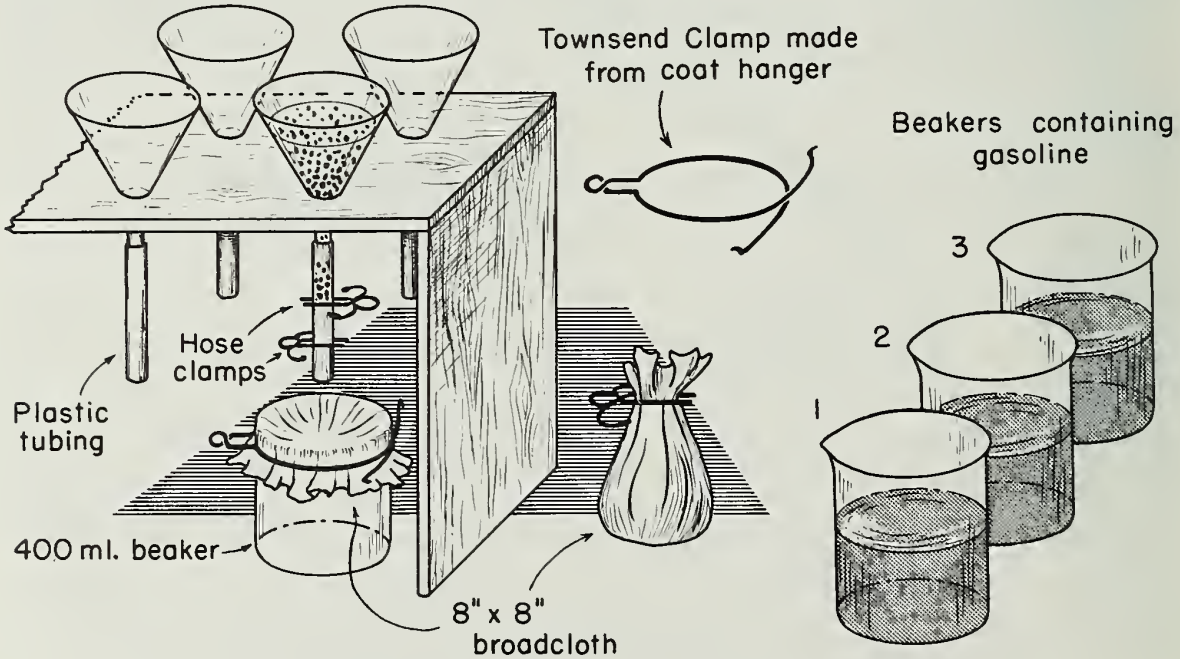

Fig. 6 - Arrangement of funnels and clamps used for separation of conodonts in heavy liquid. Fractions are caught on cloth swatches clamped over beakers. Swatches bearing the light and heavy fractions are rinsed successively in beakers of gasoline and air dried on paper towels.

hours is allowed, along with infrequent stirring of the samples. More commonly, tetrabromoethane diluted to a 2.75 gravity (calcite floats in a positive manner) is used. Settling times for such a dilution are reduced to a minimum of 5 minutes but separations are not as clean as with heavier solutions.

Filtering of Specimens from Tetrabromoethane

After all conodonts have settled in the heavy liquid, a simple technique is used to remove specimens from the liquid. An 8 x 8-inch piece of cotton broadcloth is placed over the mouth of a 400-ml beaker and is held in place by a special clamp designed by Robert Townsend (fig. 6). The cloth is tucked downward to form an inverted cone and the heavy portion of the residue is drained onto it by release of the hose clamps. The heavy liquid filters into the beaker and after it has drained from the residue the cloth is taken up, gathered into a bundle and rinsed successively in 3 beakers of white gasoline (fig. 6). After rinsing, the cloth and residue are spread on a clean paper towel to dry. Once dry, the sample is transferred to a paper envelope and is ready for microscopic examination.

The light fraction is washed from the funnel onto a second filter cloth, filtered, rinsed, and dried in the same manner as the heavy fraction. This is stored for later study or arenaceous foraminifera, spicules, ostracodes, and other associated forms.

RESTORATION OF TETRABROMOETHANE

The heavy liquid that drains directly from the residue into the beaker is filtered and returned to the storage bottle for immediate reuse.

Tetrabromoethane rinsed from the samples accumulates in the gasoline until the rinse beakers become very heavy. When one becomes heavy with dissolved tetrabromoethane, it is set aside so the gasoline will evaporate from the liquid and its normal specific gravity will be restored. A piece of clear calcite dropped into the diluted tetrabromoethane floats when the liquid is again heavy enough for filtering and reuse. When one beaker is removed from the rinse line, another containing fresh gasoline is added for the final rinse.

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