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TECHNIQUES FOR PROCESSING AND PHOTOGRAPHING CHITINOZOANS

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ABSTRACT

Chitinozoans and associated acid-insoluble forms (e.g., graptolite siculae, acritarchs, microscolecodonts, and problematica) have great potential for dating and zoning Ordovician-to-Devonian surface and subsurface sections. These microfossils occur in the heavier fraction of residues and may not appear in abundance on slides prepared by the usual spore-pollen processing techniques. Modified palynologic processing methods, however, facilitate their recovery. Special techniques, such as illumination by infrared light or a laser beam, are useful for examining and photographing thick and dark but incomplete carbonized chitinozoans and associated forms.

INTRODUCTION

In recent years the rapid application of chemical processing techniques, adaptation of specialized equipment, and utilization of improved microscopes have facilitated stratigraphic applications of many types of small acid-insoluble fossils such as spores, pollen, acritarchs, chitinozoans, dinoflagellates, microscolecodonts, graptolite siculae, conodonts, and several problematica. These fossils generally are freed by solution of the enclosing rock and concentrated before study. Modern methods of processing for conodonts, for example, have greatly increased the number of specimens available for study, and other modifications of old techniques have resulted in superior material for investigations of palynomorphs.

Chitinozoans are flask- or sac- to tube-shaped chitin-like acid-insoluble microfossils (Pl. 1; Pl. 2, fig. 3, 4; Pl. 4). First discussed systematically by EISENACK (1931), they have been observed to occur in some residues of lower Paleozoic samples routinely processed for spores. Thorough examination of such insoluble residues indicates, however, that chitinozoans may occur very abundantly in the heavier fraction together with graptolite siculae (Pl. 3, fig. 1, 2), large and heavy spores, acritarchs, microscolecodonts (Pl. 2, fig. 1), and problematica. This heavy residue ordinarily is regarded as trash remaining from the spore-processing procedure; thus, the occurrence of a few chitinozoans on a slide is largely accidental. Other processing techniques involving picking chitinozoans from less precisely prepared acid-insoluble residues commonly yield mainly the large specimens which may be quite fragmental.

Conventional palynologic processing and mounting practices, therefore, yield slides well suited for analysis of palynomorphs from post-Devonian samples, in which the lighter palynomorphs are abundant and diagnostic. In older samples, however, small and light palynomorphs

are markedly fewer and more difficult to differentiate; large and heavy forms, on the other hand, are abundant and diagnostic.

Study of the "heavy" acid-insoluble microfossils of pre-Mississippian rocks constitutes a very significant phase of paleontology that has an important potential for dating and zoning surface and subsurface sections. Although a moderate number of studies on chitinozoans have been published (Taugourdeau & Bouché, 1963), the discrimination of "heavy" forms and the recording of their age significance have barely begun. In this discussion the term chitinozoans is used for convenience to include a variety of other "heavy" forms, such as microscolecodont, graptolite siculae, acritarchs, and problematica, that all have current or potential value. Thus, a "chitinozoan study" actually involves several types of palynomorphs, just as a "spore-pollen study" is concerned with whatever palynomorphs are recovered.

Modification of spore-processing techniques to include recovery of these heavier and very valuable index fossils is relatively simple and requires only slight but important changes in technique. Seemingly, however, micropaleontologists and palynologists generally have directed little attention to this phase of acid-insoluble work.

The following processing technique has been successful in obtaining hundreds of excellently preserved chitinozoan assemblages from many differing lithologies. It is designed primarily to obtain the abundant specimens required in basic research studies, but simplications for more rapid processing, as in laboratories concerned with routine operational work, can be made readily. First, a generalized procedure suitable for a calcareous siltstone is outlined. Obviously, however, specific steps may be eliminated, generally depending on the chemical constituents of the rock. For example, a pure chert does not require treatment in hydrochloric acid, and the frequent inspections also commonly indicate shortcuts. Later, suggestions are recorded that aid in cleaning up residues, in concentrating specimens on slides, and in treating problem samples.

Subsequent discussions are concerned with photographic techniques found useful for illustrating chitinozoans and associated forms. Infrared photography, for example, provides a method for study of internal structures in specimens that are opaque to normal transmitted light.

Reviews of paleontologic techniques, such as provided in this report, describe practices used by one or more workers. The techniques and their applications commonly evolve from older techniques, from material or equipment used in other technical fields, and perhaps from some new concepts. It is impractical, however, to search the published literature and to refer appropriately to those who may have noted earlier a more or less specific procedure or one that has been modified. Thus, rarely is it determinable to what extent present work is shaped by prior studies, or is it practicable to be aware that present innovations actually are rediscoveries of methods first described some years ago.

Acknowledgment is made to R. M. Jeffords, Esso Production Research Company, for general guidance and counsel in my studies on chitinozoans and for review of the present report and to Esso Production Research Company for permission to publish this information.

PREPARATION OF SAMPLES

GENERAL

Chitinozoans have been separated from the enclosing rock material and concentrated by a variety of methods. Large specimens occur infrequently in the finest fraction of washed residues and rarely may be picked directly from such residues (Stauffer, 1933). Preliminary studies using several dozen samples of lower and middle Paleozoic shales indicate that chitinozoans (together with scolecodonts, large spores and spore-like forms, and modern plant and insect fragments) tend to be concentrated in a surface "scum" that forms as argillaceous samples disaggregate in water. Collection of this "scum" during the first decanting of the disaggregated sample may provide a crude concentration of these microfossils. Similar samples of succeeding decantations, on the other hand, generally lack the fossils. Although presence of these microfossils can be determined rather readily in this way, the

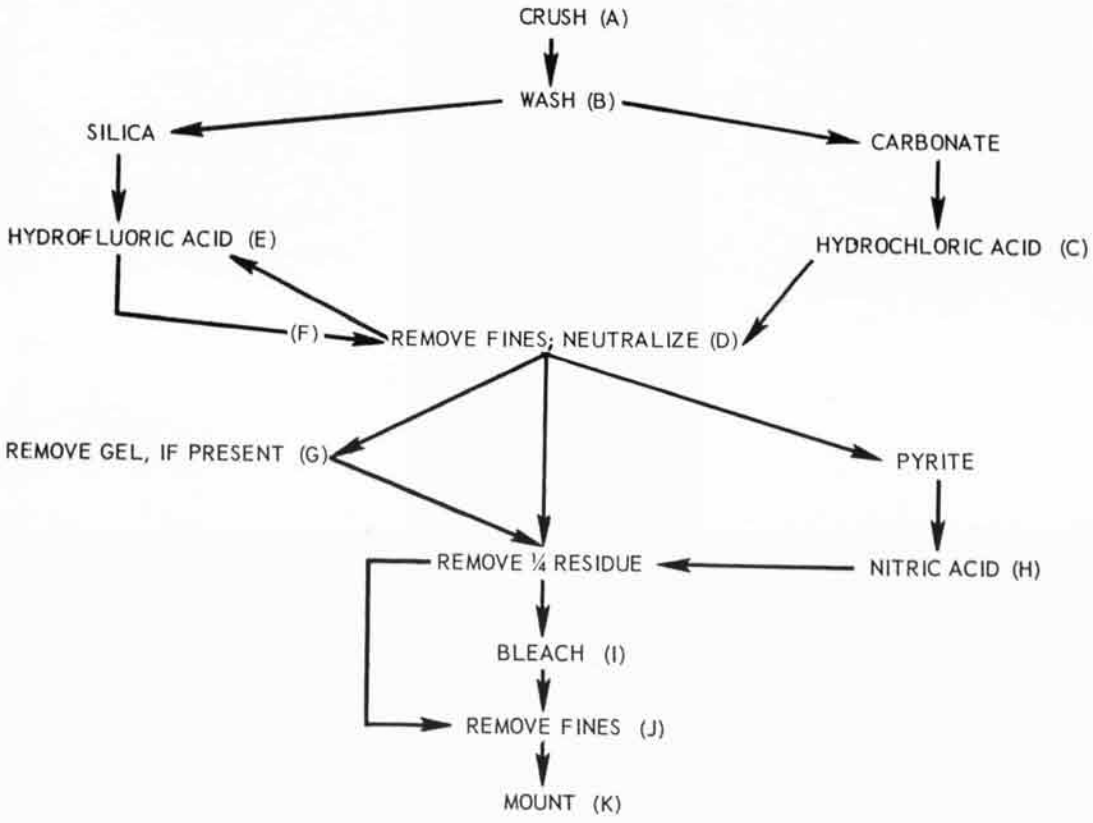


FIG. 1. Outline of procedure for treating chitinozoan samples. Letters provide a key to text discussion of specific steps. Steps *G* and *H* are described in the section on special processing procedures.

occurrence of only large specimens and the difficulty in separating the specimens from the relatively great volume of intertwined modern plant and animal debris (roots, insect carapaces and appendages, etc.) effectively prevent the practical use of such residues.

More recently workers have concentrated chitinozoans by the acid-treatment, oxidation, and gravity-separation methods extensively used in the recovery of spores and associated acid-insoluble microfossils (WILSON, 1944; JEFFORDS & JONES, 1959; FUNKHOUSER & EVITT, 1959; BALME & HASSELL, 1962; CROSS, 1964; SCHOPF, 1964). As the relatively large chitinozoans occur only rarely in the fine fraction of residues which generally is mounted on slides for the study of the smaller spores and pollen, more adequate representation of chitinozoan assemblages can be obtained by several modifications of the usual spore-pollen processing (Fig. 1). These include starting with a much larger volume of very coarsely crushed sample, carrying each acid-treatment step to completion, avoiding decantation of floating forms, and mounting a larger-size fraction of residue.

Although much of the equipment commonly used in palynologic processing laboratories can be used in parts of the processing for chitinozoans, the equipment required by the techniques here described is more modest. Needed are an acid-resistant hood, several 600- to 3,000-ml. glass beakers and plastic tubs or buckets, an aspirator-type pump, several 600-ml. polyethylene beakers, five or six 1,300-ml. white porcelain evaporating dishes, a Bunsen burner and ring stand, and an 80- to 100-power stereoscopic-type microscope. Copper beakers (for boiling in hydrofluoric acid), a porcelain sieve having 0.5-mm. openings (for removing modern plant debris), and a centrifuge are helpful.

INITIAL SAMPLE PREPARATION

From the original sample 600 grams or more of material (about 3,000 grams if abundant individuals are desired from samples known to be fossiliferous) is selected carefully so as to include a representative portion from each lithology or, for composite samples, from each rock fragment.[1] Well-preserved specimens may occur in siliceous nodules, for example, whereas associated shale or limestone may be barren. Processing such nodules separately avoids introduction of the trash that occurs in most shale residues. Samples are broken so as to fit conveniently into a 600- to 3,000-ml. glass beaker (Fig. 1,*A*); approximately 1-inch cubes are most satisfactory. A jaw crusher is adequate, but less of the fine fraction is produced when a sample is broken with a hammer on an iron block with a 3-inch pie tin to retain the sample.

Large plastic buckets or tubs permit more rapid acid treatment, because bubbles and foam will not overflow so readily. Plant roots and other modern debris are removed from samples, and rock fragments (except easily disintegrated shales) are rinsed with dilute hydrochloric acid (Fig. 1,*B*) to dislodge lichens, fungi, and similar modern contamination.

[1] Carbonates regarded as barren after repeated processing using samples of the size normally processed in palynology have yielded very diverse and abundant specimens when as much as 25 pounds is processed.

TREATMENT WITH ACID

As a general guide to processing, the following procedure is for a difficult sample (i.e., a silty limestone with dispersed pyrite) that requires all the steps essential for removal of the rock matrix. For most other lithologies many of the steps may be omitted.

To the crushed sample add dilute hydrochloric acid (Fig. 1,*C*) until the reaction is complete. The addition of a few drops of a dilute solution of Surfonic LF-7, manufactured by Jefferson Chemical Company, Inc., Houston, Texas (1 drop of concentrated LF-7 in about 3,000 ml. of distilled water), is very effective in decreasing the size of the bubbles produced by the reaction; thus, the reaction is less violent and can proceed at a more rapid and even rate.

After digestion is completed and the material has settled in the beaker, a vacuum pump[2] is used at medium velocity to remove liquid above the surface of the residue (Fig. 1,*D*). Normally, the scum of dust and lint on the liquid surface is re-

[2] Polyethylene filter pump of the aspirator type.

EXPLANATION OF PLATE 1

Chitinozoans showing the differences in surface detail recorded by several photographic methods.

FIGURE

1, 4, 5. *Illichitina* spp. from Viola Limestone, Mohawkian, Middle Ordovician, in Oklahoma; ×250.

1. Heavy-walled specimen photographed with transmitted light. The body appears black, and only the basal flange and part of the broken neck show detail.

4. View of base photographed with transmitted light. The thin peripheral flange on the base is partly transparent.

5. View of base only photographed in infrared light. The characteristic bull's-eye structure is visible in the center; the oblong structure (lower right edge) is a bubble.

2, 7. *Illichitina* spp. from Denmark Formation, Mohawkian, Middle Ordovician, in New York; ×250.

FIGURE

2. The base has been bent back on top of the body. The juncture of body and flange is seen readily in this photograph with reflected light.

7. Median thin section photographed in transmitted light showing the thin basal flange.

3. *Conochitina* sp. from Mt. Merino shale, Mohawkian, Middle Ordovician, in New York; ×250. Photographed in reflected light.

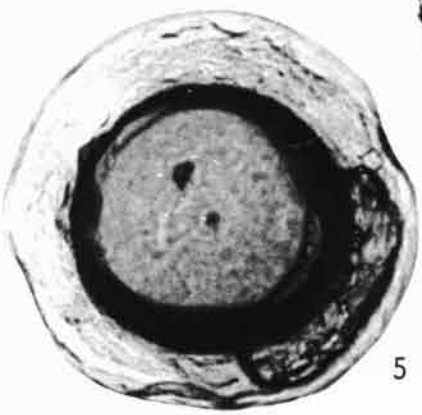
6. *Alpenachitina eisenacki* DUNN & MILLER from Alpena Limestone, Middle Devonian, Michigan; ×500; 6a, specimen photographed in transmitted light showing clearly only the spines projecting beyond the sides of the body; 6b, specimen photographed in infrared light showing clearly the spines bent back on the body and the location of spines on the reverse side.

1

2

3

4



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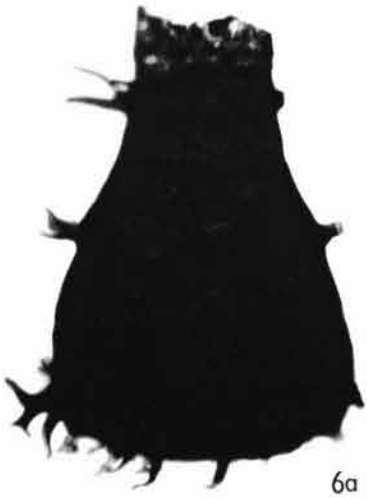

6a

6b

7

1

2

moved; the Surfonic LF-7 solution decreases the surface tension, so chitinozoans rarely occur on the surface in this step. Then the residue is put into 1,300-ml. white evaporating dishes with about 250 ml. of residue in each dish, the dishes are filled with water, and the residue allowed to settle about three minutes. A slight clearing generally is evident around the edges of the dish. About one-third of the liquid and fine particles then is removed, using a vacuum pump with the nozzle inserted in the middle of the dish just below the water surface. The process of refilling with water and allowing to settle is repeated several times until the heavy residue settles in 0.5 to 1 minute as a compact unit and the overlying water is neutral and clear. If further washing it attempted after this stage, the neutralized residue containing chitinozoans commonly becomes flocculated and does not settle out of suspension readily; the microfossils then may be lost by decanting or pumping. Chitinozoans probably cannot be distinguished in the considerable mass of residue at this stage.

To determine whether the sample is neutral, test when the residue is in suspension. Commonly, a settled residue is acid, even though the water above is neutral; this acidity generally causes crystallization later. If the sample is neutral, proceed to the hydrofluoric-acid treatment (Fig. 1,*E*). If a neutral suspension is not obtained after reasonable cleaning efforts, probably acid is "leaking" slowly either from modern plant tissue or from porous lumps of brown to black silica (not sand), chert, or dolomite. By decanting or sieving, separate this coarse residue from the neutral portion and neutralize it by washing under strong water pressure.

Careful removal of the fine fraction of the residue is probably the most critical step in processing and greatly expedites further processing (Fig. 1,*D*). Use of a centrifuge for this step is distinctly less satisfactory than gravity settling. In residues containing little siliceous material, chitinozoans can be examined in the white evaporating dishes at magnifications of ×80 to ×100 under reflected light at the end of this treatment, and, if desired, specimens can be picked and mounted.

Commonly silicified or pyritized relatively large fossils are observed in the coarser residue, and a temporary slide (glycerol plus sample) may contain fossil problematica.

Next the residue is transferred to a plastic beaker (generally one-third to three-fourths of the sample volume has been removed by hydrochloric-acid treatment, so small beakers can be used), and hydrofluoric acid is added (Fig. 1,*E*). The reaction can be expedited by treating only 100 ml. of residue in each 1,000-ml. beaker and by heating the acid nearly to boiling before carefully adding the acid to the plastic beakers. Copper beakers are needed if the hydrofluoric acid and residue are to be boiled. After the reaction is completed, allow the suspension to settle (overnight) and pump out the diluted acid (Fig. 1,*F*). Refilling the container with water and further pumping at this point are undesirable for a relatively small amount of residue, because chitinozoans and associated fossils may float or may tend to occur distributed throughout the liquid. Instead, pour the suspension into plastic centrifuge tubes, filling the tubes one-eighth full of residue. Fill with water and centrifuge at a moderate rate so as to avoid forming a consolidated cake which requires mechanical stirring. This step is to remove the acid without removal of fine particles. If the quantity of the residue is moderately large, however, neutralization may be approached by one or two refillings with water and settlings, pumping

EXPLANATION OF PLATE 2

Chitinozoans and scolecodont showing differences in slide preparation and transparency of specimens from different formations, ×200.

FIGURE

1. Residue from Ion Shale, Mohawkian, Middle Ordovician, Iowa. Specimens of *Conochitina* and *Sphaerochitina* and a scolecodont are well bleached and evenly dispersed; trash is minimal. Photographed in transmitted light.
2. Residue from Silica Shale, Erian, Middle Devonian, Ohio, containing one or two detached specimens of *Desmochitina* sp. Specimens are thick-walled and very resistant to bleaching and to infrared light. The dispersion of specimens here is poor, and an overabundance of fine material indicates inadequate removal of fines prior to mounting.

out the dilute acid. Difficulty in obtaining a neutral suspension is resolved as described for the hydrochloric-acid treatment.

The residue again is poured into white evaporating dishes, and the fines are removed as described previously for the step following the hydrochloric-acid treatment. Make certain that fines do not clump together and float on the surface. After several partial removals of fines, place the evaporating dish filled with water and residue under a microscope. By racking the microscope up and down, observe at ×80 to ×100 power when only fine unfossiliferous material remains in suspension; remove these fines with the vacuum pump. Repeat until water above fossils is clear. If pyrite is present (Fig. 1,*H*), add nitric acid to the dish and boil until the fumes lose their yellow color. Only by careful examination of the residue at this stage can it be determined that a sample lacks chitinozoans. Although these fossils may be observed during prior steps, failure to observe them prior to this step does not indicate a barren residue.

If the nitric-acid treatment is required, centrifuge once; otherwise, next add Schultze's solution (nitric acid and potassium chlorate) to bleach the microfossils (Fig. 1,*I*). Unless the original sample showed indications of having been significantly weathered (oxidized), treat the sample for 10 minutes, keeping the mixture agitated (heating to boiling may be needed for resistant residues), fill the container with water, and let cool for 10 minutes. Pour the mixture into centrifuge tubes so that each tube is only one-third full of the acid and fill the tubes with water (fine material does not settle readily in the concentrated acid). As the residue settles, decant the acid; repeat once or twice until the residue settles rapidly and the liquid is neutralized. The final washing may be done by centrifuging in 15-ml. glass tubes.

Rebleaching in Schultze's solution is not desirable, because the fossils become soft and tend to fall apart when mounted. As a precaution or control against overbleaching and possible removal of fine detail, reserve a small portion of the unbleached sample to mount with the bleached material.

Pour the small residue again into a white evaporating dish or dishes and under a microscope remove the fines, using a suction bottle (Fig. 1,*J*). By spinning the dish containing the water and residue mixture (swirl method of Funkhouser & Evitt, 1959), separate the material into a coarse, relatively heavy fraction and a fine, lighter fraction. By means of a pipette remove the fractions to separate vials. Mount these residues (Fig. 1,*K*) separately (Jeffords & Jones, 1959).

Mounting should be done soon after the bleaching, because chitinozoans tend to soften and break up if left unmounted. Also, neutralized residues (even when treated with formaldehyde solution) may develop a fungus growth and become severely clumped. The concentration of specimens on slides can be checked after the first slide is prepared, and adjustments can be made for succeeding slides so that specimens are scattered uniformly (Pl. 2, fig. 1) but are not crowded (Pl. 2, fig. 2).

In this processing, care should be taken to clean the suction tubes and other equipment before use on other samples and to label all tubes, beakers, and other containers. Faster settling and neutralizing occur after a reaction is completed if the material is poured into a clean beaker; make certain that no material is left adhering to the sides of the beaker. The heavy-liquid separations (zinc chloride, for example) found useful in most palynologic processing should be avoided, because the heavy and large lower Paleozoic microfossils tend to be separated inconsistently by this method.

SPECIAL PROCESSING PROCEDURES

FLOATING SAMPLES IN ACID

Solution of carbonates in hydrochloric acid is expedited by use of Surfonic LF-7, as noted earlier, and in acetic or formic acid (where foaming is not a problem) by dissolving samples while they float in plastic boxes. Two-mm. holes are drilled or burned about 6 mm. apart in the bottom of a 6- by 6- by 1.5-inch light plastic box. The lid is secured by a rubber band but may need a very small hole through which excess gas can escape. Add the sample to the box and place on acid in a container somewhat larger than the box and considerably deeper. Seemingly, the evolving gas causes the box to agitate the sample and to rise and fall slightly so that fine particles and spent acid are removed through the holes. Although the reasons are not now clear, samples processed for conodonts in this way normally dissolve without further attention. Comparable samples in the bottoms of similar containers commonly require

considerable stirring and change of acid to avoid the retarding effect of the calcium acetate that is formed. The box technique seems to be more effective than placing samples on a screen in the acid container (BELL, 1948).

REMOVAL OF PYRITE

Some samples contain a large amount of pyrite after the hydrochloric-acid treatment. After neutralization (or near neutralization, because these residues are very difficult to neutralize) and removal of fines in an evaporating dish, add nitric acid to the residue (Fig. 1,*H*). If the mixture is allowed to stand for several minutes, the fine pyrite, which may cause foaming when heat is added, is dissolved. Boil the residues and stir gently until the fumes change from yellow to white. If a beige-colored mineral residue remains after treatment, separate the lighter chitinozoans by decanting. Because pyrite may form on or in the palynomorphs, removal of pyrite may be accompanied by disruption of the fossils.

REMOVAL OF GEL

A substantial decrease in fluidity after removal of water after the hydrofluoric-acid treatment suggests strongly that a gel has formed. Commonly the gel is removed by flooding with water and decanting rapidly (Fig. 1,*G*). A total loss of specimens may result by this, however, even when a centrifuge is used. Preferably, such a residue is mixed with water in one evaporating dish and decanted rapidly into another. Microscopic examination then indicates where the chitinozoans are concentrated so that water and gel can be siphoned off. Repeated treatments generally are needed. Samples of this type may be very troublesome, and exceptional care is needed to recover an assemblage of palynomorphs.

When the effects of the gel are no longer noted (i.e., settling of material into a spongelike mass on the bottom of the dish), boil Schultze's solution. The remaining insoluble fluorides then are heavier than the chitinozoans and can be separated by filling the dish with water and pouring off the chitinozoans before they settle. Repeated decanting may be necessary.

CARBONIZED SPECIMENS

Carbonized and flattened chitinozoans may be light enough, after bleaching, to float at the surface of the liquid, where they can be decanted inadvertently. These residues should be transferred from the evaporating dish to centrifuge tubes, neutralized, and centrifuged before decanting.

Although some specimens may remain opaque after normal bleaching, additional bleaching commonly results in destruction of the microfossils. Very carbonized specimens may be treated with a sodium-hypochlorite solution to which has been added a few drops of dilute hydrochloric acid (HOFFMEISTER, 1960).

RESIDUES FROM CONODONT PROCESSING

The processing of carbonate samples by methods such as those described by COLLINSON (1963) also yields a fine residue that is very useful for the recovery of chitinozoans and associated forms. The residue that is wet-sieved through a 100-mesh screen can be treated by starting at the step described after the hydrochloric-acid treatment. Coarse material commonly present in these acetic-acid residues tends to impede observation of fossils and processing, however, so a hydrochloric-acid treatment commonly is needed as a first step.

INCOMPLETE SOLUTION IN ACID

As samples cannot be crushed finely without destruction of the microfossils, calcium carbonate may not all be removed by the acid, particularly carbonate dispersed in a shale. When hydrofluoric acid is added, the undissolved calcium carbonate develops a fluoride coating that effectively prevents further solution. Boiling in nitric acid may reduce the volume of rock so as to permit recovery of some fossils. Mostly, however, reprocessing with fresh material is necessary. By allowing the sample to react with acid for several days, washing under pressure and decanting fines, crumbling larger fragments repeatedly, and (when only small fragments remain) boiling for 30 minutes, such samples can be prepared for treatment with hydrofluoric acid.

VIBRATORS

An ultrasonic vibrator used in spore-pollen processing to loosen clumped masses of organic material has not been needed in the treatment of lower Paleozoic samples processed for chitinozoans. Also, mechanical vibrators used to disperse caked residues after centrifuging should be applied very carefully to chitinozoan samples so as to avoid destruction of the specimens.

STUDY AND PHOTOGRAPHY

STUDY TECHNIQUES

Detailed studies of chitinozoans and associated forms are made most conveniently and rapidly with permanently mounted slides under transmitted light at magnifications generally of ×60 to ×100. Rigidly mounted slides prepared using randomly dispersed residues have advantages in the ease and rapidity of preparation, completeness of representation for the assemblage, and convenience for uniform examination and photography (Pl. 2, fig. 1). Hand-picking of dry or wet residues (STAUFFER, 1933; COLLINSON & SCOTT, 1958; DUNN, 1959) may yield a few well-preserved specimens but is time-consuming and rarely can be expected to provide the comprehensive coverage of the assemblage and the variation in individual types that are essential.

Specimens recovered from rocks generally are flattened and may be twisted, fragmented, or distorted. Spines may be broken, bent backward along the test, or partly destroyed by oxidation. Thus, experience is needed to reconstruct or restore mentally the specimens being examined. Interpretation of specimens under transmitted light is facilitated, therefore, by concurrent examinations with a stereoscopic microscope and reflected light. The slide should be reversed with the cover slip down. Initially, at least, stereoscopic examination of free specimens in unmounted residues provides an insight into the three-dimensional appearance of the base, neck, and spine arrangement.

A device developed by D. L. DUNN during his studies on chitinozoans is very useful in removing selected specimens from wet residues for examination. A finely drawn pipette is attached to a foot or so of pliable 0.25-inch tubing, with the open end of the tubing sealed. Specimens viewed under a microscope can be drawn into this pipette gently by the release of a slight pressure on the tubing. An application of pressure then forces the specimen out into the selected container.

Photographic recording of distinctive types is made generally under transmitted light to illustrate the features observable during routine slide examination. Also, transmitted light emphasizes important characteristics of the neck region that are made more or less transparent by bleaching. Less commonly, reflected light (Pl. 1, fig. 3) or a combination of reflected and transmitted light is used in slide examination and photography to reveal the surface texture or other special features. Studies of the internal characteristics of some opaque specimens are aided by the use of infrared photography (WILSON, 1958, p. 69). Interpretative drawings also improve the understanding of chitinozoans.

PHOTOGRAPHY

Photography of chitinozoans under transmitted light generally is satisfactory if the specimens are bleached (Pl. 4, fig. 5). Many specimens are so thick-walled or so partly or entirely carbonized, however, that they photograph as black silhouettes

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EXPLANATION OF PLATE 3

Graptolite siculae and chitinozoans photographed in transmitted light, infrared light, and a laser beam. Specimens from Mohawkian, Middle Ordovician.

FIGURE

1, 2. Graptolite siculae from Viola Limestone in Oklahoma; ×100.
   1. Partly transparent sicula photographed in transmitted light (1a) and in infrared light (1b) showing characteristic structure of the prosicula and metasicula.
   2. Specimen photographed in transmitted light (2a) revealing few features and in infrared light (2b) showing the structure and the development of the first theca.

3. *Conochitina* sp. from Ion Shale in Iowa, ×500. Specimen photographed in infrared light and enlarged to show internal detail. This specimen is gray, and the image is not so sharp as for the graptolites. Although the specimen was printed from the same film strip, this negative was fogged as common in infrared film.

4. *Conochitina* sp. from Viola Limestone in Oklahoma, ×250; 4a, thick-walled specimen not transparent to infrared light and here photographed in transmitted light; 4b, photograph by transmitted red laser beam.

1a

1b

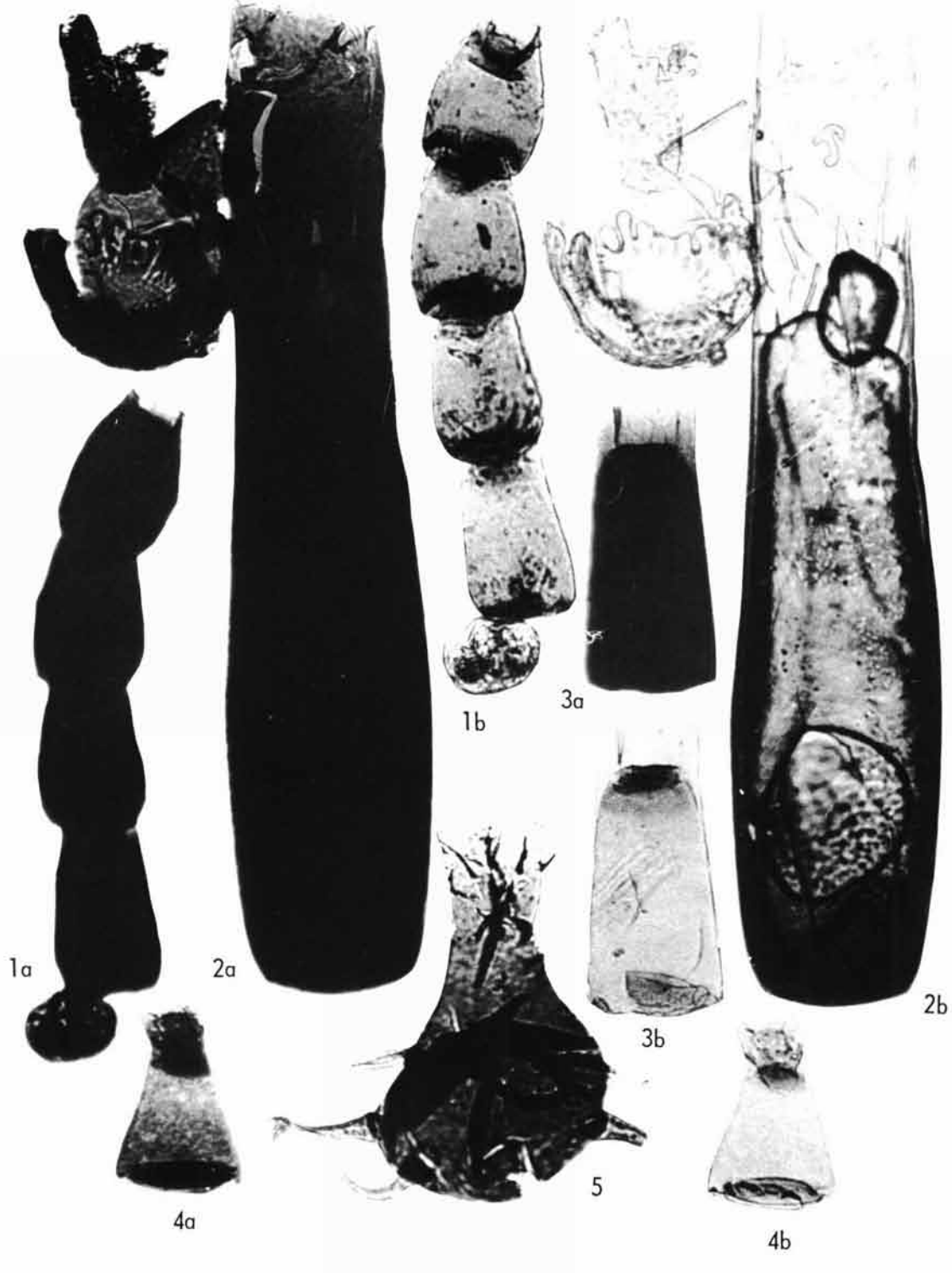
2a

2b

3

4a

4b


1a
2a
1b
3a
2b
3b
5
4a
4b

(Pl. 4, figs. 1a, 2a, 3a). If the specimen is only partly carbonized, it is possible to observe, study, and photograph internal structures by using an inexpensive infrared filter (Kodak 88A, 87, 87A, or Leitz 1R) and a device for converting invisible infrared radiation into a visible image.[3] Place the infrared filter (Kodak 88A is very effective) over the light source and observe the image through the ocular using the device.

An entirely infrared-sensitive film (Kodak 1R) is available that produces excellent results. This film, however, is highly sensitive to fogging (Pl. 3, figure 3) and requires more than ordinary care when being used and processed. Exposure time for the 1R film generally is long; the average or starting point is approximately three seconds. Trial and error will ascertain easily the correct time. Overexposure may induce fogging and result in nearly total loss of detail. When using a substage condenser, adjust the diaphragm to a closed position for maximum depth of field.

Several microscope manufacturers report that they soon will have available a microscope attachment for use with infrared film.

Among the many possible uses of the laser beam, a few may become important to the micropaleontologist (Rempel, 1963). Notably, the laser as a source of illumination for the microscope will yield light intensities several times the magnitude of conventional light sources. In addition, the light is monochromatic without additional filtration. Because the conventional lens is constructed to yield optimum results with blue-green filtration, neither of these advantages can be utilized at present. At least one of the large microscope manufacturers is reported to be currently constructing a lens system for use with the laser. It may well be expected that such photographs will be sharper and show more internal detail (as in chitinozoans and spores) with increased magnification. Future application in the new field of holography (films made and viewed in three dimensions using lasers) probably will be most signficant.

A small, portable, low-power gas laser[4] roughly mounted as a light source in a Zeiss photoscope was used to photograph chitinozoans on panatomic film with fair results (Pl. 3, fig. 4b). The potentiality of laser-beam photography seems considerable (Anon., 1966; Ellis, 1966).

[3] Detectiscope of Varo Inc., 2201 Walnut Street, Garland, Texas 75041.

[4] Laser loaned by Mr. Larry Broadway, Barnhill Associates, Houston, Texas.

EXPLANATION OF PLATE 4

Chitinozoans photographed with transmitted white light (a views) and with infrared light (b views).

FIGURE

1, 5. Chitinozoans from Birdsong Shale, Ulsterian, Lower Devonian, Tennessee.

1. *Desmochitina* sp., ×250.

5. *Ancyrochitina* sp., well-bleached specimen photographed in white transmitted light, ×500.

FIGURE

2. *Conochitina* sp. from Viola Limestone, Mohawkian, Middle Ordovician, Oklahoma, ×100.

3. *Conochitina* sp. from Ion Shale, Mohawkian, Middle Ordovician, Iowa, ×250.

4. *Sphaerochitina* sp. from Ion Shale, Mohawkian, Middle Ordovician, Iowa, ×250.

REFERENCES

ANON., 1966, *Holography:* Texas Eng. and Sci. Mag., v. 3, no. 1, p. 29-31, fig. 1-7.

BALME, B. E. & HASSELL, C. W., 1962, *Upper Devonian spores from the Canning basin, Western Australia:* Micropaleontology, v. 8, p. 1-28, fig. 1-2, pl. 1-5.

BELL, W. C., 1948, *Acetic acid etching technique applied to Cambrian brachiopods:* Jour. Paleontology, v. 22, p. 101-102.

COLLINSON, CHARLES, 1963, *Collection and preparation of conodonts through mass production techniques:* Illinois Geol. Survey Circ. 343, 16 p., 6 fig.

——— & SCOTT, A. J., 1958, *Chitinozoan faunule of the Devonian Cedar Valley Formation:* Same, Circ. 247, 34 p., 3 pl.

CROSS, A. T., 1964, *Plant microfossils and geology: an introduction:* in Palynology in oil exploration, Cross, A. T., ed., Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 11, p. 3-13.

DUNN, D. L., 1959, *Devonian chitinozoans from the Cedar Valley Formation in Iowa:* Jour. Paleontology, v. 33, p. 1001-1017, pl. 125-127.

EISENBACK, ALFRED, 1931, *Neue Mikrofossilien des baltischen Silurs, 1:* Palaeont. Zeitschr., v. 13, p. 74-118, fig. 1-5, pl. 1-5.

ELLIS, G. W., 1966, *Holomicrography; transformation of image during reconstruction a posteriori:* Science, v. 154, p. 1195-1197, fig. 1-3.

FUNKHOUSER, J. W. & EVITT, W. R., 1959, *Preparation techniques for acid-insoluble microfossils:* Micropaleontology, v. 5, p. 369-375.

HOFFMEISTER, W. S., 1960, *Sodium hypochlorite, a new oxidizing agent for the preparation of microfossils:* Oklahoma Geology Notes, v. 20, p. 34-35.

JEFFORDS, R. M., & JONES, D. H., 1959, *Preparation of slides for spores and other microfossils:* Jour. Paleontology, v. 33, p. 344-347, fig. 1.

REMPEL, R. C., 1963, *Optical properties of lasers as compared to conventional radiators:* Spectra-Physics Laser Tech. Bull. 1, 10 p., 6 fig. (Spectra-Physics, Inc., Mountain View, California).

SCHOPF, J. M., 1964, *Practical problems and principles in study of plant microfossils:* in Palynology in oil exploration, Cross, A. T., ed., Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 11, p. 29-57.

STAUFFER, C. R., 1933, *Middle Ordovician Polychaeta from Minnesota:* Geol. Soc. America Bull., v. 44, p. 1173-1218, pl. 59-61.

TAUGOURDEAU, PHILIPPE & BOUCHÉ, P. M., 1963, *Inventaire bibliographique du groupe des chitinozoaires:* Inst. Français Pétrole Rev., v. 18, p. 1559-1570.

WILSON, L. R., 1944, *Spores and pollen as microfossils:* Bot. Rev., v. 10, p. 499-523.

———, 1958, *A chitinozoan faunule from the Sylvan Shale of Oklahoma:* Oklahoma Geology Notes, v. 18, p. 67-71, fig. 1, pl. 1.