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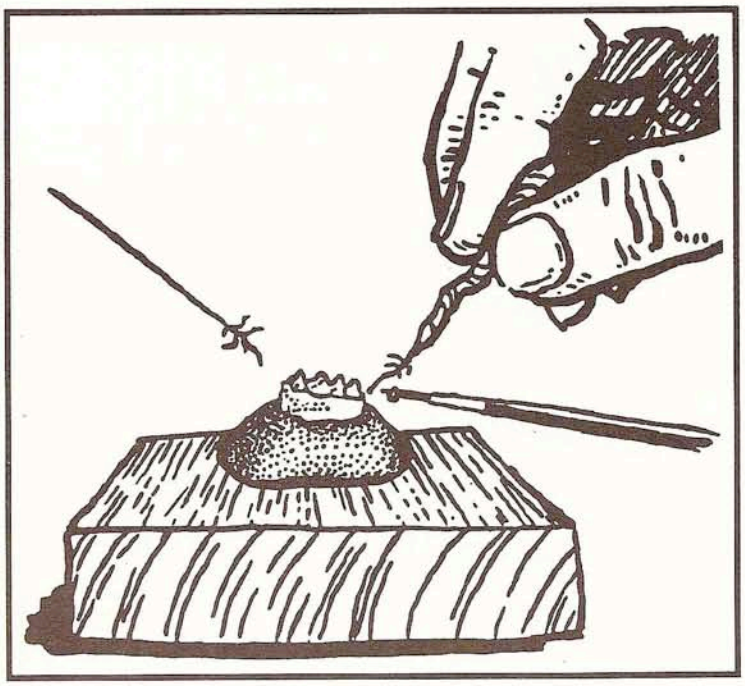

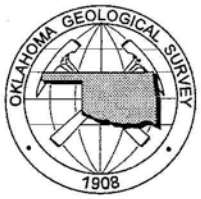

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Techniques for Recovery and Preparation of Microvertebrate Fossils

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Oklahoma Geological Survey
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SPECIAL PUBLICATION SERIES

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Front Cover

Positioning and reattachment of tooth cusp of a Mesozoic mammal (dryolestid). The main part of the specimen is embedded in modeling clay affixed to a wooden base. (Illustration is from p. 31 of this volume). *Drawing by C. D. McCallister.*

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PREFACE

Most living terrestrial vertebrates are small animals (e.g., Eisenberg, 1981); as fossils, they are important not only in constituting a major fraction of the biota but also in providing important data for biochronologic control and paleoenvironmental reconstruction (e.g., Graham and others, 1987). Microvertebrate fossils are not commonly encountered through standard prospecting methods, however, and application of specialized recovery techniques is generally required to obtain a diverse, well-represented sample of such taxa. Paleontologists have long employed the technique of underwater screening, called "screenwashing" (e.g., Hibbard, 1949; McKenna, 1962, 1965), and a variety of other techniques to recover microvertebrate fossils, as a growing body of literature on the subject attests (see, e.g., references in Hannibal, 1989). In recent years, design changes and development of new materials and approaches have permitted increased efficiency and effectiveness of microvertebrate recovery operations, provided alternatives to some of the hazardous materials commonly used, and facilitated preparation, conservation, and display of microvertebrate specimens. In addition, mechanical preparation of microscopic fossil vertebrates has become both increasingly sophisticated and more widespread, as research interests have turned to diminutive elements of paleofaunas.

A number of contributions to microvertebrate recovery and preparation have appeared in recent years, most notably those contained in the compendia of Feldmann and others (1989) and Leiggi and May (1994). The papers contained herein are designed to supplement existing accounts, with particular reference to concentration and preparation techniques. The first paper reviews microvertebrate recovery techniques using underwater screenwashing and associated concentration methods, emphasizing variation according to lithology and local conditions; the second paper describes methods for manual preparation, repair, and storage of microvertebrate specimens. The main purpose of both is to present the various methods now available, their logistical and material requirements, and the conditions under which they are applicable.

Our experience stems mainly from the collection and preparation of Mesozoic microvertebrates, with particular emphasis on mammals, and is thus based on situations in which fossils occur in consolidated to partly indurated rock and are generally small, scarce, and fragile. Although some of the advocated procedures may require modification or may be unwarranted under other conditions, our underlying theme is that the effectiveness and efficiency of a microvertebrate recovery program can be enhanced by judicious application of available techniques. In this sense, at least, we hope that this review will be useful beyond the bounds of the Mesozoic. Indeed, the impetus to produce this compendium arose from the fact that many existing references on the topic deal with specialized circumstances and prescribed methods that are not readily translated to other situations—as our own experiences, as well as those of many colleagues and acquaintances, attest. Because this contribution is directed at a wide audience, including students as well as seasoned professionals, we have included descriptions of many procedures that seem obvious. In so doing, we hope to prevent repetition of the many mistakes we have either witnessed or have made ourselves: many of the most "common sense" methods are discovered in hindsight.

Richard L. Cifelli, *Editor*

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CONTENTS

Some Techniques and Procedures for Microvertebrate Preparation

Scott K. Madsen
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ABSTRACT.—Microvertebrate specimens are generally prepared under a microscope, often under very high magnification; small errors in preparation can be catastrophic and, because procedures are often irreversible, advance planning is important. Herein I describe a micropreparation setup and the various tools, materials, and equipment needed to undertake common procedures. Glues, which are used for both specimen consolidation and repair, constitute an especially important aspect of micropreparation; polyvinyl butyral resins, polyvinyl acetate resins, and cyanoacrylates are recommended.

Field consolidation should be done only if necessary to avoid specimen disintegration, and consolidant should be applied sparingly; often, a consolidant or glue applied to the rock matrix, rather than to the specimen itself, is advisable. In the laboratory, glue can be applied to minute areas by using forceps, a needle, or a piece of fiber; because of the unforgiving nature of microvertebrate fossils, it may be useful to practice the procedures beforehand. For repair of small fossils, pieces can be manipulated with a moistened brush. Bases or pedestals, fashioned from modeling clay, can be extremely useful in positioning small fragments for reassembly.

Some situations (e.g., fossils too delicate to handle or to prepare completely; areas of fossils needing special support) require use of an artificial matrix, for which polyethylene glycol is recommended. This substance can be removed with a needle or by dissolution with water, but care must be taken that the specimen is sufficiently consolidated.

Microvertebrate fossils are commonly stored in vials; because specimens are often mounted on pins embedded in the vial corks, the specimen numbers should appear on the corks. Glue should be used if a semipermanent mount is desired (e.g., for specimens that will be handled frequently); for temporary mounts (e.g., where frequent mounting and dismounting is anticipated, as with individually sorted fragments that may later be assembled), a microcrystalline wax is recommended. In mounting specimens, the pin should be kept short, so as to avoid potential damage when the specimen is removed from and returned to its vial; the specimen can be positioned in a pad of modeling clay, mounting side up, and picked up with the glue or wax on the pinhead.

INTRODUCTION

Microvertebrate specimens that are obtained via screen-washing (i.e., underwater screening) and associated techniques generally differ from those obtained through quarrying in being less complete, in having their broken parts, if any, disassociated, and in lacking a surrounding rock matrix. Nonetheless, most preparation techniques, including repair and consolidation, are similar. Although there exists a considerable (and growing) literature describing materials and methods used in fossil preparation, very few published accounts deal specifically with the specialized techniques required when working with tiny, fragile bones and teeth of small vertebrates ("microvertebrates"). The present offering is an attempt to combine some of the accumulated wisdom of others with my own observations and experiences in preparing microvertebrates over the course of the past 15 years. The main purpose of the paper is to present the procedures, along with the required tools and materials, most commonly used in micropreparation, including specimen repair, consolidation, mounting, and vial storage. Countless variations can be made on the techniques; experimentation is of great importance in developing an appropriate procedure, given differences among specimens and preparators. I have omitted discussion of removal of rock from bone, whether through mechanical or chemical preparation, because I have assumed that the reader already has a solid background in these aspects of preparation. For further information on relevant preparation techniques, important contributions include Whybrow (1982), Berdan (1989), Amaral (1994), Davidson (1994), and Palmer (1989).

Definitions

What is micropreparation (herein referred to as "microprep")? Microprep can be defined as preparation that would be virtually impossible without the use of a microscope. One of the defining characteristics of microprep is what might be referred to as specimen "forgiveability." Large specimens are relatively forgiving of preparator error

Madsen, Scott K., 1996, Some techniques and procedures for microvertebrate preparation, *in* Cifelli, Richard L. (ed.), Techniques for recovery and preparation of microvertebrate fossils: Oklahoma Geological Survey Special Publication 96-4, p. 25–36.

in that small gouges, nicks, and scrapes may go unnoticed or may be restored, preservatives can be applied with some abandon, and mistakes can be more readily reversed (for instance, when large amounts of solvent are used to reverse a gluing procedure on a poorly set bone). Microfossils, on the other hand, can be completely obliterated with one careless slip of a needle; glue must often be applied in very precise quantities to very small areas; and glue and other treatments to a specimen are, practically speaking, irreversible: if a mistake is made, the cure can often be worse than the ill. Microfossils are, in general, very unforgiving of preparator error.

In this paper, the terms "bone," "tooth," "object," and "specimen" are used interchangeably: they refer to whatever is being worked on at the time. Likewise, the terms "glue," "adhesive," "consolidant," and "preservative" are commonly used interchangeably. In most situations, "glue" and "adhesive" refer to a material used to bond two surfaces, whereas "consolidant" or "preservative" refer to the same material, usually in a thinner mixture, used in a less topical application.

Glues, Preservatives, and Conservation Philosophy

Because microprep procedures are often irreversible, it is critical to think ahead. When choosing a preservative, one should always consider the future of a specimen, from excavation to eventual exhibition, storage, or study. Particularly relevant in this context are analytical procedures the specimen might be subjected to after work is finished on it. Will penetration of bones by a consolidant render them useless for isotope analysis? Will a film of glue result in an inaccurate cast or SEM micrograph? Will a consolidant hastily applied in the field present serious problems back in the lab?

The major practical considerations when choosing a glue are setting time, penetration (of both bone and matrix), hardness, and reversibility. Other considerations include "softening point," technically termed glass transition temperature (T_g), long-term reversibility, toxicity of solvent systems, pH, reactivity, and physical or chemical stability. Discussion of these factors is provided by Wolberg (1989; see comments by Shelton and Chaney, 1994), Johnson (1994), and Shelton and Chaney (1994). In addition, the reader is encouraged to request product information packets and material safety data sheets from manufacturers. The pros and cons of various glue types are numerous and complex; the following discussion is a brief overview of the use and characteristics of the three most commonly used glues.

The two most studied (see, e.g., Johnson, 1994; Shelton and Chaney, 1994) and widely used glues are currently Butvar (polyvinyl butyral resins; Monsanto's B-76 is recommended) and PVA (polyvinyl acetate resins). Both are available in various molecular weights and are dissolved in alcohol or acetone (or both), with approximately 6% water added. I have found great variation in the penetration, ultimate hardness, and setting time of both glues, depending on the type and ratio of solvents used; the reader is encouraged to experiment with these glues, using drops of glue in a sand table to simulate bone and matrix (or, if scraps sufficiently similar to the specimen can be sacrificed, real bone and matrix). Because of their versatility and reversibility, both glues are recommended.

Cyanoacrylates (referred to here as "superglues") have a special place in the preparator's repertoire of materials because of their great setting speed and adhesion. Information on long-term properties of superglues is not yet available. There is clearly a need for more study of these glues, although they have been used extensively in microprep for at least 20 years with few apparent problems. Superglues are available under many labels, with various setting times and viscosities. The brand Paleobond is especially formulated for paleontological applications and is highly recommended. Superglue is best used as a contact cement. Because of low surface tension, the least viscous types will disperse on a surface or penetrate into cracks with astonishing speed, a property that can be used to the preparator's advantage. Although superglue will penetrate and fill the smallest of spaces, it only coats a given surface, as can be seen under the microscope: superglue will not truly be absorbed into and through a bone surface in the same fashion as dilute PVA or Butvar. This can be a major concern when a tooth or bone is later studied or photographed with the SEM, or when it is cast. In such circumstances, it is important that surface details be true to life and not artifacts of preparation. Superglues can be used in conjunction with accelerators. A possible concern with these products is that they can sometimes form a vivid malachite-green or blue stain on a specimen. Although this stain barely penetrates the surface, its removal can be problematic.

Epoxy glues, extraordinarily useful for repairing large specimens because of their superior strength, are sometimes used in microprep if a prolonged working time is needed (W. W. Amaral, personal communication, 1995). For extremely small specimens, epoxy is not generally recommended as an adhesive because it is relatively viscous, making it difficult to register contacts precisely, and because it is very difficult to remove, even with specialized solvents.

Glue Reversibility

In a sense, any treatment of glue on bone should be regarded as "irreversible." Strictly speaking, most techniques used to remove glue, either mechanical or chemical, will leave traces, even if they are invisible to the eye. Strategies for glue application will depend on the often conflicting demands of specimen use vs. research applications and archival considerations. Many researchers prefer, when possible, to see a specimen "dry-prepped," with as little applied consolidant as possible (see Amaral, 1989, 1994). This view is shared by some conservators, who feel that a specimen should be maintained in as pristine a condition as possible throughout its treatment, from discovery to collection case (see discussions by Shelton, 1994; Shelton and Chaney, 1994). On the other hand, if a specimen is to be handled and moved about a great deal, it may be advisable to treat it enough to be "bombproof" (D. S. Chaney, personal communication, 1992). Whatever the

decision, it should be reached, in consultation with conservators and curators, with full awareness of the consequences and an eye to the future.

For all its strength, it can be seen under the microscope that superglue always remains slightly gummy and flexible, so that it can be trimmed off with a sharp needle. A carbide needle can even be used to cause a thin coat of superglue to bend under pressure, so that it can be peeled off a smooth surface. The danger with this technique, however, is that if the glue has penetrated hidden cracks, one can inadvertently peel off bone fragments as well. With microfossils this is a very risky procedure.

Superglue can also be dissolved chemically with a "supersolvent," sold by most manufacturers, or with acetone. However, it generally takes a large quantity of any solvent to do the job, and the result is often a gummy mess that is hard to clean off the specimen. There is the added risk of getting solvent where you don't want it and, through capillary action, weakening the rest of the specimen. This potential problem should be considered when dissolving any type of glue.

Sometimes different stages of preparation of the same specimen require different tactics. When I glue a minute cusp back onto a 1-mm-long dryolestid tooth, for example, I generally intend to do it right on the first try, and I want it to be permanent. When mounting that same tooth on a pin, however, it may be desirable to use an impermanent wax, so that the tooth can later be removed for casting or SEM work.

EQUIPMENT, TOOLS, ACCESSORIES, AND MATERIALS

The following annotated list of tools and materials includes those that are most essential for microprep (see Table 1 for sources).

Microscope

A high-quality stereo zoom microscope (Fig. 1) is essential. The quality of the work depends largely on the quality of the equipment used, and the microscope is the primary tool. Distortion-free optics, a wide and deep field of view, and high zoom range will enhance comfort and quality of work. For some work (e.g., picking concentrate), a zoom range of 0.7× to 3×, with 10× eyepieces (as in most budget-priced dissecting scopes), is acceptable, but for really close work, much greater magnification is required: in excess of 200× is not uncommon. Less powerful scopes can be upgraded by adding 15×, 20×, or 30× eyepieces or stronger objective lenses. It is important to remember that adding stronger objective lenses will sacrifice working room (because of decreased focal distance), will reduce depth of field, will reduce light gathering, and thus will make it more difficult to focus light on the subject. A working distance of 30–40 mm is fairly satisfactory; closer distances become very awkward. If possible, a trinocular head configuration is very useful for the microscope, as it permits mounting of photographic or video equipment in the event that demonstration or specimen documentation is required.

A fully adjustable boom stand is also essential. The base

TABLE 1.—SOURCES OF MATERIALS AND SUPPLIES

Vendor and/or Manufacturer	Product(s)
Air Products and Chemicals, Inc. Chemical Customer Service P.O. Box 2662 Allentown, PA 18001 (215) 481-3210 (800) 345-3148 (product info., MSDs)	PVA (polyvinyl acetate resin)
Baxter Scientific 201 Great Southwest Parkway McGraw Park, IL 60085 (800) 444-6464	Vials
Carolina Biological Supply 2700 York Road Burlington, NC 27215 (919) 584-0381	Corks for vials
Conservation Materials 1165 Marietta Way P.O. Box 2884 Sparks, NV 89431 (702) 331-0582	Butvar, PVA, Carbowax (polyethylene glycol), Farcolina (plasticine), microcrystalline waxes; forceps, grinders, bits, brushes, etc.
Dolan-Jenner Industries, Inc. P.O. Box 1020 Woburn, MA 01801 (800) 833-4237	Fiber-optic illuminators
Foredom Electric Tool Company 6153 N. Flint Road Milwaukee, WI 53209-3715 (414) 351-1775	Flexible-shaft power tools, bits, and accessories
Industrial Tool and Supply 1177 N. 15th St. San Jose, CA 95115 (408) 292-8853	Tungsten and carbide rod
Lectro-Stik Company 3721 N. Broadway St. Chicago, IL 60613 (312) 528-8860	Microcrystalline paste-up waxes
Monsanto Chemicals 800 N. Lindbergh Ave. St. Louis, MO 63167 (413) 730-3238 (technical information) (800) 325-4330 (sales, MSDs)	Monsanto B-76 (Butvar)
MSC Industrial Supply 6700 Discovery Blvd. Mableton, GA 30037 (800) 645-7270	Tungsten carbide rod, grinders, bits, etc.
Satellite City P.O. Box 836 Simi, CA 93062 (805) 583-0994	Cyanoacrylate glues (superglues), superglue accelerators and solvents etc.
Uncommon Conglomerates, Inc. 287 E. 6th Street St. Paul, MN 55101 (800) 323-4545 (612) 227-6526 (fax)	Paleobond cyanoacrylic glues

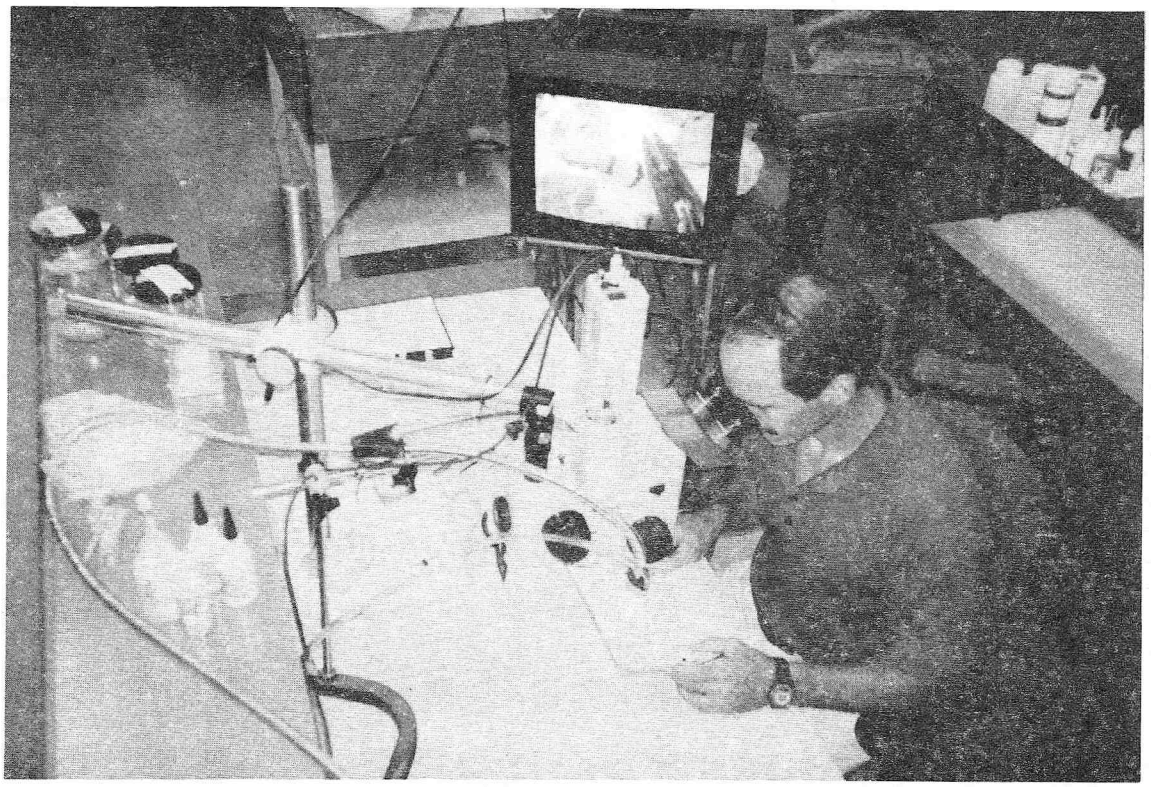

Figure 1. Binocular microscope configured for micropreparation. The scope is mounted on a long boom, permitting a wide range of movement of specimens, materials, and equipment; the boom is supported on a heavy stand for stability. The light source is a twin-pipe fiber-optic system with a long basal pipe, so that the light source itself is placed well out of the way; a clear plastic air tube, for blowing dust and small particles, is affixed to the left pipe. This microscope is configured with a trinocular head, to which a video camera is mounted. The image can be viewed via a monitor (background, center). The camera and monitor are useful for teaching preparation techniques, as well as for consultation for the study or conservation of specimens, exhibition, and for other purposes.

must be isolated from vibrations and should be heavy enough to support the microscope and all of its accessories without the risk of capsizing. For microprep on large blocks, a floor stand with adjustable scope mount may be needed.

Illuminator

A fiber-optic illumination system is vastly superior to any other type of lighting for microprep; one is well advised to get the highest quality and most versatile system that can be afforded. Highly adjustable illuminators are available with twin arm pipes or ring lights. Light pipes and focus lenses can be mounted to the microscope body for convenience (see, e.g., Amaral, 1994, fig. 6.7). The power source should be placed so that vibrations from the fan are not transmitted to either the specimen or the scope.

Flexible-Shaft Power Tool

These tools (e.g., Foredom, Dremel) are indispensable in any preparation lab. They can be fitted with hundreds of types of burrs, wheels, and bits. They are useful for trimming away rock. For rock removal, fine- to coarse-grain tungsten carbide burrs and points are most useful (as are diamond wheels), although they may sometimes transmit vibrations hazardous to the specimen, and expensive bits can wear out quickly, even on soft rock.

One of the most useful purposes of a flexible-shaft power tool is in grinding super-sharp edges on carbide needles. Diamond disks are best for this, the most useful being the ⅛ inch × ⅜ inch diamond head. Sintered points, though more expensive, are preferable because diamonds are incorporated throughout the head instead of plated on the surface, as they are on cheaper heads, where they will eventually grind off. Diamond wheels are also useful for notching carbide rod where a break is to be made.

Tungsten Carbide Rod

Carbide is blessed for being incredibly hard and cursed for being very brittle. Carbide will keep a sharp point longer than any other material—until it is stressed laterally, at which time it will snap. Unfortunately, this usually happens to the fine tip one has worked so carefully to produce.

Carbide is available in many diameters and can be cut to length. Most useful for microprep is the 1-mm-diameter rod. Points of incredible sharpness can be ground under a microscope. The Foredom handpiece can be attached to a holder or braced on a pad or sandbag. The carbide should

be ground slowly: do not apply great pressure; rather, let the tool do the work. Remove the bulk of the carbide from the end of the rod by rotating it as the tip is moved in and out along the diamond surface. The final edge is attained by placing the rod at a low angle to the wheel, with the wheel rotating away from the point. I have a dozen or more carbide needles handy when I work, each with a slightly different point. I seldom use a true conical point, but prefer a beveled or spade edge for the vast majority of my work (see examples in Amaral, 1994, fig. 6.8). Ground very fine, they can be used for scraping, peeling, probing, poking, or teasing off the tiniest rock particles, one at a time. The most important things to remember when using carbide are to keep it sharp and to refrain from stressing the tip or shaft laterally.

Many preparators seem to like fitting the needles into a pin vise. This approach is fine for many types of preparation, but for the high-magnification, precision work, the user is well advised to get accustomed to holding the needle by the index finger and thumb alone. This method generally permits much greater control of the carbide and greater sensitivity to the subtle differences in resistance of the matrix. Sometimes it may be slightly uncomfortable, but any discomfort generally goes away when calluses form in the right places.

Superglue

This amazing adhesive was developed during the Vietnam War, as a first aid skin bond for field use. There is now a wide variety of superglues, with different properties, available. Dealers sell sample kits if experimentation is called for; however, most dealers will provide product information packets on request, and these will generally include sufficient data to make an informed purchase.

Two-ounce bottles are most convenient for field and lab use. Unopened stock can be stored in a freezer to double shelf life (over 2 years for a 2-ounce bottle); opened stock should not be refrigerated because condensed moisture will reduce shelf life. Superglue will cure much more slowly when cold than at room temperature.

Curing time for superglue ranges from 6 minutes to 3 seconds or less. Generally, the slower the set time, the more viscous the fluid. This property can be used to your advantage. Accelerators are available to speed curing time. These are usually applied to the specimen first (they contain agents that clean the surface and speed curing time, even at low temperature). Accelerators dry instantly but remain effective from 3 to 12 minutes after application. It is important to use superglue sparingly and precisely: get it right the first time so you won't have to reverse it!

Polyethylene Glycol (PEG)

Generally referred to as Carbowax (a trade name of the Union Carbide Corporation), this waxy material has the useful properties of being water soluble and having a low melting point. It comes in several molecular weights, including PEG-1500 (molecular weight, 500–600) and PEG-3350 (molecular weight, 300–3700), the latter being the most satisfactory for most microprep applications. Carbowax comes in flake form, which is melted in a small container at low temperatures on a hot plate, under a heat lamp, or in a microwave; it is flammable, so that heating with an open flame is discouraged. In a liquid state, Carbowax is transparent; it becomes opaque when solid.

Techniques for the use of Carbowax are similar to those in molding small fossils; hence the entire procedure should be thought out from start to finish. Possible hazards to the fossil include thermal extremes suffered during application or removal of hot wax, mechanical- or water-induced damage during wax removal, and post-prep lack of support to the specimen once wax is removed.

Small, Adjustable Blower

This is useful in providing a gentle stream of air, directed at the immediate work area, to remove dust. The best arrangement involves running a line (with regulator, to adjust pressure) off an air compressor (see Amaral, 1994). Thin metal or plastic lines can be fastened to the scope or light pipes (Fig. 1). A cheap and versatile system can be rigged to the work area with parts from any hardware store. Lacking this, lung power or the ubiquitous rubber, squeeze-type enema syringe will do. It is essential to maintain a clean work area while using compressed air, in order to prevent loss of tiny bone fragments that may be picked up by the air. The use of aprons or partial enclosures around the table can also help prevent loss of fragments.

Modeling Clay

Modeling clay is useful for building dams to contain Carbowax and for supporting or manipulating small bones. The best types are nongreasy and nonspringy. Once moved, even slightly, they should retain their shape. The best I have found is Farcolina plasticine.

Superfine-Point Forceps

These forceps are used for manipulating bones, lifting bits of matrix, or applying glue. Many varieties are available; those requiring only light pressure to occlude are most suitable for microprep. Dumont makes the best forceps I have found.

Miscellaneous Tools and Materials

Other useful materials and tools include the following: assorted sand bags and pads for specimen support; assorted soft, fine-point brushes for applying PVA, Butvar, etc. (but not superglues) for removing Carbowax, or for picking up and holding extremely small objects; assorted dental tools for specimen preparation (although the metal is flexible and far softer than carbide, they can easily be bent or shaped with a grinder to get into those hard-to-reach areas); and a heat lamp and/or hot plate for melting Carbowax.

PREPARATION OF MICROVERTEBRATES

Field Considerations

Microprep starts in the field: once a microfossil has been discovered and the decision has been to save it, the preparation process begins. Commonly, fossils are given initial

treatment of preservative as a matter of course, a practice that is inadvisable for reasons given above. If consolidation is essential to avoid specimen disintegration, coatings should be applied evenly and sparingly, so as not to obscure detail; also, coating matrix and bone together may reduce the natural separation of matrix from bone during later mechanical preparation. If the bone appears to be intact, well consolidated, and in little danger of breaking, then glue should not be applied. The specimen should be wrapped thoroughly and tightly in toilet paper, taped, and labeled, together with any counterparts that may have been found with it. Where the fit of counterpart pieces is complex, or where the fossil is not immediately obvious, it is helpful to make registration or indication marks on the rock matrix. If the rock is badly cracked, or, as is the case with many mudstones (particularly bentonites), is in serious danger of fracturing as it dries, then a consolidant should be applied to the rock. If time is a factor and one is hurried, superglue is very useful for this purpose, but an effort should be made to keep the glue off the bone itself. If the bone needs to be stabilized, then PVA or Butvar is preferable to superglue because it will be much easier to remove in the lab.

Determination of Best Laboratory Procedures

A preparator must make the same evaluations and decisions with microvertebrates as those made with large bones, in order to decide the correct approach. These questions should be asked: What should the end result be? Is it desirable to end up with a free-standing specimen (if possible), or should it remain partially embedded in the matrix? Are there unstable cracks or loose pieces of matrix and bone that should be glued in place immediately, or can they be safely parted from the block, cleaned, and reglued later? Will any procedure you envision damage the specimen or its scientific value? Can the procedures be reversed if necessary? What exposure or presentation will maximize scientific usefulness?

The best situation, of course, is when the specimen is strong enough to be simply set on a pad under the microscope and the work begun. This is rarely the case. Often the rock and bone are fractured, little bone fragments are loose in cracks, visible bone is a mere black speck in the rock, and the object is yet to be identified. The following are a number of procedures and techniques that can be applied to a variety of commonly encountered situations in microprep.

Application of Glue

As noted elsewhere, glue may be applied to either repair a specimen or to stabilize the matrix that encloses it. Where separate elements are to be bonded, it is essential to dry-fit the contacts first, in order to determine how the fragments contact each other and where the adhesive should be applied. After application, excess glue should be cleaned off before it dries.

PVA or Butvar

If PVA, Butvar, or similar resins are to be applied, then fine (00, 000, or smaller) paint brushes with soft hair can be used. For more precise applications, drops of glue may be picked up with forceps. One should always be aware that these slower-acting fluids can temporarily weaken a specimen before the polymers bind. Caution should be used when attempting to stabilize loose or overhanging projections.

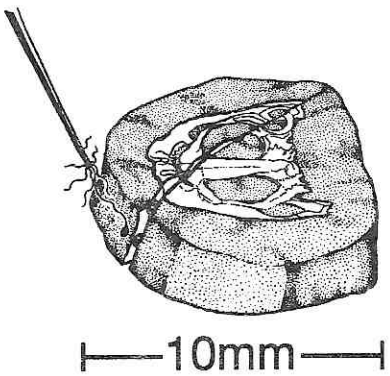

Figure 2. Microvertebrate specimen (frog skull) embedded in matrix. The crack is stabilized by application of microdroplets of superglue, using fiber, to form adherent buttresses or gap fillers.

Superglue

Cyanoacrylates can be applied with a variety of materials depending on the size of the object. For larger cracks in matrix, superglue can be applied directly from the spout of a 2-ounce bottle. Again, use it sparingly! It is not necessary to fill the whole crack; a spacer wall or gap filler (e.g., Fig. 2) will usually be sufficient. For wider cracks (e.g., 1–3 mm), I prefer the more viscous glue (e.g., Super-T or Special-T). To be effective, the glue must contact both sides of the crack. Accelerator can be applied first for a quick set near the surface, or applied after the glue, which allows for greater penetration.

For application of superglue to smaller areas, use a fine pair of forceps. Pick up a small drop of glue with the tips and just touch them to the crack or surface, and the fluid will be drawn in. This technique requires a bit of speed and finesse and works best with the thinner glues. A jar of acetone should be kept handy to rinse the forceps after use, to keep the tips from sticking together. More precision can be obtained by filing the forceps tips so that one extends slightly beyond the other, the longer point delivering the fluid.

For truly minute applications of superglue (e.g., filling tiny cracks [Fig. 2] or making bone-bone contacts [Fig. 3]), a piece of fiber works best. The objects to be glued should first be positioned under the scope and made ready for any manipulations. A useful technique is to tear off a small shred of tissue paper and roll one end between the thumb and index finger for a handle. The business end should appear pointed and slightly fuzzy. This fibrous tip should be barely touched to a drop of superglue and quickly inspected under the microscope. What you hope to see is a fiber out at the end with a microdroplet of glue at its tip

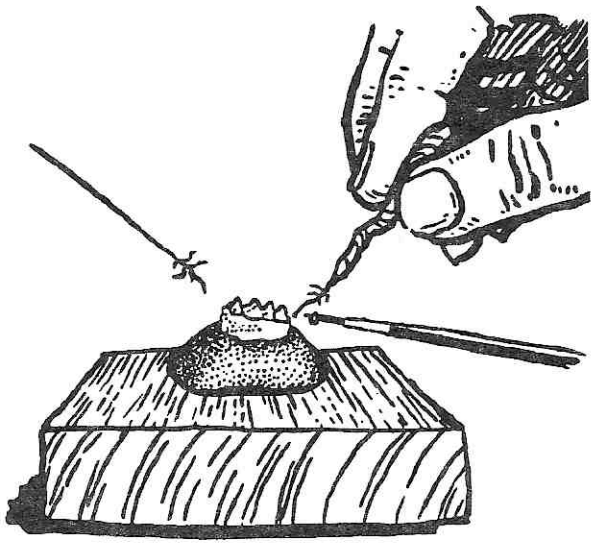

Figure 3. Positioning and reattachment of tooth cusp of a Mesozoic mammal (dryolestid). The main part of the specimen is embedded in modeling clay affixed to a wooden base.

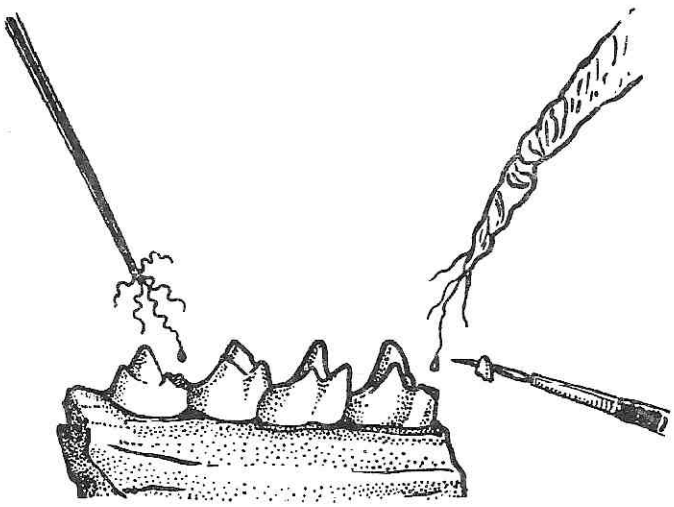

Figure 4. Repair of Mesozoic mammal (dryolestid) specimen. The fragment, held and manipulated with a slightly moistened, fine brush, is affixed with a microdroplet of superglue, applied with fibers adhering to a needle (left) or projecting from a torn and rolled piece of tissue (right).

(Fig. 4, right). It takes some practice to get this technique right, and often it will take more than one try to get exactly the right sized drop just where you can use it best. If a crack is to be filled, simply touch the drop to the crack and the fluid will be drawn in. Bone-bone contacts are discussed below.

Another technique (Amaral, 1994) is to scrape a sharp needle across a piece of cardboard wetted with superglue. The idea is to scrape off a small bundle of fibers which can

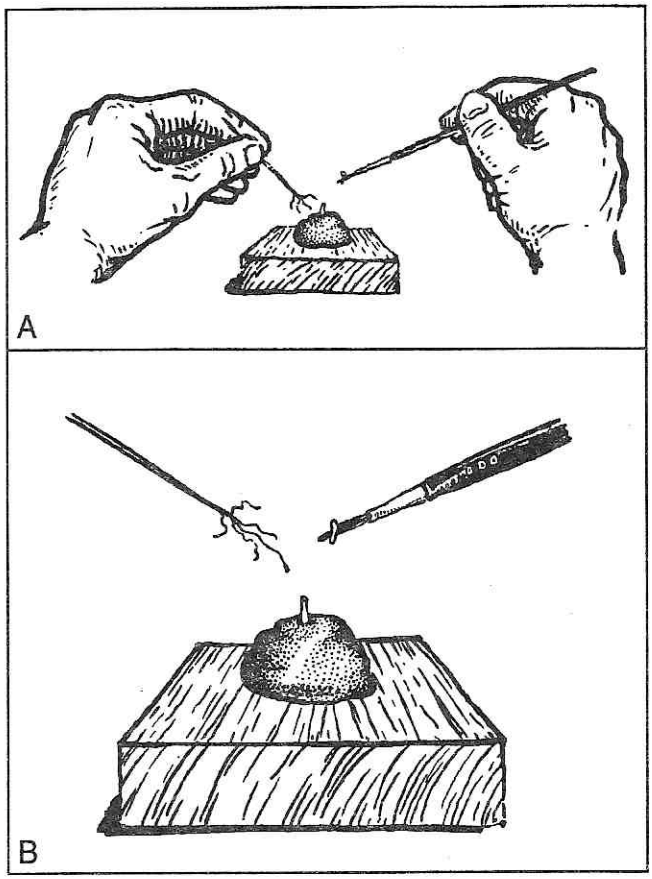

Figure 5. Repair of a small limb bone: positioning. One part of the specimen is embedded, contact up, in modeling clay affixed to a wooden base; the other is manipulated into position with a moistened, fine brush.

be used as described above (Fig. 4, left). This method has the advantage that the needle provides a rigid tool for better control.

Repair of Small Bones

Gluing small, loose fragments back together can be an extremely delicate and precise operation. If a fragment of bone or tooth (a cusp, for instance) is to be reattached, one faces the problem of lifting the fragment to its correct position and then letting go of it. A minute object can be lifted by touching a slightly moistened 000 (or smaller) brush or needle to its side and then raising it to position (Fig. 5). If the glue is already in place on the fixed target (as described above, using fiber), the fragment need only be touched to the glue drop and it will usually be pulled in and away from the needle or brush. If there is a chance that the fragment will need readjusting, then a slower-acting glue is desirable. The moves should be practiced beforehand to insure accuracy.

Modeling clay is extremely useful for positioning small bone fragments so that they can be reassembled. Depending on the situation, a clay base or clay pedestal can be used for this purpose; it may also be possible to manipulate small bones with a vacuum forceps pickup, although I

have had little success with this: the airflow and handpiece are difficult to control during complex operations.

Clay Bases

Sometimes it is necessary to reassemble small, broken long bones (limb elements, for instance) that are free of matrix. If there is a clean, relatively flat contact (i.e., broken surface), it may be practical to embed the heavier fragment contact up in a soft clay bed, and then test-fit the loose piece to be sure it will balance on the lower piece. Generally, it is advisable to mount the clay on a small wooden block so that the specimen can be rotated to visually inspect for proper alignment. If you are sure that the loose piece can be attached with no readjustments, then apply the glue to the fixed piece and attach the loose piece as described above. If a sure fit is questionable, bring the loose piece into position and then apply a tiny glue drop to the side of the contact where it will be drawn in most effectively (Fig. 6). Extra working time can be gained by using a slower setting superglue.

Clay Pedestals

If the pieces are too awkward to manipulate, or the contacts are too poor to attach by the above means, pedestals may be used effectively. Cut two tiny pedestals from a quality, nonspringy clay (e.g., Farcolina) and fix them to a clay base. Rest the bone fragments on either pedestal with the contacts close together. Use a pair of modeling tools to ease the pedestals toward each other (Fig. 7A) until the bones touch; sometimes this movement can be done by flexing the base itself. Rotate the wooden mounting block and inspect the work from all angles, making small adjustments, as necessary, until the bones are in proper alignment. Before touching the glue drop to the contact (Fig. 7B,C), make sure that the clay pedestals have not shifted apart.

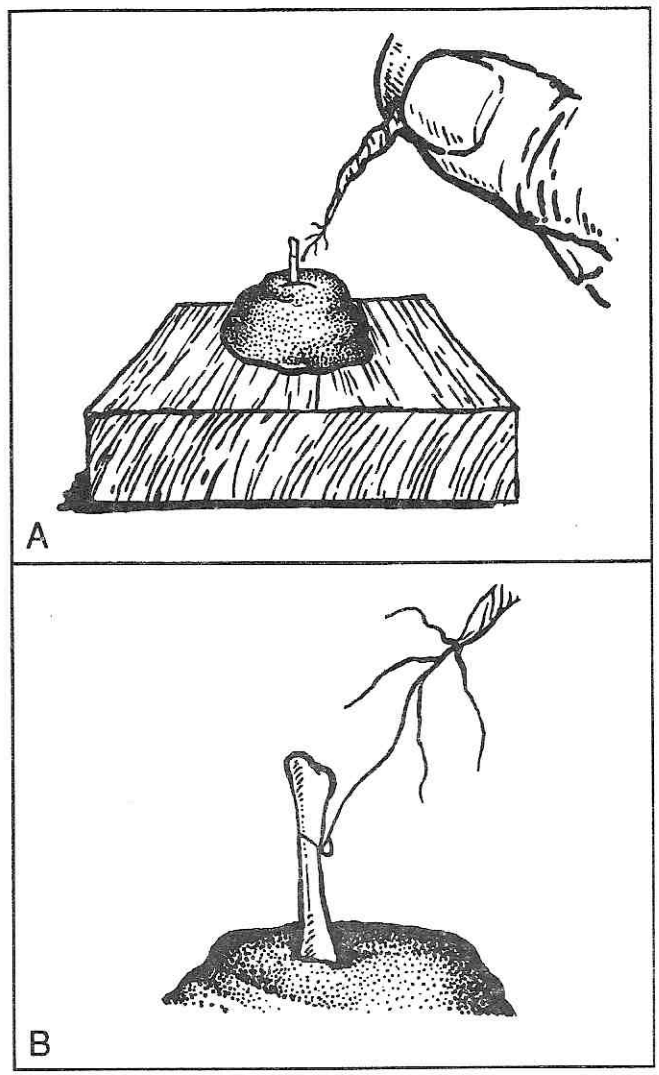

Figure 6. Repair of a small limb bone: gluing. If doubt exists as to whether the parts can be positioned correctly after gluing, the pieces should be positioned first and examined carefully. A microdroplet of superglue is then applied with fiber to an appropriate part of the joint; it will be drawn into the crack through capillary action.

The Use of Carbowax in Microprep

In some cases, a fossil is too small and delicate to handle by normal means. If a fragile bone is already free of the matrix but preparation is incomplete (as is often the case with screenwashed material), if a specimen needs to be prepared on all sides but is too fragile to be worked on while it is resting on a sand bag (Fig. 8A), or if some support is needed for another reason, then an artificial and temporary matrix may be in order. The idea behind using Carbowax is to create a moldlike, perfectly form-fitted bed that can support the fossil while it is being worked on and that can be later removed with no damage to the specimen itself. Before proceeding, the specimen should be carefully examined and the whole process thought out to be sure the bone will survive this treatment.

Use of Carbowax with Loose Bone

1. Inspect the specimen to see if it needs protection from wax or water. If later use of water will disintegrate rock or penetrate cracks, then make sure all endangered surfaces are well sealed with consolidant. It should be borne in mind that water can enter uncoated areas and loosen resin coats.

2. Cut a piece of wood large enough to brace with your fingers and hold the specimen within a clay dam. A square or oblong piece is usually best, with the dam positioned at one end. The wood surface at this end should be roughened, as needed, to give the clay and wax purchase.

3. Roll out a piece of clay long enough to enclose the specimen and wax filler. The clay won't need to be more than about 5 mm from the specimen. Cut the clay down the middle to form the dam.

4. Fix the clay dam tightly to the wood surface, roughly in the shape of the specimen. Plan for an orientation that gives you maximum visual and mechanical access.

5. Make a diagram of the specimen so you can later be sure where everything is.

6. A thin layer of Carbowax allowed to harden in the

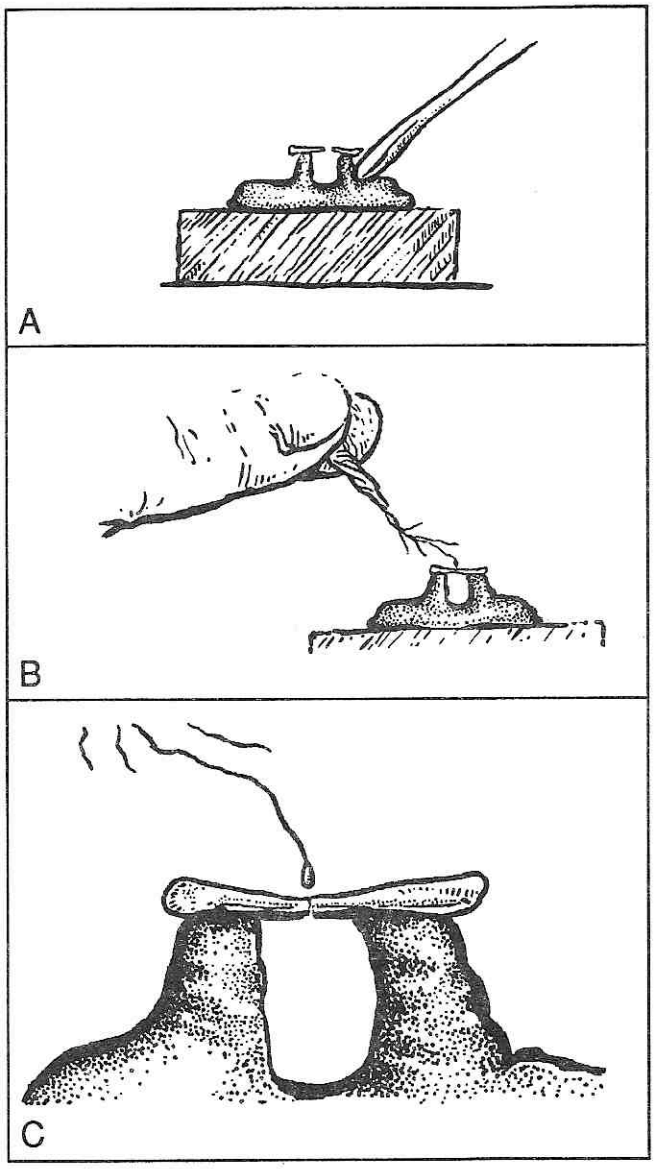

Figure 7. Repair of small bone with limited contact. Where it is not feasible to balance one fragment on top of another, each can be placed atop a pedestal of modeling clay; both pedestals, in turn, are affixed to a clay and wooden base. The separate elements can be positioned by moving the pedestals or flexing the clay base; once in correct position, superglue is applied, using fiber, to the joint.

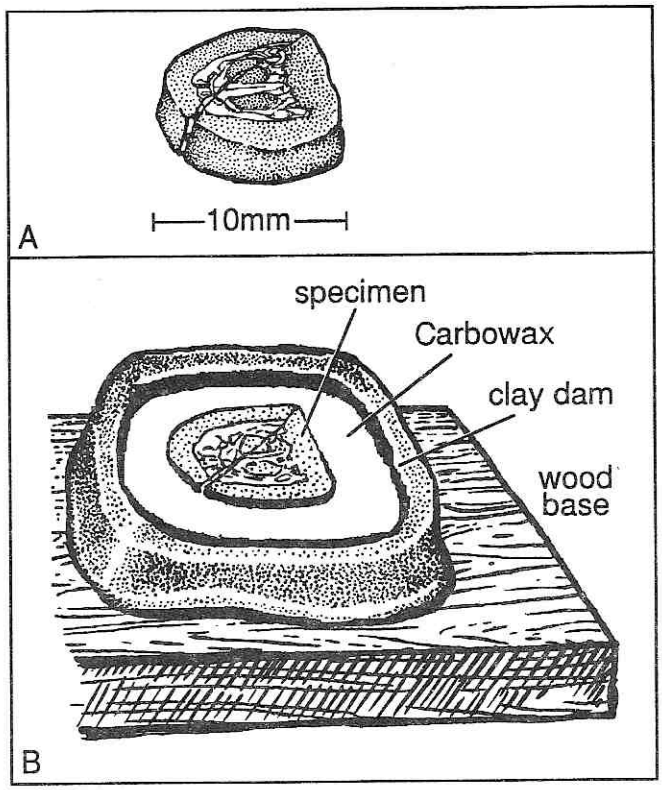

Figure 8. Embedding in Carbowax. Carbowax is useful as a temporary matrix for unstable specimens, such as this frog skull embedded in a cracked rock matrix. A clay dam is affixed to a wooden block; after positioning the specimen, filling gaps underneath as necessary, the liquid wax is poured in.

bottom of the basin prior to positioning the specimen will facilitate its subsequent removal. Position the specimen within the dam (Fig. 8B). If the specimen has a complicated shape and has gaps underneath, it may be advisable to apply a drop or two of Carbowax to these areas beforehand, in order to avoid trapping large air bubbles, adjacent to the underside of the specimen, in the Carbowax. A small clay plug is sometimes useful for orienting the specimen.

7. Heat the wax, pour it in the dam, and allow it to harden completely. Use as little wax as you can.

8. Remove the dam and prepare the specimen, removing wax as necessary. When preparation is complete, any newly exposed surfaces vulnerable to water should be sealed, as in Step 1.

9. Remove specimen from Carbowax. The bulk of this can be accomplished with a sharp, beveled needle. Care should be used when undercutting: know where the bone is hidden underneath, and work your way in gradually.

10. Turn the specimen over, if necessary, and repeat the procedure, starting with Step 3.

Final Removal of Carbowax

After the preparation, most of the Carbowax can be removed with a needle. It will often separate from the bone in the same way a soft matrix will part from a fossil. When water is used, always watch carefully for any loose bone fragments. If instability is detected, then let the specimen dry and consolidate it by any means necessary. Any wax residue can be removed by one or more of the following procedures.

1. If the specimen is robust enough, immerse it in a beaker of warm water.

2. Rest the specimen on several layers of soft, absorbent paper. Using a very soft brush, carefully dissolve away the wax with warm water, cleaning the brush regularly with warm water.

3. Rest the specimen on absorbent paper under a heat lamp and allow the wax to melt. As it melts, use a soft brush or fragment of tissue paper to absorb wax residue. Care should be used in applying heat, which can soften PVA or Butvar.

When the specimen is free of wax, let it dry completely and inspect it to be sure there is no water damage or wax residue remaining. Pay particular attention to teeth and other critical areas. Usually a thin coat of wax will give the specimen an unnatural sheen or a hazy, milky appearance. If water has seeped under a surface coat of consolidant, it usually appears as white, weblike strands. These can be removed with a needle or dissolved with acetone.

Use of Carbowax on Specimen Still Embedded in Rock

If the specimen is still resting in the matrix, the job will generally be easier. The specimen should be prepared, in situ, as much as possible according to the steps listed above. The specimen can then be stabilized with a consolidant and/or Carbowax, so that the fossil can be undercut and removed from the rock. To prepare the other side, simply turn the specimen over and follow the procedures described above.

Carbowax can also be used for spot jobs on isolated parts of bones, big or small. It is particularly useful on delicate overhangs, where any pressure could collapse unsupported bones. Simply drip a little wax around the area where support is required or, as needed, construct a small clay dam and fill with wax.

PICKING, SORTING, AND STORING MICROFOSSILS

Many vertebrate microfossils are recovered as isolated specimens (e.g., tooth, jaw fragment) through screenwashing and associated procedures described by Cifelli and others (1996). Other vertebrate microfossils, recovered through manual or chemical preparation, are often mounted and stored in a fashion similar to that for screenwashed fossils, depending on size and physical characteristics. In this section I describe procedures for sorting and reassociating screenwashed microfossils and for mounting and storing such specimens.

Vials and Vial Trays

Most microvertebrate fossils are well-suited to vial storage, whether as individual specimens (e.g., significant dentulous jaw or tooth) or specimen lots (e.g., highly redundant materials such as fish scales, lizard osteoderms, or teeth of many lower vertebrates). The most versatile and commonly used vial size is ½ dram, for which fitted corks must be ordered separately; other, larger, vials (e.g., 4 drams, 7 drams) are useful for large specimen lots or individual fossils. The tops of corks should be painted with white acrylic paint so that locality and specimen number can be written on them. Even if a label including specimen data is to be ultimately placed in vials, it is important to include the data on top of the cork, because many specimens will be mounted to pins affixed to individual corks

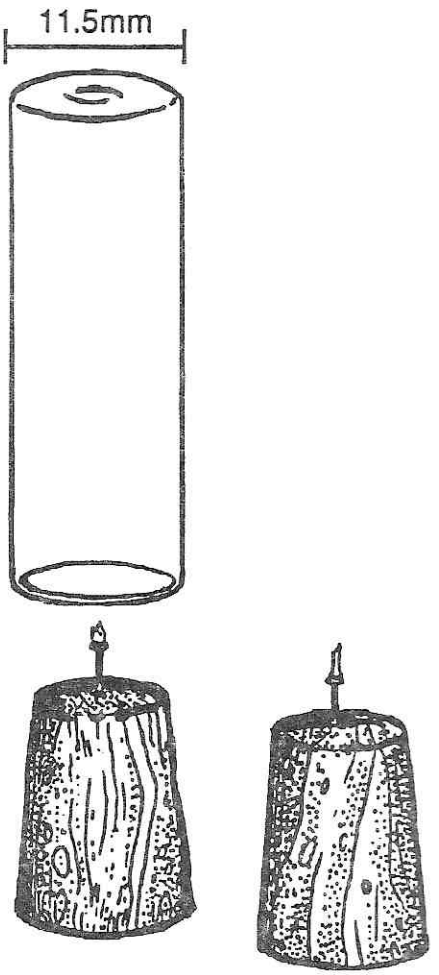

Figure 9. Typical storage for microvertebrate fossils. Specimens are mounted onto pins, which in turn are embedded in corks that are fitted into vials. The pin should be as short as possible to avoid specimen damage when the cork is removed from or inserted into the vial. Paint the bottom of the vial to avoid accidentally trying to insert the cork into the bottom and damaging the specimen.

(Fig. 9). Cork labeling will therefore assure that specimens do not become mixed if a number of them have been removed from their vials (e.g., for study or identification). One of the greatest hazards to specimens so mounted is posed by people trying to return the cork to the wrong end of the vial and crushing a specimen against the glass. This hazard can be reduced by painting the vial bottoms with an obvious color (e.g., red).

Vial boards are needed for both sorting and storing the small (½-dram) vials. These can be made from ¾-inch-thick wood (see Cifelli and others, 1996, fig. 14 [p. 22, this volume]), cast from acrylic or other resin, or fashioned from some other material (e.g., grid panel from lens of a fluorescent light fixture). The vials should fit the holes snugly but not tightly (½-inch holes work well for ½-dram vials) and should fit deeply enough so that they cannot fall

out if the tray is jarred. For sorting, a tray should have holes spaced far enough apart to permit labeling (e.g., with pieces of tape), if desired, of individual holes. I find a 3½ × 12 inch piece of pine to be a convenient size for holding 60 ½-dram vials (4 rows of 15). For specimen storage, vials can be spaced closer together; several sizes should be made, so that vials can be grouped appropriately in the collection (e.g., by element represented, taxon, or locality). The actual dimensions of the trays are not critical, but standards should be adopted so that they fit properly in cardboard trays, specimen drawers, and so forth. Larger vials (e.g., 4 or 7 drams) are often stored on their sides. Such vials should be shimmed into cardboard specimen trays with polypropylene blocks or some other material to keep them from rolling around and bumping each other when the specimen drawer is opened or closed.

Sorting Bone

While picking screenwashed concentrate, I generally sort the bone into broad categories as I go, separating vertebrates from invertebrates, limb elements from vertebrae, teeth according to major taxon, and so forth. Most important to my work (and most rare) are mammal teeth, so I pay particular attention to them. Because screenwashed material is generally fragmentary, one should always be mentally mixing and matching parts.

After a batch of concentrate has been picked, the true sorting process begins. If I have a group of mammal teeth from a given sample, I will sort them by taxon and element (e.g., tooth locus). When this is done, incomplete fragments possibly belonging together are arranged onto a piece of clay and systematically scanned for matches. A single tooth can easily have been broken into many fragments, so this can be a tedious procedure. For large samples, it is sometimes convenient to mount fragments individually by using a temporary medium such as wax. Individual fragments can then be sorted into fine categories (e.g., pieces of left-lower molars), and the potential fits can be examined closely by juxtaposing fragments under the microscope. Fragments with contacts of which I am certain are set aside for reconstruction, as described earlier.

Mounting Small Teeth and Bone

Vertebrate microfossils having individual significance are commonly mounted on pinheads (or, in the case of complex specimens, soft wire that can be formed to fit an internal or external contour) embedded in corks and stored in vials, which prevents them from moving about and provides a ready "handle" so that they can be manipulated, without damage, for study or identification. A word of caution, however, is in order. Potential damage resulting from return of the specimen to the wrong end of the vial has been noted above; damage is even more commonly inflicted when specimen users neglect to pull or push the cork straight from or to the vial, so that the specimen is either crushed against the inside of the vial or knocked off its pin. This danger can be reduced somewhat by using larger vials, as appropriate, or by positioning the pinhead as close to the cork as possible.

Various media are available for mounting specimens to pinheads. PVA or Butvar is appropriate if a more permanent mount is desired. Because these glues result in a relatively secure mount, they may be preferable if frequent specimen handling or transportation (e.g., specimen loan or exchange involving postal delivery) is anticipated. However, glue mounts may present problems if the specimens need to be removed for any reason (e.g., casting, study under SEM). Application of or immersion in a solvent may smear glue on a specimen or, worse, loosen bonds where a specimen has been glued together from various fragments.

Various types of microcrystalline waxes can be used, in lieu of glue, for mounting. These are particularly useful for temporary mounts, or where frequent mounting and dismounting are anticipated. A disadvantage with waxes is that they may not hold a specimen strongly enough to withstand jarring; additionally, temperature extremes may weaken the bond. Many petroleum-derived microcrystalline waxes tend to be messy to handle and hard to remove from the specimen. Beeswax tends to be difficult to remove from specimens; the best waxes I have found are "paste-up" waxes used in the printing industry. These are dry, positionable, and nontacky; they generally do not adhere to specimens, and removal, if necessary, can be done with needles. Carbowax has also been reportedly used as a mounting medium; in which case, the pinhead is dipped lightly into melted Carbowax before affixing the specimen, as described below (W. W. Amaral, personal communication, 1994).

Pin-Mounting Fossils by Using Glue

Position the object on a pad of clay with the surface to be glued facing up. Using a pair of needle-nosed pliers, insert a pin into the bottom of a cork. Pick up a small drop of glue with the pinhead. The glue should be slightly viscous and tacky to the touch. Touch the glue drop to the bone surface (Fig. 10, right). It will usually pick up the bone as you lift it away. If the object is a tooth, touch only the root, if a root is present. Turn the cork right side up and, if necessary, adjust the position of the bone with a needle before the glue dries; gas bubbles often form in the drop, distorting its shape.

Pin-Mounting Fossils by Using Wax

Position the specimen, pin, and cork as described above. With a fingernail, pull off a small dab of wax and form it around the pinhead, making a small point or pedestal at the tip (Fig. 10, left). Press the wax gently to the bone and lift the bone up. Often, it may be necessary to use a needle to work the wax around the bone surface a little, so that good purchase is achieved; however, assure that no important features of the fossil are obscured in the process.

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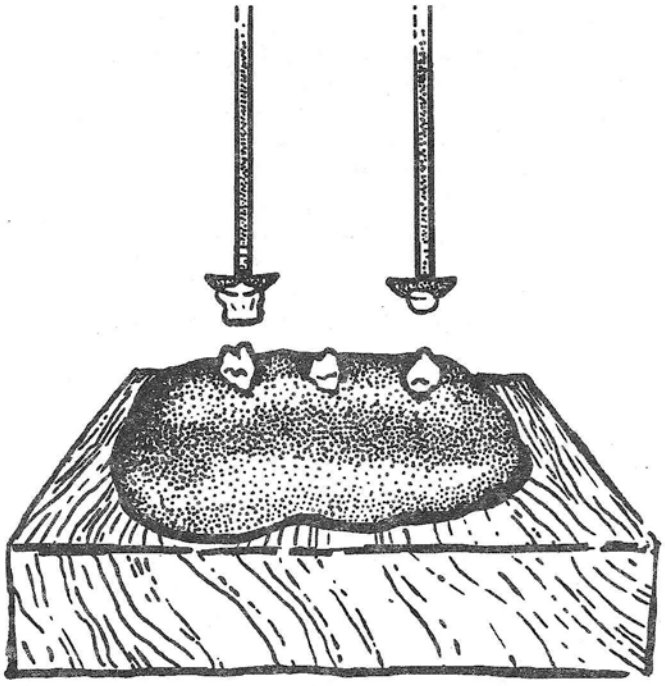

Figure 10. Mounting microvertebrate specimens. Fossils are placed on modeling clay, morphologically informative side down, and picked up with cork-mounted pins whose heads bear drops of glue (Butvar or PVA, right) or, if a temporary mount is desired, globs of wax, which can be custom-formed (left).

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