Screen Washing

In recent years great emphasis has been placed on the recovery of small specimens. For statistical and population studies large numbers of specimens are required. The best procedures are to collect matrix from fossiliferous zones in sacks, to wash large volumes of sediments through screens in water, and to carefully sort the dried concentrate (McKenna, 1962). Ideally the screen washing operation should be done in the laboratory, but the field site is often in a remote dry area with laboratory facilities too far away. The screen washing must be done at the nearest water source, whether a shallow pond, creek, or river. To be efficient, a large number of screen boxes should be used, but the number should not exceed fifty (McKenna, 1962). In pond areas with little or no water movement, the washing operation becomes more difficult due to mud accumulating on the bottom and heavy silt buildup in the water. Rivers can be hazardous because of the rapid movement of the water, and the risk of losing screen boxes and valuable fossils is increased.

Burlap bags should be used to pack and carry the fossiliferous sediments. Weight limits should be restricted to no more than 40 to 50 pounds, reducing chances of back injuries. If at all possible, the loaded bags should be transported to the wash area by vehicle. At the wash site the matrix is placed in the screen boxes in the water. The clays and chunky matrix should be allowed to totally soak up the water before any agitation is applied. The scrubbing action of the matrix against the bottom of the screen should be minimized to prevent damage to microfossils. As soon as no more sediments will pass through the screens, they can be removed from the water and allowed to dry. If the screen boxes are required for additional washing, the contents are carefully dumped and spread out on a canvas surface to dry. Avoid any manipulation of the fossil bearing concentrate while drying, as wet fossils are easily broken. A ¼-inch layer of fossil concentrate covering the bottom of the screen box should be the maximum allowed when left in the boxes to dry.

As mentioned earlier, the best results are accomplished in the wash room of the laboratory. Here a set of screening boxes can be used that will nest inside each other. The top screen will have larger openings using 1/4-inch hardware cloth which will filter out the larger rocks and debris. The finer sediments will drop into a second screen below which uses standard window screen. On the bottom tacked below the window screen is 1/2-inch hardware cloth giving added support for the matrix weight. The wooden sides of the screening trays measure 1-1/2-inch deep (Figure 5-7). These screens are stacked in the washing sink, and a hose with a shower head gently applies water until the fossiliferous matrix becomes soaked. The water movement over the sediments gently washes the material down through both screens until the only material left behind is the concentrated fossil-bearing material. If known smaller specimens are present in the sediments, a finer screen of 24 mesh can be used in place of window screen.

The larger field washing screens are modified versions of Malcolm McKenna's (1962; American Museum of Natural History). These boxes consist of deeper sides than the laboratory versions, with 7-inch sides. The bottoms and ends are covered with standard aluminum window screen with 1/2-inch hardware cloth reinforcement underneath. Furring strips of 1/4-inch thick material are tacked around the entire bottom edge to prevent the screen and hardware cloth from pulling free (Figure 5-7).

Sorting of the microfossil concentrate is done using a magnifier lamp and scanning the concentrate back and forth in a uniform pattern. The concentrate should be placed only one grain

deep and swept out of the way when scanning is completed. Small teeth or small limb elements should be placed first in gelatin capsules, and the capsules then put into plastic vials. Care should be taken to maintain locality data with each batch of matrix washed or concentrate sorted.

Mechanical Development

The term "development" has been used for several years to describe the removal of fossil material from matrix. Prior to the turn of the century, without exception, most development was performed with hammer and chisels. Today preparators must still master this skill (Stucker, 1961).

The best hammer for development work is a rolled leather mallet, like those commonly used in the auto body repair industry. It is strong enough to deliver hard blows, but normally is used with light taps. Chisels come in many shapes and sizes. The best for fine development work are the narrow-bladed, medical bone chisels. These can be purchased through many medical supply houses and come with several blade shapes.

In hammer and chisel work, the force of each blow should be limited so as not to create shock waves through the specimen. The specimen must be checked continuously for weak areas and immediately strengthened by consolidation and allowed to dry before the work continues. As a general rule, a place of weakness usually occurs at the interface of the matrix and the specimen. By driving the tip of the chisel toward the bone, the matrix will split clean at this interface. With tension on the wrist when applying the stroke with the hammer, a natural restraint tends to prevent the chisel blade from striking the bone. Every effort should be made to avoid gouging the specimen with the chisel.

Round-pointed chiseling tools can be manufactured by grinding a needle point on a dental probe or worn out drill bit. Both of these tools hold a point very well, even under very hard matrix conditions.

The development of certain specimens requires additional reinforcement around the matrix to keep the fossil together while using the hammer and chisel. Several methods may be employed. The specimen and matrix can be encapsulated in a Plaster of Paris bandage, leaving just the area to be worked exposed. Protective tissue must he applied between the plaster and the specimen. Polyurethane foam has been used successfully for several years in the place of plaster.

Polyethylene glycol wax 4000 (PEG 4000) is ideal for supporting fossil material. Since the wax is soluble in water, its removal is much simpler than plaster or plastic materials. With a melting point of about 122° F, all the wax can be removed in a small laboratory oven.

Plastics such as epoxy and polyester resins can also be used to hold a fossil rigid enough for hard hammer and chisel development. The specimen is wrapped securely in aluminum foil and placed into the liquid resin within a modeling clay dam. The side to be worked will be left exposed out of the resin. This material is one of the hardest to remove from around the specimen. Sawing and grinding is usually required in the removal.

Development of very small fossils should be performed under the magnification of a dissecting microscope. Slightly larger specimens, such as a rabbit jaw, can be comfortably worked

under a magnifier lamp. In limited space, a binocular optivisor is essential. This optical piece fits comfortably on the forehead, can be flipped away from the eyes when not in use, and frees the hands for complete control in the fossil development process.

Dental machines were used for a number of years to grind down the matrix on a fossil until it was thin enough to be removed by percussion. These have been replaced today by a number of high-speed motorized tools. Dremel makes a small hand-held grinding tool with a high-speed motor that turns at up to 30,000 RPM (Figure 5-8). Rheostatic speed controls are available for this tool that will adjust the speed from 0 to full RPM. A wide array of cutters can be used with the grinder, ranging from high-speed steel cutters to tungsten carbide to diamond cutters. Another excellent power tool is the Foredom flexible shaft power tool (Figure 5-8). This tool uses the same cutters mentioned above and comes with a 37-inch flexible shaft. The handpiece and flexible shaft allows access into difficult places.

Hard matrix is easily removed with the availability of many different shapes and types of grinding cutters. The rock hard sediments can be ground carefully away from the fossil without touching the bone at all. Either form of grinder (hand-held or flexible shaft) becomes a universal tool in a preparation laboratory. These tools can be used in any operation, from the trimming of a mold or cast to the slow process of matrix removal.

Another mechanical device that has been in use for a number of years by paleo-preparators is the engraving tool. The product called Vibrotool is one of the most useful mechanical development aids (Figure 5-9). It incorporates a pointed tip with a vibrating motion of between 50 and 100 strokes per second. In all respects it resembles a miniature hand-held air hammer tool, but without the air drive. The point of the vibrating tool is placed lightly against the matrix, and a light chipping action begins as the vibrating blows are delivered to the point. Care should be taken not to damage the fossil by driving the tip into the bone. Slowly flake the matrix with the point, working toward the fossil. The matrix should separate at the interface between the fossil and the matrix before the tip reaches the specimen.

No fossil preparation laboratory should be without a precision miniature sand-blasting unit. S. S. White Industrial Division produces the Airbrasive machine, and its use in paleontological laboratories was first described by Stucker (1961). This machine works by firing a fine stream of abrasive particles, propelled by gas pressure at a velocity of 1100 feet per second to a point of impact. Commercially the Airbrasive machine was designed for performing delicate operations on hard plastics, steel, and glass, the shaping of quartz crystal, and for the new developments in the cutting of electronic germanium. Gas-propelled to supersonic speeds through a small, precise nozzle, the finely graded abrasive particles produce a cool, shockless cutting action. There is no contact between the tool and the fossil matrix. What little heat is produced is immediately removed by the propellant gas. Both straight and right-angle nozzles with various shapes and orifice sizes are available to provide flexibility of cutting. The right-angle nozzles often enable the operator to make cuts in positions inaccessible to ordinary cutting tools.

A suitable dust collector system is required to protect the operator from overexposure to abrasive dust. When air contaminants from material being abraded might be questioned, consult the manufacturer of the dust collector for the correct filter to solve the problem. The overall effectiveness of the piece of equipment hinges, of course, on the human element. It will take the skill of the operator and his eyes, foot, and hand coordination to make the system work. As in all

precision tools, continuous maintenance is required. Periodic checks must be made for nozzle wear, tubing abrasion, and wear of the steel fittings.

There are eight standard abrasive powders offered by S. S. White. Cutting rate is materially affected by the type of abrasive used. Choosing the right abrasive is important when dealing with delicate fossils. When a large amount of matrix removal is required, the 50-micron (one micron equals one-millionth of a meter) aluminum oxide (no. 3) abrasive works best. The abrasive with the greatest latitude of application is no. 1, 27-micron aluminum oxide. This powder reduces the problem of clogging the hopper holes. The working of delicate areas close to the bone usually requires abrasive no. 5, consisting of IN-micron aluminum oxide.

The preparation of fossils in hard matrix becomes considerably easier with the use of a tool such as the Air Scribe (Figure 5-10A). The Air Scribe is a miniature, hand-held air hammer. The reciprocating motion of the chisel bits quickly and effectively removes large volumes of the hardest matrix, yet it is small enough to control even delicate matrix removal around teeth. An air supply control regulates the force and speed with which it impacts the matrix so that vibration, which could be harmful to the specimen, can be minimized. An assortment of bits allow the user to choose the one best for any given situation. By varying the amount of pressure applied to the specimen with the Air Scribe, the preparator can remove greater or smaller amounts of matrix. A light touch is best when working around fragile specimens.

Since the Air Scribe produces flying debris, the operator always should wear protective goggles. The best method of using the Air Scribe is to construct a wooden box with a glass top and two ports for the operator's hands. This way the Air Scribe is operated inside a contained area that traps debris, protects the eyes, and muffles the sound (Figure 5-10A).

The Air Scribe is powered by a compressor capable of generating 90 P.S.I. of pressure. it should be the tool of choice for mechanical preparation of fossils in hard matrix.

While the Air Scribe is best for removing large amounts of matrix down to a close proximity to the bone, another pneumatic tool is recommended for the finer work on small specimens and around teeth or other fragile structures. This is the air-powered rotary grinder, of which there are several on the market. The Starlite Rotary Grinder is an excellent choice and is reasonably priced to fit the budget of amateurs and professionals alike. Comparable in size to a penlight, it rotates at speeds up to 340,000 revolutions per minute. The wide assortment of burrs and bits, including diamond bits, can cut through the hardest materials, and the tool is small enough that the operator has complete control. However, since the bits are so small, this tool is used most effectively after the bulk of the matrix has been removed by other means (Figure 5-10B).

Like the Air Scribe, the Starlite Grinder operates on 90 P.S.I. of compressed air. The operator must also use protective goggles or perform the work in a protective box, as the one described for use with the Air Scribe.

Ultrasonic cleaning devices depend on sound waves with frequencies above the human audible range (Figure 5-11). In recent years important advances have been made in such devices. They usually consist of a transducer, a generator, and a tank which is filled with water. Electric energy produced by the generator is converted by the transducer to mechanical energy in the form of vibrations. To obtain high frequency ultrasonic vibrations, a ceramic transducer is used. A magnetostrictive metal transducer generates low frequencies. The vibrations produced by the

transducer are transmitted to the water (or other liquid) in the tank where the liquid exposed to ultrasonic energy develops zones of compression and rarefaction and disrupts the fluid to produce the effect called "cavitation" (Stevens et al., 1960). All surfaces in contact with the liquid are vigorously cleaned. It is more practical to immerse the fossil in a liquid-filled beaker, which is then placed in the tank, rather than placing it directly into the tank. Many types of solvents can be added to the beaker to accelerate the cleaning. These will depend solely upon the type of matrix involved.

It is considered best to use a low frequency when cleaning fossils. When compared to the high frequency units, it was found that magnetostrictive transducers require less power and use smaller input equipment. They are safer to operate and db not require safety precautions. Also, if operated for extended periods of time, there is little danger of such units overheating.

The length of time required to clean an individual fossil is determined by the type of fossil and by the character of the matrix. Insoluble residues such as dolomites may be removed faster if a combination of ultrasonic and acid digestion are used. The chemical reaction along with the mechanical breakdown are increased by the vibration. It is risky to process badly cracked specimens in an ultrasonic cleaner, because the formation and implosion of the vast number of small bubbles can shatter cracked fossils.

There are many different forms of mechanical development that can be adapted to the requirements of a particular fossil preparation. This book cannot cover them all, but attempts to mention the more commonly used methods. For example, x-ray units could be useful to every preparator on some occasions. The cost of such units would prohibit most laboratories from having one. In large natural history museums, however, the facility may be made available for several departments to use. in paleontology, x-rays can be useful for showing unerupted teeth in a jaw section and can save the time required to open a window in the side of the specimen. X-rays can be shot on Polaroid Type 55 (4x5 size) film, giving the preparator an instant black and white photograph plus an excellent quality, fine-grain negative. Thin-sectioning equipment is sometimes needed by a preparator. Without precision diamond-wafering equipment, this task would be nearly impossible. Buehler, Ltd. manufactures a low speed saw called ISOMET (Figure 5-12) which uses relatively low speeds (300 rpm maximum) coupled with a thin, continuous, rim diamond-impregnated blade to accomplish true cutting of nearly all solid materials. The concept of low speed cutting was borrowed from the diamond cutters of Antwerp who have been using 3 to 4-inch diameter thin diamond-edged blades for decades. The use of simple mechanical principles, such as gravity specimen feed and drag application of lubricant, makes the system exceptionally easy to use. The ISOMET is rapidly becoming a valuable tool for the paleontologist, as well as for the biologist and pathologist. The superior cutting capability of the device allows retention of sample integrity and character by avoiding distortion or damage. Wafer-thin cutting of specimens, such as horse teeth, to illustrate the unerupted dental patterns can be performed with a minimal cutting loss.

Chemical Development

In many cases when mechanical development is not adequate or efficient enough to remove the specimen from the matrix, chemical means can be utilized. Toombs and Rixon (1959) described the procedures they developed at the British Museum for the acid preparation of

vertebrate fossils. The use of acids always raises questions regarding the problem of chemical damage to the bone and the safety of the preparator and the laboratory environment. Acetic acid is appropriate for matrix containing calcium carbonate. This does not mean that the matrix must be pure limerock. Even a small percentage of calcium carbonate present can cause the weakening of the matrix structure when immersed in the acetic acid bath. Toombs (1948) discovered that pure acetic acid would not attack the calcium phosphate of which bone is composed. It reacted only with the calcium carbonate of the calcareous matrix. When the preparator considers using an acid bath, he must plan to stay with the job until it is complete. Walking away could spell disaster for the fossils.

The concentration of acetic acid that works best for chemical preparation is a 10 to 15 percent solution. The bone must be totally immersed in the acetic acid bath. If a portion of the specimen is left out of the liquid, calcium acetate crystals will form and this crystallization can cause severe bone damage. A check should be made of the specimen to be treated by putting a few drops of 15 percent acetic acid through a pipette onto the matrix. Observe the speed of the reaction and the length of time it takes the matrix to dissolve. A weaker concentration may produce a safer job. If there is any doubt about the strength of the bone to be treated, coat exposed surfaces with polyvinyl butyral (BUTVAR B-76) and allow to dry thoroughly before placing in the acid bath. Once in the bath, frequent checks must be made of the progress. When weak areas are observed, the specimen should be removed and hardened before going any further. The chemical action can be stopped at any time by removing the specimen from the acid bath and pouring ammonia over it. Water does not stop the action immediately, indeed adding of water will start a short burst of activity. After neutralization in ammonia, place the specimen into a water bath until the specimen is free of any salt accumulation. Frequent changes of the water may be required. If any white calcium acetate deposits form on the surface of the specimen during drying, the washing process must be resumed.

Once dry, the softened matrix should be removed carefully using fine needle probes and brushes. Magnification with a good binocular dissecting microscope or a magnifier lamp may be required to perform this process. As stated by Toombs (1959): "The art of good preparation lies in seeing what you are doing." As the matrix is removed from around the bone, protective coats of Butvar B-76 should be applied to strengthen the bone. After the specimen and sealant have thoroughly dried, continue the matrix dissolving in the acid bath. The entire matrix removal process being performed in the acid bath can be accelerated greatly if the bulk of the matrix is removed by mechanical methods prior to the acid bath. Extreme care must be taken not to break any bones during the mechanical removal of the matrix.

Some vertebrate fossil matrix dissolves unevenly in acetic acid. There are times when only certain areas need to be confined to the acid attack. All surrounding bones and matrix can be masked by a coating of beeswax. Beeswax is a much harder wax than paraffin. It can be flowed over the specimen or simply brushed on. The area requiring the acid reaction is left exposed. Frequent checks must be made while in the acid bath. The acid will undermine the wax masking as the work progresses, and additional wax must be applied as the matrix is worked down. Latex rubber is impervious to, and not affected by, the actions of acetic acid. A generous coating should be applied over the matrix block. A flexible container does not offer the necessary support required to prevent fracturing of the specimen as the matrix is etched away by the acetic acid. The casing around the block must be rigid. A polyester resin normally is used to encase the specimen, providing the necessary rigidity. As the acid etching progresses, the polyester casing and the rubber can be trimmed away. Many cave deposits consisting of breccias and fissure fillings once

required the mechanical process of rock breaking to expose the hidden bones inside. The acetic acid bath can play a very important role in extracting the many small vertebrate remains from the matrix.

Cave breccias usually require some precaution be taken. Many times the bones are replaced by carbonates and will react when immersed in acid. Samples of the breccia should be tested prior to the acid bath treatment to see if the bones will survive the acid. Microscopic observations should be made on the bones for any possible erosion damage. There are several acid-bath methods by which cave matrix can be removed. An entire large block can be placed in the acid solution and allowed to totally break down. The residue then is passed through a series of sieves to collect the fossil remains. Another method is to immerse the matrix, placed in acid resistant sieves, into the bath and allow it to dissolve. The blocks of matrix also can be enclosed in a casing of latex and resin, and each individual specimen ran be picked from the matrix as it is loosened.

The "transfer method" (Toombs and Rixon, 1950) has worked successfully in the removal of delicate specimens, such as teleost skeletons. The exposed bone surface of the specimen is imbedded into a clear plastic resin while the matrix side is left open for acid etching. Prior to this procedure the ostracoderm plates would fall to pieces as the acid removed the matrix. This procedure requires a hard-setting transparent plastic that can be applied in a liquid or paste form. The specimen is cleaned by immersion for a few minutes in an acetic acid bath. It is neutralized and washed, then allowed to thoroughly dry. The specimen is placed into a retainer wall made of aluminum foil with the bone facing upward. The margins around the specimen should be no more than 1/4 inch all around the specimen. The walls of the retainer wall should rise above the specimen by at least 3/4 inch. The resin material is poured in layers around the specimen, none being more than 1/2-inch thick. These layers are allowed to harden before the next layer is poured. Successive layers of resin are built up until the top of the specimen is approximately 1/8-inch below the top of the set plastic. This plastic block is then removed from the retainer wall and allowed to cure for several days. After curing, any excess plastic is trimmed from the back of the specimen until the matrix is exposed. The acid preparation can now begin. Place the specimen into the acid bath with the exposed matrix side down. This allows the residue to fall from the matrix by gravity.

The same procedure for general acetic acid etching applies. A specimen should never be left long in the acid bath that has become concentrated with salts, as the salts will crystallize and may damage the fossil. Once the bone becomes exposed, the block is removed from the bath and neutralized, washed, and dried. All loose matrix material is carefully removed by needle and brush. A protective coating of Butvar B-76 is applied. Once the specimen has been thoroughly dried, it is returned to the acid bath and the operation is started over again. Mechanical procedures using the airbrasive machine may be required in the removal of any matrix that will not dissolve in the acid bath. The preparation exposes all parts of the skeleton once covered by matrix and is visible from all sides.

At the British Museum specimens prepared with this process are still in excellent shape after more than thirty years of storage. Polystyrene dissolved in acetone makes an excellent protective coating for acetic acid etching. The polystyrene is not water soluble and is not affected by acids (Williams, 1953). When a fragile specimen requires acid preparation, a thin coating of a polystyrene solution should be placed on all exposed bones, including all break areas. If the polystyrene is applied too thick it will simply peel away from the specimen. The specimen is prepared in the acid bath as mentioned previously in this chapter. Check frequently, depending on

the action of the acid. Remove and wash using the standard procedures. Brush the loose matrix from the specimen, then recoat the newly exposed bone with additional polystyrene. When the preparation is completed the specimen should be allowed to thoroughly dry. A thin protective coating of Butvar B-76 should be applied over all exposed bone surfaces.

The few limitations of the acetic acid bath depend virtually on the proportions of calcareous material of the matrix. Phosphatic nodules will not dissolve, and clays or iron-bearing sediments are very difficult to work. The acetic acid method has been tried on many different forms of matrix and a number of vertebrates, and in most cases the results have been excellent.

Another acid that can be used in the same manner as acetic acid to remove matrix is formic acid. This acid requires special care in its handling. It should never be used outside a fume hood. Severe damage to the eyes can occur. Gloves should be worn at all times when handling this acid. If acetic and formic acids are mixed, they will attack the bone. Special care should be stressed to neutralize and wash a specimen before going from one acid to the other. Formic acid has a slight edge over acetic acid in that it will attack certain matrices that acetic will not. There are many other acids that can be used in fossil preparation. Thioglycollic acid reacts with haematitic matrix by converting the ferric ions to the ferrous stage, then to soluble ferrous salts. A mixture of hydrochloric and dilute hydrofluoric acids was used successfully by G. McGeevy and Dr. Rochow of Harvard University to remove iron oxides along with silicified matrixes from fossil bones. Hydrochloric acid is not a satisfactory acid, except as used by some preparators to dissolve away bone in order to leave a natural mold of the specimen in a non-soluble matrix. Sodium hypochlorite, commonly called bleach, has been used for the removal of fossils from carbonaceous matrixes. This chemical also works well for some other forms of matrix breakdown. Small expendable samples should be tested before any experimental chemical procedures are tried.

Heavy Liquid Separation

Heavy Liquid separation is another type of chemical development that is finding an increasing number of applications. With this method two or more components of a matrix may be separated into isolated phases for further study. A simple analogy would be to put a handful of soil into a beaker of water. The organic component in the soil, i.e. leaf litter, humus, twigs, and insect casings, would float on the surface of the water. At the same time, you would see the sand and other mineral components of the soil sink to the bottom of the beaker. This separation has occurred because of differing specific gravities or densities of the materials involved. Water by definition has a specific gravity of 1.0. Materials that have specific gravities less than 1.0 will float in water, such as the organic material in this case. Materials with specific gravities greater than 1.0 will sink in water, as did the sand and mineral component in the beaker.

Using this analogy we may then separate any different components as long as we have a liquid that possesses a specific gravity in between that of the components we wish to separate. Liquids exist that have such variable specific gravities, and they are known to chemists as heavy liquids.

Heavy liquids have a long history of use in industry and science. Many of the liquids used, especially bromine-based liquids such as bromoform and tetrabromoethane, are extremely toxic

and should be avoided if other less toxic compounds will suffice. Many museums are now using zinc bromide and polytungstate, which are relatively safe compounds.

A simple heavy liquid separation procedure will now be described. For our example, we will use zinc bromide, a compound available at most chemical supply companies, such as Fisher Scientific. Zinc bromide is a crystalline powder that is mixed with water in a ratio of 100 grams of zinc bromide to 20 milliliters of water. This mixture will produce a liquid with an S.G. (specific gravity) of about 2.6.

In this example, the material we wish to separate is a washed and screened matrix sample that is known to contain bones of small mammals, birds, reptiles, or any other microfauna. Be sure to wear protective goggles and rubber gloves and work in a well ventilated area or use a fume hood when attempting any heavy liquid separation. Fill a beaker with the zinc bromide solution. Into this solution introduce a small amount of the fossil-bearing matrix sample. Stir vigorously and wait a few minutes, then stir again. The fossil material from most sites will sink to the bottom, while the sterile matrix will float or remain suspended in the liquid. The floating or suspended phase of the matrix can be skimmed off with a wire strainer and the rest of the liquid poured off the dregs (the fossils). The fossils should be washed to remove all traces of the heavy liquid, then dried. The heavy liquid can be filtered to remove debris and recycled (Figure 5-13).

An alternate set-up to the beaker is to use a large glass laboratory funnel with a 5-inch length of tubing attached to the bottom of it. Place a clamp at the bottom of the tubing. The fossil material will fall through the bottom of the funnel and collect in the tubing. When separation has occurred, a clamp is placed at the top of the tubing leaving the fossil material trapped in the tubing between the two clamps. The liquid and debris is then poured off, and the material in the tubing washed and dried(Figure 5-14).

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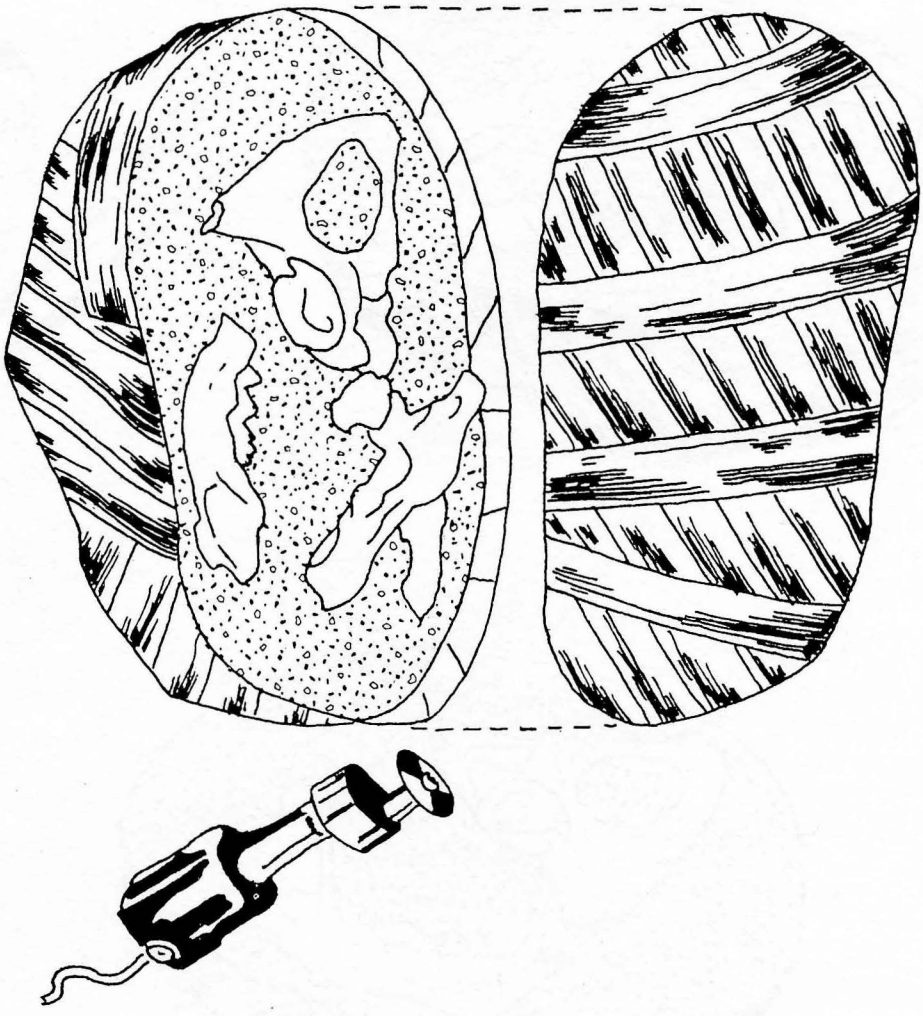


FIGURE 5-1. The plaster jacket is opened using a Stryker electric cast cutter. The depth of the cut is guaged so as to only penetrate the plaster shell.

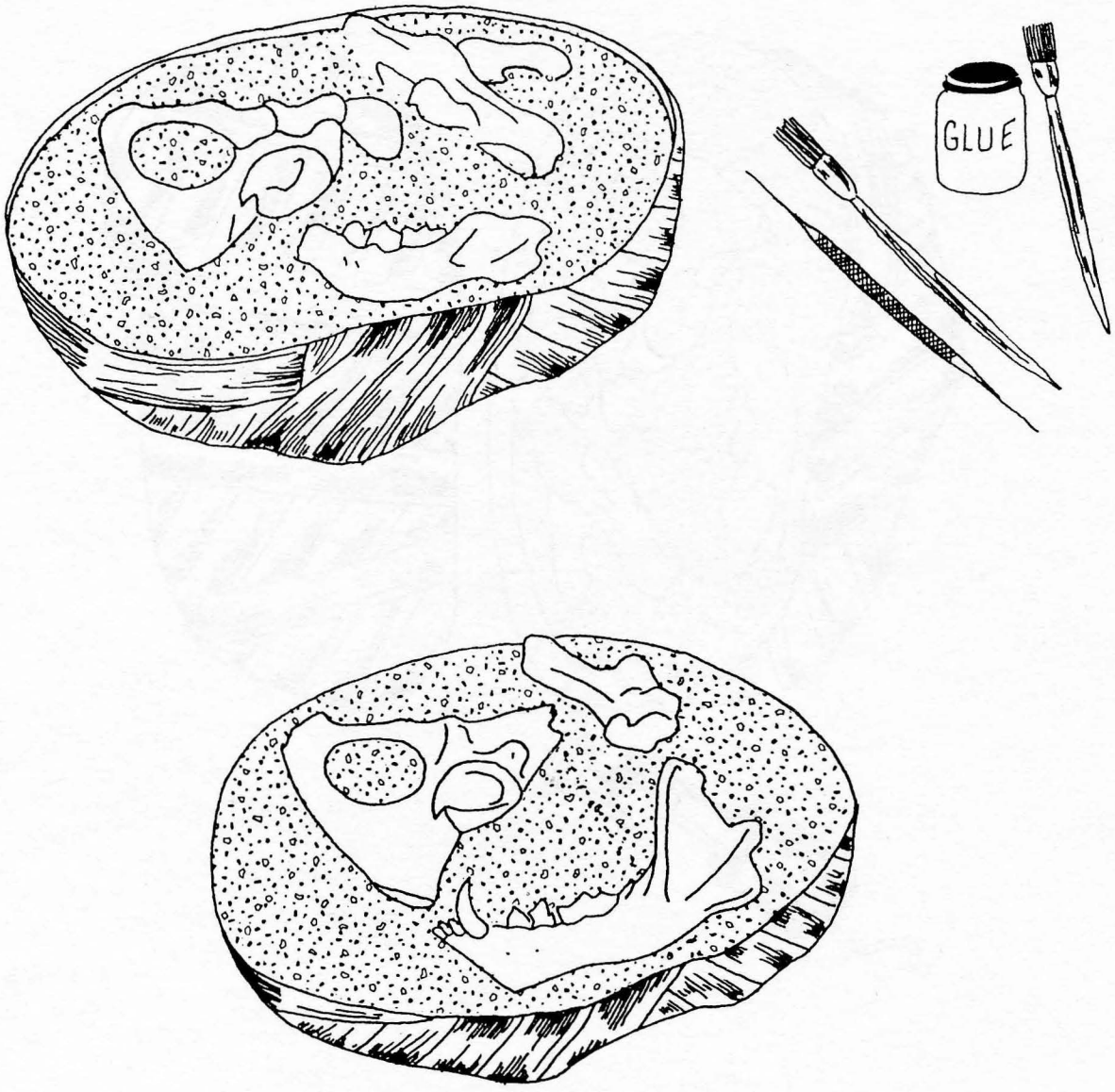


FIGURE 5-2. Top, a thinned solution of consolidant is applied when cracks are noticed. The specimen should be allowed to harden before working deeper into the matrix. Bottom, the high walls are trimmed off as the matrix is worked down. Vibrations should be kept to a minimum with the bone material exposed.

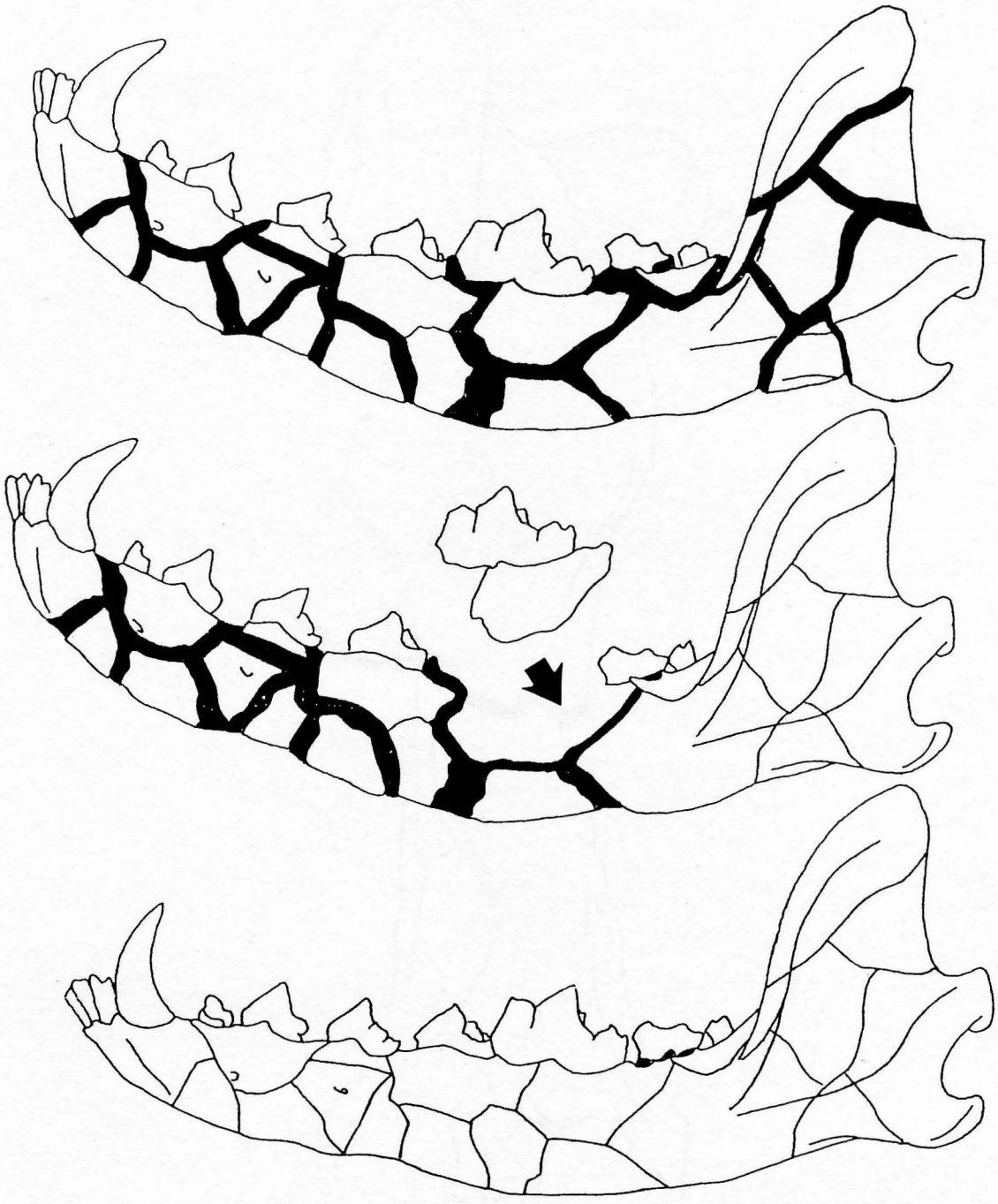


FIGURE 5-3. Once the specimen is removed from the jacket, clean each fragment thoroughly and glue it back to its proper contact point. No more than one or two pieces should be removed at a time. When finished, a three-dimensioned specimen is prepared.

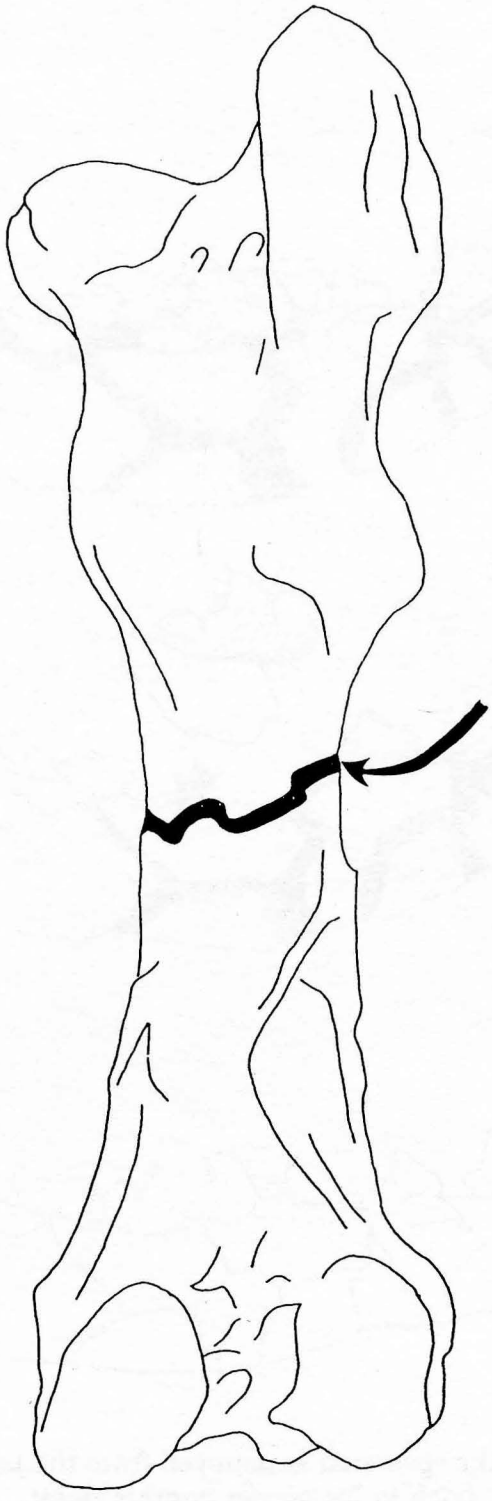


FIGURE 5-4. Major breaks are repaired with stronger epoxy glues. Marine-Tex brand is recommended highly.

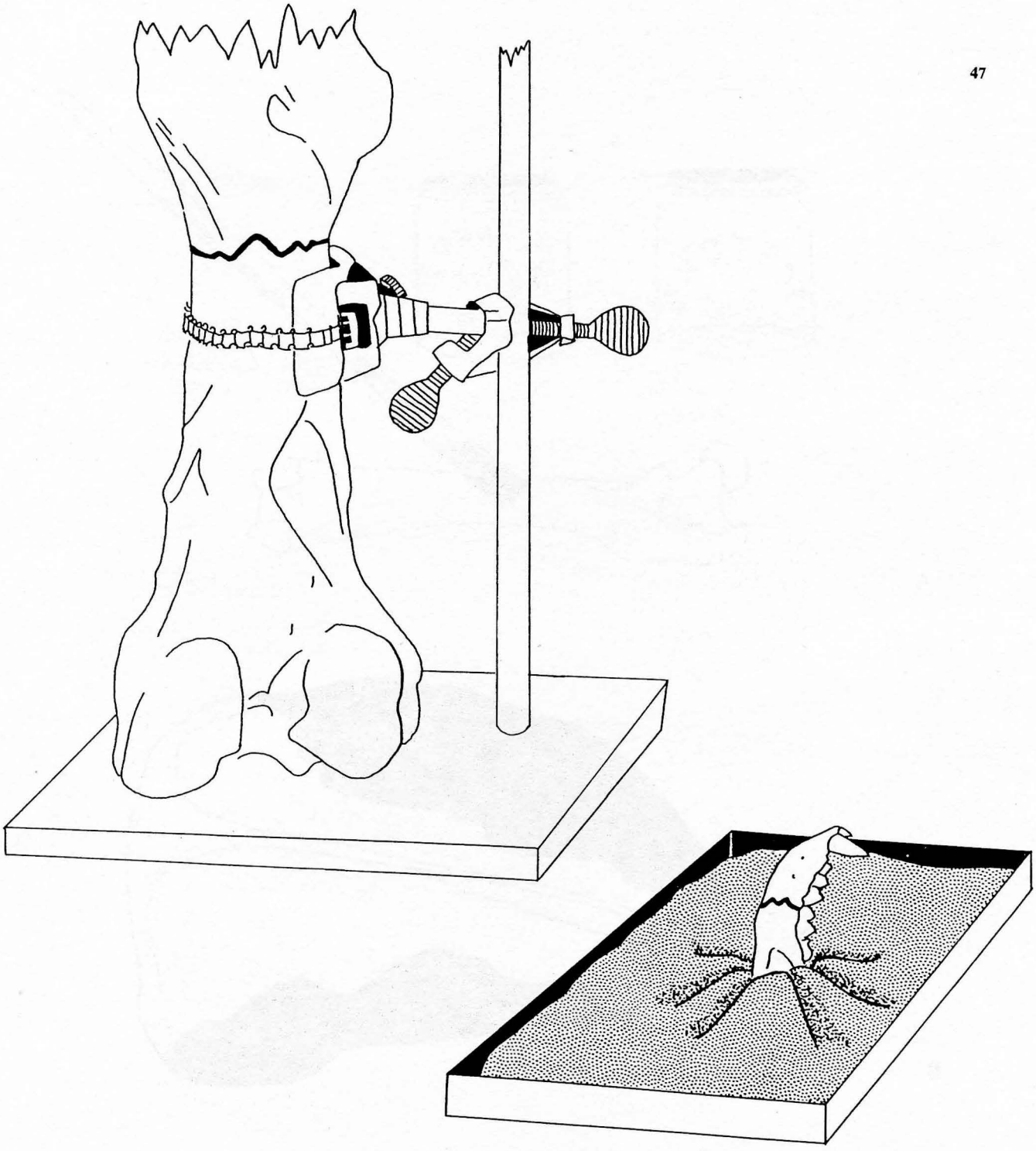


FIGURE 5-5. Ring stands and sand boxes are excellent supports during the repair or restoration process.

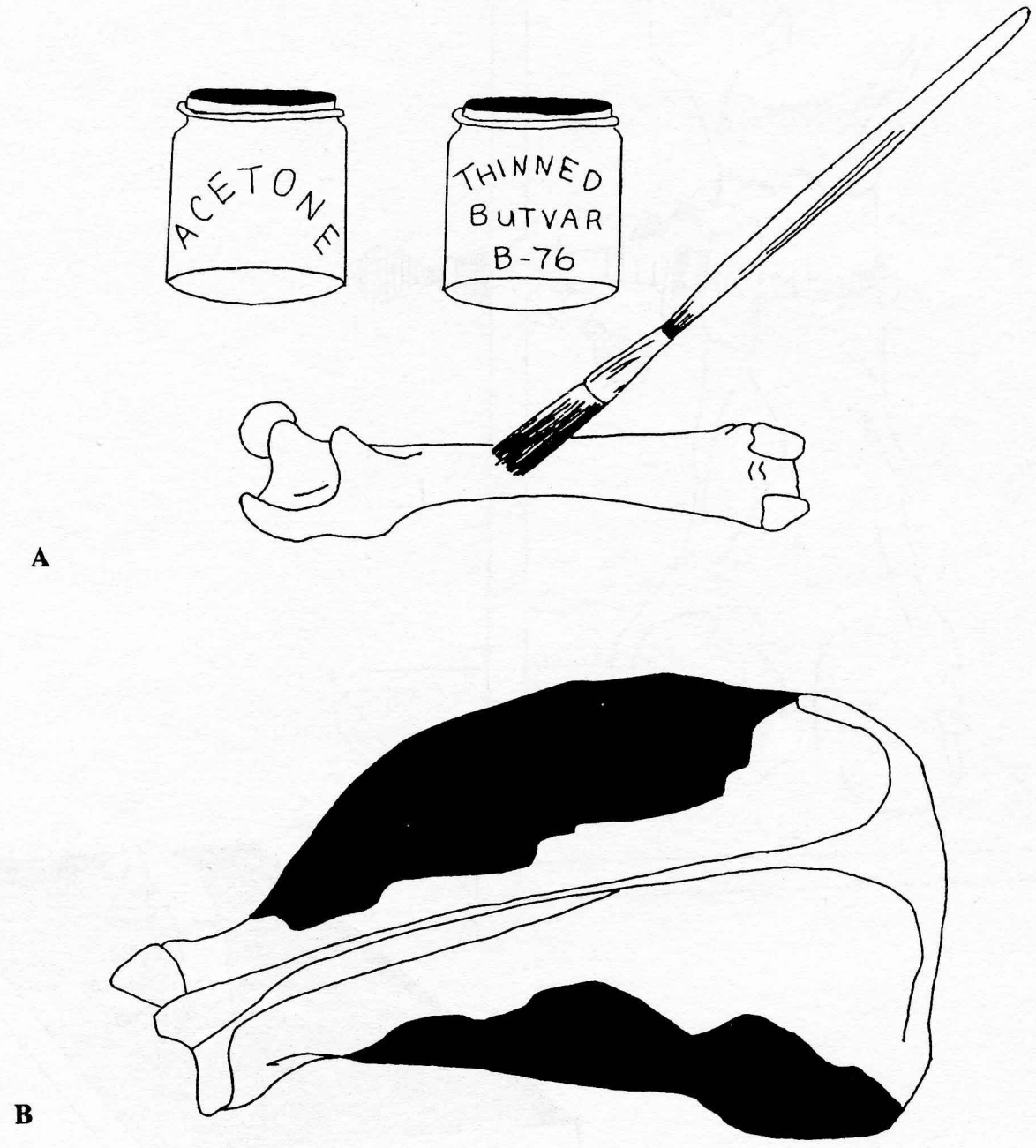


FIGURE 5-6. **A, a protective coating of consolidant is usually required for most fossils. B, missing portions of specimens can be easily replaced with a mixture of maché and plaster.**

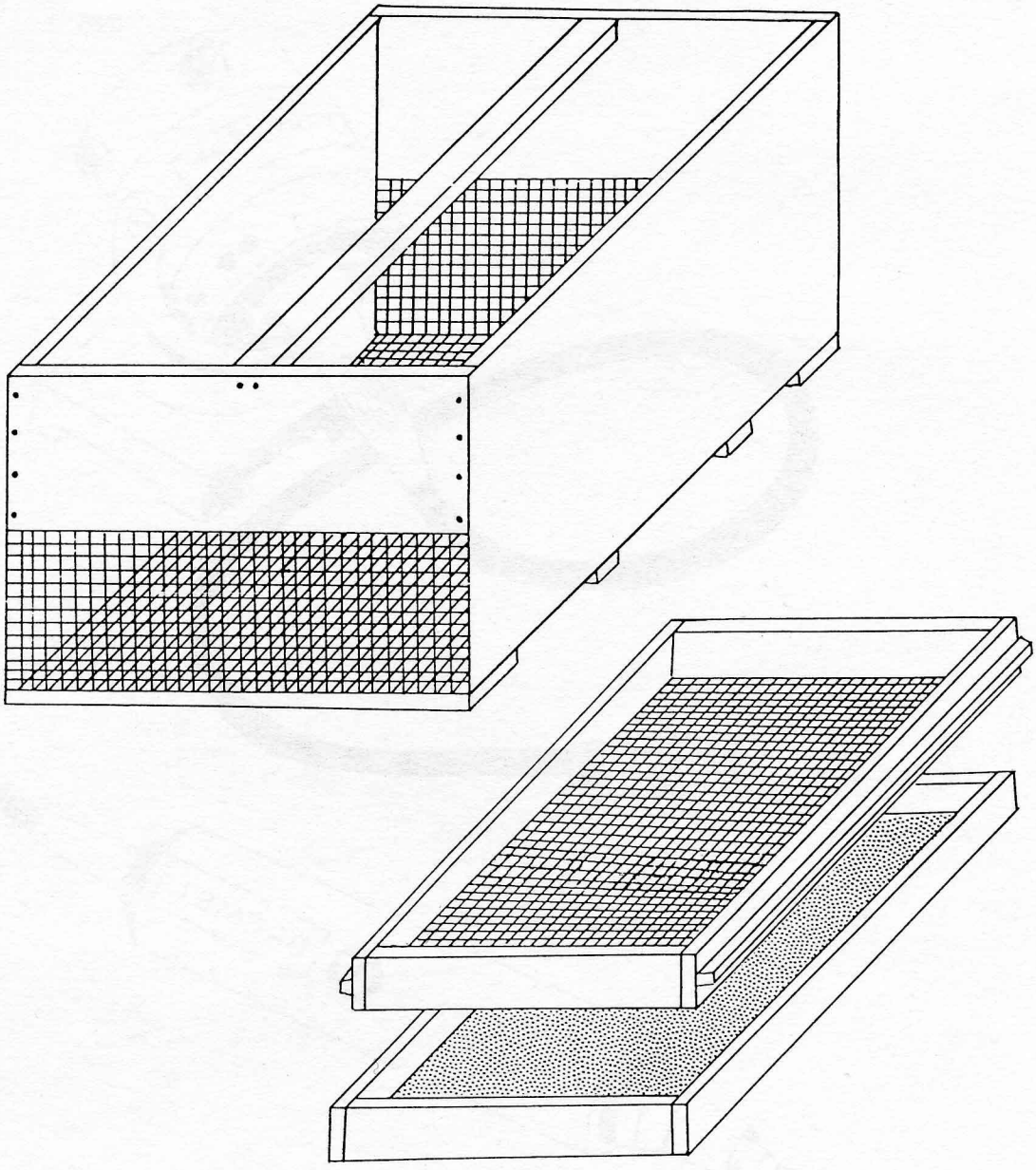


FIGURE 5-7. Top, large field screen box to use in rivers and ponds for washing fossiliferous sediments. Bottom, smaller laboratory screens nest together so larger rocks and debris on top can be separated from the finer sediments and microfossils on the bottom.

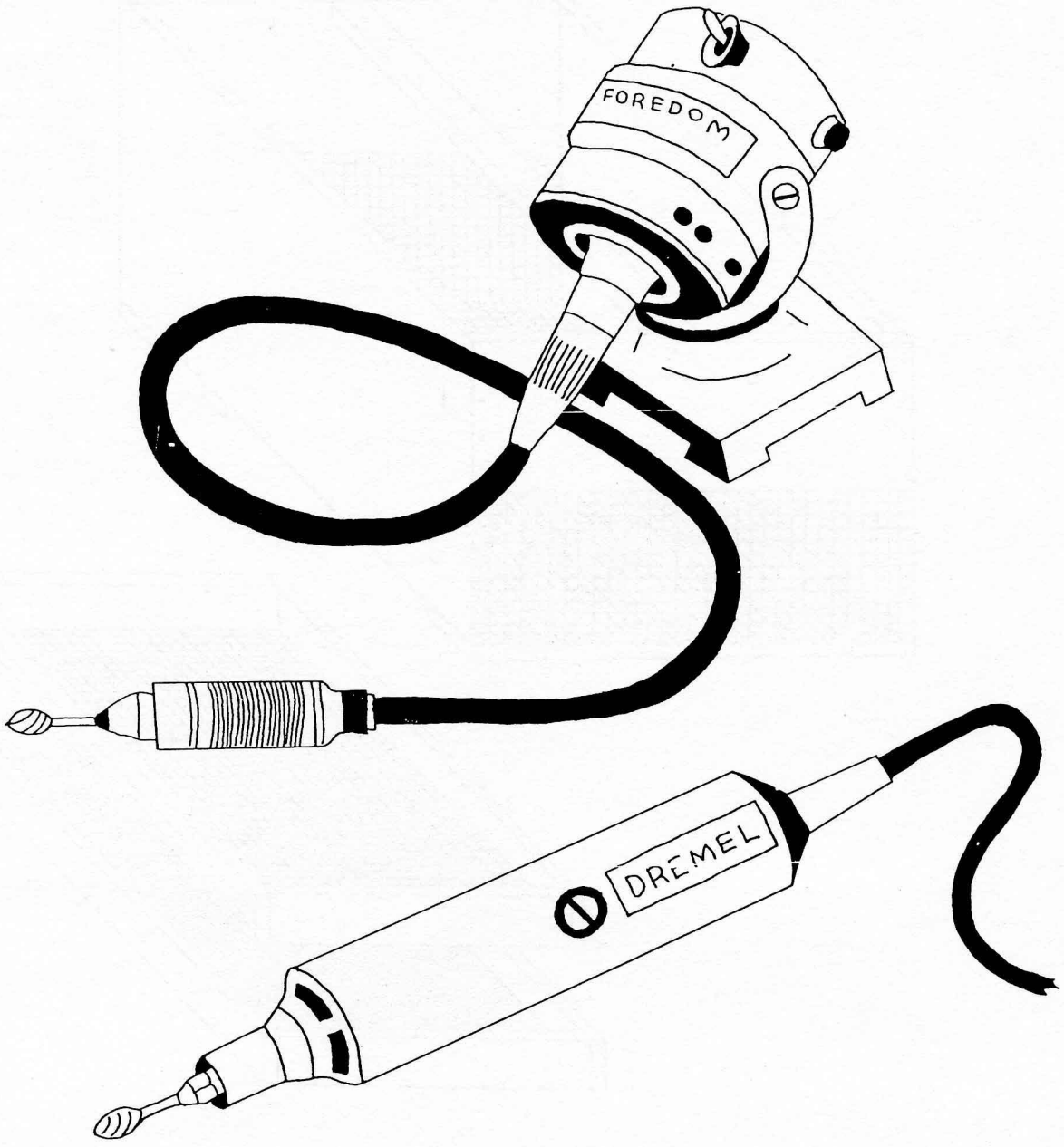


FIGURE 5-8. The Foredom flexible shaft motor tool and the Dremel hand-held motor tool are used for the mechanical grinding operations of fossil matrix.

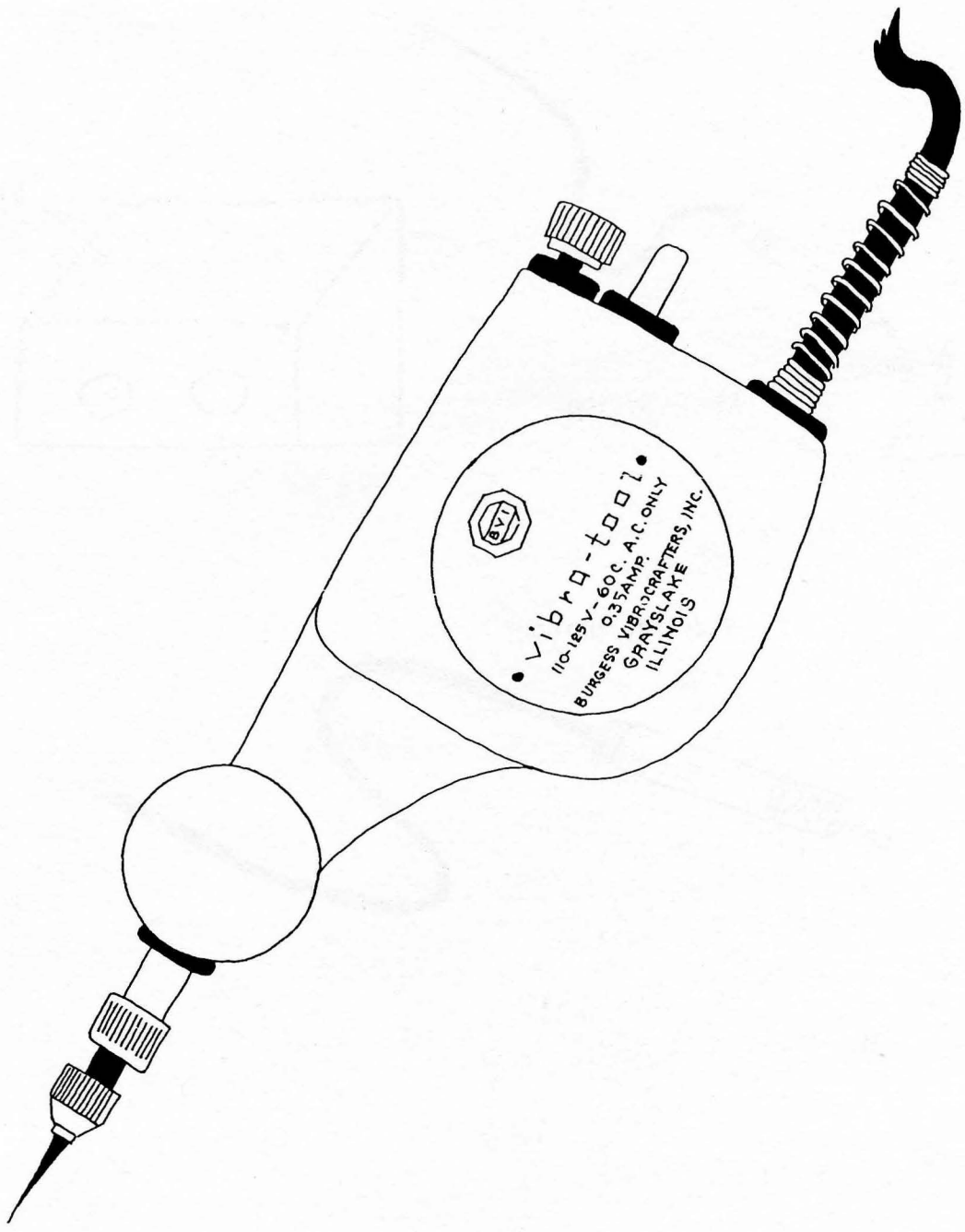
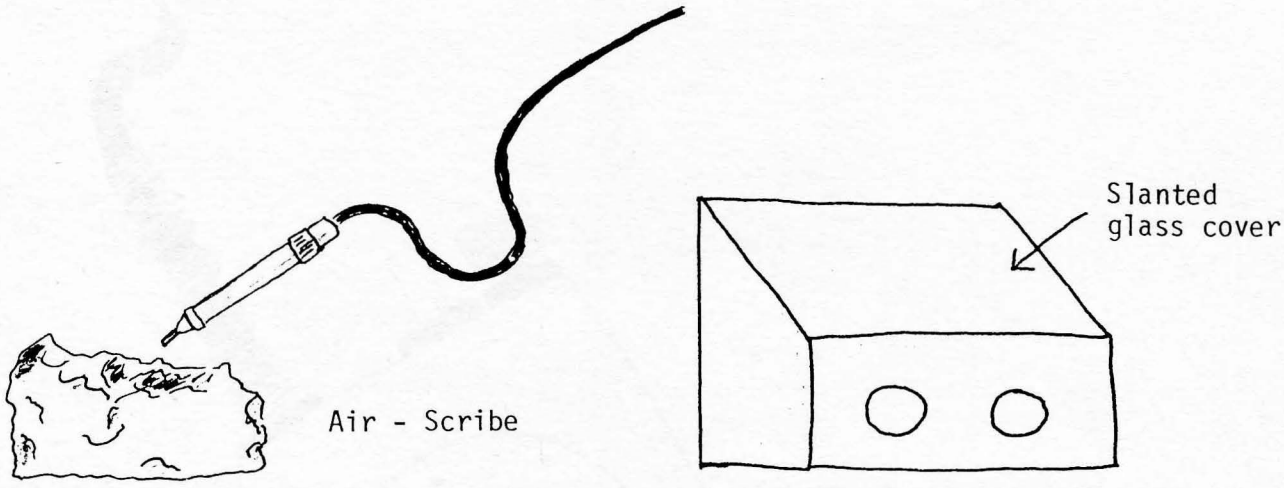
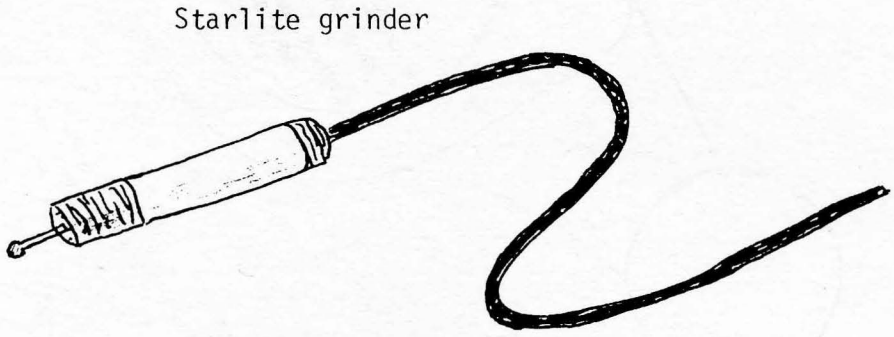


FIGURE 5-9. The Vibrotool incorporates a pointed tip with a vibrating motion that lightly chips away matrix from around the specimen.



A



B

FIGURE 5-10. A, Air Scribe and work chamber for small pneumatic tools. B, Starlite grinder.

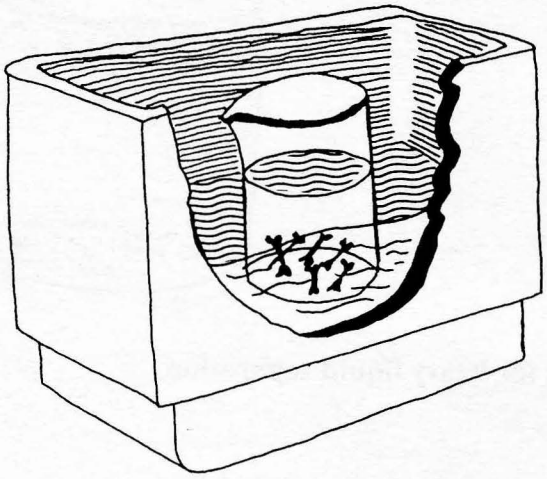


FIGURE 5-11. Ultrasonic cleaners are used to vibrate matrix and sediments from around fossils by using sound waves having a frequency above the audible range of humans.

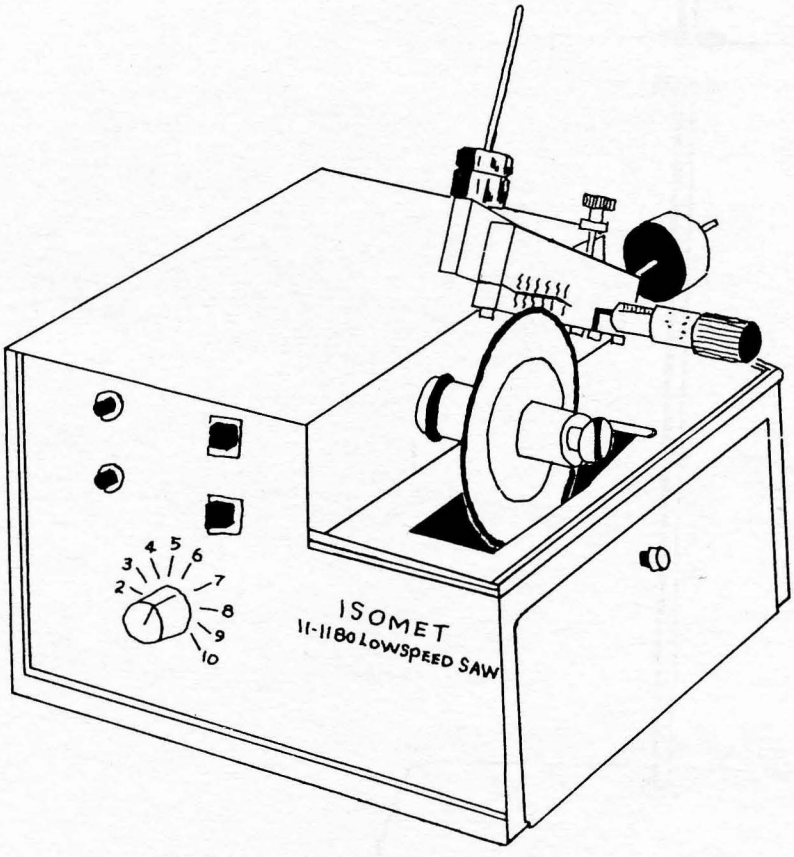


FIGURE 5-12. The Buehler Isomet diamond wafering machine has superior cutting capability and allows retention of sample integrity and character by avoiding distortion or damage. Wafer-thin cutting is performed with a minimal of cutting loss.

FIGURE 5-13. The beaker method for heavy liquid separation.

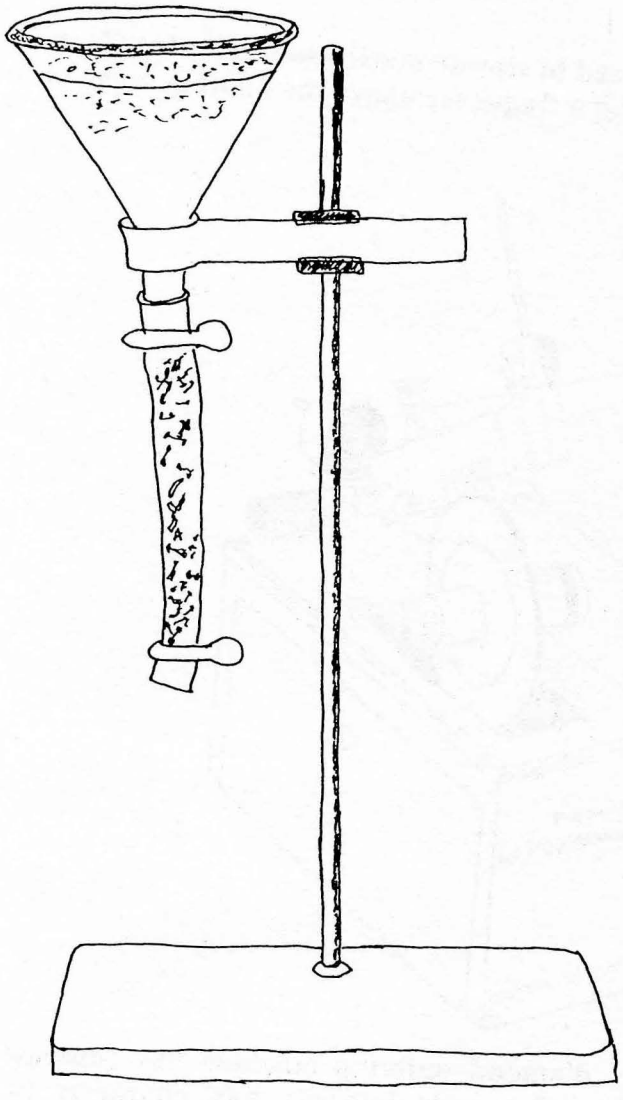


FIGURE 5-14. The funnel method of heavy liquid separation.

Chapter 6

RESTORATION OF FOSSILS AND EXHIBIT PREPARATION

Restoration of Fossils

In restoring and exhibiting fossils, the basic scientific skills of preparation become interwoven with artistic and interpretive skills. Before beginning the task of restoring a fossil for exhibition, the scientific as well as educational goals of the project must be clearly defined. The preparator also must take an inventory of the fossil material at hand and realistically evaluate its potential. For instance, if you found that you only had the lower jaw, one femur, one radius, and several vertebrae of a mastodon, it would be impossible to reconstruct a complete mastodon. Certainly it is possible to sculpt and fabricate missing portions of a skeleton, but there are limitations which the preparator must acknowledge. These limitations should, of course, include the preparator's level of skill and the availability of comparative specimens with which to judge the progress. Artistic skills are of little use if the preparator has no knowledge of anatomy and osteology. Granted, there is something called "preparator's license" that allows for some degree of individual interpretation in the final outcome of a restoration, but speculation and runaway imagination have no place in scientific restoration.

It may be assumed that most specimens will be brought to the laboratory in plaster jackets. The jackets must be worked down following the general procedures outlined in Chapter 5. After all the bones have been consolidated securely together and removed from the remaining matrix and jacket, each piece must be carefully cleaned and glued to its appropriate contact point. Whenever possible use a comparison specimen (Recent or fossil). Many times there are no living members of an animal group, and the specimen may be a new branch of the family tree. Restoration may have to be performed from a published drawing at the family level or contours and shapes derived from other known members of a family group. Regular consultation with scientists familiar with the group are essential. Fortunately, many animals, such as horses, camels, capybaras, large cats, and proboscideans, are found living today, so Recent skulls and postcranial materials are available to use as models in restoring the specimen to its three-dimensional shape.

Specimens such as skulls can be proportioned back into shape with the use of modeling clay. A central core is formed to the approximate shape and configuration of the specimen. Individual pieces or larger sections can be fitted into place on the modeling clay core. As the restoration of the skull proceeds, missing areas may be blended into the rest of the skull using the clay material. Continue this piece by piece construction until the specimen has been returned to its original form. While still mounted on the modeling clay core, make any necessary adjustments required to refine the shape. Once satisfied with the restoration, the clay is carefully removed from under the glued bone sections. Missing areas must have the clay scrapped down approximately ¼-inch and a smooth application of paper maché filler applied. This maché filler is a mixture of paper maché

and plaster of Paris combined at a ratio of 1:1. The surface may be blended smoothly with surrounding bone by using a spatula. This procedure must be performed until all missing areas have been filled with the maché filler material. Now continue removing all of the modeling clay from inside the skull until a hollow specimen remains. Coat the entire specimen with a thinned solution of Butvar B-76 to seal and harden the bone and maché filler (Figures 6-1, 6-2).

Long bones or any other post-cranial specimens may have this same procedure applied for complete restoration. Many times the use of Butvar consolidants do not give the necessary strength required to hold two pieces of a large specimen together. The use of an epoxy compound such as Marine-Tex should be employed.

When skull specimens have been crushed flat, the risk of creating a jigsaw puzzle is greatly increased. It has been found that a photograph of the top and bottom of the specimen aids in relocating the bones when several pieces must be removed for cleaning. Each piece within the photograph may be assigned a number, and corresponding numbers are marked on the proper piece of the skull. Use a marking device that can be easily removed from the bone such as standard pencil. This procedure is much like painting a picture by numbers, but instead you are actually working with a three-dimensional specimen (Figure 6-3).

There are times when true basket cases are brought into the laboratory. The preparator is advised that it represents a nearly complete skull but is only an assemblage of fragmented bones. With great patience each piece must be studied and the possible contact points searched out. The many long hours required in attempting to reassemble the specimen are a preparator's nightmare.

When restoring both halves of a mandible, repairs should be done while it is still in the plaster jacket. Usually the ascending ramus fragments vary due to its very thin walls. Also, most specimens usually are separated at the symphysis and packed together in the matrix. Many times distortion occurs, and these twists and distorted contours must be straightened. This may involve carefully removing many pieces from the mandible and realigning the sections. Due to the delicate nature of the symphysis area, reinforcing rods may be required between the two halves of the mandible (Figure 6-4B). This reinforcement keeps the two halves from flexing which may cause breakage at the symphysis region.

When fossilized, ivory tusks become very fragile and tend to separate along each of the growth ring interfaces. When working with just sections of tusks, a good bonding agent, such as Butvar B-76, is required and is allowed to penetrate deep between these growth ring layers. This usually is all that is necessary to hold the specimen together. Large, complete, or nearly complete tusks will require much more preparation. Specimens found in the far north, such as Alaska, are solid like recent ivory. Only a wash of a thinned consolidant is required to fill any small hairline cracks. Ivory that has been exposed to pressures while in the earth or those exposed to weathering usually start crumbling and splitting at each growth ring interface. When found in the field in this condition, a plaster jacket must be carefully applied and the jacket brought back to the laboratory for further preservation. While still being cradled in the plaster jacket, seal all internal cracks with a suitable consolidant. Remember, if the specimen is wet, Butvar B-76 cannot be used. Use the white polyvinyl acetate (white glue) and allow it to flow deep into all cracks. The specimen may require additional support once the glue has dried. The bottom portion of the plaster jacket can be used for support while being sealed and makes an ideal cradle for storage on the collection shelf. Simply cut away all excess jacket material until the specimen is cradled in a strip its own width.

Wire banding may be required to bind together the many cracking growth rings. These bandings were used commonly on ivory tusks that were required for elephant mounts. Today most of the original ivory tusks have been replaced with lighter weight fiberglass copies. The bands are carefully wrapped tightly starting at one end and coiling around the tusk with approximately 1/2 to 3/4-inch spacing between each band. Once tightly in place, a coating of consolidant is applied to bond each band to the tusk.

Reinforcing rods may sometimes be required to strengthen otherwise weak joint connections. Holes are usually required to fit these rods between the joint. These holes can safely be drilled using carbide-tipped masonry bits. It is better to use a hand operated brace or an electric drill if used at a low speed. Each hole should be deep enough to provide good support; the size of the specimen will govern this depth. The rod or rods are locked in place by putting a small amount of epoxy in the holes and sliding the rod tightly in place. Allow the epoxy to set before proceeding. Once dry, slide the rod or rods into the matching holes in the opposite joint and epoxy tightly together.

Many fossilized teeth are discovered in eroded gullies or spoil mounds and have been shattered into many pieces. All possible pieces, no matter how small, should be collected and placed in either a plastic bag or vial. They may seem beyond recovery, but with proper care a good specimen can usually be saved (Figure 6-5).

At the laboratory the fragmented pieces are sorted by the different forms of material present. Enamel is easily distinguished from dentine and root material and can be separated. Each form of material should be sorted and kept in separate piles to the best of one's ability. The crown ridges and cusps are usually in larger pieces, so the tooth crown is the best area to start assembling. A small amount of Butvar B-76 is all that is required to tack each contact together. To find a good tight contact, the broken edges are compared and when contours of one are found to fit the contours of another, it may be assumed that they join. Magnification helps distinguish texture or grain orientation, and usually one can tell at a glance if it is a good contact or not. Shape and color also play an important part in determining a contact point. There are times when the internal dentine either has been eroded away or simply crumbles. This inner portion of the tooth can be filled using plaster of Paris or maché material. Use caution not to overdo filling of the cavity or other contact points cannot be met. On nearly complete teeth, the area being filled is hidden by the enamel crown or the root assembly. As the assembly progresses, it may become necessary to use a sand box to help hold the assembly in the proper position.

After all the crown pieces have been glued back together, work continues down to the roots. The roots of teeth break in a different manner than enamel due to the higher density of enamel. Enamel has an approximate density of 2.8 to 3.0, whereas dentine is basically the same as bone at approximately 2.1. Mineral penetration will vary the densities somewhat. Root material has a tendency to crumble more readily than enamel, thus causing smaller and additional pieces to assemble.

As mentioned earlier in the chapter, a general knowledge of anatomy is essential for the restoration of any vertebrate fossil. As is the case with many Florida sites and others around the country, the fossils are deposited in abandoned river channels or boggy marshes. The bones have become broken and mixed over the ages. Without a knowledge of anatomy much time could be wasted in piecing the fossils back together. In skull material the foramina and suture lines are

readily distinguishable and offer clues as to what might fit together. The proximal or distal ends of limb bones may be recognized and one may separate left from right. Shafts of long bones may be recognized by their thickness or shape. The vertebrae stand out from other bones because they are usually more robust. Ribs are flatter in the shaft regions and the ball of the rib heads are readily distinguished. The above-mentioned fragments are fairly simple to sort, but there are pieces that fit between and cannot be sorted on anatomical grounds. These may be sorted into the various categories by using thickness and color. All of these broken fragments are joined together with an appropriate consolidant, depending upon size and weight, after a good contact point has been established.

Exhibit Preparation

Occasionally a preparator is called upon to assist in preparing an exhibit for public display. The exhibit may range from a few specimens for a travelling educational case to a free-standing fossil mount for a major permanent exhibit.

In preparing fossil material for an exhibit case, the first question is whether all or some parts will use original specimens. Original material is usually very fragile, and one runs the risk of breakage during mounting. Accurate casts can be poured and painted to resemble the original fossil. They are more durable, will withstand a lot of abuse, have proven to hold up better under the vibrations caused by moving the display cases and temperatures of the high intensity display lights, and are easily replaced if vandalism occurs. The original specimen could be lost to the scientific world. The cast, whether plaster or resin, may be drilled, mounting rods or wires attached, and securely fastened without worry of damages occurring (Sizer, 1960). Many times there may be only one good specimen of a certain animal in a collection. Here again, a cast leaves the specimen free for scientific study.

If an original fossil is required for the exhibit, a good consolidant hardener must be applied to make the specimen stable while away from the collection. Apply the hardener in thinned coatings and continue to apply until a slight glaze appears, but avoid getting the consolidant so thick that it has a bright glossy surface.

When the specimen is small and not too heavy, it may be fastened to a case panel by gluing with silicone caulk. The silicone caulk is stable enough to provide a tight bond for many years and is simpler to remove than any other glueing agent. Any sharp blade will severe the specimen from the panel, and the remaining silicone can be rubbed off by finger action.

When a complete mount is required for public exhibition, careful study and planning must be done first. For many years fossil remains have been assembled and mounted with iron rods that were either welded together or held with nuts and bolts (Bessom, 1963). These time-honored techniques have proven to provide many undesirable features. They were formed at the outside surface of the bones, but concealed as much as possible. The scientific world had much difficulty in dismantling them when scientific study was demanded. When dismantling has been necessary during the last several years, the newer internal mounting techniques have proven to be superior (Barthel, 1966). In this text the older method of external bar mounting will not be discussed, but the procedure for internal mounting covered.

Seldom are two fossil mounts preserved or prepared exactly the same way. Several considerations must be carefully thought out. When internal supports are used, the bone must be drilled, broken, repaired, and restored many times. With each break there is always some loss. First, the specimen to be mounted must be laid out in the workshop (Gilpin, 1959). If there are major missing areas, the collection should be searched for replacement specimens of similar size and shape. Composite skeleton mounts are quite common at most major museums around the country. A survey of the missing portions to be manufactured is studied. Major missing components such as sacrum, pelvic, limb elements, and vertebrae. They are the first to be mounted and serve as the foundation for assembling the other component parts (Figure 6-6).

Next the structural pose of the mount must be considered. A simple walking pose is common for most mounts. Action is sometimes desirable to add life to an exhibit. The desired pose will govern the proper curvature of the spinal column and the lengths of the limb supports. The spinal curvature should be studied and carefully plotted out before any attempts are made to bend the metal bars required. If in doubt as to what diameter the main support bar should be, contact a structural steel engineer for advise. One might be dismayed at the sizes required for very large mounts such as dinosaurs. A rod of 1½ inches in diameter may be.required. For small mounts of no more than a foot or two in height may only require brass welding rods for mounting. One specimen at the Florida Museum of Natural History, a *Parahippus* horse mount, required ¼-inch diameter brass rods to support the collie-size mount.

With the spinal curvature laid out and the proper thickness of the mounting rod selected, a decision must be made on the area through which the rod should run. Many times the spinal mounting rod may be run through the neural canal. If this is impossible a hole must be drilled through the center of the vertebra centrum. All vertebrae must be drilled and proper alignment maintained. Carbide-tipped bits are essential for the drilling operation. The bit should be powered by a slow speed electric drill. High speeds could shatter the specimen being drilled. For later drilling operations, this same type of carbide-tipped bit will be required and must be braced onto longer shafts so as to be able to penetrate through the long bones.

Drill the mounting holes into the vertebrae and start the threading process on the mounting rod. A filler material will be required for the spacing of the vertebral discs. Pieces of felt work very well on smaller mounts. Many other forms of material may be considered when mounting larger animals. Once all the vertebrae and discs have been mounted on the main support rod, the careful alignment of the spinal column must be checked. When the shape or bone alignment does not conform properly, all the bones and discs must be removed so adjustment can be made to the rod. Extremely large mounts sometimes require a forge to enable the preparator to perform these slight adjustments. A good set of heavy-duty pipe benders work well for medium to small mounts. After all adjustments are made, each vertebra is locked into place on the metal bar with a strong epoxy material. This insures the vertebrae will not slip at any time while on display or during movement from the workshop to the display hall.

Next the limbs must be plotted and rods shaped to the proper pose. Must mounts require some very sharp bends to be made in the mounting rods. A simple walking pose for many animals still require these sharp bends. Usually the bones at the upper and lower ends of this rod can be drilled and slid over the rod. The bone in the center must be split or drilled out to be able to fit around the rod. Good bone articulation must be maintained at all times during this mounting operation. Any misalignment must be corrected before continuing any further in the mounting of each limb assembly. Epoxy should be used for attaching the assembled limb bones together. Each

forelimb and hindlimb assembly are to be mounted on an individual rod. These rods will slide into sleeves welded to the vertebral column rod. A set screw is used to lock each limb assembly in place.

In mounting the hind limbs, the femur must be drilled. This bone is usually relatively straight and a drill shaft can normally run through without damaging any external features. The rod that threads through the femur will require little bending at the lower end. Working through the tibia does require some special care. Usually a fairly sharp curve must occur at the articulated surface between the femur and the tibia. This bend may make the threading of the tibia impossible. The bone may require splitting longitudinally and formed around the mounting rod. The center of the tibia may need to be ground away for the necessary clearance around the rod. The fibula will be epoxied in place on the tibia before continuing into the astragalus, calcaneus, navicular, cuneiform, and cuboid assembly. This assembly is fitted to the rod by grinding clearance slots in the necessary components and epoxying in place. A good tight articulation must be obtained with the astragalus cradled properly with the tibia. In most animals the balance of the assembled bones are simply glued together. The metacarpals and phalanges are epoxied to their appropriate articulate surface. Ungulates have greatly modified their hind limbs. The horse has a well-developed calcaneus and astragalus. A flat navicular lies just distal to the astragalus. A cuboid, a large flat third cuneiform, and a small bone represent the fused first and second cuneiforms, forming the distal row and articulating with the third metatarsal, which bears one digit with three phalanges (Figure 6-8). The metatarsal and phalanges must be drilled and threaded with their proper articulated surface on the mounting rod. Two vestigial metatarsals are present in the late fossil forms of horses, but are complete side toes in the primitive or early forms. These, if not already connected to the third metatarsal, are normally glued in place. Several tiny sesamoid bones are present on the posterior base of the digit. These too are glued in place.

In the ruminants, two functional fused metatarsal are present and support two complete digits of three phalanges each. Usually the mounting rod terminates at the base of the metatarsals and forks running through the two digits and into the mounting platform (Figure 6-7).

The hind limbs articulate in the acetabulum of the pelvic girdle. In mammals the three elements of the posterior girdle tend to fuse together so that the ilium, pubis, and ischium are not distinct in adults. The ilium is the bone articulating with the sacrum. This portion of the mount requires delicate work. The ilium is usually very thin in most animals, yet it must support the weight of the hindlimbs. A metal bar must be rolled into a diameter that will match the configuration of the pelvic girdle. In larger animals this ring can be embedded into the bone of the pelvic, but smaller mounts will require the bar to be epoxied along the inner surface so it cannot be seen once mounted. Usually the pelvic girdle is permanently attached in medium to small mounts to the sacrum as part of the spinal column and the sacrum and pelvic girdle is mounted around the bars. A sleeve with a set screw is embedded into the acetabulum for the attachment of the hindlimb assemblies (Figure 6-9).

The forelimbs are assembled in much the same manner as the hindlimbs, but the attachment to the main mount is different. All mammalian forelimbs terminate at the top with the scapula. This bone in most animals does not connect to the main skeleton frame and is held in place by muscular attachments. In many animals, the scapula is tied into the frame by the clavicle, making it a useful element for those animals that pull with their forelimbs. The clavicle is absent in many ungulates and is present in some carnivores, such as cats, as a reduced and unattached bone.

In mounting the articulated forelimb assembly to the main mount, rods must be run from behind the scapula at the level of the spinal column and into sleeves welded on the main spinal column bar. The limbs can be welded to the main frame in smaller mounts or attached with set screws for the larger ones.

One of the final items to be mounted onto the skeleton is the skull and mandible. For small- to medium-sized mounts this is a fairly simple task. A metal sleeve is mounted within the foramen magnum. This sleeve can be epoxied solidly into the skull to give adequate support. A hole is drilled into the side of the condyle giving access to the sleeve for a locking set screw. The skull with sleeve is slid onto the spinal column bar and articulated snugly with the atlas. Here again watch carefully the alignment to maintain a natural appearance.

The mandible is simply attached to the skull by inserting pins into the glenoid fossa of the skull and into the condyle of the mandible and epoxying in place. Another pin must be embedded into the premaxilla area just behind the incisors of the skull and attached to the mandible in the same location. This gives a three-point support with all attaching bars hidden from sight.

Larger skulls must be mounted with additional supports. The overall weight can reach hundreds of pounds, and for an internal mounted skeleton this amounts to a tremendous weight hanging out in mid-air. Once again a large enough diameter rod must be selected to be able to safely support such a weight. The rod is fed through the foramen magnum and out at the presphenoid region on the underside of the skull. The rod is continued forward over the palatine to approximately the junction of the premaxilla and the maxilla. All necessary bends must be made to conform to the skull contours. Cross bars are formed to the contours of the palate and maxilla regions (Figure 6-10). These cross bars are welded to the central bar forming a rigid cradle for the skull. The cross bars can be anchored into the more solid regions of the bone near the ends of the bars. Expanding anchors can be inserted into predrilled holes and the bars screwed in place. The area running through the skull around the main bar must be filled with a strong epoxy compound to prevent any shifting of the skull on the bar. The main bar is then locked in place through the atlas with a series of bolts.

The heavy mandible will require a three-point connection with the skull similar to the ones used for smaller mounts. The main difference is that a bar complex must be constructed on the inside surfaces of the mandible. The front of the mandible will have a single connector rod that will fasten onto a sleeve welded onto the end of the main skull support rod. The base of this rod will be securely mounted into the front of the mandible. From this point, bars will be run along both inside surfaces to a point near the ramus. Small side bars must be welded in place and mounted securely into the sides of the mandible. The two upright bars will fasten into a sleeve mounted on the rear cross bar of the skull mount. If the configuration of the skull prevents this arrangement, add an additional support bar. Two or more heavy duty bolts should fasten the bars into the sleeve assemblies.

To hold everything in place during the mounting operation of the skull and mandible, scaffolding should be used. This gives adequate support to the specimen and a safe working area for the preparator.

It is advisable to consult a structural steel engineer before attempting to mount a large skull. The individual can remove the risks of disaster by determining stresses and load capacity for the proper size mounting supports.

Many times just an articulated limb assembly is all that is needed for the exhibit. For example, a display showing the reduction from several toes to a single hoof in horses may be desired. Once the specimen has been laid out in the laboratory and a good articulation fit can be achieved, the bones should be epoxied together for small mounts or fastened with metal dowel pins for the larger mounts. For the latter, simply locate the position desired between the two bones. Mark this position and then drill two holes, one for each bone, just slightly larger than the dowel diameter. Insert the dowel and assemble the two bones. Check for proper alignment, make the necessary adjustments, and then epoxy the pins into both bones. After the epoxy has set, then move on to the next bone assembly. Repeat the same process. Calcaneus, navicular, cuneiform, cuboid, and sesamoid bones may be epoxied in place without the use of pins.

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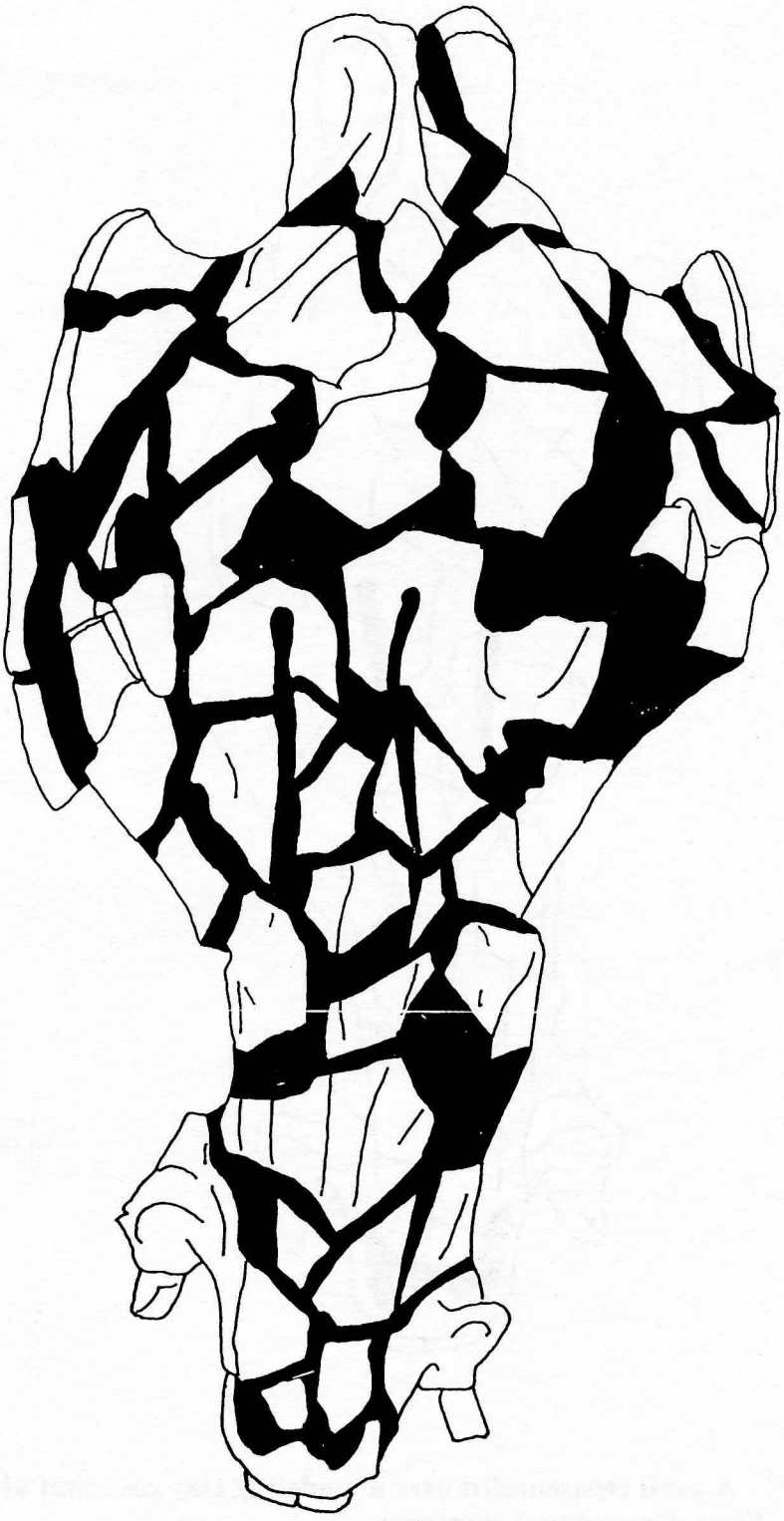


FIGURE 6-1. A crushed skull as removed from the plaster jacket. The matrix is still between the bone fragments.

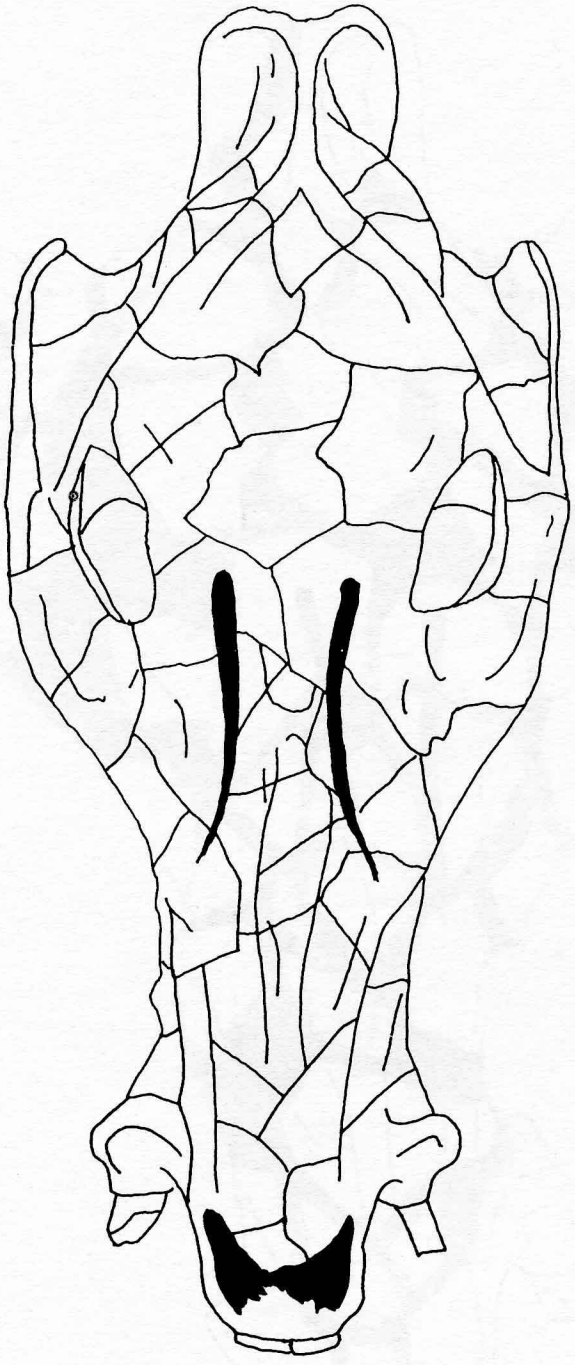


FIGURE 6-2. A skull reassembled over a modeling clay core that aids in restoring the skull to a three-dimensional specimen.

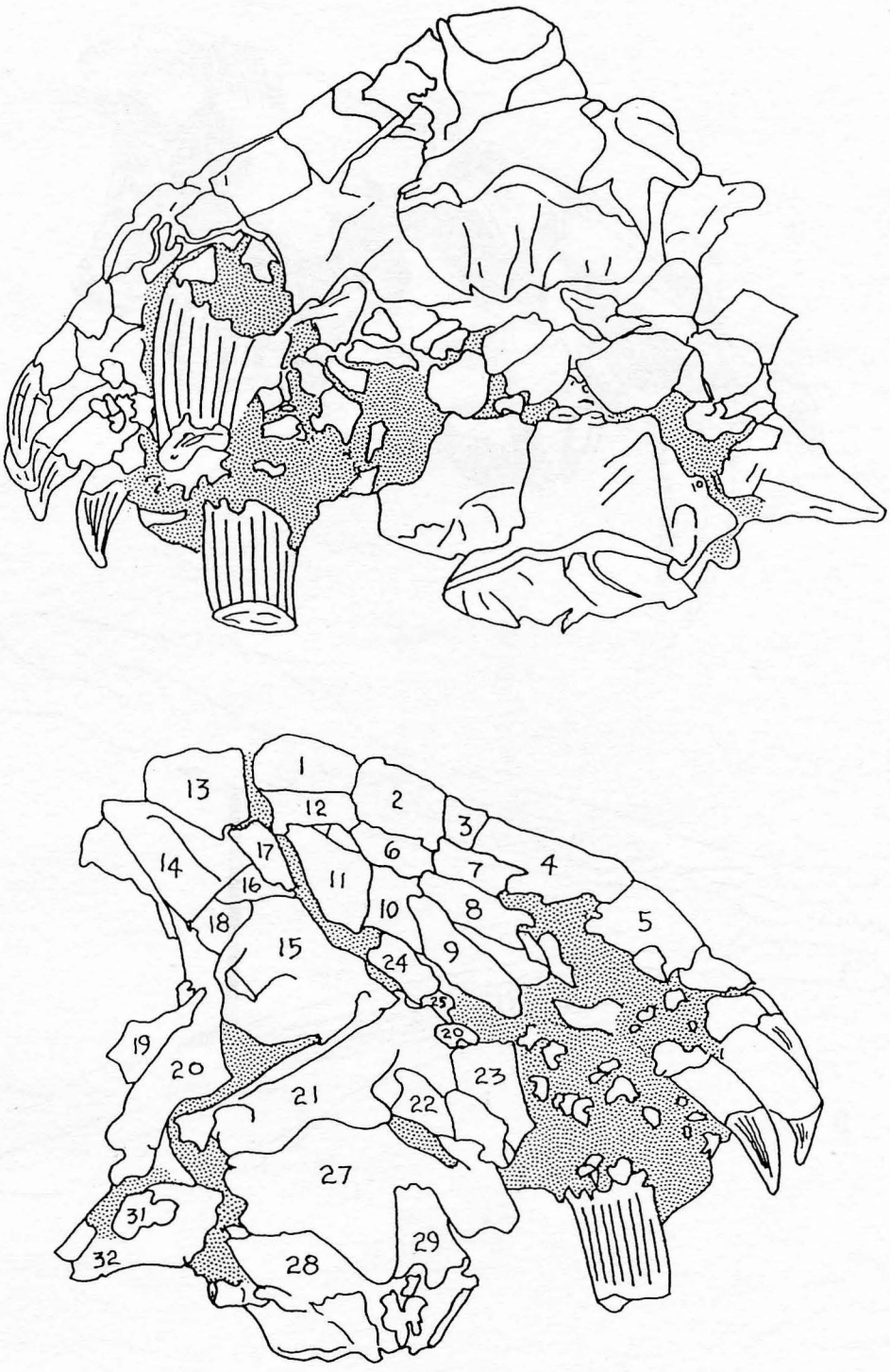


FIGURE 6-3. A flattened, crushed skull as removed from the plaster jacket. Numbering a photo of the specimen and placing matching numbers on the specimen helps prevents the problem of a jigsaw puzzle.

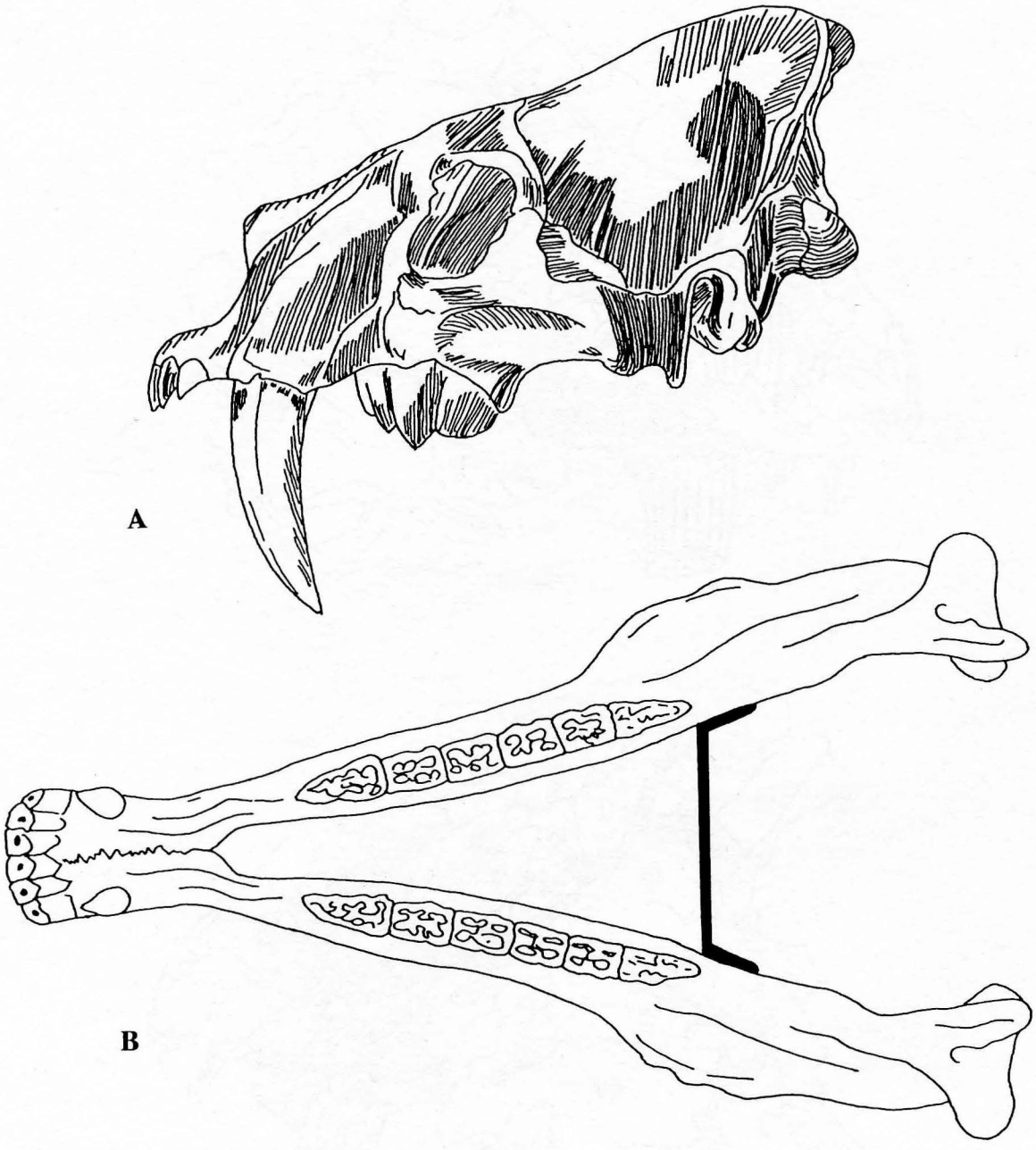


FIGURE 6-4. A, a completed restored skull. B, reinforcing rods may be required between the two halves of a mandible. Epoxy the rod in place.

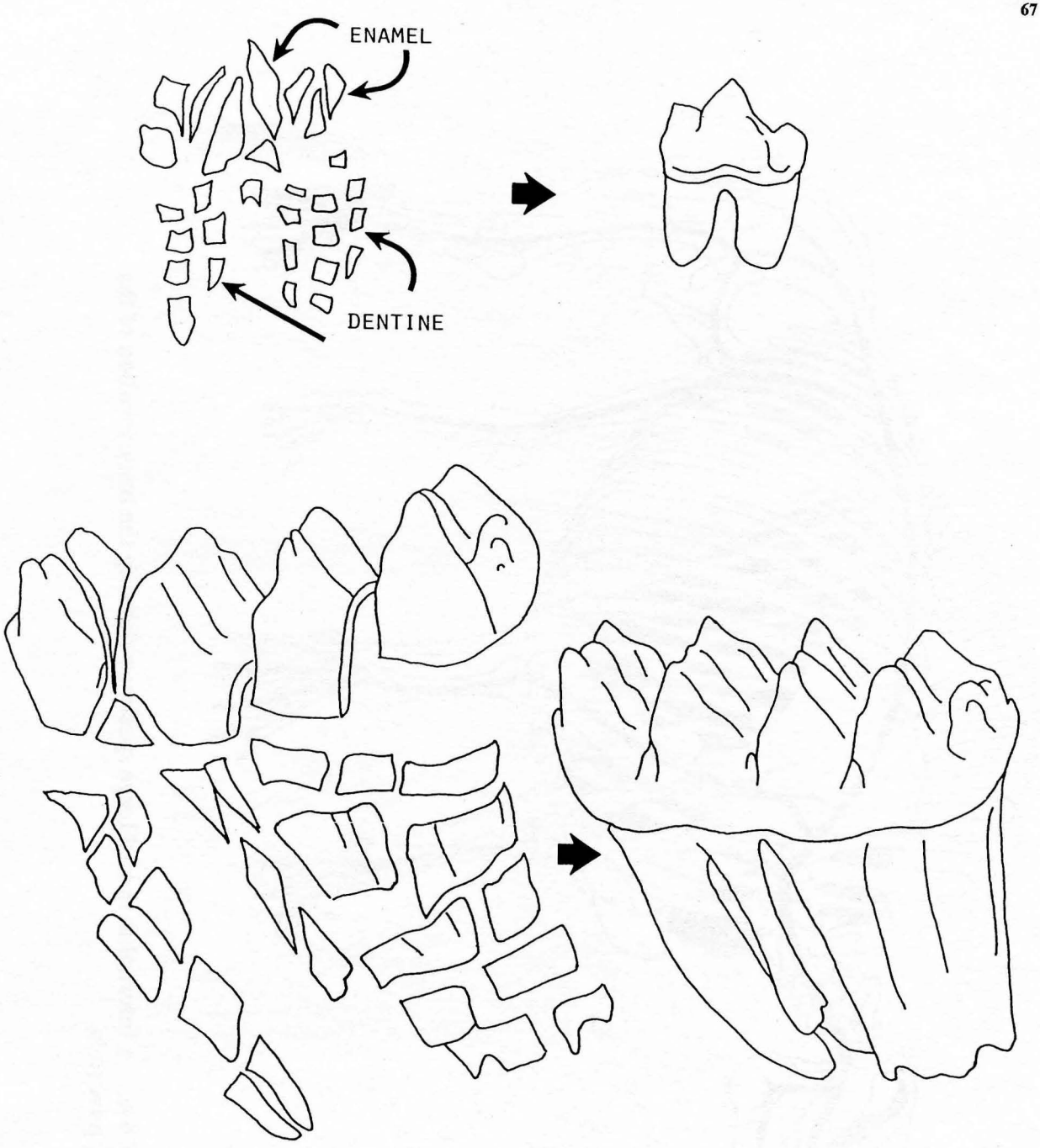


FIGURE 6-5. Extremely fragmented teeth may be saved with proper care. Sort the pieces by enamel and dentine and start restoration at the crown.

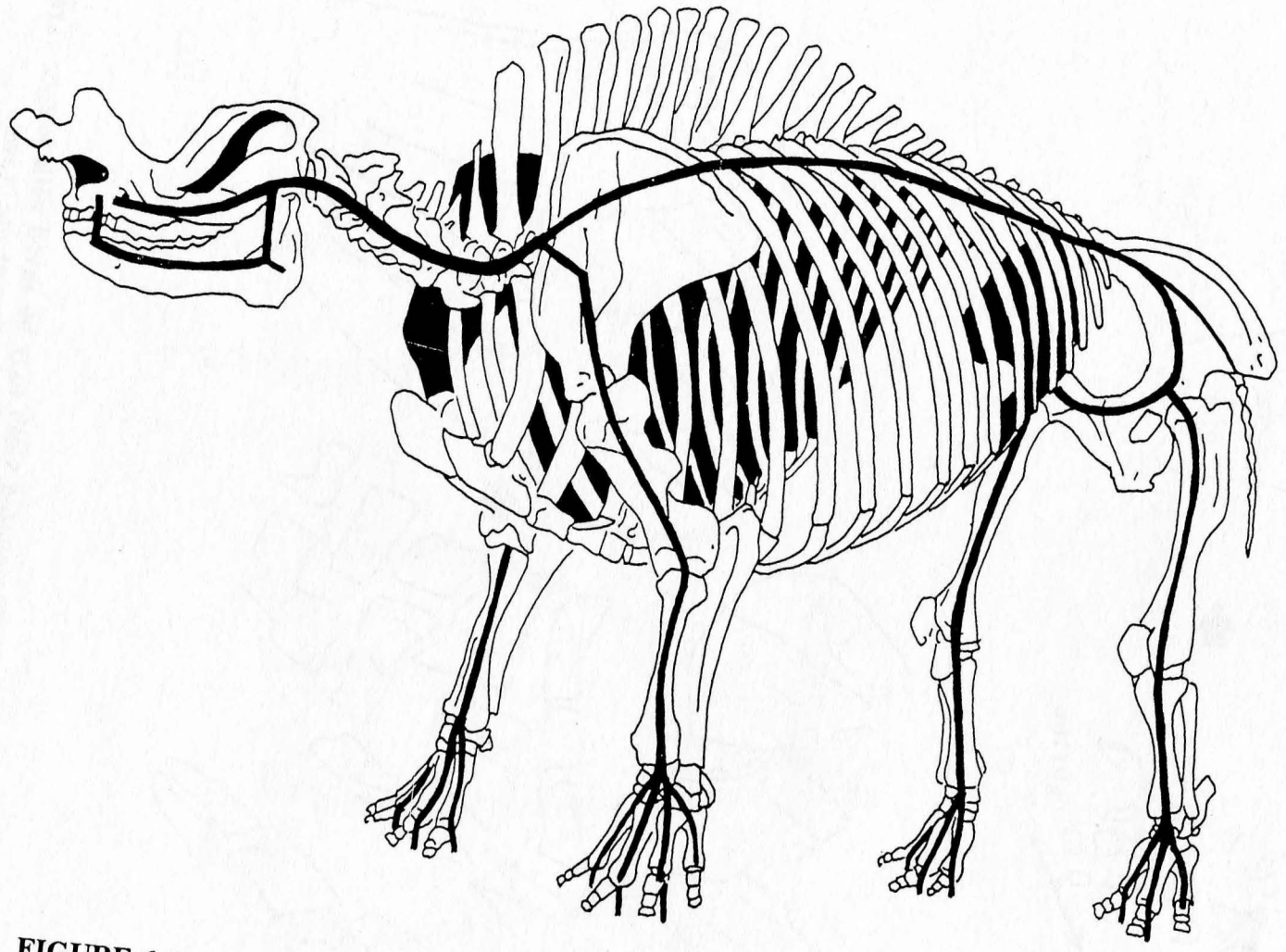


FIGURE 6-6. A internal mounted large specimen showing the basic location of the main support rods.

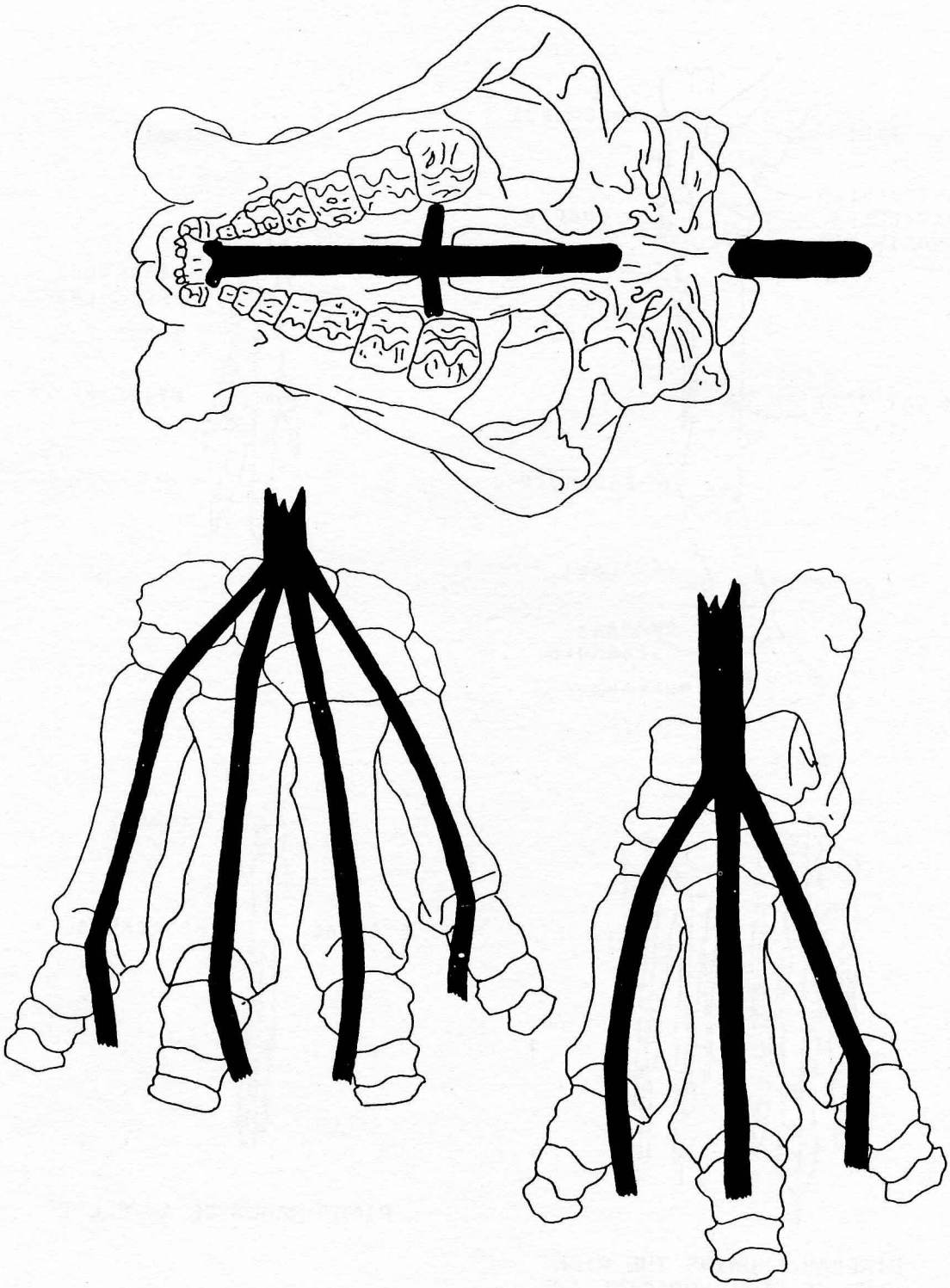
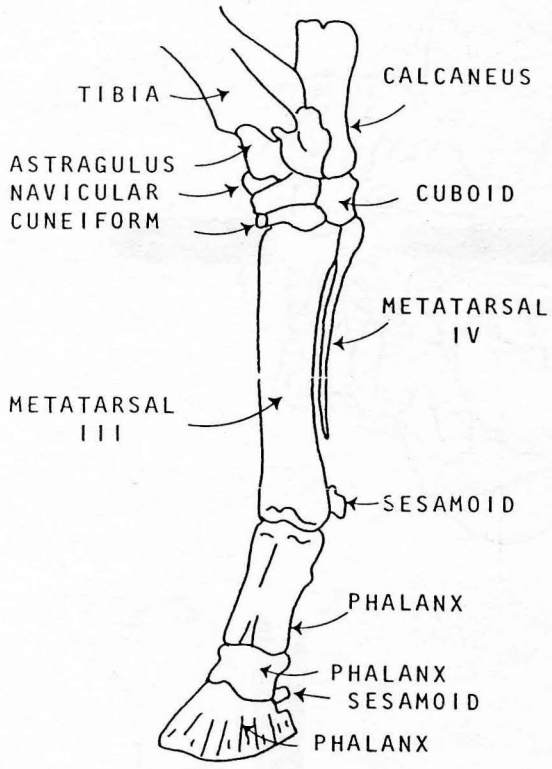
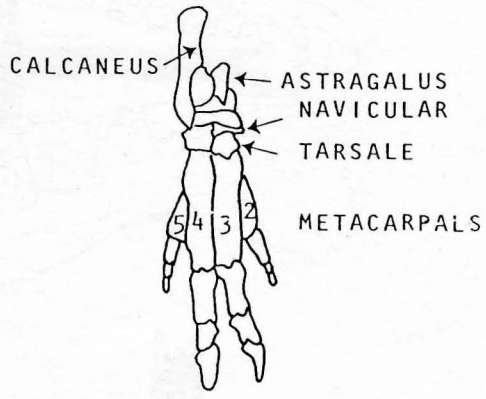


FIGURE 6-7. Bar orientation through the skull, front limbs, and hind limbs for a large mount.



HORSE



PIG

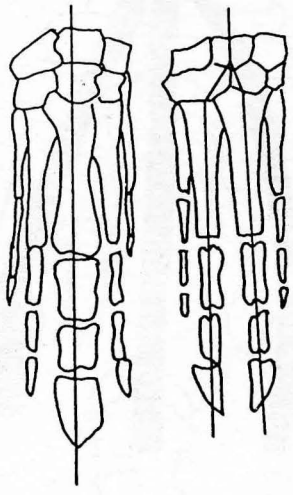
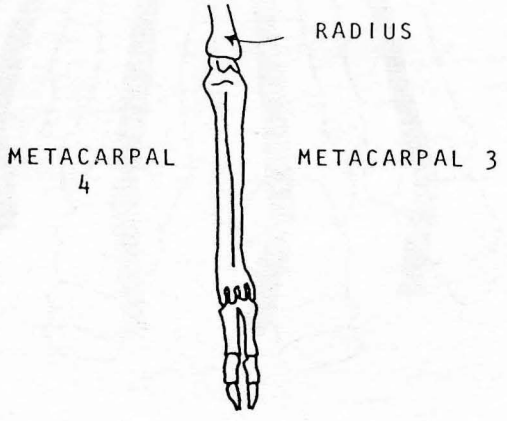


DIAGRAM SHOWING THE RIGHT HAND OF PERISSODACTYL AND ARTIODACTYL.



RIGHT MANUS OF ANTELOPE

FIGURE 6-8. Limb bone articulations.

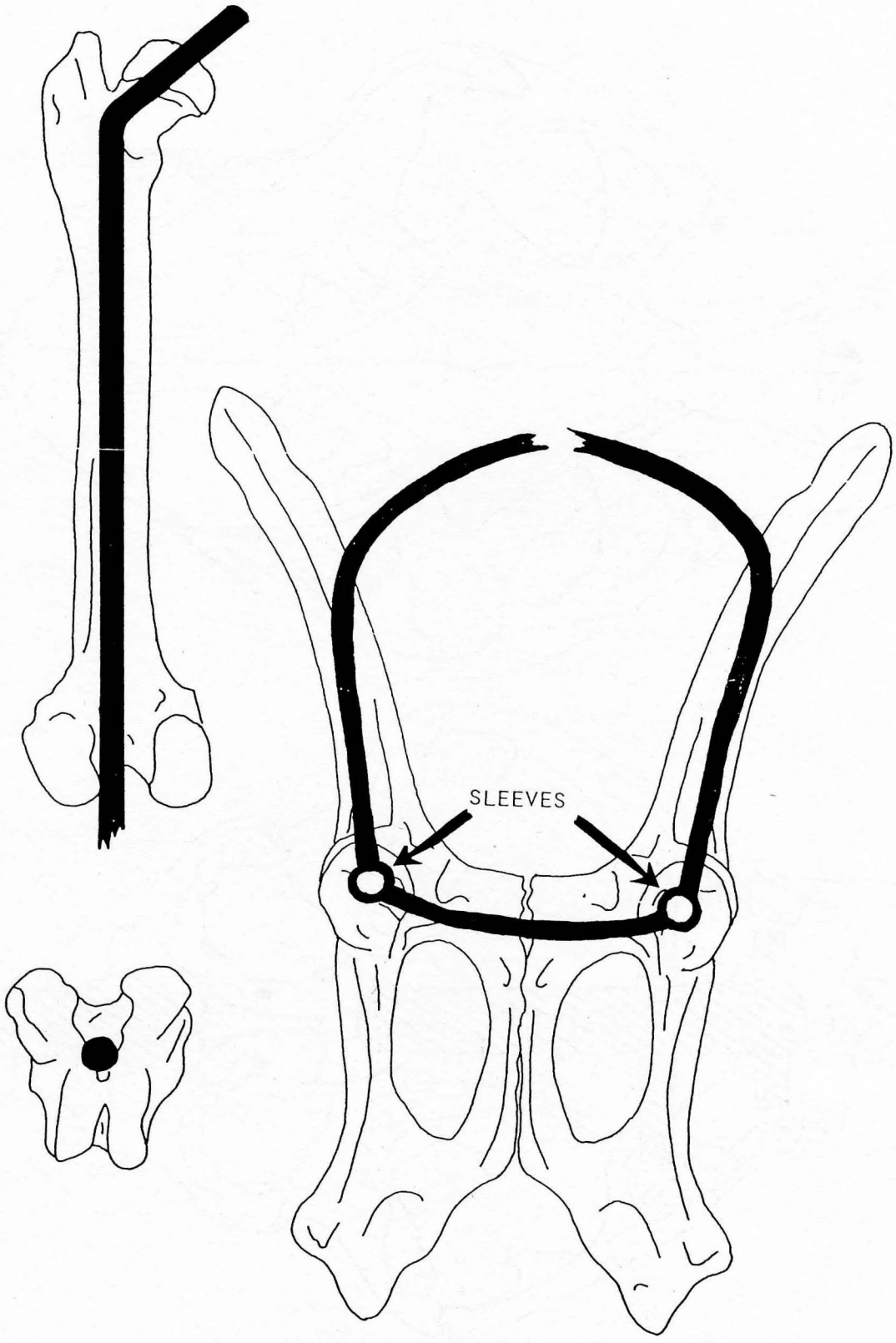


FIGURE 6-9. Bar location through the femur and pelvic girdle. Sleeves are embedded within the acetabulum for the limb attachment.