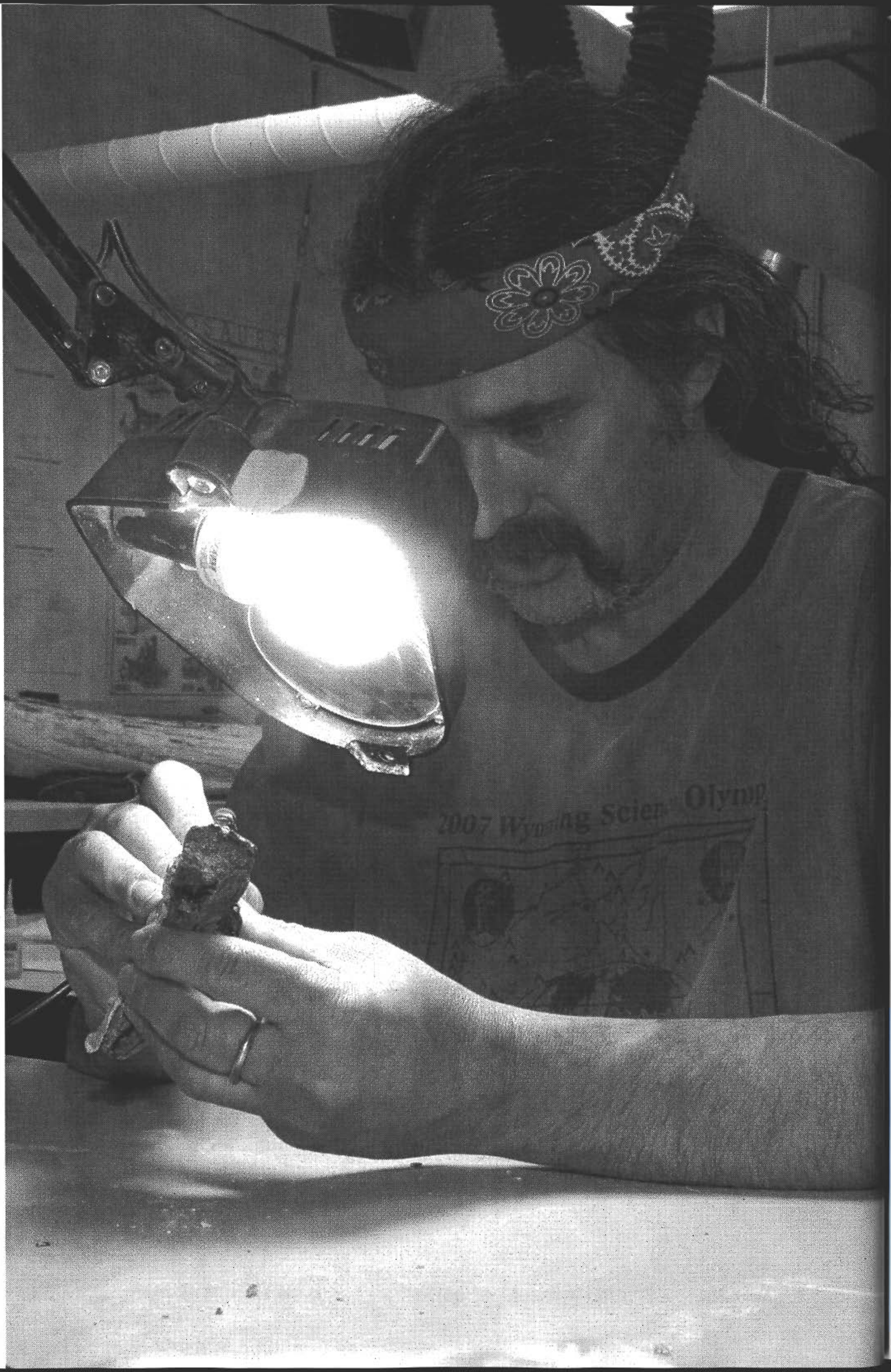

Jean-Pierre Cavigelli - Tate Geological Museum, Casper College

A Primer to Polyethylene Glycol Use in Paleontological Preparation

or

How I Learned to Stop Worrying and Love Prepping Thin and Delicate Bones

Jean-Pierre Cavigelli, Tate Geological Museum, Casper College, Casper, Wyo.

Introduction

What do make-up, toothpaste, suppositories, organic insecticides, soldering flux have in common? Carbowax™. Carbowax™ is a trade name for polyethylene glycols (PEG) and methoxy-polyethylene glycols manufactured by Dow Chemicals. The name is a registered trademark of Union Carbide, which was bought by Dow Chemical Company after the Bhopal incident in 1984. Carbowax™ is available in food grades, including kosher varieties. Its uses in industry are multitudinous. It is in many different products (the list above is just the beginning) and its properties make it useful in the manufacturing of thousands of others. Some of these properties include its low melting point, its nonreactiveness, its lack of odor, its safety and its water-solubility. (Carbowax™ web site)

And what does this have to do with fossils?

Carbowax™ is a water-soluble wax, often referred to as PEG, used to make temporary supports for delicate fossils. Fossils are embedded in the wax, providing added strength and rigidity, so that they can be prepared while minimizing risk to the fossil. The idea is fairly simple. A preparator can prepare one side of a fossil, set the fossil in Carbowax™ with the prepared side down, prepare the other side and finally remove the wax by immersing the whole thing in water. The following is a how-to based on my experience as well as that of others. Its use in paleontology was first described by Rixon (1965).

The Procedure

Figures 1-13 show steps in using Carbowax™ to support a fossil for preparation.

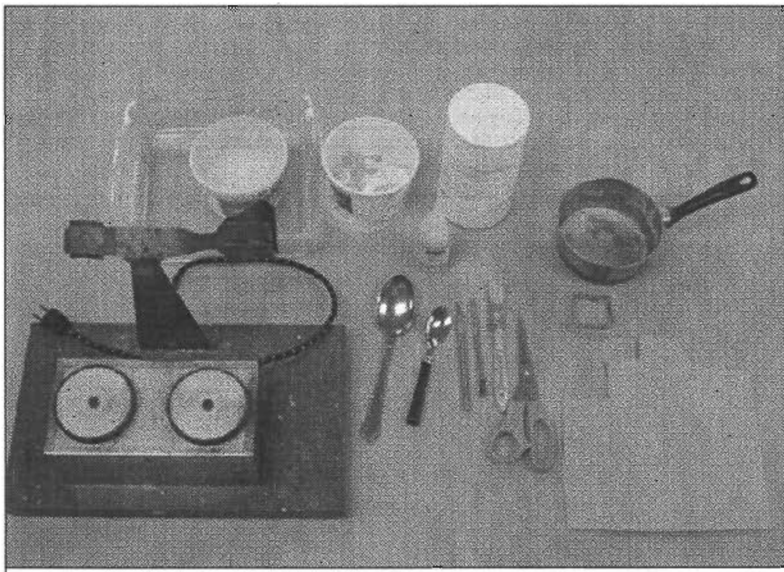

Figure 1. A collection of tools used to mount a fossil in a temporary Carbowax™ mount, and remove it. Front row: a hot surface, two spoons, X-acto® knife, dental pick (sharpened to a chisel point), ½ inch paintbrush, scissors, a Carbowax™ frame, cardboard. Back row: glass baking dish and plastic container, recycled Carbowax™ in container, cyanoacrylate glue, Carbowax™ and pot. Missing from photo: tweezers and razor blade.

The first step is to prepare the fossil on one side and prepare the necessary tools (Figs. 1 and 2). Be sure to stabilize this side of the fossil as necessary. If cracks need to be filled with either glue or epoxy putty, do so. A fossil that will be set in Carbowax™ should not be stabilized with water soluble glue. With a thin or delicate fossil, it is imperative that the fossil be able to support its own weight after it is fully prepared. If there is any doubt about this, it may be more important to leave some matrix on the fossil than to completely remove it from the matrix.

After preparing and stabilizing one side of the fossil, the preparator should make or find a frame for the fossil and Carbowax™. The requirements of a Carbowax™ frame are fairly simple; the base needs

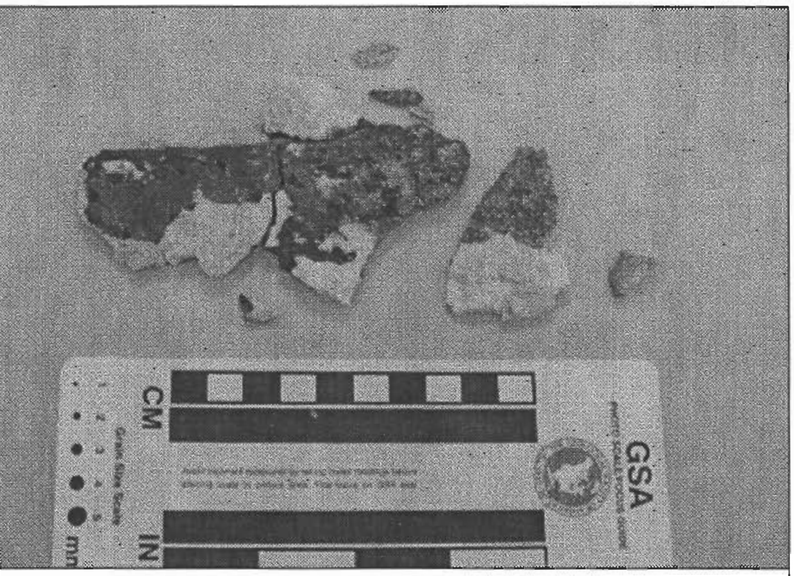

Figure 2. The specimen used in this set of photos is a piece of dinosaur bone from the Morrison Formation. As we were collecting it, it popped off the matrix with only a little bit of matrix stuck to it. In contrast to the procedure described in main text, this specimen has not been prepared on one side first. The specimen was embedded in Carbowax™ to prepare the first side, removed from Carbowax™, then re-embedded to prepare the second side. The piece on the left in this photo is the piece featured in Figures 3 to 13.

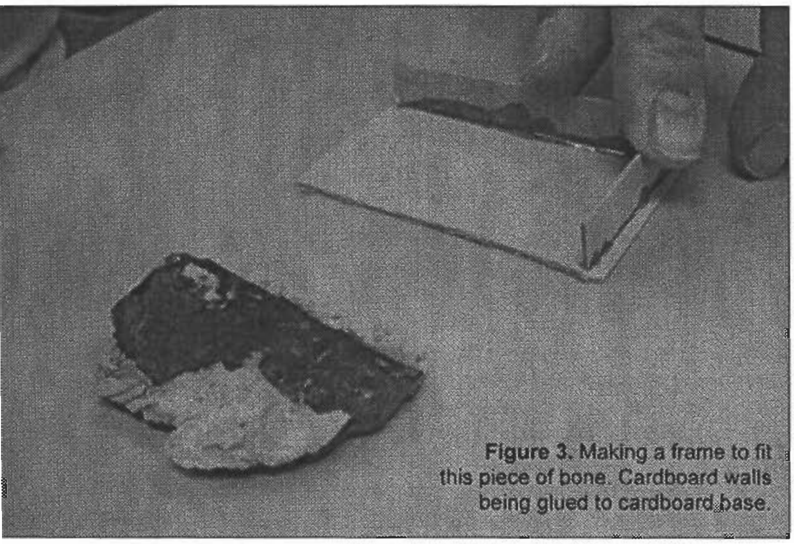

Figure 3. Making a frame to fit this piece of bone. Cardboard walls being glued to cardboard base.

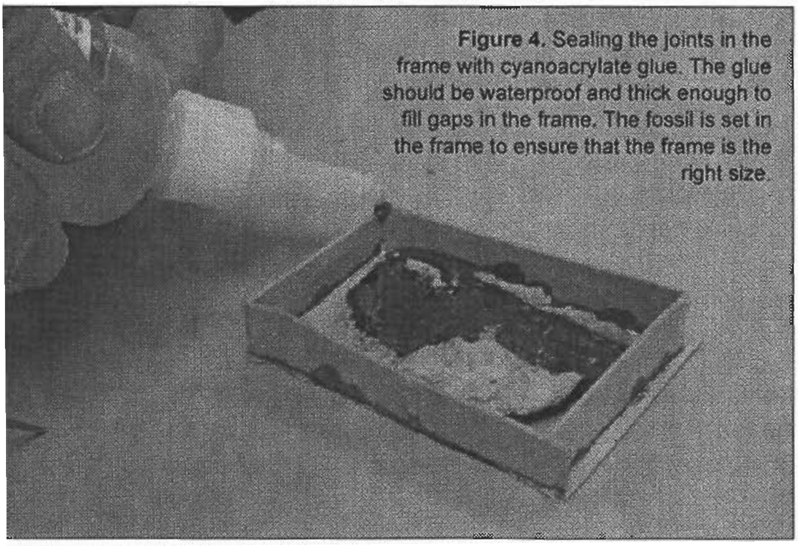

Figure 4. Sealing the joints in the frame with cyanoacrylate glue. The glue should be waterproof and thick enough to fill gaps in the frame. The fossil is set in the frame to ensure that the frame is the right size.

to be fairly rigid and the walls need to be high enough to contain enough Carbowax™ to hold the specimen. A custom sized frame can be made in a matter of minutes from thin (noncorrugated) cardboard or paperboard and glue (Figs. 3 and 4). The cardboard that backs a pad of paper is a good example, or the paperboard used for cereal boxes. Medium thickness cyanoacrylate glue is useful, as it is somewhat gap-filling and dries quickly. First, a base is cut that is a little bigger than the fossil. Then walls are cut that will be erected on the base. The walls should be placed vertically to outline an area into which the fossil will fit. Glue these in place in a form that will contain the bone. Voila... a custom frame.

Lego™ building bricks can also be used to make custom containers. Experience has shown that a Lego™ base should not be a thin Lego™ sheet, but rather a plate that is the same thickness as a regular Lego™ brick. When it comes time to take the frame apart, a thinner sheet will tend to bend and possibly break the fossil. Be aware, also, that very hot Carbowax™ can bend thin Lego™ pieces. It is best to let the Carbowax™ cool for a minute before filling the frame.

Carbowax™ can be melted on a heater in a pot or a pan. It is best to allocate a single pot to the Carbowax™ and not contaminate it with other chemicals. When melting Carbowax™ it is best to stick around and patiently watch it melt. Avoid the temptation to work on something else. Burning Carbowax™ will create a smoky, stinky mess. It apparently loses its effectiveness when overheated (unnamed Dow™ sales representative, pers. comm.), but I have not noticed this to be the case for paleontological concerns. Once the Carbowax™ has melted, it takes several minutes (up to a half hour) to recrystallize as it cools. The fossil can be placed into the frame and Carbowax™ poured around it to the correct level. Alternatively, the Carbowax™ can be poured into the frame and the fossil placed upon in it (Figs. 5 and 6). A spoon can be used to transfer some liquid Carbowax™ from the pot into the frame. Pour enough Carbowax™ into the frame to support the bottom (prepared) side of the fossil. Leave the unprepared side and matrix sitting above the wax. The Carbowax™ can also be poured directly from the pot, but his will invariably leave some Carbowax™ dripping down the outside of the pot. This excess will burn off unpleasantly next time the pot is heated. The prepared side of the specimen can also be painted with a layer of Carbowax™ before embedding it in the frame. This is especially useful if the specimen has hollow areas on the prepared side. If the specimen is simply placed into the molten Carbowax™, these hollows may trap air and therefore not benefit from the Carbowax™ support. On larger specimens, painting the Carbowax™ on can also be an alternative to the Carbowax™ frame.

A frame two inches square containing Carbowax™ a quarter inch deep and a specimen will set up in approximately a half hour. In a frame like this, the Carbowax™ will often shrink as it dries. Generally the areas that congeal first do not shrink, but the last areas to congeal will have holes in them due to shrinking. Areas contacting the frame and the specimen tend to congeal first, so the shrinking does not directly affect the specimen. Such hollows are visible in the front edge (next to the matrix) of the frame in Figure 7. I have never noticed this behavior to be a problem.

Something to consider before placing the specimen in Carbowax™ is "Will I be able to easily find the fossil within the matrix?" Often, a specimen placed in Carbowax™ appears as a lump of matrix in Carbowax™, with no fossil visible. If the shape of the fossil allows, it is helpful to first prepare around an edge of the fossil, exposing some of the fossil on the matrix side. When the whole thing is set in Carbowax™, with the matrix side up, the preparator will be able to see this edge of the fossil, giving him/her a good place to start preparing. This is better than preparing semi-blindly through matrix and hoping not to leave a tool mark of discovery. For example, if the fossil is a small mammal jaw, while preparing the first side, a little bit of the base of the jaw on the second side may be prepared (around the ventral edge of the bone). This edge will be exposed above the Carbowax™ when the prepared side is embedded in Carbowax™.

After the wax has cooled, the side of the fossil not in Carbowax™ can be prepared by the usual means. Excess Carbowax™ can also be prepared off with the same techniques. The Carbowax™ frame becomes a convenient way to hold the fossil. The frame can also be carved to allow access to different parts of the specimen from different angles (Fig. 8). Once the fossil is prepared it should be stabilized as needed. Now we are ready to remove it from the Carbowax™.

In order to speed up the dissolving of the Carbowax™, one can remove some of the base in the frame. A chisel-shaped dental pick works well for this, as does a scalpel or X-acto® blade (Fig. 9). A

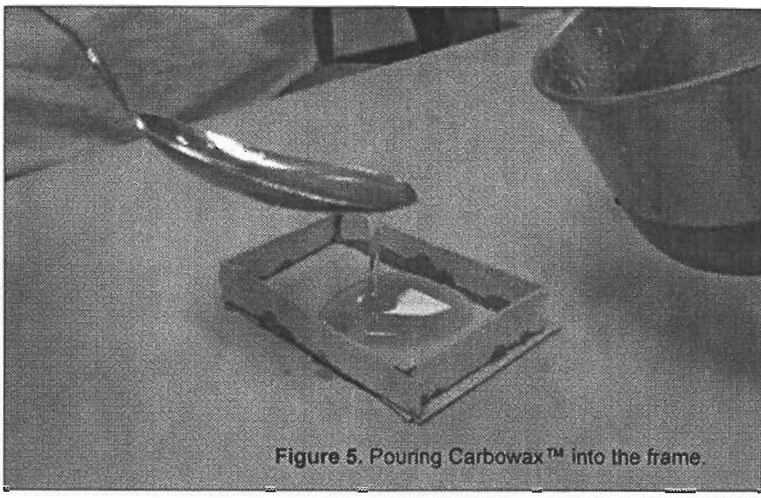

Figure 5. Pouring Carbowax™ into the frame.

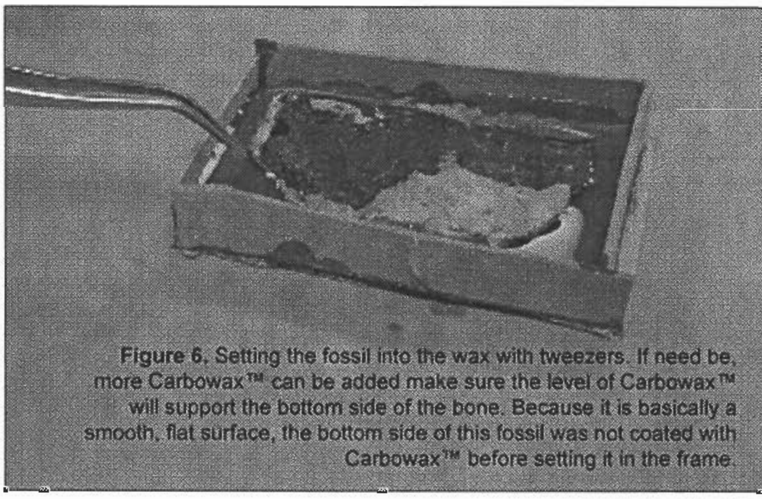

Figure 6. Setting the fossil into the wax with tweezers. If need be, more Carbowax™ can be added make sure the level of Carbowax™ will support the bottom side of the bone. Because it is basically a smooth, flat surface, the bottom side of this fossil was not coated with Carbowax™ before setting it in the frame.

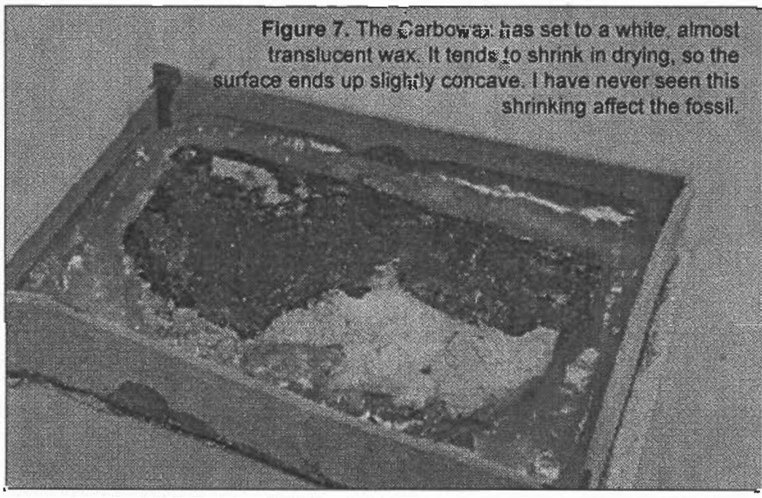

Figure 7. The Carbowax has set to a white, almost translucent wax. It tends to shrink in drying, so the surface ends up slightly concave. I have never seen this shrinking affect the fossil.

pointed tip will simply stab the Carbowax™ base, removing only a small quantity. Do not remove all of the Carbowax™, as soaking in water will do this with much less risk of breaking the specimen. The preparator can choose to remove the frame, leaving the fossil and its Carbowax™ support by separating the Carbowax™ from the bottom of the frame. This should only be done manually if one can actually carve out enough Carbowax™ from under the fossil to allow good frame/Carbowax™ separation. If there is

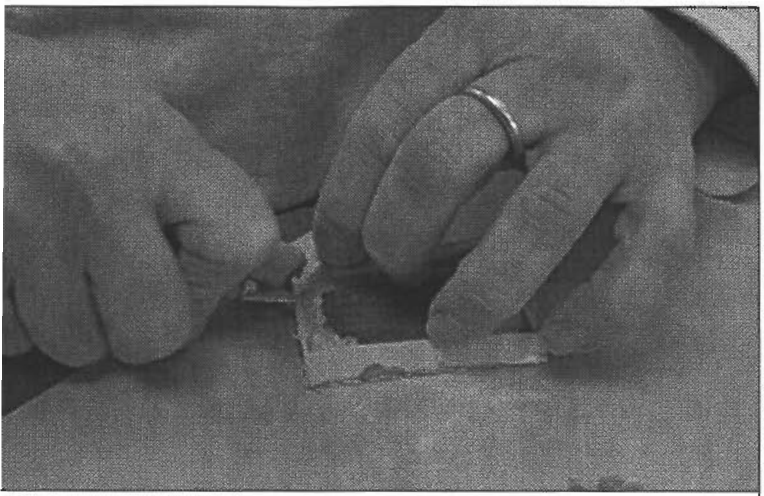

Figure 8. Here the fossil has been mostly prepared on this side using air scribes and air abrasive. The frame does not allow access to the left edge of the fossil, so an X-acto® knife is used to carve a notch in the frame making it easier to prepare this edge. One can go further and cut down into the level of the Carbowax™ and physically remove it to effectively access the fossil from different angles.

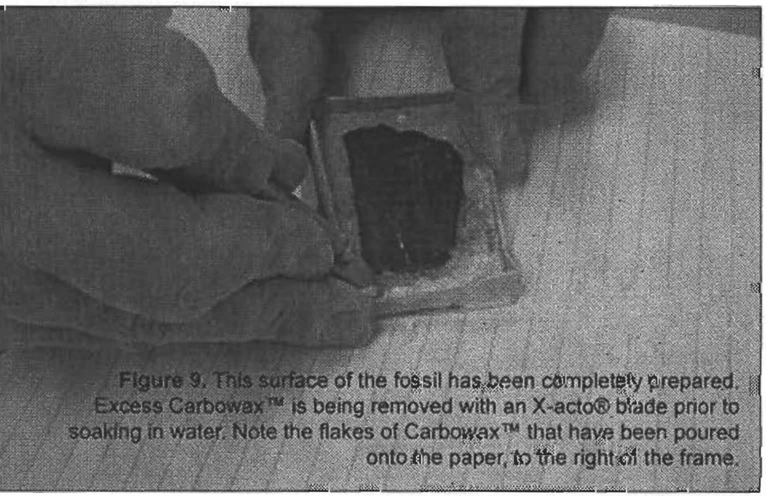

Figure 9. This surface of the fossil has been completely prepared. Excess Carbowax™ is being removed with an X-acto® blade prior to soaking in water. Note the flakes of Carbowax™ that have been poured onto the paper, to the right of the frame.

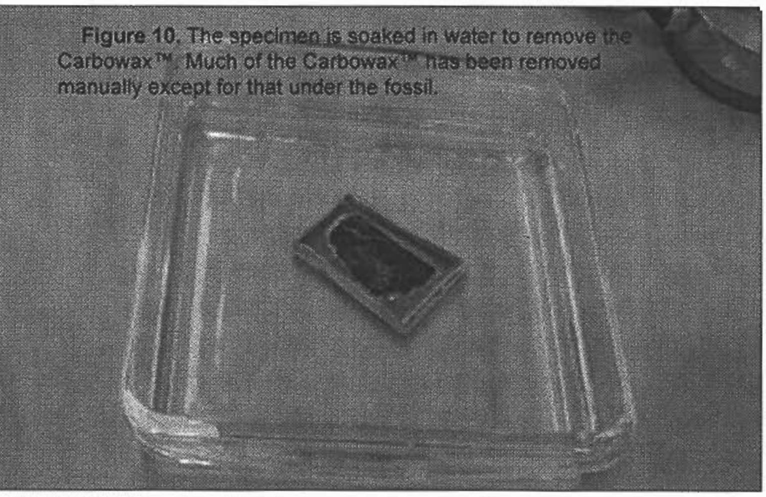

Figure 10. The specimen is soaked in water to remove the Carbowax™. Much of the Carbowax™ has been removed manually except for that under the fossil.

any doubt, the whole set-up should be allowed to soak in water; fossil, wax and frame. For large flat fossils, this is certainly the only safe technique. Even for less flat fossils, separating the Carbowax™ from the base of the frame brings the risk of breaking the fossil. If the fossil sits on a layer of Carbowax™ (rather than the base of the frame), there is better chance of separating the Carbowax™ from the frame. The advantage to separating is only that it will reduce soaking time. Again, if there is any doubt, soak the whole thing.

For dissolving Carbowax™, any water-tight container will work (Fig. 10). Warm water will speed up the process. Specimens I have prepared under the microscope, where the amount of Carbowax™ is very small, say the size of a pea, have dissolved the Carbowax™ in a matter of a few minutes. The more Carbowax™, the longer the time needed to dissolve it. As a rough guide, with specimens the size of a small rodent jaw, I have immersed the specimen, wax and frame in water, the dissolving takes about an hour (see also section on "Different Molecular Weights"). As the water cools, replacing the warm water will speed up the process.

When removing a specimen from water, either fingers or tweezers are often sufficient (Fig. 11). The fossil should be rinsed in a different container of warm water to minimize Carbowax™ residue (Fig. 12). Smaller or more delicate specimens may be too delicate to risk handling with fingers or tweezers, especially when wet. For these, most of the water may be decanted off, leaving the fossil at the bottom of the container in a small quantity of water. Decant the water into a separate container; if the small fossil accidently gets decanted, it is not lost. Use a natural bristle paintbrush to pick up these delicate fossils, (roughly size 1 or 2), by sliding the bristles under the fossil and picking it up from underneath such that the fossil rests on the sides of the bristles.

After rinsing, the fossil should be set to dry on a piece of absorbent yet tough paper. Tissue is inappropriate; when the fossil dries, it tends to stick to the tissue. (Whether this is due to dried minerals in the water causing adhesion, or fibers in the tissue physically holding onto the specimen, or to some other force is unclear). Paper towel is better suited to this, as is blotting paper. The frame can also be removed from the original water bath, rinsed and set aside to dry for re-use (Fig. 13).

Sometimes when stabilizing the fossil as it sits in the Carbowax™, excess preservative or glue will seep out onto the Carbowax™ surface. After the fossil has dried thoroughly, these may show up as a white plastic-looking film flapping about on the edge of the fossil. These can be either removed manually or bonded to the fossil by applying an appropriate quantity of the same preservative or the solvent used. Make sure the fossil is thoroughly dry before applying solvent-based products.

Carbowax™ can be recycled and used over and over again. The Carbowax™-rich water can be allowed to evaporate leaving behind the Carbowax™, which can then be harvested. A glass baking dish is useful because its allows for a large surface area of water, speeding up its evaporation. A razor blade can easily be used to scrape the dried Carbowax™ off the glass after the water has evaporated, (Fig. 14). This material can then be stored to be used again. The recycled Carbowax™ is kept in a separate container than the virgin stuff. If Carbowax™-rich water is to be thrown out, contact the local landfill to find out what to do with it; is it permissible, in your area, to dispose of small quantities down the sink? If Carbowax™-rich gets contaminated with small pieces of matrix, it can be filtered through a coffee filter before evaporating it.

If a specimen is very small it may sink in the Carbowax™ and may be difficult to find again without first dissolving the Carbowax™ off and starting all over. To avoid this, very small specimens should be floated on top of the Carbowax™ after it has started to crystallize. Use tweezers under the microscope to lay such small fossils on top of the Carbowax™ after small, round white crystals of Carbowax™ start to form. If a fossil is to be set in Carbowax™ and prepared under the microscope, it should be mounted on Carbowax™ under the microscope as well (Figs 17 and 18). Additional quantities of Carbowax™ can be built up along vertically protruding parts of the fossil if needed (Fig 19). A paintbrush dipped into the molten Carbowax™ can be useful for detailed Carbowax™ placement.

Different molecular weights

Carbowax™ comes in a variety of different molecular weights and properties. The ones useful to paleontology labs are those that are solids at room temperature. These include molecular weights of 1450, 3350, 4000, and 8000. A sample of each was used for a simple usability study. As a disclaimer, this

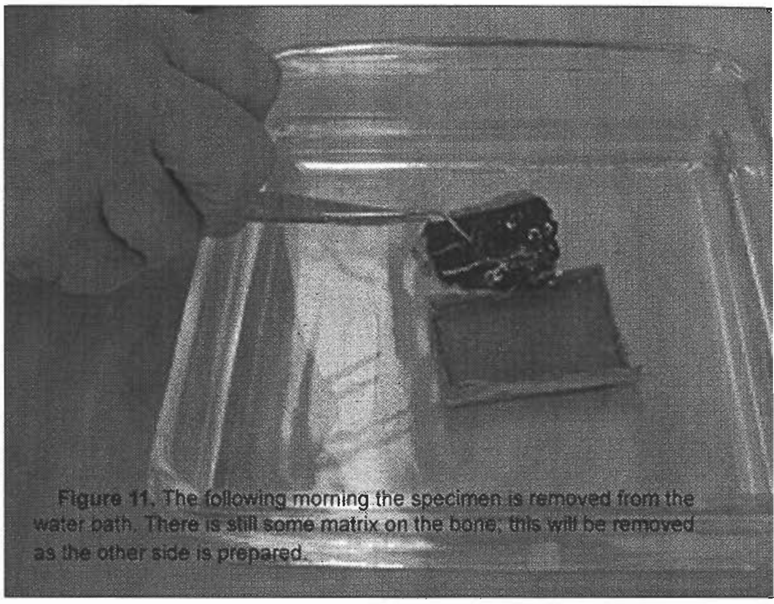

Figure 11. The following morning the specimen is removed from the water bath. There is still some matrix on the bone; this will be removed as the other side is prepared.

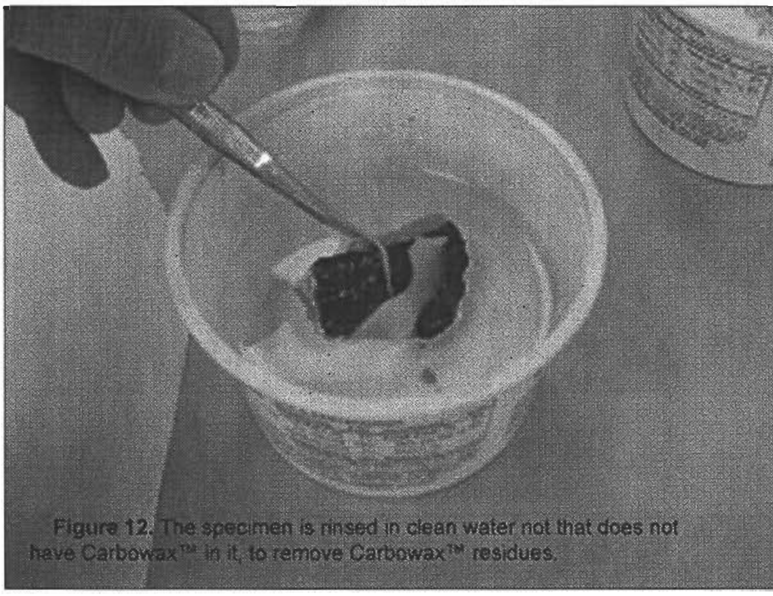

Figure 12. The specimen is rinsed in clean water not that does not have Carbowax™ in it, to remove Carbowax™ residues.

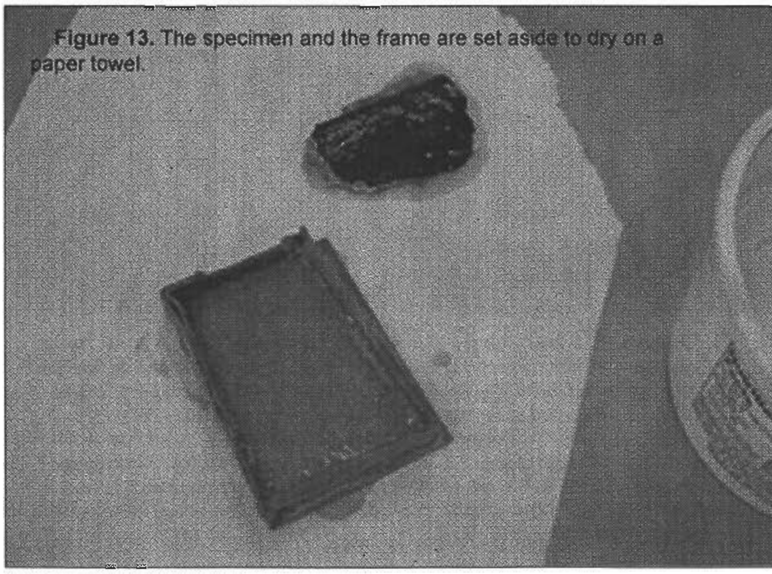

Figure 13. The specimen and the frame are set aside to dry on a paper towel.

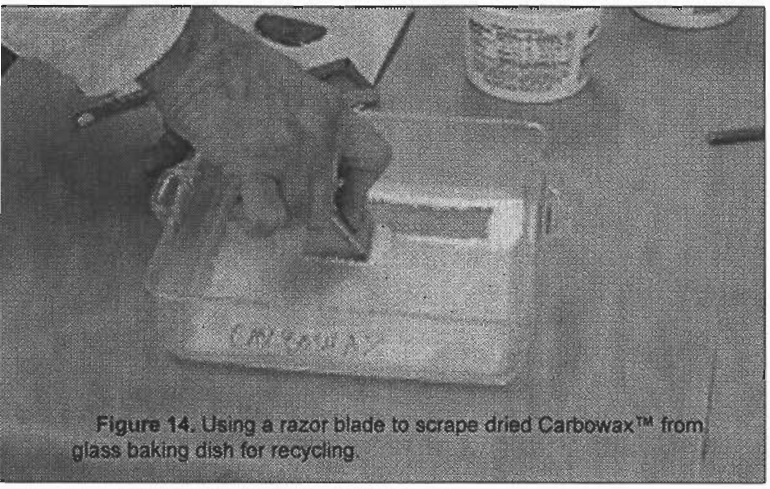

Figure 14. Using a razor blade to scrape dried Carbowax™ from glass baking dish for recycling.

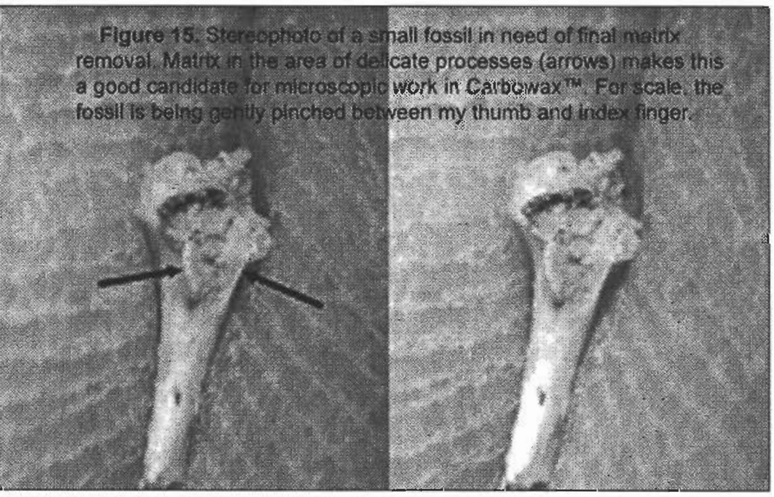

Figure 15. Stereophoto of a small fossil in need of final matrix removal. Matrix in the area of delicate processes (arrows) makes this a good candidate for microscopic work in Carbowax™. For scale, the fossil is being gently pinched between my thumb and index finger.

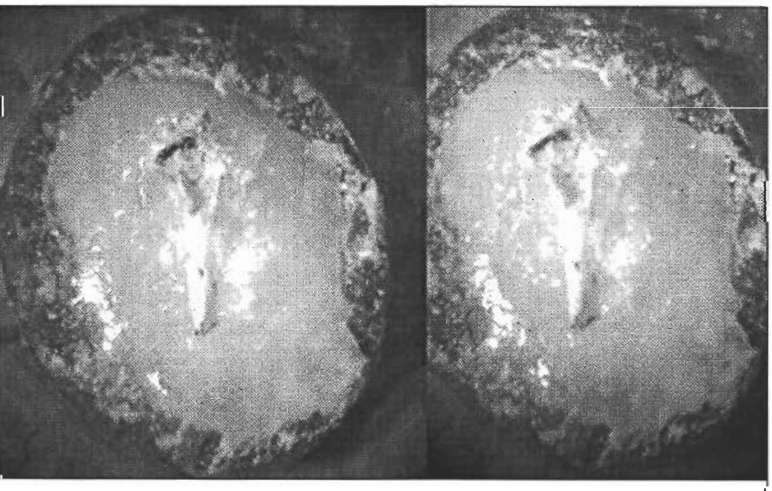

Figure 16. Stereophoto of the same specimen lying on a small bed of Carbowax™. Note the process coming toward the viewer just below the dark crystal in the matrix. As it stands, it is not protected from stresses that will be incurred in removing the matrix. The process on the right has a Carbowax™ backing. The fossil was set in Carbowax™ after the wax started to crystallize. Figure 17. A small drop of molten Carbowax™ has been added to the left of the process with a number 0 paintbrush to give it support. In this photo it has cooled and the specimen is ready for further preparation.

was not a rigorously controlled experiment, but rather a test to get some basic comparisons. In a clean pot, three heaping spoonfuls of each were melted and poured into a 1 3/8 x 1 7/8 inch specimen box. Each was timed to see how long it took to set up solidly. Each sample was also tested to see how easily it is carved and to see which dissolves the fastest.

The lower the molecular weight, the longer it took to set, but the results are not different enough to be a concern in the prep lab. (8000 took 24 minutes; 1450 took 29 minutes). In solidifying, the three smaller weights first developed a skin on top of the pool of wax. The 8000 seemed to solidify by crystallizing throughout the sample. The 8000 solidified with many small gaps in between crystals. The other three weights solidified with a few large gaps of empty space in the final solid. These gaps do not seem to affect the solidity of the whole mass, at least not in terms of simply stabilizing a fossil. My experience with Carbowax™ in the past suggests that Carbowax™ drying in layers (as when it is painted on a specimen) is not likely to create these empty spaces when solidifying. Painting Carbowax™ onto the back of a fossil before embedding is useful. A thin layer of Carbowax™ painted onto the back of a fossil tends to set up quickly.

Before immersing a Carbowax™ and fossil frame into warm water to remove the Carbowax™, physically removing a large amount from the frame will help speed up the dissolving process. The four samples were attacked with a dental pick sharpened to a chisel end. A subjective comparison of the four waxes was made. The 1450 is very plastic; pieces of the wax simply were pushed aside to allow the chisel in. The two middle weights were easily scraped (rather than carved) with the chisel. The 8000 was stronger yet more brittle than the others. When the chisel broke through, pieces of the hardened 8000 were sent flying and the chisel jerked forward into the mass of wax. Removing Carbowax™ 8000 from a frame is not easily controlled, making it the less useful for the prep lab. The plasticity of the Carbowax™ 1450 makes it less useful in this regard than the two middle weights. A fifth sample of Carbowax™ was melted and solidified to further test this property: an equal mix of 1450 and 3350. This material chiseled very satisfactorily and was easily carved. In terms of ease of physical removal, this mixed batch performed the best. For ease of physical removal, either the 3350 or the 4000 is the best pure molecular weight. Carbowax™ 8000 and 1450 should be completely immersed in warm water to remove them.

The same five samples were dissolved in warm water to see which dissolved fastest. They were all put into a glass baking pan which was filled with warm tap water. The pan was set on an electric griddle set at "warm" to keep the water from cooling. They were checked every ten minutes. The Carbowax™ 1450 melted in two and a half hours, while the Carbowax™ 8000 melted in four hours and 10 minutes; not quite twice as long. Melting times followed molecular weight except for one sample. The 4000 melted faster than the 3350. At one point the wax in this sample was seen floating in the water column, while all other samples remained on the floor. This is likely why it melted faster, as water would be acting on the bottom as well as the top side of the wax block, speeding up dissolving time.

As a note, the specimen boxes used had black paper on them. This paper bled into the melted Carbowax™ samples as well as into the water used to dissolve them.

In conclusion, Carbowax™ 3350 and 4000 are the best weights of Carbowax™ to use for fossil preparation.

Where to get Carbowax™

Carbowax™ is available from Dow Chemicals. Small quantities of some molecular weights are available for free. These include (as of this writing) Carbowax™ 8000, Carbowax™ 4000, and Carbowax™ 3350. The smallest available quantity is a quart, which should be enough to last a paleontology lab for a long time if it is recycled. Other useful grades (e.g. 1450) cost roughly $60 for a quart.

Safety Concerns

When ordering Carbowax™, make sure to ask for the accompanying MSDS. Without going into too much detail, Carbowax™ is a fairly safe product to use, (Carbowax MSDS, 2008). When melting Carbowax™, as well as chipping it out of the frame, it is best to wear protective eyewear. Overheating or burning Carbowax™ makes a smelly, smoky mess that may be a cause for changing the air. Regular safety concerns should be heeded, such as using sharp tools and heating units.

When to use Carbowax™

Or, when not to use Carbowax™. Any fossils that are sensitive to water should not be treated with Carbowax™. If the matrix is water sensitive and the fossil is to be left in matrix, Carbowax™ should not be used. If the matrix is to be completely removed, it may be okay to use Carbowax™. This should be considered carefully, as there may be enough matrix filling cracks in the fossil that the results may be less than ideal.

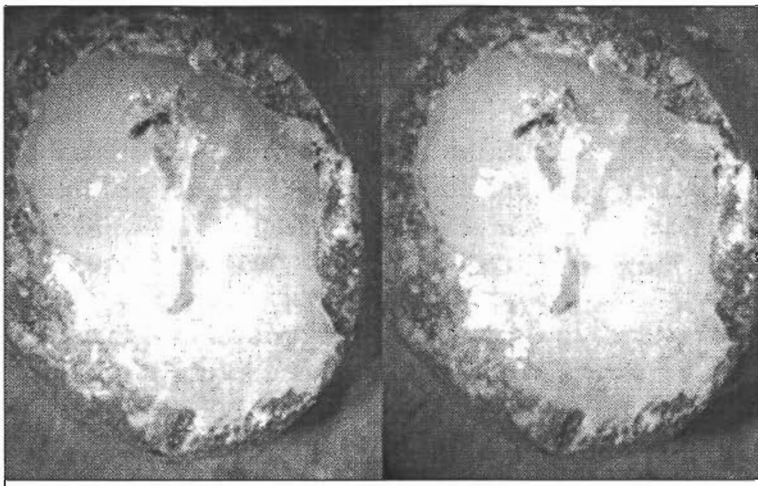

Figure 17. A small drop of molten Carbowax™ has been added to the left of the process with a number 0 paintbrush to give it support. In this photo it has cooled and the specimen is ready for further preparation.

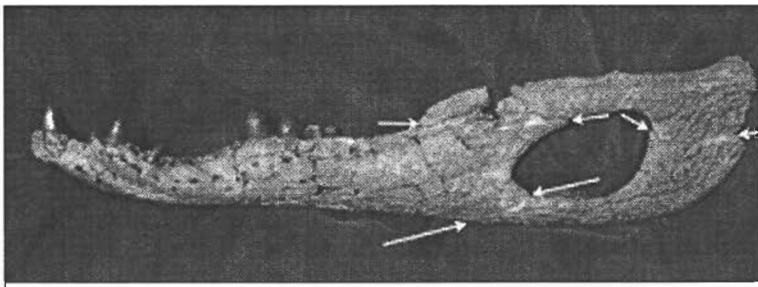

Figure 18. The multitudinous fragments in this Eocene alligator jaw are all held together with cyanoacrylate. The arrows show where the separate bones (dentary, angular, and surangular) are held together with Carbowax™ (barely visible as white fill somewhat connecting arrow pairs). Specimen is 16 inches (40 cm) long.

Many thin bones can put up with the force of an air-abrasive machine, but air scribes are generally more powerful. A thin bone that is to be worked on with an air scribe is an ideal candidate for a Carbowax™ support. Small bones that are difficult to handle are also good candidates for temporary Carbowax™ supports.

When water is an issue, the preparator may want to consider using cyclododecane as a temporary support (Brown, 2004). Cyclododecane is a similar wax product that sublimates at room temperature, thereby eliminating the need to immerse the specimen in water. Cyclododecane sublimation is considerably slower than Carbowax™ dissolving; measured in weeks, not hours. Cyclododecane's safety factors are not yet clear (Cyclododecane MSDS, 2006).

Other paleontological uses for Carbowax™

Carbowax™ can be used to form joints between fossil bones. Often broken bones are glued together using glues that do not dissolve in water. Carbowax™ can be used to at least temporarily glue these bones together. When needed, the bones can be soaked in water without the risk of ungluing the previously broken parts. Carbowax™ joints such as this may not be strong enough to support free standing skeletal mounts of fossil animals (this was not tested). Carbowax™'s slow set time makes it useful for articulating bones with several points of contact, such as the alligator jaw in Figure 18. The dentary was joined to the angular with a layer of Carbowax™. While this first joint was setting, the third bone (surangular) was joined to each of these previous bones. Since the Carbowax™ was still pliable in each joint, the correct alignment between the three bones was attained before the Carbowax™ set up. The specimen can be soaked in water to disarticulate the bones without risking the cyanoacrylate bonds holding all the little pieces together.

Delicate fossils that need to be shipped can also be coated in Carbowax™ to protect them from the rigors of the shipping industry. The recipient can then soak the fossils in water to release them.

Carbowax™ could be used as a temporary filler in bones that are to be molded, either for reconstruction or to keep silicone out of cracks. I have not tried this, but my guess is that it would form a very smooth surface that will be inordinately smooth on a cast. A little texturing of the waxy surface may be appropriate.

Carbowax™ has also been used recently to mount small fossils on pinheads. Rixon (1965) also mentions a Carbowax™-based paste that can be used for this purpose. The advantage to the paste is that one does not need to repeatedly melt a supply of Carbowax™.

Naturally, all these applications should only be done with fossils that can withstand immersion in water.

A Cautionary Tale

Recently I have been preparing a small crocodile skeleton (skull is three inches or eight cm long). It is in somewhat soft sandstone. Some parts needed temporary supports and Carbowax™ was my first choice. I placed a piece of matrix in water to see if it disaggregated. It did, but only slightly. A second piece of matrix was covered with vinac (polyvinyl acetate in acetone) and let dry. This was then immersed in water to see if the vinac kept the water out, which it did. I also tested a scrap of bone from the specimen in similar ways. The bone stood up to water, with and without a vinac coating. I set a small piece of matrix into a Carbowax™ frame and prepared it. When it was time to soak off the Carbowax™, I did so. After soaking up some water, the rock broke in half and became rather soft. I gently... ever so gently... took it out of the water and let it dry overnight before reapplying more vinac to the two pieces of rock. A near disaster, but in the end, the two halves fit together nicely and very little bone was lost. Was there a weaker spot in the rock? In the vinac coating?

Unfortunately, there was still some Carbowax™ on the specimen, but I didn't want to expose it to more water. I removed as much Carbowax™ as possible by hand under the microscope. Several tenacious pieces of Carbowax™ still clung to a few areas on the rock. I prepared a hot water bath big enough to hold a smaller container that held hot water, like a double boiler. Since Carbowax™ dissolves faster in hotter water; the hotter the water, the less time the specimen would have to be wet, and hopefully the less additional damage would ensue. The inner container held only enough hot water to dip one end of the specimen that had remnant Carbowax™. The specimen would be dipped, not immersed. I held the specimen in water for a very short time, watching the water soak up into the matrix. Before too much rock became wet, I removed it from the water. Then I let it dry overnight. More vinac was applied to the newly exposed matrix. This process was repeated until all of the Carbowax™ was gone. As most of the Carbowax™ was removed manually, the last thin layers actually dissolved away quite quickly, and no additional damage was done to the specimen.

Looking back, I think I should have done more tests on this matrix. I have been using Carbowax™ for years and on many specimens. This is the first instance where it failed me. I used cyclododecane for other parts of this specimen.

You have been warned.

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