Molding and Casting of In-situ Articulated Skeletons in Soft Matrix: A Case Study from the Ashfall Fossil Beds, Nebraska

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ABSTRACT

Due in part to their excellent release properties and variable viscosities, modern silicone molding materials have greatly simplified the process of molding and casting well-preserved fossil specimens in the laboratory. Porous bone and, in particular, bone still partially embedded in a soft and porous matrix, however, still present serious challenges to successful molding. In addition, uncontrolled environmental conditions, lack of access to standard laboratory equipment, and unique conservation concerns multiply these challenges significantly when molding specimens remaining is-situ.

In 2004, we began a project to mold several complete, articulated Clarendonian rhino (*Teleoceras*) and horse (*Cormohipparion*) skeletons preserved in-situ in soft volcanic ash at the Ashfall Fossil Beds near Orchard/Royal, Nebraska. Although the overall design of the one-piece molds is relatively straightforward, achieving a flawless mold and assuring safe, stress-free demolding in this situation requires subtle but important variations to our standard molding procedures including: 1) the use of cyclododecane to seal porous matrix and bone, 2) control of molding compound viscosities using fumed silica rather than liquid thixotropic additives, 3) incorporation of fabric reinforcement into mold perimeter, and 4) choice of addition-cure, platinum-catalyzed silicone RTV molding compound for its superior release properties, long mold life, and chemical resistance.

During casting, the use of talc-extended polyester resin provides an ideal consistency for brush application and results in a high-resolution bubble-free cast that readily accepts acrylic paints and stains.

Maintaining substrate and specimen integrity while minimizing alterative chemical treatments is an important goal in all molding projects, but is essential to the long-term survival of specimens being maintained in-situ under minimal environmental control.

INTRODUCTION

Ashfall Fossil Beds State Historical Park, located in northeast Nebraska, features a large deposit of Miocene volcanic ash containing the articulated skeletons of hundreds of rhinos, horses, camels and associated Clarendonian fauna. Specimens left in-situ are protected by the "Rhino Barn", a covered, partially enclosed structure built over a portion of the site. Since the skeletons are still in contact with the ash substrate, however, they are exposed to considerably more environmental influences than a typical museum collection. In-situ "storage" is essentially an "open system", thus long-term preservation is always a major challenge.

Ever since its discovery in 1972 (UNSM Locality Ap-116, Poison Ivy Quarry), it has been our dream to mold and cast a representative sample of the articulated skeletons from Ashfall. In addition to their obvious scientific importance, these unique fossils, preserved in their death-poses and maintained in-situ, provide an ideal setting for informal science education. Exhibits developed from casts of these specimens would extend the reach of this education resource well beyond the park boundaries. In addition, high-resolution casts would also provide a permanent scientific record of these unique specimens in the even of any catastrophic loss at the site.

In 2004, a grant from the David Jones Foundation made this dream a reality. Funding was provided to allow us to mold and cast three specimens. From the dozens of skeletons preserved in the Rhino Barn, we selected:

Figure 1. Overview of a portion of the "Rhino Barn", Ashfall Fossil Beds State Historical Park, Royal, Nebraska

1) An adult horse, *Cormohipparion occidentale* (nicknamed "Cormo").
2) An adult rhino *Teleoceras major* (nicknamed "Sandy").
3) A calf rhino, probably Sandy's offspring (nicknamed "Justin"). To date, two of these molding/casting projects have been completed. The large adult rhino "Sandy", scheduled for molding in 2009, will require a different molding technique, discussed briefly at the end of this paper.

CHALLENGES

Although the overall mold design required for these specimens was relatively simple, there were several unusual challenges that had to be addressed:

- The skeletons are preserved in a soft, un-cemented, porous volcanic ash. Cohesiveness of the unconsolidated ash is due solely to imbrication of individual glass shards.
- Effective penetration of consolidants into the ash is limited to between one and two centimeters. This leaves consolidated pedestals and the ash surrounding the specimens superficially hard but structurally weak sub-surface and thus prone to delamination or plucking during de-molding.
- Maintaining the skeletons in-situ (in full contact with the substrate) under minimal environmental controls makes long-term preservation extremely tenuous. The use of irremovable chemical separators or barrier coats to facilitate mold release could interfere with ongoing conservation efforts and adversely impact long-term preservation of the specimens.
- Lack of normal laboratory equipment and environmental control complicates the molding process. Lack of a vacuum chamber to de-air molding compound, lack of work-space temperature control, dust contamination, specimen inaccessibility, distraction from park visitors, etc. add potential difficulties to successful in-situ molding.

PREPARATION AND CONSOLIDATION

Actual excavation took place long before the molding project began, and utilized standard methods. Since the skeletons were to be left in-situ indefinitely for viewing, however, they were prepared far more completely than would normally be done in the field. Due to the soft nature of the ash substrate, generous support pedestals were left around all specimens. Consolidation of the specimens and ash matrix with Vinac B-15 (polyvinyl acetate) proceeded as needed only after the specimens and surrounding matrix were dry.

Approximately two weeks prior to molding, specimens were again thoroughly consolidated, this time with Acryloid B-72 (ethyl methacrylate copolymer), concentrating on the ash supporting the specimens and the sides of pedestals which would be subjected to molding (see Fig. 2)

Figure 2. Consolidating ash matrix with Acryloid (Paraloid) B-72 prior to molding. Cormohipparion occidentale.

MOLDING

Selection of molding compound

There are many molding compounds available. This project required a compound with easily-controlled rheology, minimal adhesion and good chemical resistance to casting resins. Polyurethane molding elastomers, commonly used in model-making and industry, form a strong chemical adhesion to most surfaces, requiring liberal use of a mold release compound on the specimen. These compounds were deemed unsuitable for this project. Indeed, good conservation practice would suggest that they are seldom suitable for use on *any* scientific specimen. Silicone based molding compounds, however, do not chemically bond to most other materials; adhesion is strictly by microscopic mechanical interlocking (discussed later). There are two principle families of silicone molding compounds available, each with a wide range of viscosities, cured-hardness and tear strength. Both produce extremely high resolution molds:
1) Condensation-cure tin-catalyzed silicone RTV is most commonly used in vertebrate paleontology molding laboratories. The principle advantage of these compounds is that they are generally lower in cost and less prone to cure

inhibition. Tin-catalyzed systems suffer from some shrinkage (typically 0.3%) due to loss of generated alcohol after cure. 2) Addition-cure platinum-catalyzed silicone RTV is also available at a slightly higher cost. These molding compounds are cure-inhibited by certain oils, amines, polyesters, sulfur and tin compounds, so more care and testing is required during their use. Platinum-catalyzed silicone RTV does not shrink during or after cure and, most importantly for our project, has slightly better release properties. The cured product is also somewhat more resistant to chemical attack by casting resins, which results in longer mold life and more casts from each mold.

We chose Polytek PlatSil 73-29 platinum-catalyzed RTV for its superior tear strength, medium hardness (Shore A 30) and good flexibility, which make it ideally suited for brush-on glove molding.

Pre-molding treatments

As noted earlier, due to the fragile nature of the ash substrate and pedestals, assuring safe release of the mold during de-molding was critical. While there are any number of release agents available that would achieve this goal, we wanted to avoid using any non-removable mold separator since any permanent alteration of physical properties of the ash/specimen/consolidant system could seriously jeopardize long-term preservation of the in-situ specimens. Prior to molding, a saturated solution of cyclododecane (CDD) in VM&P naphtha was applied by brush to all matrix areas that would come into contact with the mold (see Fig. 3). Neither Acryloid nor Vinac are soluble in naphtha so no disruption of consolidated material occurred. This unique, temporary release (CDD) agent slowly sublimates at room temperature, ultimately leaving virtually no trace behind. We then waited 12 hours before beginning the molding process. This delay allowed any surface buildup of CDD that could obscure detail to disappear by sublimation. CDD remained in the matrix pore spaces, however, eliminating the problem of mold adhesion due to microscopic mechanical interlocking.

Application of molding compound

PlatSil 73-29 has a low viscosity of about 15,000 cP and continues to flow for approximately one hour after application. While this is ideal for poured molds and detail capture, it is difficult to build up a suitable thickness in glove molds, especially over high-relief areas, without "thickening up" the compound. Chemical thixotropic additives are available, but it is difficult to control the degree of flow of the mold rubber with these; it often becomes a non-flowing, stringy paste. We chose to thicken the initial coats, at least, with about ¼ cup of Cab-O-Sil fumed silica per 150 gram batch of mold rubber. This formulation provided sufficient flow to capture detail and allow the release of entrained and entrapped air while preventing the mold compound from flowing completely away from high-relief areas. Later coats with additional Cab-O-Sil or PlatThix (Polytek's thixotropic additive) allowed quicker buildup to the final mold thickness required.

The mold compound was applied by brush. Working time limited each batch size to approximately 200 grams. In the case of the baby rhino "Justin" (see Figs. 4 and 5) the complete mold, built up to a thickness of 3/16 inch, required about 22 batches, totaling about 10 pounds of molding compound. Each coat must be partially cured before the next coat can be applied. It is important, though, especially with some addition-cure platinum-catalyzed silicone RTVs, to apply subsequent coats before the prior coat has *fully* cured to assure full adhesion between coats. This is even more important if the potential for dust contamination between coats is present.

Figure 3. Applying a solution of cyclododecane in VMP naphtha to seal porous matrix areas.

Figure 4. Applying the first coat of silicone molding compound to the calf rhino "Justin".

Figure 5. First coat of silicone molding compound completed. This coat is thin and delicate, but captures maximum detail. Subsequent coats must be applied only after prior coat has gelled and partially cured.

Figure 6. Undercuts are filled with removable plaster filler blocks and numbered for easy locating.

To prevent tears propagating from the edges of the mold, strips of Tietex reinforcing fabric were added around the circumference of the mold with the last two coats of molding compound. After curing for 24 hours, small filler blocks of plaster were added to eliminate serious undercuts that might lock the shell to the mold (see Fig. 6). The shell was made from standard plaster medical bandage and allowed to set for 48 hours.

De-molding

After removal of the shell, the mold was slowly peeled from the specimen. Release was clean, with no damage to either the more porous bones or to the ash pedestals and matrix surrounding the skeletons (Figs. 7 and 8). Although cyclododecane could still be detected, mold release was probably facilitated by its continued slow sublimation during the molding process, which created a microscopic gap between the mold and the matrix. After approximately two weeks, CDD had disappeared completely, leaving no discernable residue.

Figure 7. Removal of the shell or mother mold..

Figure 8. After filler blocks are removed, the silicone mold is carefully peeled away from the skeleton.

Figure 10. Cast of "Justin" in the Museum's discovery center fossil dig.

CASTING

Casts were made using Bondo or Evercoat polyester finish coat resin combined with Milwhite talc and Cab-O-Sil to produce a thick paste that was applied to the molds by brush.

Figure 9. "Nature-faking" using acrylic paints and a combination of dry brush and wash techniques..

A small amount of white opaque resin pigment was added to the resin to achieve a base color that matched the gray ash matrix. For casts intended for display or educational purposes, the bone areas were then painted with acrylic paint using a combination of washes and dry-brush technique to simulate the actual fossil material at Ashfall (Fig. 9).

A cast thickness of 3/16 inch is sufficient for most purposes and needs no glass fiber reinforcement. Casts destined for the Museum's discovery center dig site (Fig. 10) are made slightly thicker and reinforced with ¼ inch chopped fiberglass to withstand the zealous excavation techniques of children (and a few parents).

OBSERVATIONS AND CONCLUSIONS

1) Cyclododecane is an excellent temporary barrier or release agent for porous bone and matrix during molding. It is essentially non-contaminating and sublimates completely over time. Experiments on Ashfall samples without using cyclododecane resulted in serious adhesion and plucking of both consolidated and unconsolidated matrix (see Fig. 11).
2) Truly thixotropic molding compounds should not be used for initial mold coats. Some flow is needed to allow good detail capture and release of entrapped air. Fumed silica provides easily controlled thickening of the mold compound and does not appreciably degrade cured rubber properties.
3) Addition-cured platinum-catalyzed silicone molding compounds have excellent release and cured properties and are a viable substitute for the more commonly used condensation-cure tin-catalyzed silicones. They have good chemical resistance and provide longer mold life.
4) A Cormohipparion is about the largest critter that can be easily molded by one person using hand-mixed silicone batches applied by brush. Total mold compound application time for one person working almost continuously was 18 hours (Fig. 12).

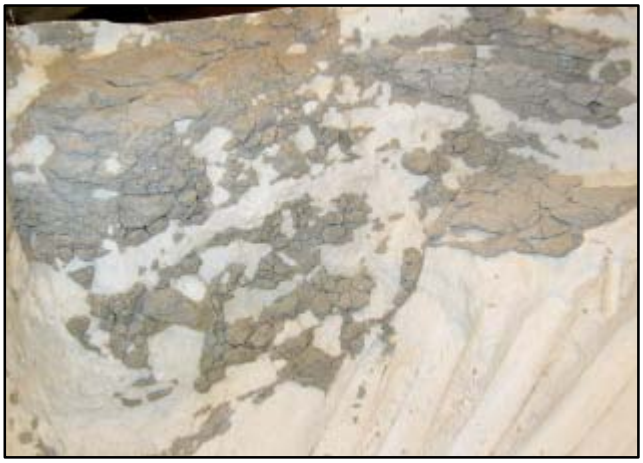

Figure 11. Matrix plucking by mechanical adhesion of silicone molding compound to matrix not sealed with cyclododecane

Figure 12. Completed mold of Cormohipparion skeleton ready for shell mold.

FUTURE PROJECT

The adult rhino "Sandy" remains to be molded. An adult Teleoceras is definitely "BIG GAME!" and requires a big gun...in this case, a Cox HSS (high solids spray) spray gun using Polytek TinSil Spray 25 RTV. This new process using relatively inexpensive equipment and materials holds great promise for other future large molding projects.

Figure 13. High-Solids Spray (HSS) dispensing gun facilitates application of silicone molding compound to large objects.

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The author is Chief Preparator at the University of Nebraska State Museum, where he has been employed since 1978. His first project with the Museum was the excavation and preparation of the Ashfall Fossil Beds lagerstatte (then known as UNSM Locality Ap-116, Poison Ivy Quarry).

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