NOVEL USE FOR CYCLODODECANE IN ACID PREPARATION OF RECENTLY RECOVERED PALEOCENE LIMESTONES FROM THE WESTERN CRAZY MOUNTAINS BASIN, MONTANA

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INTRODUCTION

An impressive diversity of late Paleocene and early Eocene mammals are known from the Clarks Fork and Crazy Mountains Basins. Most smaller species recovered from mudstones are represented only by isolated fragments, among which postcranial remains are rare (Winkler, 1983; Bown and Beard, 1990). Recent efforts in the preparation of limestone nodules from Montana and Wyoming have recovered associated skeletal material of previously documented and undocumented small mammals and reptiles (Bloch and Boyer, 2001; Bloch and Bowen, 2001).

As limestone nodules are acid-etched during preparation, element associations are mapped; meticulous mapping facilitates informed inferences regarding associations of postcranial elements for mammals previously identified only by cranial material (Bloch and Boyer, 2001). Associations are preserved as long as possible by gluing adjacent surfaces (bone to matrix and bone to bone) as bone is exposed.

In the case of some nodules, uneven reaction rates along exposed matrix surfaces result in expanding cracks that can widen into fissures (Fig. 1). This threatens documentation of bone associations and subsurface bone not treatable with solvent-dispersed plastics.

Figure 1: Block of fossiliferous limestone displaying cracks created by uneven rates of reaction with acid.

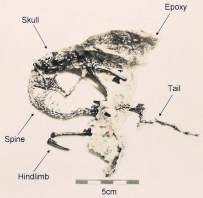

Figure 2: Skeleton prepared from limestone using irreversible epoxy (in red). Note that some morphology is permanently obscured.

Modified transfer methodology involving **resin embedment (Rutzky et al., 1994) was not applicable for preserving associations**, since we desired to see all elements in isolation after associations were documented (**Fig. 2**). Modified transfer would furthermore be impractical due to the three-dimensional nature of nodule taphonomy (Bloch and Boyer, 2001). Hence the application of a bulk filler was deemed necessary to prevent cracks from expanding.

It was important to us to have a bulk filler that flowed effectively into cracks and fissures to prevent subsurface etching, as well as one that could be applied and removed without damaging bone. Non-wax methods can be time consuming (latex) or expensive (silicone) (Levinson and Gow,1981). Wax and wax-like materials are not always able to effectively penetrate cracks in the matrix (paraffin and clay), or are sometimes soluble in water (Carbowax). Moreover, all of the above materials must be removed by physical means. **We became interested in cyclododecane ($C_{12}H_{24}$) as a bulk filler because its physical properties (low melting point, high liquid-phase viscosity, *room temperature sublimation*, lack of reactivity to acid, and insolubility in water) were consistent with our preparation goals**. It is also inexpensive, easy to use, and readily available.

MATERIALS AND METHODS

Materials used in this study include: Cyclododecane, 5 3/4" Pasteur capillary pipettes, hot plate, beaker and rubber bulb. The limestone nodules (BT03048 and BT03049) used in this experiment came from the Crazy Mountains Basin. In the application of $C_{12}H_{24}$, we generally followed the methodology as outlined by Bruckle et al. (1999):

(Materials and Methods, Cont'd.)

1. Place beaker over the hot plate until $C_{12}H_{24}$ melts (61° C).
2. After completely melting $C_{12}H_{24}$, maintain hot plate temperature to prevent recrystalization during the procedure.

3. Using a pipette fitted with a rubber bulb, begin applying material to nodule.
4. Apply or reapply $C_{12}H_{24}$ until the area is filled to satisfaction.
5. Wait until $C_{12}H_{24}$ recrystallizes completely to begin acid etching.

RESULTS

$C_{12}H_{24}$ proved to be an effective bulk filler on BT03048. Fractionation of matrix was notably reduced on BT03048 (**Fig. 3**).

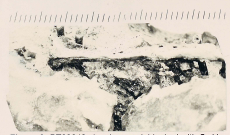

Figure 3: BT03048 showing crack blocked with $C_{12}H_{24}$. Scale bar interval = 1mm.

Areas and bones below the etching plane, unreachable with a brush for a protective coating of glue, were protected from etching by $C_{12}H_{24}$ (**Fig. 4**).

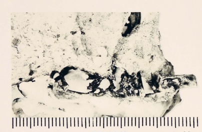

Figure 4: Some bone in BT03048 was protected by $C_{12}H_{24}$ before being exposed at the etching plane. Scale bar interval = 1mm.

Bones do not appear to be adversely effected by contact with melted $C_{12}H_{24}$. In all situations encountered, the effects of $C_{12}H_{24}$ were completely reversible. The fossils encased in BT03048 were revealed to be semi-articulated to associated remains of a mammal and a lizard (**Fig. 5**).

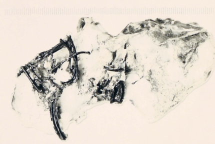

Figure 5: Elements of BT03048 represented include ribs, femur, vertebrae, phalanges, and a claw. Scale bar interval = 1mm.

Using $C_{12}H_{24}$ to support elements at angles not parallel to the etching surface, as well as to fill cracks in the matrix, prolonged articular relationships and provided for excellent documentation (**Fig. 6**). **Consequent sublimation allowed for passive or minimally intrusive extraction of elements for study after documentation (Fig. 7).** It was necessary to reapply $C_{12}H_{24}$ several times during the course of preparation to compensate for material lost to sublimation during the drying cycle. $C_{12}H_{24}$ also proved to be useful in protecting matrix where the outer epoxy encasing applied to blocks prior to preparation had etched away.

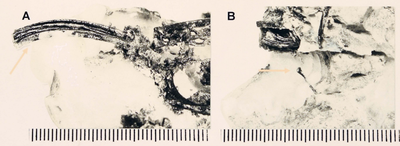

Figure 6: Elements within BT03048 being physically supported by $C_{12}H_{24}$ **A**, A yellow clay bolus provides substrate for $C_{12}H_{24}$ holding delicate, projecting ribs in position. **B**, $C_{12}H_{24}$ is used to maintain positional information for an element projecting nearly perpendicularly from etching plane. Scale bar interval = 1mm.

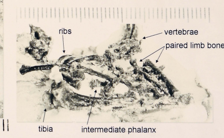

Figure 7: After etching is completed, sublimation allows for extraction of associated elements without additional mechanical stresses required to remove other bulk fillers. Scale bar interval = 1mm.

DISCUSSION AND CONCLUSIONS

The pattern of fossil preservation, revealed by this method to exist in block BT03048 from the Crazy Mountains Basin, is similar to that seen in other Clarks Fork Basin limestones (Bloch and Bowen, 2001; Bloch and Boyer, 2001; Bowen and Bloch, 2001). This taphonomic similarity represents the first documented evidence that fossiliferous limestone nodules from the Crazy Mountains Basin were created in a depositional setting similar to that which created the Clarks Fork Basin limestones.

In previous work on Crazy Mountains and Clarks Fork Basin limestone nodules, a large amount of glue (a solvent-dispersed vinyl or acrylic copolymer, or cyanoacrylate) was applied to bone as it was exposed. This was done to maintain positional relationships with regard to other elements (Bloch and Boyer, 2001). This method of preservation has limitations. Glue obscures morphology and increases the overall risk of breakage because: (1) it supports agglomerations not able to withstand jolting or pressure (as applied by a clumsy finger, paintbrush or pin vice); (2) it must eventually be mechanically or chemically removed. **In addition to the initially desired use as a bulk filler, we found that of $C_{12}H_{24}$ can sometimes be used in place of glue** to hold together such agglomerations. This mitigated some of the problems resulting from excessive glue accumulation, as it provided a direct structural support as well as not requiring preparation to remove.

From our perspective, the only drawback to using $C_{12}H_{24}$ is its slow rate of sublimation. Although it has not been a critical problem for us, it may affect other situations in which faster removal is required. In such a case, we advise moderate increases in temperature in an oven, along with careful mechanical scoring of surface material using a small tool (such as a pin vise) to increase surface area and sublimation rates.

Given our findings, **the use of $C_{12}H_{24}$ in the acid preparation of fossils should be more widely investigated. In particular, it may have an important role in the recovery of vertebrate specimens preserved in highly laminated (two-dimensional) limestones traditionally prepared using modified transfer (resin embedment) techniques.** Replacing resins with an acrylic copolymer primer plus $C_{12}H_{24}$ should, so long as all external surfaces of $C_{12}H_{24}$ are protected from contact with air after solidifying, allow for the traditional result of the method (preservation of associations for purposes of documentation). Once acid preparation of the second surface is completed, application of a solvent to remove the plastic barrier coat will allow sublimation to begin. **The end result should be the virtually passive extraction of elements for study in three-dimensions. Using $C_{12}H_{24}$ in a modified transfer regime may have particular appeal for preparators dealing with the skeletons of extremely small or volant animals.**

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