Collection Forum

PARALOID^{TM} B-72: PRACTICAL TIPS FOR THE VERTEBRATE FOSSIL PREPARATOR

Amy Davidson[1] and Gregory W. Brown[2]

[1]*Division of Paleontology, American Museum of Natural History, Central Park West at 79th Street, New York, New York, 10024-5192*

[2]*Division of Vertebrate Paleontology, University of Nebraska State Museum, W-436 NH UNL, Lincoln, Nebraska 68588-0514*

Society for the Preservation of Natural History Collections

PARALOID™ B-72: PRACTICAL TIPS FOR THE VERTEBRATE FOSSIL PREPARATOR

Amy Davidson[1] and Gregory W. Brown[2]

[1]*Division of Paleontology, American Museum of Natural History, Central Park West at 79th Street, New York, New York, 10024-5192*

[2]*Division of Vertebrate Paleontology, University of Nebraska State Museum, W-436 NH UNL, Lincoln, Nebraska 68588-0514*

Abstract.—Paraloid™ B-72, an ethyl methacrylate/methyl acrylate copolymer manufactured by Rohm and Haas, is increasingly favored as the first choice of conservators and vertebrate fossil preparators for a wide variety of tasks. Scientific tests of this acrylic resin have demonstrated outstanding resistance to degradation under normal conditions of exposure and the ability to remain clear, soluble, and removable or reworkable over time. Paraloid B-72 has an intermediate hardness and strength and is soluble in acetone, ethanol, and other solvents, each of which imparts different working properties. These intrinsic properties of Paraloid B-72 are advantageous, but appropriate use also depends on technique—the practical aspects of handling and manipulating this polymer. Many of these techniques come from diverse conservation disciplines unrelated to paleontology and are scattered throughout the literature. Others, particularly those developed by paleontology preparators, are not published at all. Although by no means complete, this literature review and compilation of practical tips contributed by our colleagues provides guidance to the use of this valuable polymer in vertebrate paleontology. Topics include mixing ratios, an easy way to make solutions using cheesecloth, recommendations for containers, how to easily clean jars and keep lids from sticking, various means of dispensing solutions such as tubes, bottles, and syringes, advice for consolidation by immersion or spray application, tips for reactivation of dried resin with solvent or heat, joining techniques for very small and very large specimens, and tips for removal. Although no single adhesive or consolidant is suitable for every situation, Paraloid B-72 is an excellent candidate for many vertebrate fossil preparation tasks.

Paraloid B-72

Fossil preparation typically includes many tasks, such as joining, consolidation, coating, and gap filling, that require the use of adhesive resins or polymers. Those who prepare fossils are responsible for evaluating the specimen and the task at hand and for choosing an appropriate adhesive and consolidant. It is a responsibility they share with conservators of objects in other fields such as art, ethnography, and archaeology. Although no single adhesive is perfect for every situation, one type of acrylic co-polymer, Paraloid™ B-72, is increasingly favored as the first choice of conservators and fossil preparators for a wide variety of tasks. Custom-made solutions of Paraloid B-72 dissolved in various solvents have many advantages over other polymers or resins commonly used in paleontology.

Advantageous Properties

Paraloid B-72 Is a Very Stable Material

Conservators and a growing number of fossil preparators favor Paraloid B-72 for its outstanding resistance to degradation under normal conditions of exposure and its ability to remain clear, soluble, and removable over time. Cast films of Paraloid B-72 have been extensively tested (Feller and Curran 1975; Feller et al. 1981; Down et al. 1996; Lazzari and Chiantore 2000; Chiantore and Lazzari 2001; Down 2009). In his 1978 paper ‘‘Standards for the Evaluation of Thermoplastic Resins,’’ R.L. Feller designated Paraloid B-72 as a Class A resin, a classification given to the few polymers that have expected useful lifetimes of greater than 100 years (Feller 1978). Used as a picture varnish in average museum conditions, Paraloid B-72 should remain colorless and soluble in its original solvent for more than 200 years (Feller et al. 1981:194). Of course, the suitability of any adhesive is dependent upon the application (Down 2009:97). Although not directly related to its use on fossil substrates, test results demonstrating the superior long-term stability of Paraloid B-72 together with a long history of various uses on a wide variety of objects since 1947 (Horie 2010:165) support the reasonable expectation of good long-term performance on fossils under museum conditions. A very good overview of polymer science, including testing, is provided by C.V. Horie in the second edition of his classic reference book *Materials for Conservation: Organic Consolidants, Adhesives and Coatings* (2010).

Paraloid B-72 Is Reworkable

Like other common solution adhesives such as polyvinyl butyral (PVB) and polyvinyl acetate (PVAC), Paraloid B-72 sets by the evaporation of the solvent and can be redissolved repeatedly as needed. The ability to be redissolved and reworked is generally preferable to the insolubility of adhesives that set by chemical reaction (cyanoacrylates and epoxies), unless these are required for other reasons. For a basic introduction to solution and reaction adhesives see Davidson and Alderson (2009). Paraloid B-72 may also be softened and reworked with heat; see the discussion below on heat reactivation and manipulation.

Paraloid B-72 Has an Intermediate Hardness and Strength

Paraloid B-72 as a pure solid has an intermediate hardness, is resilient but rigid, and has a relatively high glass transition temperature [Tg] of 40°C [104°F]) (Rohm and Haas 2007). This means that, when fully set, it should not flow or slump under moderate environmental conditions. Paraloid B-72 has a higher Tg than polyvinyl acetate polymers such as McGean B-15 that may become tacky or slump at elevated room temperature (Horie 2010:137). For a general discussion of glass transition temperature see Horie (2010). Paraloid B-72 generally forms weaker bonds than the reaction adhesives (e.g., epoxies and cyanoacrylates) but is strong enough for many structural joins, particularly if the specimen is afforded proper support. Paraloid B-72 is, however, slow to release the last traces of solvent and develop a full strength bond (Horie 2010:155; Podany 2001:27). For more discussion of solvent retention times see Horie (2010:89–92), Carlson and Schniewind (1990), and Schilling (1988:111).

Paraloid B-72 Is Versatile

Solutions of Paraloid B-72 are readily manipulated to control viscosity, set time, and penetration. Concentrated solutions of Paraloid B-72 mixed with acetone are remarkably sticky adhesives and are often an excellent substitute for less desirable fast-setting adhesives frequently used for quick assembly of fragments, such as 5-minute epoxies (which are likely to degrade over time) or cyanoacrylates sprayed with accelerators (which often cause green discoloration). By changing solvents, altering solution concentration, adding a bulking agent, or modifying the application technique, Paraloid B-72 can be used as a consolidant, coating, or gap filler. Paraloid B-72 may also be used with sheets of pliable materials such as Reemay® spunbonded polyester or thin fiberglass cloth as a facing or backing. Two case studies illustrating multiple uses of Paraloid B-72 for single specimens are provided by Buttler (1994) (a sub-fossil hippopotamus) and Stollman et al. (2005) (a recent blue whale). The use of Paraloid B-72 to make very strong but reversible structural joins on stone objects, either alone or as a barrier layer with epoxy, is discussed in Podany et al. (2001) and Jorjani et al. (2009). For examples of bulking Paraloid B-72 for gap filling of stone and fossils, see Krumrine and Kronthal (1995), Larkin and Makridou (1999), and Wolfe (2009). Examples of consolidation with Paraloid B-72 are provided by Rossi et al. (2004) (cremated bone), Snow and Weisser (1984) (ivory), and Koob (2009) (ceramics and glass). The various solvents for Paraloid B-72 and their effects, properties, and uses are discussed in more detail in a subsequent section.

Buy the Right Product

Industrial names and numbers for polymers are confusing, and manufacturers or formulas can change over time, resulting in purchasing errors. Paraloid B-72 is widely available through conservation suppliers, but caution should be exercised to ensure that the correct product is ordered. Paraloid B-72 is currently manufactured by Rohm and Haas, a subsidiary of Dow Chemical, and is identified chemically as a copolymer of ethyl methacrylate and methyl acrylate monomers (PEMA/PMA). Other Rohm and Haas "Paraloids" such as Paraloid™ B-67 are not PEMA/PMA and are not equivalent to Paraloid™ B-72. The abbreviation "B-72," used by itself, can be confused with other types of adhesives such as Butvar® B-72, a polyvinyl butyral (PVB) manufactured by Solutia. Before 1997 Paraloid was marketed outside Europe as "Acryloid™." Paraloid products purchased before 2001 were manufactured before Rohm and Haas was sold to Dow Chemical (presumably without changing the formula). Paraloid B-72 purchased before 1976 had a different appearance (white, irregular lumps), a slightly different chemical composition, and was not soluble in ethanol (De Witte et al. 1978). Links to more information about Paraloid B-72 are listed in the Appendix under Useful Websites.

The best way to ensure that you are purchasing the right product is to use the chemical identity in addition to the trade name, grade, and manufacturer (i.e., Rohm and Haas Paraloid B-72 ethyl methacrylate/methyl acrylate copolymer).

Shelf Life

Paraloid B-72 is extremely stable and has an indefinite shelf life. It is normally supplied as pellets (Fig. 1) in quantities as small as eight ounces, but larger quantities may be purchased and stored for many years without risk of deterioration. The very long shelf life of Paraloid B-72 as a solid is an advantage compared to liquid reaction adhesives with relatively short shelf lives.

Solvents

Paraloid B-72 is readily soluble in acetone. It is also soluble in lab-grade ethyl alcohol (ethanol), although some workers report problems with cloudiness from water in the ethanol, possibly exacerbated by high RH (Phenix 1992:25; Koob 2009:118). Toluene may also be used, as well as some other less common solvents (Rohm and Haas 2010); each solvent imparts different properties to the liquid and ultimately to the solid. For a discussion of solvent effects on polymer properties see Hansen (1995) and Sakuno and Schiewind (1990). It is preferable to purchase solvents from laboratory suppliers; hardware store solvents are more likely to contain unwanted additives or impurities (Erhardt 2001). Chemical contamination from impure solvents may cause yellowing and deterioration of otherwise pure Paraloid B-72.

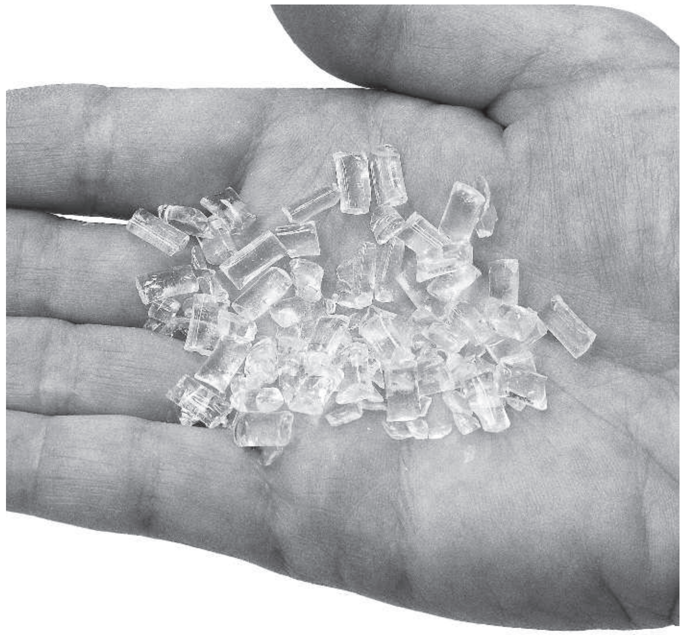

Figure 1. Paraloid™ B-72 is supplied as pellets of pure polymer with an effectively indefinite shelf life.

Acetone as a Solvent for Paraloid B-72

Solutions of Paraloid B-72 in acetone are more volatile than those in ethanol and thus set faster. This makes acetone a good solvent for a quick-setting adhesive, e.g., for rapid assembly of fragments; however, acetone may not always be the best choice of solvent for a penetrating consolidant. Even if acetone solutions penetrate deeply, rapid evaporation tends to draw the polymer back out to the surface—a phenomenon known as "reverse migration." Reverse migration is readily observed when consolidating in hot, windy field conditions but also occurs under common laboratory conditions. Reverse migration may be mitigated by slowing evaporation, e.g., by covering with polyethylene sheeting or by lowering the temperature. The volatility of the solvent is not the only issue that influences the effectiveness of consolidation. Good penetration and retention are also dependent upon the complex physical and chemical interactions of a given solvent, polymer, and fossil substrate. Since these interactions are not well understood and every specimen is different, experimentation is almost always required when consolidating fossils. Experiments conducted by one of the authors (G.W.B.) with Paraloid B-72 in acetone suggest that the relationship between solution concentration and substrate porosity plays an important role in polymer penetration and retention. Best polymer distribution and retention was achieved by "priming" (pre-wetting) the specimen with pure acetone or very dilute consolidant solution, then applying the most concentrated solutions that would readily penetrate a given fossil. The author also experimented with slurries of sand and acetone solutions of Paraloid B-72. His results, figured by Horie (2010:110), demonstrated decreased reverse migration with increased concentration. For a discussion of the factors involved in penetration and migration, see Domaslowski (1987–1988) and Hansen et al. (1993).

A Paraloid B-72 solution in acetone is usually the best choice for joining fragments, and very rapid assembly is often possible, especially of porous fossils that can absorb the

Figure 2. Developing tack for adhering two fragments.

solvent. More dense, less absorbent fossils may require special manipulation to speed setting. For example, Koob describes a technique he calls "developing tack" by repeatedly pulling apart and rejoining fragments until the adhesive grabs (Fig. 2) (Koob 1986, 2009). This is often very effective for dense fossils that are sturdy enough to tolerate the process.

Using acetone alone with Paraloid B-72 for joining fragments or for surface coatings sometimes results in rapid "skinning" of the polymer and the creation of bubbles, an effect that may be reduced by the addition of up to 10% ethanol.

Ethanol or Toluene as a Solvent for Paraloid B-72

Ethanol is less volatile than acetone thus ethanol solutions of Paraloid B-72 set more slowly. Ethanol solutions may set too slowly for convenient use as an adhesive for joins, but in some situations they may perform better than acetone solutions for consolidation. Paraloid B-72 is also less readily soluble in ethanol than in acetone, which may result in better consolidant penetration and polymer retention. As mentioned previously, consolidation of fossil substrates usually requires experimentation to achieve the best results. Penetration may be aided by pre-wetting the substrate with ethanol before applying the consolidant solution.

Toluene is an effective solvent for Paraloid B-72, with a volatility even lower than ethanol, and is often preferred by conservators as a solvent for coatings and consolidation (of wood, for example: Kucerova and Drncova 2009). Toluene, however, is a much larger molecule than acetone and results in a significantly higher viscosity than similar concentration solutions in acetone (Koob pers. comm.). Although this may limit primary penetration of the consolidant solution, it may also limit the adverse effects of polymer reverse migration. Toluene is more toxic than acetone or ethanol, and it is especially important to acquaint oneself with the risks and employ appropriate precautions when working with toluene, particularly for consolidation tasks requiring large volumes of solvent. A great deal of information about solvent safety is available online.

For more tips on consolidation and how to counter reverse migration, see the discussions of immersion and vapor chambers below.

Acetone and Ethanol Mixtures as Solvents for Paraloid B-72

Mixtures of acetone and ethanol are sometimes used to manipulate viscosity and set time, but the user should be aware that these solvents are more toxic when combined (see below). The addition of ethanol (5–10% by volume) to Paraloid B-72 solutions in acetone often helps to reduce bubbling, e.g., when a very smooth base coat is required when labeling specimens. Koob recommends the addition of 10–15% ethanol, when using acetone solutions of Paraloid B-72 in hot conditions, to decrease bubbling and stringiness and to increase working time (Koob 2009:118).

Solvent Health and Safety

Most organic solvents, including acetone, ethanol, and toluene, are toxic and flammable to some degree. All solvents should be used with a good understanding of their hazards. Keep solvents away from sources of ignition. Avoid contact with the skin. Use appropriate personal protection from fumes. A well-ventilated room may suffice for small quantities of acetone or ethanol, but a fume hood is recommended for handling larger quantities (e.g., when mixing solutions or consolidating large surface areas). Toluene should be handled under a fume hood. Extra caution is appropriate when handling mixtures of acetone and ethanol because acetone acts synergistically to increase the toxicity of ethanol (Canadian Centre for Occupational Health and Safety 1997–2000; Caledon Laboratory Chemicals 2010).

Containers

When it comes to choosing a container for Paraloid B-72 solutions, the choice is usually between glass and solvent-resistant plastic. However, even the most resistant plastic containers are acetone permeable, and their contents tend to thicken and solidify over time. Most plastics, even Nalgene® low-density polyethylene, are eventually degraded by solvents and may release contaminants into the solution. Glass jars do not degrade, but the materials lining the inside of lids may be prone to deterioration and may require isolation with a nonstick liner (see discussion below on how to keep lids from sticking or deteriorating). Lab-grade glass jars are more expensive than Mason jars or common food jars but may be cleaned and re-used repeatedly.

An Easy Way to Clean Jars

An easy way to clean residual solution and gummy rims of glass jars is to soak them in water. If the jar is filled with water before the solvent has evaporated, the residue will immediately become opaque and rubbery and peel off easily like a skin (Fig. 3).

How to Keep Lids from Sticking or Deteriorating

Stuck jar lids may be avoided using several methods. Jim McCabe of the Royal Tyrrell Museum, Canada, uses Formula Five® mold release wax to prevent lids from sticking (McCabe, pers. comm.). Other workers have used Teflon® plumber's tape. Many conservators and fossil preparators prefer to use silicone-coated Mylar® (available from conservation suppliers). A small square is placed over the jar and the lid screwed down tight to prevent evaporation (Fig. 4). Silicone-coated Mylar also protects the solution if

Figure 3. An easy way to clean glass jars by soaking in water before the solution has evaporated and peeling out the residue.

the lid liner decays. Silicone-coated Mylar is usually supplied in large rolls that are pricy but worth the expense.

Preparing Paraloid B-72 Solutions

If simply added to a container of solvent, Paraloid B-72 pellets take considerable time to dissolve and have a tendency to settle as a thick, gummy layer on the bottom of the container. Constant stirring helps, either by hand or with a magnetic stirrer. An interesting technique used by Vicen Carrió-Lluesma at the National Museum of Scotland employs a lapidary polisher to provide constant rotation of the jar (Carrió-Lluesma pers. comm.). Paraloid B-72 is more soluble in acetone than in ethanol; thus it may dissolve faster and form more concentrated solutions in acetone than in ethanol.

Figure 4. A baby formula jar. The lid is screwed down over a small square of silicone-coated Mylar to prevent sticking.

Figure 5. An easy way to mix Paraloid B-72 by suspension in a cheesecloth bundle tied with sewing thread inside a glass jar partially filled with solvent.

The Cheesecloth Method of Mixing Paraloid B-72

The most efficient and effective method to dissolve Paraloid B-72 does not require any stirring and was first described by conservator Stephen Koob in his excellent 1986 paper on the use of B-72 as an adhesive for ceramics (updated in Koob 2009). Koob weighs B-72 beads and then wraps them in a cheesecloth bundle. The bundle is tied and suspended with sewing thread inside a glass jar partially filled with solvent (Fig. 5). The height of the bundle is adjusted so that the bottom lightly touches and wicks up the solvent, visibly releasing a stream of dissolved B-72. The dissolved polymer settles to the bottom of the container, leaving relatively pure acetone above to rapidly dissolve the remaining solids in the cheesecloth bundle. It is important to leave the mixing container undisturbed until the solids are completely dissolved (4–12 hours, depending upon the concentration of the solution being prepared). The empty bundle is then removed, and the solution is simply swirled to mix. For very large quantities, one of the authors (G.W.B.) reports success using Hubco® cloth geological sample bags instead of cheesecloth to mix gallons of solution.

Concentration

Weight-to-Weight versus Weight-to-Volume

Adhesive and consolidant solutions can be prepared either by combining specific weights of polymer and solvent (w/w) or by combining a specific weight of polymer and a specific volume of solvent (w/v). In each case, the resulting concentration can be expressed as a percentage. For most uses on fossil vertebrates the difference is not critical. The important point is to properly indicate on the container label and in your documentation which method you are using to prepare your solutions and to designate the units of measure used (w/w or w/v). Also keep in mind that concentrations will tend to increase over time because of solvent evaporation from storage and dispensing containers

Table 1. Approximate mixing formulae for Paraloid B-72 solutions.

Solution	Paraloid B-72 (g)	Solvent	Fumed silica	Actual concentration (%)
1:1 (w/w) stock adhesive	100	100 g	1.5 g (2 tablespoons)	50
1:5 (w/v) stock consolidant	100	500 ml	None	~17
1:20 (w/v) dilute consolidant	25	500 ml	None	~5

during use. In any case, regardless of the concentrations prepared, adjustments usually must be made to accommodate specific uses and specimen/substrate properties (especially porosity).

Accurate percentage concentration can be calculated for either weight/weight or weight/volume solutions, but in common practice in preparation labs, this is not necessary. Perhaps the most convenient way to prepare solutions is to simply combine ratios of polymer and solvent using weight-to-volume units, for example, 30 g of Paraloid B-72 to 100 ml of solvent. This would result in a 3:10 (w/v) solution. Precise percentage concentrations, if needed, can be simply calculated using readily available formulas; see Table 1 for examples. Either method of preparing and labeling stock solutions is acceptable as long as the method and labeling are consistent and understood by lab staff.

1:1 Weight/Weight "Koob Recipe" for Paraloid B-72 Adhesive

The cheesecloth method is effective for preparing solutions in acetone for concentrations up to 50% (weight/weight). To prepare very concentrated solutions (above 80%) Koob recommends allowing evaporation of acetone from the solution to achieve the desired concentration. To improve rheology and other properties of high-concentration solutions intended for use as an adhesive, Koob adds a small amount of fumed silica. One of the author's (A.D.) stock adhesive solution is made with 100 g of Paraloid B-72 in 100 g of acetone with two rounded teaspoons of Cabosil® fumed silica added. The solution is allowed to sit before use in order to release the air bubbles introduced by stirring.

1:5 Weight/Volume Stock Solution for Consolidation, Dilute as Needed

The cheesecloth method also works for thinner solutions. It is often convenient to make a 1:5 (w/v) stock solution of Paraloid B-72 (e.g., 100 g of Paraloid B-72 in 500 ml acetone or ethanol). This may be diluted with more solvent as needed. Preparators often work with small containers of consolidant that are left open for hours, and concentrations will change with evaporation of the solvent. Fedak (2006) discusses a method of using capillarity to monitor concentrations. Finding the best concentration to consolidate a particular fossil substrate is often a matter of "feel" and may require experimentation. As mentioned previously, best results may be achieved by pre-wetting the specimen with pure solvent or very dilute consolidant and then applying the most concentrated solutions that will penetrate readily.

Tips for Dispensing Concentrated Solutions

Concentrated ("thick") solutions of Paraloid B-72 in acetone are very sticky and make excellent adhesives for joining, as described by Koob for ceramics. However, their stickiness and stringiness can make them challenging to dispense.

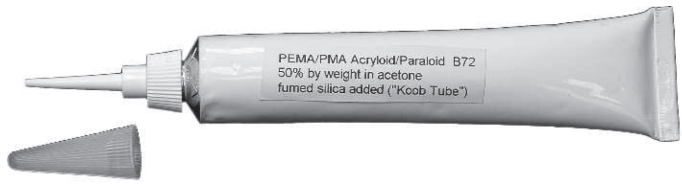

Figure 6. The "Koob Tube," a self-loaded tube for dispensing thick solutions of Paraloid B-72 in acetone.

Tubes for Dispensing Thick Solutions

Koob (1986, 2009) describes a very good method for dispensing thick (50%) solutions by self-filling aluminum tubes (the "Koob Tube" is ubiquitous in conservation laboratories) (Fig. 6). Filled tubes may be stored unopened for years without drying out. Commercially filled tubes of Paraloid B-72 are available through conservation suppliers, and for small quantities the convenience may be worth the extra expense. Note, however, that these commercial formulations may contain unwanted additives. HMG B-72 is a popular brand that currently contains 10–25% nitrocellulose (Conservation Resources 2008). Nitrocellulose is a compound known to age poorly and was apparently added to the formula beginning in 1995 (Nel and Lau 2009).

Squeeze Bottles for Dispensing Thick Solutions

Plastic squeeze bottles are effective for dispensing or for transferring thick solutions to tubes or syringes without a sticky mess. Matthew Brown at the University of Texas recommends 2-ounce (60 ml) Nalgene® drop-dispenser bottles (Brown, pers. comm.). Plastic bottles, unlike glass, are not completely impermeable or resistant to attack by acetone and are not recommended for long-term storage of solutions.

Syringes for Dispensing Thick Solutions

Conservators at the American Museum of Natural History prefer syringes to dispense viscous adhesive solutions (Alderson, pers. comm.). The Monoject™ 412 is a large syringe with a curved plastic tip that may be trimmed if necessary (Fig. 7, top). BD Luer Lok™ syringes may be purchased in a variety of sizes (e.g., 3 ml and 10 ml). These are used with interchangeable plastic Luer Lok™ tips that screw in place (Fig. 7, bottom). Tips may be stopped by inserting a ball-headed sewing pin or insect pin.

Figure 7. Syringes for thick and thin solutions: (top) Monoject™ 412, stopped with a ball-headed sewing pin; (bottom) a BD Luer-Lok™ syringe with Luer-Lok™ tip.

Figure 8. A clean paper towel wrapped around a sandbag is a stable, convenient way to wipe brushes after cleaning with solvent.

Jars and Brushes for Dispensing Dilute "Thin" Solutions

Fossil preparation often requires constant application of small amounts of consolidant by brush from a jar and then rinsing the brush in solvent. Small, bottom-heavy glass containers such as baby formula jars work well for this. As mentioned previously, a sheet of silicone-coated Mylar prevents jar lids from sticking. Brushes with solvent-proof handles may be kept inside larger jars to prevent the brushes from drying out. A clean paper towel wrapped around a sandbag is a stable, convenient way to wipe brushes (Fig. 8).

Nail-Polish and Other Brush Bottles for Dispensing Thin Solutions

One of the easiest ways to dispense thin solutions of Paraloid B-72 is with nail-polish bottles (Fig. 9). Bottles of either clear nail polish or nail hardener may be emptied, cleaned thoroughly with acetone, and refilled with Paraloid B-72 solutions. Nail-polish bottles and brushes are very commonly used to coat numbers with B-72 when labeling specimens, but they are also useful for repair of small specimens. Nail-polish bottles are especially good for students, volunteers, and researchers who may not be accustomed to handling adhesives. One of the authors (G.W.B.) uses low-density polyethylene bottles with conical Yorker dispensing caps for dispensing thin as well as thick solutions (Fig. 10). A solvent-proof brush may be inserted through the cap aperture and left in place. This makes it easy to slide the brush down as the solution drops, keeping the bristles wet. To use, the cap is simply unscrewed like a nail-polish bottle. Because of the solvent permeability of polyethylene, however, solution concentration can increase over time. Using Yorker caps on glass bottles with compatible threads rather than polyethylene bottles would probably limit solvent loss.

Figure 9. For dispensing thin solutions, clear nail-polish bottles are very convenient (rinsed well, refilled, and relabeled).

Squeeze Bottles, Droppers, and Syringes for Dispensing Thin Solutions

Small plastic squeeze bottles may be fitted with various needle tips for dispensing drops. Justy Alicea at the American Museum of Natural History and Joe Groenke of Stony Brook University use Nordson EFD® dispense tips of either metal or flexible plastic, of various diameters, for dispensing Paraloid B-72 (Fig. 11). These are adhered onto small drop-dispenser bottles with thick Paraloid B-72. The tips may be removed and cleaned by soaking in solvent for re-use (Alicea, pers. comm.). Large squeeze bottles are often employed in the field for bulk consolidation, but one of the authors (A.D.) prefers a more controlled application with disposable plastic droppers out of a wide-mouthed plastic jar. Droppers are equally useful in the lab and the field for dripping applications over large areas and into cracks and for squirting up into undercuts (Fig. 12). Thin solutions may also be loaded into syringes and injected into cracks. Koob (2009) describes the repair of glass objects by assembling fragments with tape and injecting Paraloid B-72 into the joins.

Immersion in Thin Solutions

Achieving deep penetration of solution adhesives like Paraloid B-72 is often problematic, and numerous workers have experimented with immersion using different polymers, solvents, and concentrations. Schniewind and Kronkright (1984) compared Paraloid B-72 with Butvar B-98 PVB and various PVAC resins for immersion treatment of a large wooden canoe. Barclay (1981) experimented with many resins including Paraloid B-72 in toluene for the consolidation of a wooden fire engine by brushing and also by immersion under vacuum. Nakhla (1986) studied natural resins and synthetic resins including Paraloid B-72 in various hazardous solvents for consolidation of wooden Egyptian artifacts by brushing, dripping, and immersion under vacuum. Kres and Lovell (1995) used four different resins, including Paraloid B-72 in toluene, for consolidation by brushing and immersion of archaeological bone. Koob (2009) describes an interesting technique for consolidating ceramics inside a plastic bag by capillary action ("wicking

Figure 10. A low-density polyethylene bottle with a Yorker cap. The bottle on the right is outfitted with a solvent-proof brush.

up") using 5–15% solutions of Paraloid B-72 in acetone or acetone/ethanol. For vertebrate fossils, useful descriptions of immersion techniques (not specific to Paraloid B-72) are provided by Rixon (1976:18–25), Anderson et al. (1994), and Koob (1984). The effectiveness of immersion as a consolidation treatment and the ability of a specimen to withstand immersion will vary considerably among different fossils and substrates. The literature cited above should be reviewed thoroughly to enable an informed decision regarding the safety and suitability of this technique for a given fossil.

Consolidation with Thin Solutions in a Vapor Chamber

Deep penetration may be encouraged by applying the consolidant to the specimen inside an enclosure containing a solvent vapor atmosphere. Vapor chambers are often simple bags or tents of polyethylene sheeting filled with fumes from open dishes of solvent (Fig. 13). Hansen et al. (1993) introduced the use of vapor chambers for the consolidation of porous, matte paint. In addition to aiding penetration and counteracting polymer reverse migration, vapor chambers help reduce the glossiness that many workers have noted is typical of Paraloid B-72 on the surface of objects. Koob's capillary consolidation technique uses a bag that functions as a vapor chamber to slow evaporation and reduce gloss (Koob

Figure 11. Two-ounce Nalgene® drop-dispenser bottles may be fitted with Nordson EFD® dispense tips.

2009). It should be noted that vapor chambers can be a very effective way to soften and release prior joins made with Paraloid B-72 or other soluble adhesives. This effect must be considered before placing a specimen in a vapor chamber to avoid unintentional damage to anything soluble on the specimen, including joins, labels, and inks.

Spray Application of Thin Solutions

One of the authors (G.W.B.) has had success in large-scale consolidation using a commercial-grade sprayer designed to apply acetone-based stains and sealants to concrete. An SP Systems® SP35ACT sprayer was used with acetone solutions of Paraloid B-72 to consolidate multiple *in situ* skeletons preserved at Ashfall Fossil Beds State Historical Park, Nebraska (Fig. 14). The highest concentration used was approximately 1 part Paraloid B-72 to 9 parts acetone by weight (a 10% w/w solution.) Four soaking applications were made over 2 days, each application consisting of about 2 gallons of solution. For this particular bone preservation and porous ash substrate, no surface gloss was noted. Depth of penetration and retention of polymer were excellent.

Tips for Reactivating Dried Solutions

Solvent Reactivation with Brushes, Syringes, and Tweezers for Large and Small Joins

Sometimes joins may be made by painting or dripping Paraloid B-72 solution on the surfaces to be adhered, allowing it to dry and then redissolving the surface with more

Figure 12. Disposable plastic droppers are equally useful in the lab and the field for dripping applications over large areas and into cracks and for squirting up into undercuts.

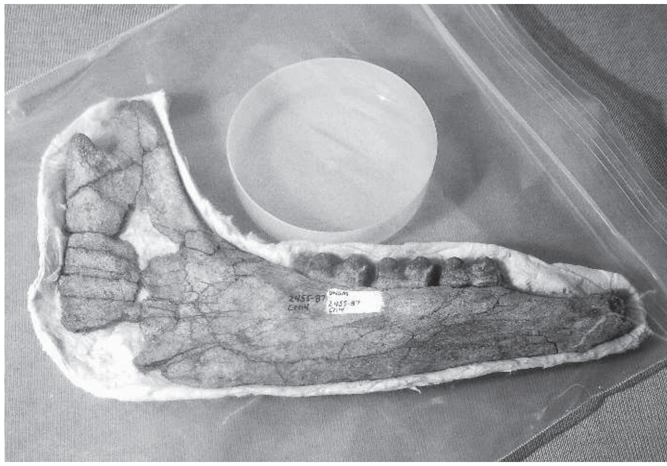

Figure 13. A simple vapor chamber made from a polyethylene bag filled with fumes from open dishes of solvent.

solvent before joining. This technique has been refined by Jim McCabe of the Royal Tyrrell Museum, using acetone as the solvent. As the adhesive dries he uses a spatula to work out any bubbles that form. Once the adhesive has set up and all the bubbles are worked out, he reactivates the bonding surface by brushing on acetone or applying it with a syringe. In some cases the pieces can be reassembled dry and acetone wicked into the join with a syringe to reactivate the adhesive (McCabe pers. comm.). This technique minimizes the amount of solvent (and solvent retention) inside joins with large bonding surfaces (see previous section on hardness and strength for discussion of solvent retention).

Figure 14. One of the authors (G.W.B.) using a SP Systems® SP35ACT sprayer to apply a solution of Paraloid B-72 in acetone at Ashfall Fossil Beds State Historical Park, Nebraska. Active ground-level ventilation prevents the heavier acetone fumes from rising to breathing levels.

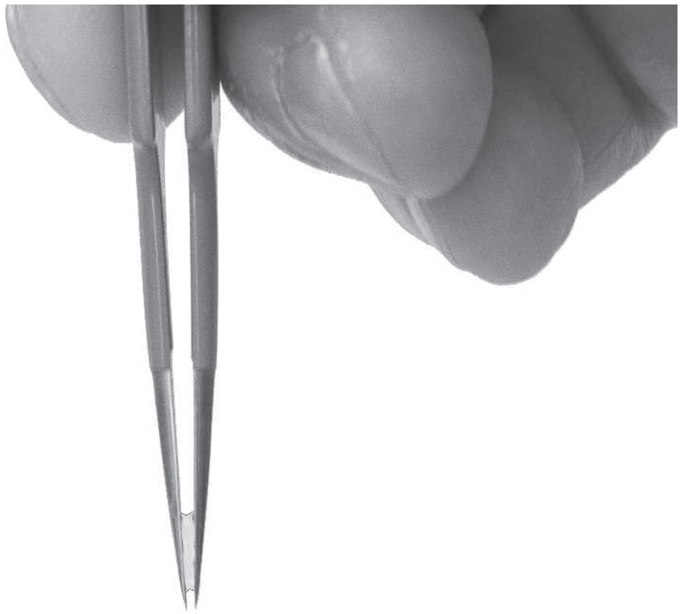

Figure 15. Tiny joins may be made by reactivating and reworking Paraloid B-72 with tweezers and a drop of acetone.

McCabe has also developed an innovative technique for making very small joins using a fine syringe (1 ml with a 30 gauge needle) filled with acetone. A small globule of thick Paraloid B-72 is picked up and transferred with the syringe tip. The adhesive is deposited on the fossil surface by gently flowing acetone out of the syringe. One milliliter syringes allow excellent precision to apply small amounts of solvent (McCabe pers. comm.). Minute amounts of solvent can be dispensed without using the syringe plunger; finger warmth on the syringe barrel will provide a very controlled flow due to thermal expansion of the solvent.

For the application of very small amounts of Paraloid B-72 with a brush it is not always necessary to dip into a solution. Marilyn Fox of the Peabody Museum, Yale University, keeps a small porcelain teacup at hand with a dried residue of Paraloid B-72 on the bottom. She reactivates the residue as needed with solvent and a small brush (Fox, pers.comm.). It may also be possible to detach a tiny piece of dried film, place it where needed with tweezers, and then reactivate it with solvent *in situ*.

Very fine, pointed tweezers are commonly used by preparators to wick up and apply tiny amounts of cyanoacrylate adhesives, but this technique usually does not work for Paraloid B-72 solutions because of overly rapid solvent evaporation and polymer stickiness. A clever technique used by Joe Groenke at Stony Brook University and Constance Van Beek at the Field Museum, Chicago, employs a brush to apply the solution and then tweezers to transfer tiny amounts of pure solvent to redissolve and rework the dried Paraloid B-72 (Fig. 15) (Groenke and Van Beek pers. comm.). This is an excellent technique for micro-applications of Paraloid B-72.

Heat Reactivation and Manipulation

Paraloid B-72 is a thermoplastic resin with a Tg of 40°C (104°F) and thus may be softened and reworked with gentle heat. Conservators commonly exploit this property using hair dryers and heated tools. Use of a desk lamp and hair dryer to adjust joins made with Paraloid B-72 on ceramics is discussed briefly by Koob (2009:116–117). One of the authors (G.E.B.) has used a heat gun (held at a distance with his hand as a temperature indicator) to soften and realign joins when rebuilding complex comminuted fossil specimens and considers it far superior to solvent for this purpose. Obviously, care must be taken to ensure that the specimen can withstand heating without incurring damage. Wolfe mentions the use of heated spatulas to apply dried mixtures of bulked Paraloid B-72 for filling gaps and losses (Wolfe 2009:135). Anthropology conservators at the American Museum of Natural History make frequent use of an Englebrecht temperature-controlled electric spatula with an overlay of silicone-coated Mylar to manipulate solidified fills made with Paraloid B-72 and glass micro-balloons. Heat may also be used to help remove lids or caps that have become stuck to jars of consolidant or adhesive (Koob pers. comm.). Exploiting the thermoplastic properties of Paraloid B-72 is currently not a common practice in vertebrate fossil preparation but would be worthy of further investigation.

Removing Paraloid B-72

Reversibility (a polymer's ability to be removed without damage to the specimen) should be considered before applying any polymer. For a discussion of the conservation principle of reversibility and practical problems of reversing treatments see Appelbaum (1987) and (Horie 2010). In our experience, Paraloid B-72 is less easily redissolved and adheres more strongly to fossil substrates than Butvar® B-76 PVB and McGean B-15 PVAC. As mentioned in the discussion of hardness and strength, Paraloid B-72 retains solvent for a very long time, thus going through rubbery and leathery stages before becoming hard and more brittle when the solvent has completely evaporated. These stages may be exploited when removing fresh coatings or fresh excess adhesive squeezed out of joins. Earlier stages are easier to redissolve; later, more brittle stages may be easier to pick off with a needle, especially if the excess has bubbled. Older, completely set coatings may be removed by brushing with acetone until redissolved and then blotting with brushes, cotton swabs, or tissue, or by applying a poultice with an absorbent material such as cotton or tissue soaked in solvent, covered with polyethylene sheeting, as long as the specimen surface is not damaged by this treatment. Surface consolidants may be removed or reduced in this manner, but penetrating consolidation treatments in general are not fully reversible, even by soaking in solvent. For discussion of the limitations of removability, especially of consolidants, see Horie (1982). Undoing joins generally requires time for the solvent to penetrate into the interior of the join. Small or fresh joins require little time; large and completely set joins are much slower to release. Soaking in solvent to undo joins is possible only with very robust specimens that can withstand this treatment without damage. Other methods of feeding solvent into a join over time include vapor chambers (described in the discussion on consolidation) or poulticing as described above.

Conclusion

Paraloid B-72 has many desirable properties, but even the best materials can fail if they are not appropriate for a particular application. Successful use of any adhesive requires thought and a good understanding of the specimen, knowing what you want the adhesive to do, and a familiarity with what the adhesive is *capable* of doing. This familiarity can come only with experience. The authors recommend that all fossil preparation labs keep at least two stock solutions available for experimentation: thick Paraloid B-72 in acetone and a thinner solution in ethanol. Various combinations and concentrations can be mixed from these stock solutions to suit the needs of the job at hand. Although no single adhesive or consolidant is suitable for every situation, Paraloid B-72 is an excellent candidate for many vertebrate fossil preparation tasks.

Acknowledgments

This paper obviously could not have been written without many contributions from fellow preparators and researchers who have used Paraloid B-72 in their own creative ways. We thank Jim McCabe for his reviews, comments, and great tips. A. Davidson is deeply grateful to Samantha Alderson, Conservator, Anthropology Objects Conservation lab, and Lisa Kronthal Elkin, Director of Conservation, Natural Sciences Collections, American Museum of Natural History, for 16 years of mentoring and friendship and for reviewing early drafts. Some of this paper is derived from the authors' 1996 presentation at the annual meeting of the Society of Vertebrate Paleontology. Velson Horie provided invaluable instruction through his writing, lectures, and Chemistry for Conservators correspondence course. Special thanks to Lisa Herzog for organizing the third annual Fossil Preparation Symposium, which was the inspiration for writing this paper, and to Matthew Brown for encouraging us to publish. G. Brown is grateful for the inspiration and guidance provided over the years by Frank Howie, Jerry Fitzgerald, Rob Waller, Chris Collins, and Sally Shelton, and to the University of Nebraska State Museum and Dr. Mike Voorhies for providing both time and encouragement for research projects in preparation, conservation, and collections care. Steve Jabo and Stephen Koob reviewed and improved this paper with their many useful comments and suggestions.

Literature Cited

Anderson, K., J. Davids, and T. Hodorff. 1994. Nonpetrification preparation. Pp. 140–146 in *Vertebrate Paleontological Techniques,* Vol. 1. (P. Leiggi and P. May, eds.). Cambridge University Press, Cambridge, England. 344 pp.

Appelbaum, B. 1987. Criteria for treatment: Reversibility. Journal of the American Institute for Conservation 26(2):65–73.

Barclay, R. 1981. Wood consolidation of an eighteenth century English fire engine. Studies in Conservation 26:133–139.

Buttler, C.J. 1994. The conservation of the Sedgwick Museum Barrington (Quaternary) hippopotamus skeleton. Geological Curator 6(1):3–6.

Caledon Laboratory Chemicals. 2010. Materials Safety Data Sheet: Acetone. http://www.caledonlabs.com/upload/msds/1200-1e.pdf (25 February 2012).

Canadian Centre for Occupational Health and Safety. 1997–2000. Acetone Dangers. http://www.entheology.org/tips-acetone/acetone.htm (25 February, 2012).

Carlson, S.M. and A.P. Schniewind. 1990. Residual solvents in wood-consolidant composites. Studies in Conservation 35:26–32.

Chiantore, O. and M. Lazarri. 2001. Photo-oxidative stability of Paraloid acrylic protective polymers. Polymer 42(1):17–27.

Conservation Resources (U.K.) Ltd. 2008. Technical data sheet: HMG "Acraloid" [*sic*] B72 (SY-7T). Revised April 2008. HMG Paints Ltd., Manchester, UK. 6 pp.

Davidson, A. and S. Alderson. 2009. An introduction to solution and reaction adhesives for fossil preparation. Pp. 53–62 in *Methods in Fossil Preparation: Proceedings of the First Annual Fossil Preparation and Collections Symposium, Petrified Forest National Park* (M.A. Brown, J.F. Kane, and W.G. Parker, eds.). Petrified Forest National Park, 142 pp.

De Witte, E., M. Goessens-Landrie, E.J. Goethals, and R. Simonds. 1978. The structure of 'old' and 'new' Paraloid B-72. Paper 78/16/3. Pp. 1–9 in *International Council of Museums, Committee for Conservation, 5th Triennial Meeting,* 1–8 October 1978, Zagreb. International Council of Museum, Paris [various pagination].

Domaslowski, W. 1987–1988. The mechanism of polymer migration in porous stones. Wiener Berichte über Naturwissenschaft in Kunst 4/5:402–425.

Down, J.L. 2009. Poly(vinyl acetate) and acrylic adhesives: A research update, Pp. 91–106 in *Holding It All Together: Ancient and Modern Approaches to Joining, Repair and Consolidation* (J. Ambers, C. Higgitt, L. Harrison, and D. Saunders, eds.). Archetype Publications, London, UK. 210 pp.

Down, J.L., M.A. MacDonald, J. Tetreault, and R.S. Williams. 1996. Adhesive testing at the Canadian Conservation Institute: An evaluation of selected poly (vinyl acetate) and acrylic adhesives. Studies in Conservation 41(1):19–44.

Erhardt, D. 2001. Solvent grade: Does it matter? Solvents considered at AIC annual meeting in Dallas. AIC News 26(5):6–7.

Fedak, T.J. 2006. Using capillarity for determining and maintaining a polymer consolidant concentration after solution preparation. Collection Forum 20(1–2):108–112.

Feller, R.L. 1978 Standards in the evaluation of thermoplastic resins. Paper 78/16/4. Pp. 1–11 in *International Council of Museums, Committee for Conservation, 5th Triennial Meeting*. 1–8 October 1978, Zagreb. International Council of Museum, Paris [various pagination].

Feller, R.L. and M. Curran. 1975. Changes in solubility and removability of varnish resins with age. Bulletin of the American Institute for Conservation of Historic and Artistic Works 15(2):17–26.

Feller, R.L., M. Curran, and C. Bailie. 1981. Photochemical studies of methacrylate coatings for the conservation of museum objects. Pp. 183–196 in *Photodegradation and Photostabilization of Coatings, American Chemical Society Symposium Series 151, 179th Meeting of the American Chemical Society*. American Chemical Society, Washington, DC. 308 pp.

Hansen, E.F. 1995. The effects of solvent quality on some properties of thermoplastic amorphous polymers used in conservation. Pp. 807–812 in *Materials Issues in Art and Archaeology IV, Cancun, Mexico, Materials Research Society Symposium Proceedings, vol. 352*. Materials Research Society, Pennsylvania. 918 pp.

Hansen, E.F., R. Lowinger, and E. Sadoff. 1993. Consolidation of porous paint in a vapor-saturated atmosphere: A technique for minimizing changes in the appearance of powdering, matte paint. Journal of the American Institute for Conservation 32(1):1–14.

Horie, C.V. 1982. Reversibility of polymer treatments. Pp. 3/1–3/5 in *Resins in Conservation, Proceedings of the Symposium, University of Edinburgh, UK*. Scottish Society for Conservation and Restoration, Edinburgh, UK. [various pagination].

Horie, C.V. 2010. *Materials for Conservation: Organic Consolidants, Adhesives and Coatings,* 2nd ed. Butterworths, London, Elsevier Ltd., Oxford, UK. 489 pp.

Jorjani, M., G. Wheeler, C. Riccardelli, W. Soboyejo, and N. Rahbar. 2009. An evaluation of potential adhesives for marble repair. Pp. 143–149 in *Holding It All Together: Ancient and Modern Approaches to Joining, Repair and Consolidation* (J. Ambers, C. Higgitt, L. Harrison, and D. Saunders, eds.). Archetype Publications, London, UK. 210 pp.

Koob, S.P. 1984. The consolidation of archaeological bone. Pp. 98–101 in *Adhesives and Consolidants, Preprints of the Contributions to the Paris Congress, IIC (International Institute for Conservation of Historic and Artistic Works)* (N.S. Bromelle, E.M. Pye, P. Smith, and G. Thompson, eds.). The International Institute for Conservation of Historic and Artistic Works, London, UK. 222 pp.

Koob, S.P. 1986. The use of Paraloid B-72 as an adhesive: Its application for archaeological ceramics and other materials. Studies in Conservation 31:7–14.

Koob, S.P. 2009. Paraloid B-72®: 25 years of use as a consolidant and adhesive for ceramics and glass. Pp. 113–119 in *Holding It All Together: Ancient and Modern Approaches to Joining, Repair and Consolidation* (J. Ambers, C. Higgitt, L. Harrison, and D. Saunders, eds.). Archetype Publications, London, UK. 210 pp.

Kres, L.A. and N.C. Lovell. 1995. A comparison of consolidants for archaeological bone. News and Short Contributions, Journal of Field Archaeology 22:508–515.

Krumrine, C. and L. Kronthal. 1995. What a relief! A practical, inexpensive approach to the conservation of a large XIX dynasty sandstone stela. Pp. 21–38 in *AIC Object Specialty Group Postprints, vol. 3, Proceedings of the Object Specialty Group Session, 23rd Annual Meeting, American Institute for Conservation. St. Paul, Minnesota*. American Institute for Conservation Object Specialty Group, Washington, DC. 137 pp.

Kucerova, I. and D. Drncova. 2009. The consolidation of wood with Paraloid B-72® solutions. Pp. 150–156 in *Holding It All Together: Ancient and Modern Approaches to Joining, Repair and Consolidation* (J. Ambers, C. Higgitt, L. Harrison, and D. Saunders, eds.). Archetype Publications, London, UK. 210 pp.

Larkin, N.R. and E. Makridou. 1999. Comparing gap-fillers used in conserving sub-fossil material. Geological Curator 7(2):1–90.

Lazzari, M. and O. Chiantore. 2000. Thermal-ageing of paraloid acrylic protective polymers. Polymer 41(17):6447–6455.

Nakhla, S.M. 1986. A comparative study of resins for the consolidation of wooden objects. Studies in Conservation 31:38–44.

Nel, P. and D. Lau. 2009. Identification of a formulation change in a conservation-grade adhesive. Pp. 99–106 in *Holding It All Together: Ancient and Modern Approaches to Joining, Repair and Consolidation* (J. Ambers, C. Higgitt, L. Harrison, and D. Saunders, eds.). Archetype Publications, London, UK. 210 pp.

Phenix, A. 1992. Solvents for Paraloid B-72. Conservation News, United Kingdom Institute for Conservation 49:23–25.

Podany, J., K.M. Garland, W.R. Freeman, and J. Rogers. 2001. Paraloid B-72 as a structural adhesive and as a barrier within structural adhesive bonds: Evaluations of strength and reversibility. Journal of the American Institute for Conservation 40(1):15–33.

Rixon, A.E. 1976. *Fossil Animal Remains: Their Preparation and Conservation*. University of London, Athalon Press.

Rohm and Haas. 2007. Paraloid B-72 100% Technical Data Sheet. http://www.dow.com/assets/attachments/business/pcm/paraloid_b/paraloid_b-72_100_pct/tds/paraloid_b-72_100_pct.pdf (25 February 2012).

Rohm and Haas. 2010. Paraloid® Acrylic Resins, Solid Grade. Solvent Selection Guide http://talasonline.com/photos/instructions/paraloid_solvent_guide.pdf (25 February 2012).

Rossi, D., S. De Gruchy, and N.C. Lovell. 2004. A comparative experiment in the consolidation of cremated bone. International Journal of Osteoarchaeology 14:104–111.

Sakuno, T. and A.P. Schniewind. 1990. Adhesive qualities of consolidants for deteriorated wood. Journal of the American Institute for Conservation 29:33–44.

Schilling, M.R. 1989. The glass transition temperature of materials used in conservation. Studies in Conservation 34:110–116.

Schniewind, A.P. and D.P. Kronkright. Strength evaluation of deteriorated wood treated with consolidants. Pp. 146–150 in *Adhesives and Consolidants, Preprints of the Contributions to the Paris Congress, IIC (International Institute for Conservation of Historic and Artistic Works)* (N.S. Bromelle, E.M. Pye, P. Smith, and G. Thompson, eds.). The International Institute for Conservation of Historic and Artistic Works, London, UK. 222 pp.

Snow, C.E. and T.D. Weisser. The examination and treatment of ivory and related materials. Pp. 141–145 in *Adhesives and Consolidants, Preprints of the Contributions to the Paris Congress, IIC (International Institute for Conservation of Historic and Artistic Works)* (N.S. Bromelle, E.M. Pye, P. Smith, and G. Thompson, eds.). The International Institute for Conservation of Historic and Artistic Works, London, UK. 222 pp.

Stollman, S., Bell, M., Denize, S., Lutzke, B., and D. Kellles-Krause. 2005. The conservation treatment of Canterbury Museum's blue whale skeleton. Records of the Canterbury Museum 19:35–60.

Wolfe, J. 2009. Effects of bulking Paraloid B-72 for marble fills. Journal of the American Institute for Conservation 48:121–140.

Appendix

Useful Websites

http://cameo.mfa.org/
http://www.conservation-wiki.com/index.php?title=Chapter_V_-_Polymeric_Varnishes
http://talasonline.com/photos/instructions/paraloid_b-72_data.pdf
http://www.dow.com/products/product_detail.page?display-mode=tdsandproduct=1121222

Suppliers

Acetone resistant sprayer, SP Systems®, SP35ACT sprayer, http://www.spsystemsllc.com/industrialcon/sp10act_sp35act.html.

BD Luer Lok™ syringes, 3 to 10 ml, \$15–\$25 per box of 100, http://www.coleparmer.com/catalog/product_index.asp?cls=15116, also available from ConservationResources.com.

Disposable plastic droppers (polyethylene transfer pipettes), Fisher Scientific no. 13-711-7M, \$42.29 per box of 500.

Englebrecht WzII control unit and heat spatula arm, \$310 for unit, \$44 for heat spatula arm, available from Kolner LLC, 23 Grant Avenue, New Providence, New Jersey 07974, tel.: 718-802-1659.

Glass jars, 32-oz-wide-mouth clear glass Wheaton jars, Scientific Instrument Services no. W216907, $80.86 per case of 12.

Luer Lok™ polyethylene taper tip needles, LEM954 blue tip (smallest), $17.00 per pack of 50, https://www.labemco.com/pages/cart.php?s=LEM954.

Monoject™ 412 curved tip syringe, about $3.00 each. Pet and craft suppliers sell smaller quantities than medical or veterinary suppliers.

Nail-polish bottles, Rachael's Supply.com, no. K08, $12.95 per case of 10 bottles with brushes and caps (note: requires assembly), http://www.rachelssupply.com/bottle.htm.

Nail-polish bottle alternative, Brucci®; nail hardener has a good brush. Empty and rinse well with acetone. Duane Reade pharmacy or similar store. About $5.00 each.

Nalgene® LDPE drop dispenser bottles, 60 ml (2 oz), https://www.fishersci.com.

Nordson EFD® dispense tips, 5120-B (pink), 5125-B (red), 5125PPS-B (plastic), http://www.efd-inc.com/Tips/.

Paraloid™ B-72, Talas no. TFK028003, $47.50 per 5 lb bag. Also available from ConservationResources.com.

Self-loading metal tubes, Conservation Resources Int'l, $14.00 per box of 10, http://www.conservationresources.com/Main/section_21/section21_13.htm.

Silicone-coated Mylar®, Talas no. TFM004004, $75.00 per roll (15 inches×150 feet) (38 centimeters × 46 meters).

Yorker spout caps, http://www.yorkerpackaging.com/spout.html.