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Gap fills for geological specimens – or making gap fills with Paraloid

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What is a gap fill?
A gap fill is a material used to fill a gap where a piece is missing either to provide structural support or to make the specimen look better. Some gap filling materials can also be used as an adhesive to effect the actual repair too.

Gap filling materials can also be used to mount specimens and fix them onto backing boards for display.

Review of materials used for gap fills
Many different materials have been used in the past as gap fills with similar materials being used across disciplines. A gap fill needs to be malleable in order to shape it to fill the gap but once shaped, to set sufficiently to complete the integrity of the object. Gap fills are used on all types of materials from paper documents to palaeontological specimens. An appropriate gap filling material should be weaker than the material being filled, so the fill, rather than the specimen breaks if there is any strain.

In the 1980s there was a view that the restoration achieved through gap fills should be obvious and so such repairs were not re-touched and were often painted in a contrasting bright colour, such as yellow on dinosaur bones or filled in with closely spaced vertical lines or *tratteggio*. Tratteggio was developed as a technique for gap fills on paintings and wall paintings, such as those in Egyptian tombs.

Other authors have covered areas of this topic, for example, Howie(1984) reviewed materials used for geological conservation since the 1930s. Larkin and Macridou (1999) compared the effectiveness of gap fills for sub-fossil bone. This paper is intended to provide an overview of both historic and current practice for gap fills in all types of geological material.

19th and early 20th century products

Plaster of Paris – white or cream colour plaster made of ground gypsum (calcium sulphate) – it is made up by mixing the powder with water. Generally, the thinner the mix, the quicker the set. The setting reaction is exothermic and shrinkage can occur.

Plaster of Paris is often used to mount marine reptiles (encased in wooden frames and boxes) and to provide a join between blocks – however is was usually only to provide a flat surface layer with the areas beneath packed out with all manner of materials.

Rixon (1976) described the method to cast specimens into plaster of paris blocks but points out that weight will be a serious problem for larger specimens. Conservators at the Natural History Museum (NHM) reported the use of wood, string, hemp, cotton, horsehair, scrumpled newspaper, iron nails, sand, pebbles, wax and even sulphur as packing out in the large number of mounted marine reptile specimens conserved in the Gallery 30 project (Cornish, Doyle and Swannel, 1995). Straw, tiles, brick fragments and fragments of stone have also been reported by NHM conservators and other conservators (Doyle, 2008).

The water in the plaster mix however raised the relative humidity and can induce pyrite decay in specimens. The resultant expansion from both the exothermic reaction of the plaster setting and the subsequent pyrite decay can cause the gap fills to fail.

Plaster of Paris was also commonly used to "stick" specimens to back boards in displays – an early 20th century technique. With large flat backed blobs often obscuring data labels.

Other types of plaster – all manner of plasters tend to be encountered, some blueish grey and very coarse,

others more akin to lime plaster. Modern Portland cement based plaster however is not common on specimens.

Cornish, Doyle and Swannel (1995) reported finding asbestos fibres mixed in plaster gap fills on some of the marine reptiles during the work on the gallery 30 wall mounted specimens at the Natural History Museum. This technique appears to have been developed in the 1970s but was not documented.

Wax – often used on nineteenth century marine reptile mounts to fill small gaps, such as joins between pieces of matrix and gaps in ribs where a small chip might be missing. Some types of wax are surprisingly hard but very brittle, sometimes the characteristic smell can be used to identify it as beeswax. Using a warmed metal tool or a hair dryer is the most effective way to softening wax. Presumably originally it was applied in a malleable warm state and coloured before application, since the wax is normally the same colour all the way through.

Petroleum wax and coloured furniture conservation wax was used successfully as a gap fill on decorative Blue John artefacts, including an obelisk and a goblet conserved for Birmingham Museum and Art Gallery. No other material had the same translucent quality and the coloured wax, mixed in with the colourless wax proved to be a good match for the deep purple blue flourite.

Red letter sealing wax – this wax, applied in a hot molten state is not the most effective gap fill since it is so obvious and detracts from the aesthetic appearance. It has been encountered on a few rather amateurish repairs on 19th century geological specimens, without any attempt to disguise it with paint. Sealing wax is occasional found as a repair medium on ceramics, it tends to be rather brittle but was probably water-proof unlike most nineteenth century adhesives, so allowing a cracked container to continue to be used rather than thrown away.

Lead – seen on a specimen at Haslemere Museum to hold a metal staple in place on a Giant Irish Elk skull – the same technique was used to hold cast iron railings in place in stone.

Glaziers putty – a mix of linseed oil and dry plaster of paris. Quite commonly found used as a gap fill and adhesive on sub-fossil elephant teeth in particular. Becomes dry and brittle and looses adhesion leading to failure.

Taxidermists "compo" – a pale coloured plastic material that sets hard and is a mix of plaster of paris, paper mache and animal glue used to model soft parts on taxidermy mounts. Not something knowingly encountered on geological specimens but since it is a similar in consistency to glaziers putty, it may well have been used and not yet identified.

Mid 20th century products

Fibronyl or AJK dough – a dough used by mixing Alvar (a polyvinyl alcohol), kaolin and jute flock and sepiolite clay together produces a brown fibrous, fairly light weight, strong but drying to quite a shiny material. It is malleable when first made and remains so if stored in a sealed container. It can be used as a gap fill and painted. Rixon (1976) advocates the use of this material for gap filling both freshly collected damp material such as sub-fossil tusks and on dry material. Even as late as 1995, staff at the NHM were using the last of their stocks of Alvar to make AJK dough as a gap fill on Gallery 30 specimens (Cornish, Doyle and Swannel, 1995). AJK dough does shrink when dry.

This dough was also used extensively in the late 60s and 1970s as a mount method for geological specimens – a large blob placed on the reverse and shaped to the allow the specimen to hang as required, often a brass key-hole surround pushed into the dough to allow the specimen to hang from a nail on the display back board.

Polyfilla – Polyfilla, a plaster of paris and cellulose based product has been used as a gap fill for wall paintings conservation and ceramics. It can be mixed with water from a powder or bought in a ready-mixed form. It is apparently stable and effective, it can be smoothed with damp tools before it is fully set and can be sanded and painted. It is not an effective adhesive and when filling large areas such as a missing piece in a ceramic vessel, needs to be supported, for example with netting.

Polyurethane foam – Rixon (1976), suggested that polyurethane foam might be a suitable "modern" replacement material. Given the toxicity of the components of this material when being mixed and its extreme instability in light, polyurethane foam is in fact a far from suitable material. It was used to support the cradle for the plesiosaur specimen re-mounted in the 1980s at the Sedgwick Museum in Cambridge by Simon Timberlake.

Milliput – Milliput is a two part epoxy putty available in standard and superfine grades. Equal lengths of the two parts are cut and kneaded together, it has the consistency of rather sticky plasticene which can be shaped with damp tools before setting to a very hard material which can be sanded and painted. The superfine grade was often used in porcelain restoration.

The two parts do tend to go off if unused and a far more easy to work material epoxy based material is now available.

Buttler (1994) used milliput successfully to model the missing section of a tusk of the Barrington hippopotamus. Since epoxy resin based products are hard to break down, a barrier layer of a reversible adhesive should be used to separate sections modelled from Milliput from the original matrix.

Resin and rock-dust fills
An effective gap fill can be made by mixing ground rock with any resin or adhesive. Epoxy resin and rock dust fills are widely used on "enhanced" specimens to disguise joins between the matrix and an added specimen or section. Due to the nature of epoxy resins, these are not reversible and so are not usually used by conservators.

Paraloid based gap-fills
Paraloid B72 has been a favoured conservation adhesive and consolidant since the 1980s due to its good ageing properties – it does not cross-link, it is supposed not to yellow and it remains easily reversible, however, it does have a high glass transition temperature.

Glass transition temperature is the temperature at which a polymer changes from a glassy state to a rubbery state. Polymers with low glass transition temperatures can become sticky and attract dust or cold flow even at moderately low temperatures, polymers with high glass transition temperatures will be brittle. (Horie, 1987)

A gap fill can be made by mixing a solution of Paraloid B72 in a suitable solvent with any kind of filler, from Plaster of Paris, marble dust to specially manufactured fillers.

To make up a solution of Paraloid, the beads of adhesive museum be dissolved in a solvent (Fig 1). This is most easily achieved since simply adding solvent to the beads lead to the beads softening and forming a solid layer in the bottom of the container with a layer of acetone lying above.

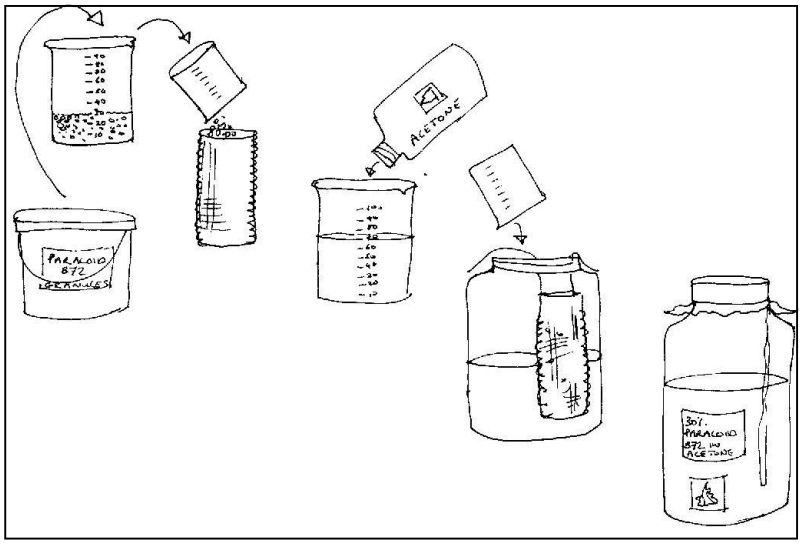

Fig 1. Diagram illustrating how to mix up paraloid B72 beads with acetone.

Glass bubble and Paraloid gap fills

SP systems glass bubbles (also known as microspheres or microballoons) make an effective filler mixed normally with a 30% Paraloid in acetone to the consistency of butter cream icing in a flexible polythene container. It is most effective to measure out the quantity of fill required, add the consolidant then mix up to the required consistency. Approximately 30% consolidant to 70% filler is suggested by the manufacturer. It can be applied as a thick slurry, or allowed to dry out a little and applied as more of a paste.

Fig 2. shows the process for mixing and colouring.

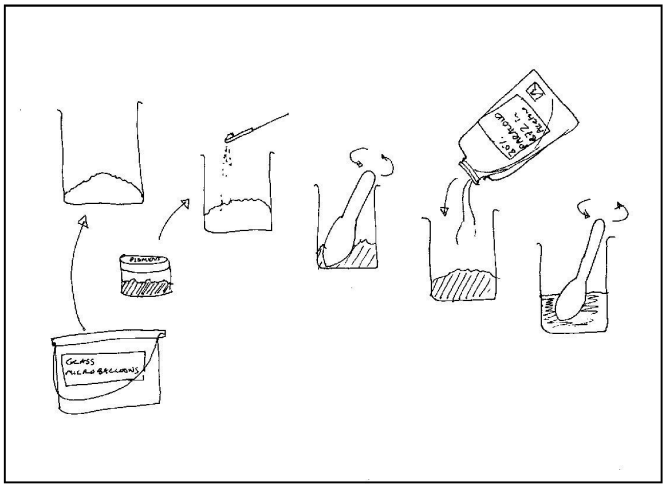

Fig 2. Diagram illustrating the process for mixing and colouring.

The filler will set hard in the container but can be cracked off the sides of flexible containers and then re-mobilised with additional acetone or Paraloid in acetone. In situ, the fill dries to a hard and rather brittle finish, which is not that strong but is easily reversible by dropping acetone onto the fill from a pipette.

The filler can be packed and smoothed with either metal or nylon tools. As the acetone evaporates, the mix becomes slightly elastic before it sets and it is at this stage that it is best to compress and smooth it to the desired finish with tools dipped in acetone. Since it doesn't sand down that well, it is best to get a smooth finish with a tool before it sets hard, alternatively, it can be smoothed once set with acetone swabs. Buttler (1994) suggests building up areas requiring deep fills in thin layers and used this technique extensively on a sub-fossil hippopotamus skeleton.

The filler can be effectively coloured with artists pigments in its dry state before adding the consolidant - earth pigments and ivory black will make most colours needed for palaeontological specimens. Colouring the filler before application requires only tiny amounts of pigment and is far quicker than painting afterwards. The fills can also be painted once dry with acrylic medium mixed with dry pigment or acrylic paints.

It is best to consolidate the join surfaces before applying a gap fill with dilute Paraloid B72 (5 to 10% in acetone). This is particularly important on sub-fossil bone, otherwise the adhesive property of the fill will pull material away from the matrix.

Using a thick paste of filler mix on breaks works very well for dry sub-fossil elephant teeth that have broken into several slabs as once consolidated, this consistency will act as both adhesive and gap fill. Such specimens should be left to set in a sand tray or on sand bags with each joint horizontal, and with careful setting, more than one break can be fixed at once. Some compression from masking tape can be effective but not at the risk of pulling further crumbs off the tooth surface. A sprinkling of yellow ochre into the filler mix is a good colour match for the dentine element which tends to be what fails on such specimens.

Paraloid and glass bubble fill was used extensively on the wall mounted marine reptiles at Whitby Museum conserved from 1994 to 1997 and was still stable and undamaged when inspected whilst treating a later outbreak of pyrite decay in 2007 (Andrew, 1999). This filler has also been used on subfossil elephant teeth (including one in the re-displayed Kelvingrove geology gallery), sub-fossil bone and other smaller teeth (eg woolly rhino) as a packing material around dowells for the tines of Giant Irish Elk antlers for the specimen at Kendal Museum, as gap fills in joins of fully fossilised material and as gap fills and to fill cracks between plaster and original mounts on marine reptile material.

Since creating localised high relative humidity is not advisable for many types of geological specimens, water based consolidation is not normally appropriate to museum specimens and therefore, I've not tried mixing glass micro bubbles with water based consolidants or dispersions.

Other types of glass bead fills

Larger sizes of glass spheres and beads are also available and can be used to create gap fills where greater

structural strength is required, but these products are considerably more dense than the glass bubbles. It is also possible to use glass airbrasive powder and Paraloid B72 in slurry form to fill in large areas around specimens, in the same way that plaster of paris was used historically to set specimens into wooden frames or boxes. Glass airbrasive powder is quite dense, so the resultant block will be heavy. .

Health and safety

Consult the material data sheets prior to use and put together an appropriate risk assessment for the procedure and use (COSHH regulations in the UK).

Although not classed as hazardous to health, eye and face protection are recommended for handling glass bubbles at close quarters because of the small particle size. The concentration of acetone in the Paraloid mix will require the user to adopt appropriate protection from inhalation or use with extraction.

A note on replacement sections

Geological specimens are rarely complete, so replacement parts are common on specimens, either composed of pieces from other specimens or made from some other material and added. Most of the materials listed above can be used to model replacement parts. Where large sections are missing (for example on mounted skeletons), replacement parts made of wood, cork or cut down pieces of modern bone, or carved pieces of matrix are common. The practice of improving the aesthetic appearance of specimens has been commonplace from when geological specimens began to have monetary value, and is still ongoing. The distinction between aesthetics and forgery is a fine one.

Acknowledgements

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UK Suppliers

Acetone – conservation suppliers and chemical supply companies
Paraloid B72 granules – conservation suppliers such as Conservation Resources and Conservation by Design
Milliput – DIY, car repair and modelling shops
SP Systems glass bubbles – Conservation by Design sell three grades 0.34-0.4 particle size is recommended for fills.
www.conservation-by-design.co.uk
Artists dry pigments – Cornellisen & Son sell 15ml pots for £2 or £3 each (depending on the type of pigment) and a starter kit of all their pigments for £72.90 including P&P. www.cornellissen.co.uk
Sculpting tools – Tiranti Ltd sell a big range of tools www.tiranti.co.uk

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Further Reading

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