E. T. J. Mibach, Conservation Division, National [illegible]
1570 Liverpool Ct., Ottawa K1A 0H4, Ontario, Canada.

The Restoration of Coarse Archaeological Ceramics

1. INTRODUCTION

Before a pot reaches restoration, the stage to be described in this paper, it is assumed that it will have received careful conservation treatment in the field and laboratory to remove encrustations, salts and stains, without damaging the basic constituents of the pot (e.g. lime temper) or delicate decoration. Patches of the surface will not be missing in tape-shaped rectangles, and it will not have received treatment which might prejudice future analysis, such as destruction of content residues, or overheating (above about 100°C) or radiography which could affect thermo-luminescence dating. For TL a sample is generally best preserved damp in its earth matrix. It will also have been consolidated if necessary, with a suitable material on the surface or in depth.

The reader is referred to Dowman [1], Gedye [2] and Larney [3] as basic texts.

2. MENDING

This is generally best carried out by starting at the base of the pot (or a the top if there is no base), and building up one sherd at a time. It will be easier to find the correct sherd if they have been sorted out on the bench by position (rims, bellies, bases), orientation (from inner throw lines and other clues), and colour variations. The result of yielding to the temptation to build up two or three large pieces is usually that the accumulated errors in each section make perfect joining impossible. Each successive sherd is tested to be sure that it fits perfectly and does not need further cleaning, and that it will not 'lock out' a sherd to be added later. Sherds must never be filed down to fit in. If the edge of the ceramic is friable enough to need consolidation, it is often advisable to consolidate all the fragments, rather than the edges only, since this may result in a new break at the interface of the consolidated and untreated zones. The needs of each pot must be judged individually.

Sufficient, but not excessive adhesive is applied lightly to the centre of the broken edge on both sherds. They are then joined, 'wiggled' slightly to settle them, and dried in equilibrium in a box of fine, clean sand. The mend is judged satisfactory if the edge of a fingernail can be drawn across the join in either direction w h no sensation.

In cases where the pot has sprung, or where many supporting pieces are missing, padded clamps, string bindings, and other devices may be required.

3. GAP-FILLING WITH PLASTER

The use of plaster is an art which requires experience. A.J.K. dough can also be extremely useful by itself, or to build a supporting framework for plaster reconstructions. The advantages of plaster are that it is inexpensive, quick and easy to make up, and heavy enough to act as a counter-balance when half of a heavy pot is missing. The filled area can be sculptured precisely to irregular shapes following the lines of the extant portions. The disadvantages of plaster, 'ghosting' (traces of plaster left in surface irregularities) and fragility, can largely be overcome by proper working techniques. Plaster is not recommended when the finished product will be incorrectly handled.

'Ghosting' can be minimized by careful workmanship, by using pre-tinted plaster, and by the application of a coat of PVA solution to the surface around the area filled. This is removed afterwards by careful rolling with a solvent-soaked swab. Plaster can be strengthened by mixing it up with very dilute PVA emulsion instead of with plain water.

Other materials can be added to plaster to make it more plastic or to change its colour. These additives must not exceed a total of 25-30% dry weight, or the plaster will be weakened. Plasticizing materials include kaolin barium sulphate, calcium carbonate, non-bake modelling clay, carboxymethyl cellulose, Polyfilla, marble powder and gum arabic. Standard recipes can be drawn up after experimentation with local materials to determine working properties and degrees of shrinkage.

Pre-coloured plaster is easier to work with than white plaster: precision of form is easier if the colour contrast between pot and plaster is minimized, final painting may be avoided or lessened (particularly on cracks where neatness is difficult), and any scratches received in the future will not show up so glaringly. Powdered earth pigments may be used to colour plaster, but the colours used by building construction firms to tint cement are often less expensive and have greater tinting power, so that smaller amounts can be used. Dilute PVA emulsion should be used with bone and lamp blacks, as these are especially weakening. The final effect of standard colour recipes can be tested rapidly by mixing a small amount, spreading it on a piece of semi-absorbent paper and pressing to dry on the side of a tungsten table lamp, which is also used to provide raking light for refinishing.

The main disadvantage of pre-coloured plaster is that if new plaster must be added to already set plaster, even of the same recipe, the colour will not be the same at the join. This can only be overcome by carefully sculpting down the entire plaster area to precisely the same shape, but 2 mm lower than the final surface, and using a batch of plaster to cover the entire area.

Successful plaster working depends on thorough mixing, precise application, and refinishing when the plaster has set, but is still damp.

1. Prepare a support for the area to be filled by pressing flat, smooth, talc-dusted plasticine, or a sheet of dental wax which has been softened in hot water and trimmed to shape, against the inside of the extant part of the pot. If possible, this should be done diametrically opposite the missing area to reproduce any irregularities

shape produced during manufacture. Plasticine is useful if the support shape must be created ex novo, but dental wax gives a less easily deformed shape, and is likely to drop out at a critical moment.

2. Attach the support inside the pot by pressing the perimeter of the plasticine against the pot (being careful not to deform it or push it into the area to be filled), or by attaching the wax form on the inside with masking tape.

3. Wet the fracture surfaces with water (if the ceramic has not been made impermeable by consolidation), so that the ceramic will not draw water from the plaster. PVA emulsion can be used if additional strength seems necessary.

4. Sift dry plaster into water until the plaster forms a cone-shaped mound protruding slightly above the surface of the water. (The author has always done this the other way round, using a medium-sized enema bulb as a conveniently balanced and controllable water dispenser. This method makes it easier to judge the amount of dry plaster needed, but does not work for everyone.) Mixing is most conveniently done in a shallow half-soccer-ball. Hold the container in the palm of one hand and mix the plaster into the water with a plaster spatula, gently at first to avoid bubbles, then by crushing the mixture against the bottom with a sideways motion. When the plaster no longer feels gritty and has begun to set, it is applied first around the edges of the gap and then in the middle until the entire area is slightly proud.

Any manipulation of the plaster after it has set past creamy consistency will weaken it. This may be compensated by using PVA emulsion in the water, if putty consistency is needed, but this is never as satisfactory.

5. When the plaster has set but is still damp, use a straight-sided, toothed plaster tool, held perpendicular to the surface, to cut the filled area to its final shape. This is more easily controlled than a straight blade.

6. While the plaster is still damp, remove finishing marks and perfect the shape of the filled area with moistened medium grade 'wet or dry' emery paper, followed by fine grade. Do not use excessive water or pressure. Manual sensitivity is critical at this point: hand and wrist should be used as a sensitive but rigid template.

7. Any small hollows or pockmarks can be filled at this point by using some of the damp, slaked plaster used for the gap filling. Small amounts can be crushed into a little more water and applied with a fine paint brush. If a new batch of plaster is mixed and added on, the old plaster will absorb water from the new, causing a difference in colour and making the new plaster much harder. Finishing will wear away the softer plaster around the new area, leaving bumps and valleys. It is usually easier to remove an insufficiently filled area and start again, than to patch.

8. Final surface texturing to match a coarse surface is best done while the plaster is damp. Smooth finishing is done dry with fine emery paper, avoiding dust. At no time must tools or emery paper touch the original ceramic.

9. Cracks can be filled with coloured plaster, acrylic putty, or Polyfilla. They should be trimmed while damp.

4. RECONSTRUCTION OF SMALL AND MEDIUM-SIZED POTS

There are many ways of reconstructing pots of which large areas are missing. Variations of gap-filling may be used, with papier maché or A.J.K. dough lattices; one of the easiest ways is to use a clay inner form.

This is done by first using geometric drawing techniques to construct a full-scale cross-sectional drawing of the complete pot, based on the sherds present and comparable pots. The assistance of an archaeologist or curator should be sought for this, if there are not enough critical pieces, or if a nearly identical pot is not known, it may be better to reinforce those mends which are possible, and leave it at that. When the drawing is complete, it is used to make a template in masonite of the inner surface of the pot.

Clay is centred and roughly shaped to correspond to the inside of the pot, upside down, on a turntable or potter's wheel. The mended fragments are tried in position, and clay is added or subtracted to conform to irregularities of shape. The fragments are now placed in position (some previously unidentified sherds may now find a home); tiny balls of clay are used to tilt or level.

Plaster is then used as in gap-filling to complete the missing areas.

If the vessel has no undercuts at the mouth, and if it is felt that the clay form is so accurate that little interior refinishing will be required, the clay may simply be allowed to dry and free itself from the pot as it shrinks. If the vessel is narrow-mouthed, or if interior refinishing will be necessary, the clay should be scooped out while damp.

Plasticine can also be used, but it is more difficult to work with and to clean off.

Odd-shaped areas to be added can be modelled, moulded, cast and attached, or can be built up around a core (e.g. of A.J.K. dough) with plaster or epoxy putty, thus avoiding the need for wire armatures.

5. RECONSTRUCTION USING POLYSTYRENE INNER FORM AND POLYESTER PASTE

This method of restoration, which was devised by Mr B. V. Arthur,* is normally only employed when the pot is either massive in size with few fragments remaining, or when the pot is smaller but has only one or two disjointed fragments. It is based on the use of layers of polystyrene foam sheet to make the inner form.

A full-size archaeological drawing of the pot is first prepared, as in Section 4. On this, horizontal lines are drawn across the pot from one inside contour to the other, at one or two inch intervals, according to the thickness of foam sheet available. From the length of these lines the diameter of each individual circular layer of polystyrene is calculated. If one has a polystyrene cutter with a tilting head, it may be possible to cut the circles to the largest diameter of each layer. These are then glued one on top of the other to resemble the interior shape

*Chief [illegible]

of the pot. If the edges have been cut vertically to the largest diameter, it will be necessary to trim down the edges with a knife and heated spatula. If they have been cut to the minimum diameter of each layer, it will be necessary to fill in the angles between one layer and the next with plaster or similar material. This has, in fact, some advantages, as one can give the inner form a slightly more characteristic irregular shape than would be possible by cutting alone.

When the plaster on the polystyrene has dried thoroughly, a sealant coat of brown shellac or other suitable varnish should be applied. The fragments of the pot can then be sorted and positioned on the contoured form. It may be possible, by examining the contour of each fragment, to fit it in an approximate position. The individual fragments are held in place by bent pins pushed into the form down the edge of each sherd. It may be necessary to fill some of the small gaps between neighbouring sherds with plaster. This should certainly be considered when the pottery is very friable, as the plaster is perhaps more easily removed than polyester paste. (In the case of a much harder body, it may be considered permissible to butt the polyester paste right up against the fragment.)

Reinforcement should now be placed around the inner form. This can be plastic mesh, galvanized wire net, or aluminium rod or tube, whose diameter is not more than half the thickness of the sherds. This reinforcement should be bent around the entire exposed surface of the form, and between the individual fragments. It should occupy no more than half the depth of the sherds.

At this stage the polyester paste may be applied. (Most of the commercial automobile body filler pastes have proved satisfactory for this use, and are more convenient than making one's own.) The paste should be applied all over the form, covering the reinforcing material. It should still be left lower than the outer surface of the original sherds. It will help if the polyester paste is not made too smooth, as it will be necessary to apply the finishing plaster over this layer. Two or three days should now be allowed for the polyester paste to set. It is essential that it be allowed to cure thoroughly before the finishing plaster is applied.

Immediately before the plaster is applied to the polyester resin, a priming coat of PVA emulsion should be applied, as plaster will not adhere directly to the polyester. The plaster finishing layer is applied in the conventional manner, covering all of the polyester and bringing the restoration up to the level of the existing fragments.

It now only remains to remove the core from the interior of the pot. This may be achieved by cutting with a hot spatula, or, if all else fails, acetone can be poured carefully into the pot to reduce the polystyrene to a 'gooey' mass.

It is of course possible to debate these methods of restoration on the grounds of fidelity to the original, but they may be the only means of showing the public, in a conventional display, what the pot may have looked like before it was broken, since it is possible by these methods to reconstruct an entire pot when very few individual sherds are in actual contact with each other.

6. FINISHING

The ethics and aesthetics of degrees of imitation of the original depend largely on individual opinion and the use for which the finished pot is intended. The author's personal opinion is that the 'six feet–six inches' rule is a good one, i.e. that restoration should not be noticeable at a viewing distance of six feet, but should be clearly distinguishable at six inches. It should be remembered that the idea of reconstruction is to present an idea of the pot as it once was, and that restoration should not distract from the object by presenting a visual pattern of contrasting geometric shapes which have nothing to do with the object.

In many cases, pre-tinted reintegrations (a shade lighter, not darker, than the base colour, so as not to create an optical 'hole') may be sufficient. If painting is required, acrylic paints, or dry pigments in Acryloid B72, are to be preferred to casein, oil, or water-colour paints. Test colours should be matched after drying. Glossy paints can be adjusted with a matting agent such as aerogel silica; variations in colour tone can be stippled in over the base colour; texture can be added with pigments and glue. Final adjustment can be made by rubbing on pastel colours or dry pigments with a finger.

ACKNOWLEDGEMENTS

The author would like to thank Mr B. V. Arthur, Miss Virginia Greene, Mr C. E. S. Hett, Prof H. W. M. Hodges, Miss Barbara Keyser, Mr J. C. McCawley, Mr R. M. Organ, and Mrs J. Wight for their very kind assistance.

REFERENCES

1. Dowman, E., 'Conservation in Field Archaeology', Methuen & Co. Ltd., London, 1970.
2. Gedye, I., Pottery and glass, in 'The Conservation of Cultural Property', UNESCO, 1968, pp. 109-113.
3. Larney, J., Ceramic restoration in the Victoria and Albert Museum, 'Studies in Conservation' 16 (1971), 69-82.
4. Wilson, W. and Forshee, B. W., 'Preservation of documents by lamination', National Bureau of Standards Monograph 5, Washington, D.C., 1959.

Other references:

Clark, C. D., 'Molding and Casting', John D. Lucas Company, Baltimore, Maryland.

Feller, R. L., Stolow, N. and [illegible]ates, E. H., 'On Picture Varnishes and Their Solvents', revised ed., Press of Case Western Reserve Univ[illegible]sity [illegible]and London, 1971.

New York, N.Y. 10017, USA

UHU (yellow tube) — adhesive

Mixture of different grades of PVA, or may be cellulose nitrate, depending on country of manufacture; goo working characteristics; stable.
Available from hobby shops.

MOWILITH 60 — adhesive

Supplier: Canadian Hoechst Ltd
40 Lesmill Road
Don Mills, Ontario, Canada

or: Farbwerke Hoechst AG
45 Bruningstrasse
Frankfurt am Main, West Germany

VINAVIL K60 — adhesive

Make thick stock in industrial methylated spirits (powder dissolves easily) and dilute with same as neede Particularly useful degree of plasticity.

Supplier: Montecatini Edison SpA
Via F. Turati 18
Milan, Italy

PVA EMULSIONS ('WHITE GLUES')

Often used for convenience, especially on porous ceramics. Formulae subject to change without notice; tend give way in damp climates or storage. Form better optical bridge across cracks than solvent glues.

RESISTOL 850 — adhesive

Starch included in formulation; almost impossible to reverse on fragile ceramics.

ELMER'S GLUE-ALL — adhesive

It appears that the formula has been changed; this may now become irreversible.

LE PAGES BONDFAST — adhesive

Not very strong; very flexible (sherds tend to sag); durability unknown.

Available in hobby sho

BULLDOG GRIP WHITE GLUE — adhesive, consolidant

Good working characteristics; dibutyl phthalate plasticizer; information on other additives not available, b implication is that it should be fairly stable.

Supplier: Canadian Adhesives
420 Marien
Montreal East, P. Q., Canada

PROMATCO A1023 — adhesive, consolidant

Vinyl acetate homopolymer; plasticized with dibutyl phthalate; 63% solids; 16,000-18,000 cps viscos emulsion; pH 5.6; protective colloid, stabilizing agents, detoxicants added. Preliminary experiences w promising; high strength adhesive, excellent ageing characteristics claimed. Ivory coloured paste: can be diluted used full-strength (e.g. with Japanese tissue fibres as reinforcement). Will redissolve in cold water.

Supplier: Process Materials Corp.
Carlstadt, New Jersey 07072, USA

EASTMAN 910 — adhesive

Cyanoacrylate; appears to break down fairly rapidly; useful, like epoxies, in dots to hold heavy ceramics in pl while other glues set.

Supplier: Eastman Chemical Prod. Inc., Chemicals Division
Kingsport, Tennessee 37662, USA

or: Armstrong Cork Co.
Kingsbury
London NW9, England

GE SILICONE RUBBER ADHESIVE

May remain too flexible; difficult to remove (requires hot water and force); primarily useful for modern wa which find their way into the laboratory; will withstand dish-washers.

Supplier: Canadian General Electric Ltd
Chemical and Metallurgical Section
1025 Lansdowne Avenue
Toronto, Ontario M6H 3Z6, Canada

POLYFILLA — filler
Calcium sulphate plus cellulose powder. Useful additive to plaster.
Available from hardware stores or: Niagara Chemicals,
Burlington, Ontario, Canada

DENTAL PLASTER (calcium sulphate)
Available from dental suppliers.

MOULDING PLASTER (calcium sulphate)
Available at less cost from construction firms.

STAYBRITE COLOURS
Colours intended for tinting concrete; used with plaster
Supplier: W. R. Grace and Co. of Canada Ltd
Construction Products Division
Toronto, Ontario, Canada
(branches in Montreal and Edmonton)

GRUMBACHER POWDERED EARTH PIGMENTS
For tinting fillers and for final retouching.
Available from art supply stores or: M. Grumbacher Inc.
New York, N. Y. 10001, USA
or: M. Grumbacher Inc.
723 King Street
Toronto 213, Ontario, Canada

HYPLAR ACRYLIC COLOURS
For retouching.
Available from art supply stores or from Grumbacher.

EPOXY RESINS

Usually reversible by swelling in methylene dichloride, if pot geometry allows this; can be used where high strength is required (e.g. handles) to avoid need for dowelling, or with filler as putty.

ARALDITE AY 103 with HARDENER AY 951 or AY 956
Supplier: Ciba (A.R.L.)
Duxford
Cambridge, England

EPO-TEK 301
Supplier: Epoxy Technology Inc.
65 Grove Street
Watertown, Massachusetts 02172, USA

DEVCON 5-MINUTE EPOXY
LE PAGES 5-MINUTE EPOXY
Results not entirely predictable.

EPOXY PUTTY — modelling material
Convenient two-part paste system; excellent working characteristics.
Supplier: Ralph E. Bautz (Manufacturer's Representative)
143 Tilford Road
Somerdale, New Jersey 08083, USA

POLYESTER RESINS

Can be excellent on heavy pots or where there are gaps between joins; filled versions shrink less. May discolour slightly.

AKEMI TRANSPARENT — adhesive
AKEMI ORIGINAL (filled) — filler
Supplier: Jaeger and Condino Inc.
P.O. Box 592, 35-44 61st Street
Woodside, New York 11377, USA

SINTOLIT TRANSPARENT STRAW — adhesive
SINTOLIT FILLED — filler
Supplier: 4114 Fifth Avenue
Brooklyn, New York 11232, USA
or: A. Pisani and Co.
Carrara Wharf, Ranelagh Gardens
London SW6, England

CAR BODY FILLER — filler
Distributed nationwide in Canada by Canadian Tire Corp.

BONDAFILLA — filler
Supplier: Bondaglas
55 South End
Croydon, Surrey, England

OTHER MATERIALS

DENTAL WAX (toughened)
Available from dental suppliers or: Amalgamated Dental Co.
132 St Patrick Street
Toronto 2B, Ontario, Canada

PLASTICINE — modelling and moulding
Available from art supply or hobby stores.

ACRYLIC MODELLING PASTE — filler
Considerable shrinkage; may be useful for stuccoing cracks.
Available from art supply stores.

Nimmo, B. A. F. and Prescott, A. G., Molding, casting and electrotyping, in 'Conservation of Cultural Property', UNESCO, 1968, pp. 95-108.
Torraca, G. (ed.), Synthetic materials used in the conservation of cultural property, in 'Conservation of Cultural Property', UNESCO, 1968.
Skeist, I., 'Handbook of Adhesives', Van Nostrand Reinhold Co., New York, 1962.

APPENDIX: ADHESIVES AND OTHER SUPPLIES FOR CERAMIC RESTORATION

A wide range of adhesives is used in conservation laboratories for different aspects of ceramic restoration. Ideally, a standard adhesive should satisfy several criteria: correct degrees of plasticity and viscosity for the work in hand, physical and chemical stability, rapid drying, reversibility. This last will affect the ease of removal of any excess adhesive, but reversibility itself will often depend on the type and condition of the individual pot.

NATURAL ADHESIVES

SHELLAC
Strong; darkens and embrittles with age, becomes very difficult to remove; thick — often remains as a visible layer between joins; use of flame may singe pot or prejudice TL dating.

ANIMAL GLUES
Yellow; inconvenient to use; shrink; tend to embrittle in time.

CELLULOSIC SOLUTIONS

HMG (cellulose nitrate) adhesive
In general use: experience has shown it to be useful, durable, and lastingly reversible.
Supplier: Marcel Guest
Collyhurst
Manchester 9, England

AMBROID (cellulose nitrate) adhesive
Does not stick very well; amber colour may remain visible.
Supplier: Ambroid Inc.
Boston, Massachusetts, USA

DUCO (cellulose nitrate?) adhesive
Dries quickly, also breaks down quickly; may exert contractile forces. Deficient in plasticizer?

UHU HART (blue tube) cellulose adhesive
Model makers' glue; very strong (has been used to mend an iron cauldron); quick-drying; ageing characteristics unknown.
Available from hobby shops.

HOME-MADE CELLULOSIC FORMULATIONS

As with consolidants, solvent combinations can be varied according to resin solubility, working characteristics desired, and ambient temperature and relative humidity.

CELLULOID (cellulose nitrate) adhesive
See Dowman [1] p. 71. Dissolve celluloid in acetone and amyl acetate (1:1), add dibutyl phthalate 0.5–1% v/v.

MOTORCYCLE WINDSHIELDS adhesive
Cut up and dissolve in acetone and alcohol. For emergency field use when no other supplies are available. Adhesion poor.

CELLULOSE DI-ACETATE adhesive
Less adherent than cellulose nitrates, but may be more stable; ethyl acetate is a good solvent. Suggested by Mr R. M. Organ* (with note that additive plasticizers tend to be lost in time). Use di-acetate, not mono-acetate; triphenyl phosphate (5%) or dimethyl phthalate (20%) are recommended in this case rather than dibutyl phthalate. Incorporation of an acid acceptor (magnesium acetate 0.5%) is suggested, as is addition of a U.V. absorber (resorcinol benzoate or Tinuvin T). [4]

PVA SOLUTIONS

BAKELITE AYAF (V15) consolidant; adhesive
BAKELITE AYAT (V25) adhesive (somewhat brittle if used alone)
We have used the following with some success: 25% w/v PVA resin (equal parts AYAF and AYAT); 63% v/v methanol; 8% v/v ethyl acetate; 4% v/v acetone.

V15 V25

*Chief Conservator, [illegible]