The use of flexible synthetic rubbers for casts of complex fossils from natural moulds

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(Plate 1)

Summary. Some commercial silicone (Dow Corning Silastic E, J) and PVC (Dugdale DD118) synthetic rubbers make excellent casting materials for the production of high-fidelity replicas of fossils from complex natural cavities. The methods described avoid tearing of the cast and damage to the mould.

1. Introduction

The use of various flexible casting agents in the production of high quality replicas of fossils from natural rock moulds was reviewed recently by Kelly & McLachlan (1980). They described the methods of use and results from such commercially available silicone rubbers as Silastic 9161 RTV, Silcoset 105, Tiranti RTV 11, and Tiranti RTV 700. However these materials were only successful with low to medium relief moulds without overhangs. High relief or complex cavities could not be cast without tearing the rubber, or destroying the rock mould.

In this paper, we report the application and results achieved on casting complex fossil vertebrate bones with some other readily available silicone rubbers and commercial PVC. The methods described allow multiple casts to be made from highly complex moulds without tearing and without destruction of the mould.

2. Materials

The characteristics of the silicone rubbers are given below, and details of their use are given in Section 3. Suppliers are listed in the Appendix.

Table 1. Summary of important properties of the silicone rubbers discussed in the text. Silastic E, J (Hopkin & Williams, 1978); Dugdale PVC DD118 (Dugdale, n.d.). All properties measured at 25 °C.

	Catalyst (%)	Pot life (h)	Tensile strength (psi)	Elongation (%)	Tear strength (ppi)	Linear shrinkage (%)
Silastic E	10	1–2	700	400	90	0
Silastic J	10	1	750	175	70	0
Dugdale PVC DD118	0	∞	1200–1500*	380*	*	0

* Properties of cured PVC depend on casting and curing parameters.

Silastic E RTV (Dow Corning; Hopkin & Williams, 1978)

A white-coloured viscous fluid that cures at room temperature on addition of 10% of the supplied catalyst. It has a pot life of 1–2 h at 15 °C, and a cure time of 24 h. In its final cured state it is an opaque white-coloured rubber which shows fine detail.

Silastic J RTV (Dow Corning; Hopkin & Williams, 1978)

A tan-coloured viscous fluid which cures at room temperature by the addition of curing agent included in kit. With 10% catalyst it has a pot life of 1 h at 25 °C and a cure time of 24–36 h. In its final cured state, it is an opaque light-green coloured rubber, but fine detail is not heightened for photography unless the cast is coated with, for example, ammonium chloride.

PVC Paste DD118 Natural (S. Dugdale)

A white coloured free-flowing fluid which may be coloured. It cures at 160 °C and the final cast is an opaque rubber which records the finest mould detail and, depending on the colouring agent used, is excellent for photography.

3. Method

3.a. Silastic E, J RTV

The natural cavity in the rock that is to be cast (the mould) is first cleared of all debris, or remaining fossil material. Cleaning may be done mechanically or by the use of acids. We have used dilute or concentrated HCl to remove bone material from sandstones well cemented with silica. The specimen is then neutralized with NH_3 solution, and the HCl and NH_3 vapour driven off by prolonged gentle heating.

If the rock is not well cemented, the surface may be hardened with Butvar in thin solution (Kelly & McLachlan, 1980), or with araldite dissolved in acetone. Transport of the hardening agent into the rock may be enhanced by the use of a vacuum chamber.

A release agent should next be applied to all surfaces where rock and casting agent will come into contact. Possible releasers include soft soap or Teepol (Kelly & McLachlan, 1980), and various silicone release agents (e.g. Dow Corning Releasil), obtainable as sprays or paintable fluids. The hardener and release agent should be applied thinly in order to avoid obscuring fine surface detail.

If the mould is in several pieces, these must be stuck together tightly using adhesive. If the mould has to be broken apart into the same segments to extract the cast, the joins may be made air-tight with petroleum jelly or silicone grease, and the individual blocks clamped tightly throughout the casting process with elastic bands, string, or woodworking clamps.

Gaps between blocks should be filled and a wall may be built around the pouring area to contain the silicone in its fluid state. Plasticine, card, and/or aluminium foil may be used for these purposes, but it is important to block every gap where fluid might escape. Small specimens may be almost completely encased in aluminium foil.

The silicone base is then mixed with the appropriate catalyst at room temperature. The mixing must be thorough so that the curing agent is well disseminated. This process tends to introduce air into the mixture, and it must be debubbled in a vacuum chamber for several minutes before pouring. The mixture froths up to four times its original volume, and then subsides after most of the air has been extracted. There is no need to debubble the rubber after it has been poured, as suggested by Kelly & McLachlan (1980) for RTV 700. If a vacuum pump is not available, the silicone rubber and curing agent may be left to stand for 15 minutes to allow bubbles to rise. Alternatively, the silicone rubber may be painted on in layers, or it may be diluted with up to 10% silicone fluid (Dow Corning 200/20 cs) before adding curing agent. This increases the fluidity and pot life, and aids debubbling. Of course, the total curing time will also be increased.

The silicone rubber fluid is poured slowly into the lowest point of the specimen, and this must be carefully planned with a multipiece mould to avoid trapping pockets of air. In cases with several 'high points', a sequence of pouring points or air outlets may have to be used. These are blocked with Plasticine sequentially from the bottom of the specimen upwards as rubber fluid spills from each. The specimen may be gently tilted or tapped to clear bubbles, and it may have to be topped up a few minutes after pouring when the silicone rubber has moved through the finest recesses of the mould.

When the rubber has cured (24–48 h), the walls may be removed and the cast extracted. With multipiece moulds, this may involve the separation of the blocks by gentle levering. However, because of the high tear strength of the cured RTV compounds, the cast will stand considerable tugging to remove it from awkward spaces.

3.b. Dugdale PVC Paste DD118

The PVC casting technique involves heating to 160 °C, and all materials used must be capable of withstanding this temperature. Durofix, or petroleum jelly with clamps, are suitable. The specimens may be hardened, the releaser applied, and walls built as described above for the silicone rubber casting.

Next, the slightly viscous white-coloured paste must be prepared. It may be used directly, or it may be coloured in order to heighten detail for photography. We have found that dark brown is most suitable for fossil reptile specimens. The pigment is ordinary powder (water-colour) paint. A smooth paste is made with dibutyl or dioctyl phthalate and this is thoroughly stirred into the PVC paste. The mixture must be left for an hour or more so that bubbles rise. The mixture could be debubbled in a vacuum chamber, but bubbles are far less of a problem than with the silicone rubbers.

Pouring should proceed as described above, and the specimen left to stand for a while in case it has to be topped up. It is then placed in a thermostatically-controlled oven at 100 °C. At this temperature, the PVC 'pre-gels', that is, it is now solid but not flexible. The Plasticine wall may then be stripped off without fear of damage. If Plasticine has not been used, the pre-gel stage may be omitted.

The PVC gels finally at 160 °C, and the specimen may be removed from the oven just after attaining that temperature if it is small. Larger specimens may have to be left in the oven for an hour at 160 °C to allow the heat to penetrate, or the oven temperature may be raised in steps. The specimen is then allowed to cool to room temperature before separating cast and mould. If this is not done, the PVC will tear or distort.

This PVC method is an adaptation of that described by Rixon & Meade (1956) and Rixon (1976, pp. 218, 225–6).

3.c. PVC dip moulds

Moulds and casts can be made rapidly from fossil specimens by heating the specimen to 100 °C. Cold PVC paste is poured slowly over the surface, and it immediately pre-gels. The specimen is then heated to 160 °C, and final gelling is rapid because of the thin PVC layer. After cooling, the mould may be cut off and used for casting with PVC (use a releaser), or with cold-curing silicone rubbers.

4. Results

We have used these techniques largely with fossil reptile material. The Permo-Triassic reptiles from Elgin, northeast Scotland, are two faunas of about ten distinct species. Their remains are preserved in generally well-cemented white to yellow sandstone, and the bone may be absent, very soft, or partially replaced by iron minerals. In most cases, it has proved impossible to prepare specimens by mechanical means in the past, and little more could be seen than what lay on the broken surfaces of blocks. After removal of remaining bone, the rock moulds have proved excellent for casting.

From the mid 1950s A.D.W. has cast large numbers of the Elgin reptiles mostly in PVC, and this has yielded much new information (Walker, 1961, 1964, 1970, 1973; Benton, thesis, in prep.). The casts display the finest detail of surface textures on the bone, vessel openings, patterns of tooth wear, and even features like the tear ducts and semi-circular canals. Highly complex casts have been made of complete skulls, vertebrae, and other postcranial elements, and this has only been possible by the use of the tough flexible synthetic rubbers described here. Some examples of our casts are illustrated in Plate 1.

The casting methods described here have also been applied with equal success to complex trilobite, brachiopod, and trace fossil moulds. In the example of casts of borings described by Kelly & McLachlan (1980, p. 451), the original specimen could probably have been saved by the use of a tougher silicone rubber, or with PVC.

5. Discussion

This paper has been concerned with describing a few currently available materials that give tough flexible casts of fossils. There are many brands of silicone rubber and PVC pastes, and most manufacturers will have some with similar properties to those described here.

When deciding whether to use silicone rubbers or PVC, there are several factors to be borne in mind concerning cost, method of use, qualities of cast, and adaptability.

The disadvantages of PVC, and advantages of silicone rubbers, are important. PVC gives off some toxic fumes if overheated, and it may give off small amounts of toxic gas on storage, although we have no evidence of this, Also, the PVC cast cannot be stored in a plastic container since the plasticiser in the cast may exert a solvent effect on the container, and cause the two to adhere. The PVC technique also requires an oven, and the temperatures and times must be right or the cast may not gel sufficiently. Finally, broken PVC casts are difficult to repair. There are some glues available for repairing flexible PVC objects, but they are not wholly satisfactory.

The disadvantages of silicone rubbers include the cost. PVC is about one-twentieth of the price of the tough silicone rubbers (PVC: 85p; Silastic E, J: £16 per kg (1980)); see also Kelly & McLachlan, 1980, p. 452. Silicones are more messy, and even the cured rubber is hard to remove from glass or metal mixing containers. PVC may be gelled and peeled readily from containers made of these materials. The curing agent for silicones has to be measured and stirred in very thoroughly, and this creates considerable problems with bubbles, all of which is generally avoided with PVC. PVC has a very long pot life (i.e. pouring does not have to be carried out rapidly), the PVC may be coloured to suit the purpose of the casts, and the gelling process is very rapid (1–2 h, as compared to 12–48 h with silicone rubbers).

PVC casts made 25 years ago retain their form, but loose a little flexibility. Many other flexible synthetic casting materials become brittle in that time. Silicone rubbers have only been available since the 1960s, but their storage properties are probably good.

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Appendix

Addresses of suppliers: Hopkin and Williams, P.O. Box 1, Romford, Essex, RM1 1HA, England, Silastic E; J. Dow Corning Corp., Midland, Michigan 48640, U.S.A., Silastic E; J. S. Dugdale, Son & Co. Ltd., Valley Mill, Sowerby Bridge, Yorkshire, HX6 2AA, England, PVC DD118 Paste.

EXPLANATION OF PLATE

Plate 1. Casts of fossil reptile remains from the Elgin area, north-east Scotland. Figs. 1–5 from the Lossiemouth Sandstone Formation (late Triassic), Fig. 6 from the Hopeman Sandstone Formation (Permo-Triassic boundary).

Fig. 1. PVC cast of *Leptopleuron lacertinum* Owen 1851. Cast from natural rock mould showing detail of tiny skull. Flash lines, marking boundaries between blocks, show up as fine ridges. × 1.0.

Fig. 2. PVC cast of *Leptopleuron lacertinum* Owen 1851. Cast from natural rock mould showing vertebrae, ribs, and hind limbs. × 0.75.

Fig. 3. Silastic J RTV cast of *Hyperodapedon gordoni* Huxley 1859. Cast from natural rock mould showing distal end of femur, with details of fine bone crushing that occurred during fossilization. × 1.1.

Fig. 4. PVC cast of *Hyperodapedon gordoni* Huxley 1859. Three-dimensional cast of a nearly complete half skull, showing complex internal detail. This is the fourth cast taken from the natural rock moulds which have suffered little during the process. × 0.67.

Fig. 5. PVC cast of *Hyperodapedon gordoni* Huxley 1859. Detail of the skull in Fig. 4, showing different bone textures – grooves, rugosities, vessel openings, and thin bone laminae. × 1.0.

Fig. 6. PVC cast of *Elginia mirabilis* Newton 1893. Detail of remarkable pitted and spiked external surface of cheek region of skull. × 0.95.

Geol. Mag. Vol. **118**, 1981, Benton & Walker, Plate 1, facing page 556.

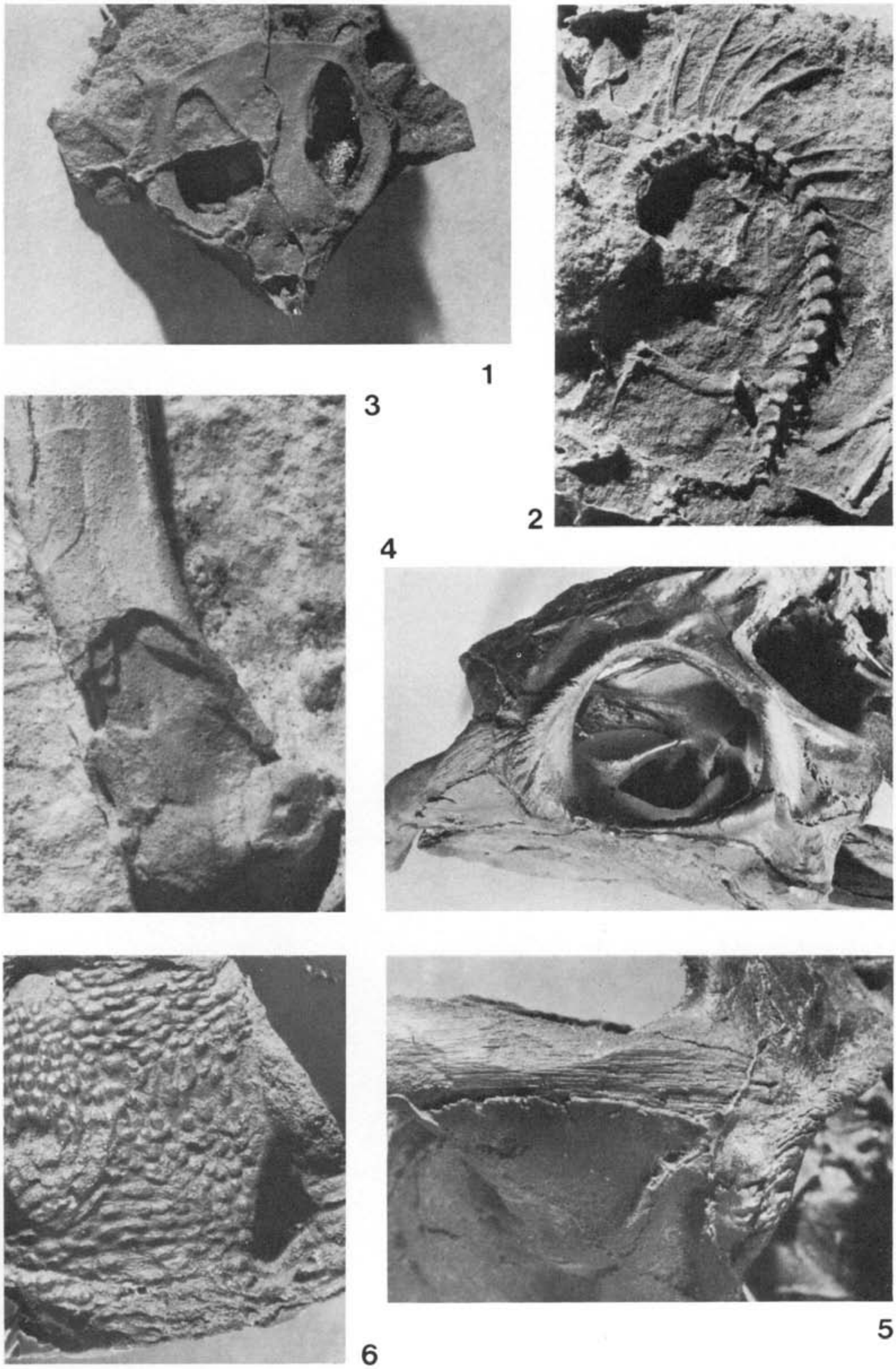

Plate 1. Casts of fossil reptile remains.