Cleaning, conservation, moulding, casting, photogrammetry, 3D printing, blacksmithing, welding and heaps of horse manure: essential ingredients to successfully display a recently deceased fin whale skeleton.

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Abstract

The skeleton of a sub-adult fin whale that died in 2014 and washed up on the Cumbrian coast was recently installed in the Tullie House Museum in Carlisle. The project to collect, clean, curate, conserve, mount and install the 12m-long specimen required numerous processes and skills, some quite unusual. Due to unavoidable delays in the carcass being collected, many bones were lost: the left side of the mandible, the left portion of the front of the skull including the maxilla, fourteen vertebrae, both of the lower forelimbs below the humerus (except one ulna) and the small pelvic bones. As the specimen was to be mounted hanging from a ceiling and up against a brick wall above the reception area, only some of these missing bones had to be replicated: the 14 vertebrae, the lower right forelimb bones and the pelvic bones. Traditional moulding and casting techniques were used to replicate some bones whilst others required modern photogrammetry and 3D printing processes.

Unfortunately, many of the bones were quite oily and smelly with adipocere attached still and these could not be cleaned effectively with traditional techniques used to clean old museum bones. They required burial for several months in horse manure, followed by rinsing and sterilisation with ammonia.

The cleaned bones (and the replicas made of the missing vertebrae, pelvis and forelimb) were mounted in sections on curved steel armature fabricated by blacksmithing and welding. The 12m-long skeleton was suspended from a steel beam in a dynamic steep diving pose between 4 and 12m off the floor, to greet visitors as they entered the museum - and a new museum icon was born.

Methods and materials:

1.Cleaning

The bones were mostly defleshed on the beach during collection (see images top left & top right). They were then buried in sand and compost for 18 months followed by further cleaning by staff and volunteers at Tullie House Museum. However, upon arrival at the conservator's workshop many bones were still dirty with sand, soil and gristle (Fig 1). This was cleaned off easily enough with brushes and hand tools and blowfly larvae cases were found in the skull cavities (Fig 2).

Unfortunately, the vertebrae of the rear half of the spine were still oily, very smelly and retained thick patches of adipocere fat on many surfaces. As the skeleton was still relatively fresh, conventional methods of cleaning old whale bones using various solvents (e.g. Turner-Walker, 2012) did not work. Discussions with world experts in cleaning fresh whale bones (Ososky, 2012) led us to cleaning the bones with an unconventional conservation method: burying the worst bones in deep piles of horse manure for several months (Figs 3 & 4).

The temperature deep in the manure was recorded every day to check that the heat did not rise too much and it was mostly in the 20°C to low 30°C range. What was it that cleaned the bones so well? The invertebrates, the microbes or the heat? Or a combination of these? Research in this area would be a useful project. After removal from the manure the bones were rinsed in water with light scrubbing to remove traces of the manure and were then immersed in ammonia hydroxide at about 4% in water for a minimum of a week to kill all the bacteria etc otherwise they would smell and could pose a pest risk once in the museum.

Fig 1. Vertebral disk with sand, soil and gristle still attached.

Fig 2. *Protophormia terraenovae* blowfly larval cases from within the skull.

Fig 3. Placing vertebrae in the horse manure: more manure was added on top.

Fig 4. For once worms and other invertebrates are a conservator's friend.

2. Conservation

Only a couple of bones were broken and required repair. This was undertaken with Japanese tissue paper and Paraloid B72 (Larkin, 2016).

However, as the whale was a juvenile, many epiphyses remained unfused, such as the discs either side of the centrum of each vertebra (5) and near either end of the humerus (6). These loose pieces of bone were adhered in place with Paraloid B72 after the surfaces had been consolidated with Paraloid B72 in acetone.

Fig 5 above**.** Vertebrae with their loose epiphysis disks.

Fig 6 right. Humerus in three pieces before joining, as the epiphyses were unfused.

3. Replicating missing bones

Fig 7. Steven Dey photogrammetry scanning the lower right forelimb of the larger fin whale in Cambridge.

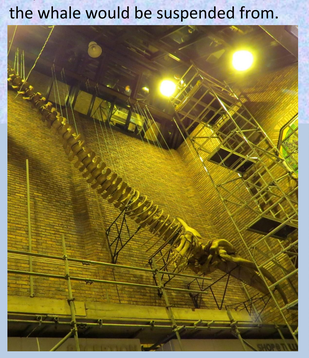
Fig 8 above. Replicas of the 14 missing vertebrae in the foreground, made by moulding the vertebrae preserved adjacent to the gaps in the vertebral column and making casts in Jemonite acrylic resin.

Fig 9 left. Replica of the missing lower right limb bones scaled down and 3D printed in gypsum by Steven Dey but mounted by N. Larkin. The missing pelvic bones were replicated in the same way.

4. Mounting

Figure 10 above**.** Fabricating one of the five large steel brackets that held the skull, mandible and ribs securely to the wall (see figs 13, 14 & 15).

Fig 14 below**.** A 14m-high scaffolding tower was required so that we could access the specially made steel girder to emplace the brackets and cables that the whale would be suspended from.



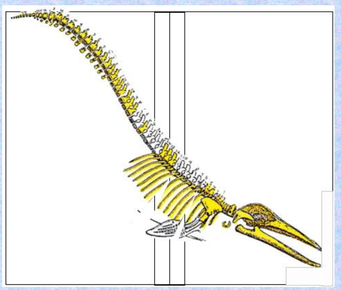


Figure 11 above**.** The dynamic pose planned for the skeleton, for which metal mounts and fixings had to be designed and made. The pose was dictated to an extent by the space available in the foyer of the museum.

Figure 12 above. Five holes were carefully drilled through the thickest skull bones and threaded bar inserted, secured at the lower end with nuts, spring washers and a wide steel flange lined with Plasatzote foam. The skull is hung from eyed hanging bolts at the top end.

Fig 13 right. Trimming the threaded bar that secures one of the large skull brackets to the wall. Here, the skull is hanging from straps attached to the chain hoists.

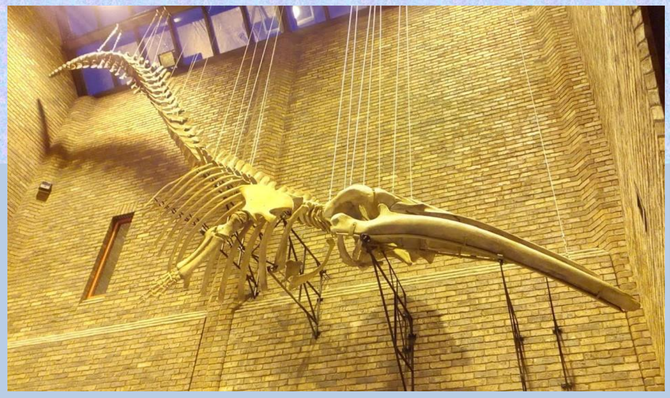


Fig 15 left**.** The installed skeleton suspended in its dynamic pose using 22 cables and 5 brackets. **Fig 16** below. The bones and all the metalwork are checked regularly, using a large cherry picker.

5. Installation

After cleaning and conservation, the whale bones had to be mounted in sections. The vertebral column, including the painted resin replicas of the missing vertebrae, was mounted on four curved interlocking sections of steel tubing. These were designed and shaped by the conservator to present the dynamic diving pose of the skeleton. Accuracy was crucial as there were only a few inches spare at either end in the reception area where it was to be hung. Supporting armatures of Plastazote foam-lined steel were also fashioned for the undersides of the skull and mandible and to hold the ribs. The mounted spine and the skull were to be suspended by thin (3mm diameter) twisted wire cables (at least four for each section for safety and stability). However, wall-mounted steel brackets had to be made to stop the asymmetrical skull from twisting (much of the front left of the skull is missing), and to hold the right mandible and ribs on the right side in place as these were not going to be in line with the steel beam that was installed specifically for the whale to hang from - the whale and its armature being about a ton in weight.

The whole 12m-long skeleton in articulated mounted sections was transported from Shropshire to Carlisle in two Luton vans by carefully 'double-stacking' the material. The specimen was installed in the reception of the museum over the course of a week, working only overnight for safety and logistical reasons, using a 12m-high scaffolding tower and manual chain hoists.

Discussion & Conclusions

There are ethical issues to consider when replacing missing bones with replicas. Labels should make clear what is real and what is not. When 3D printing the missing forelimb and pelvic bones we used the most benign and stable of 3D printing materials, a gypsum-based product which provides a dry, matt texture that is very appropriate for replicating bones.

This project required several months of cleaning, conservation, scanning, digital modelmaking, 3D printing, moulding, casting, painting, designing, blacksmithing, welding and grinding – and, unusually, between 1 and 2 tons of horse manure. This method of cleaning oily whale bones is a ripe area for research.

References

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