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DINOSAUR FRAUDS, HOAXES AND "FRANKENSTEINS": HOW TO DISTINGUISH FAKE AND GENUINE VERTEBRATE FOSSILS

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ABSTRACT

Dinosaurs and other fossils have been artificially enhanced, or totally forged, to increase their commercial value. The most problematic forgeries to detect are based on original fossils that are artificially assembled. Several techniques are suggested for detecting hoaxes: detailed visual examination, chemical analysis, X-ray or CT-scan, and ultraviolet light.

It is recommended that museums and paleontological researchers do not purchase and/or trade fossils lacking clear provenience information. Exceptions to that general rule should be closely examined using techniques described herein.

RESUMO [in Portuguese]

Os dinossauros e outros fósseis têm sido melhorados artificialmente ou completamente falsificados de forma a aumentar o seu valor comercial. As falsificações mais problemáticas são montagens artificiais de fósseis verdadeiros o que torna a detecção da fraude mais difícil. Várias técnicas são sugeridas para a detecção destes embustes: exame visual pormenorizado e crítico, análise química, raios X e tomografia computorizada e observação sob luz ultravioleta.

Os investigadores e os museus de paleontologia são recomendados a não comprarem e comercializarem fósseis de proveniência duvidosa. Se isso for absolutamente necessário, sugere-se que efectuem os testes aqui sugeridos.

SAMENVATTING [in Dutch]

Dinosauriërs en andere fossielen worden mogelijk kunstmatig verbeterd, of compleet vervalst, om de commerciële waarde te verhogen. De meest problematische vervalsingen zijn gebaseerd op originele fossielen die kunstmatig zijn vervaardigd waardoor het lastig is om ze te identificeren als vervalsingen. Verschillende technieken zijn gesuggereerd om vervalsingen te herkennen: gedetailleerde en rationele visuele inspectie, chemische analyse, X-ray of CT-scan, en ultraviolet licht.

Paleontologen en musea worden aangeraden om geen fossielen aan te kopen en te verhandelen van twijfelachtige herkomst. Als het absoluut nodig is, gebruik dan een gedetailleerde inspectie met de technieken die hier beschreven staan.

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INTRODUCTION

The high economic value of rare fossil specimens has fuelled their market value, firing the imagination of fossil dealers and collectors and increasing demand for fraudulent specimens. The production of fake fossil specimens is particularly common in poorly developed areas where fossil trading can represent one of the few ways to achieve economical survival. For example, China and Morocco are known to produce both genuine and fraudulent fossils, making the detection of fake all the more difficult (Dalton, 2000, 2004a, 2004b, Milner *et al*. 2001, Padian, 2000). Because complete specimens are rare, they command higher price. For this reason, forgers often find it profitable to join multiple specimens in order to assemble a fraudulent single skeleton that appears complete. Padian (2000) discusses in some detail the problematic nature of fossil trade and forgery with respect science and education in the United States.

A subject of shame and embarrassment for the researchers involved in their study, certain frauds have been divulged to the public. For example, the famous "Piltdown Man", a forgery merging a modern human skull with the jaw of an orangutan, was advanced as a single specimen of a putative primitive human ancestor that fooled anthropologists for decades (Weiner, 1955).

One of the most conspicuous recent examples of fraudulent composite dinosaur fossils is the famous *Archaeoraptor* specimen from the Liaoning Province of China. This "discovery" was the subject of coverage by media sources including *National Geographic* and *Nature* (Rowe et al., 2001; Sloan, 1999; Zhou et al., 2002). Careful examination subsequently revealed that the specimen represents at least two and up to five, separate specimens that were fraudulently merged to assemble a single "individual" (Zhou et al., 2002).

Fossil frauds are usually forged to obtain not only profit, but also publicity. Cunning forgers may put much training and effort to render hoaxes as realistic as possible. Some forged fossils are fantastically verisimilar to real fossil specimens and may easily fool an incautious fossil-buyer.

The aim of this paper is to give the method of fraud recognition. The goal is to discuss a methodology to detect frauds, and not to discuss a buying setting, ethical behaviours or even to recommend how to buy fossils.

WHAT IS A FOSSIL FRAUD?

The degree of fossil authenticity is broad, ranging from unadulterated fossils, to enhanced or merged original specimens, to complete forgeries containing no fossilized material at all. Milner *et al*. (2001) report several cases of sculpted "fossils" from Asia, particularly from China.

A fraudulent fossil specimen is an object that has been artificially transformed in order to deceive potential purchasers that it represents a genuine, unaltered fossil.

There are three main kinds of hoaxes:

1) Those that contain no original fossil material, such as shapes carved in rock;
2) Those that do contain original fossil material, but are entirely or partially altered in order to give the appearance of a more complete specimen (example: a sculpted carved skull from a fragment of a limb-bone);
3) Those that are true fossil but artificially combine from multiple individuals (mostly from the same species). Many of the most successful frauds are half-faked by incorporating general fossil material to form a chimera. Such frauds are more difficult to detect because they create "Frankenstein specimens" in which several specimens are joined to form a single individual, a term evoking Doctor Frankenstein's monster created from parts of several human individuals in the 1818 novel by Mary Shelley. The chimera from the Greek mythology had different species parts: lion head, posterior body of snake and main body of a goat, while Frankenstein's monster was a human made from parts of other humans.

HOW TO DISTINGUISH FAKE AND REAL?

To distinguish a real fossil from a fraud can be difficult. Although many fraudulent fossils seem authentic at first glance, with experience, one can distinguish a fraud by simple observation. For those without such experience, a few simple but effective techniques assessing specimen authenticity are suggested here, including CT-scans, acids, and UV-light.

Close visual examination is capable of catching most attempts at fossil fraud. "Frankenstein fossils" can be distinguished with the naked eye, or with the assistance of a microscope. Such fossils comprised of multiple individuals merged into a single specimen can be detected by identifying colour differences associated with differences in preservation. Colour differences

can be relatively minor, with one bone slightly darker than the others, or major, preserving range of different colours. Although such forgeries can seem realistic to the untrained eye, certain types of colour differences within a given specimen are not natural, and present a good indication that the specimen is suspect.

The completeness of a fossil skeleton can be the first key in detecting a fraud. Although genuine complete fossils are not unknown to science, it is important to realize that such fossils are rare and valuable. Not coincidentally, it is this rarity which encourages the forgery of complete skeletons. Imperfections in fossil specimens are often filled in with waxes, glues or other materials (figure 1). Such media can be used to attach two dissociated specimens, or to replace bones entirely. Detection of these forgery techniques is often facilitated by using a stereomicroscope or binocular lens, whereby waxes are easily distinguished from true bone based on their surface textures, reflective properties, and colour patterns. Wax or glue can also be distinguished from bone by scratching the surface carefully with a needle or airscribe. Bone tends to be harder and more brittle than wax and inconsistencies in texture and scratch properties can often reveal areas for concern.

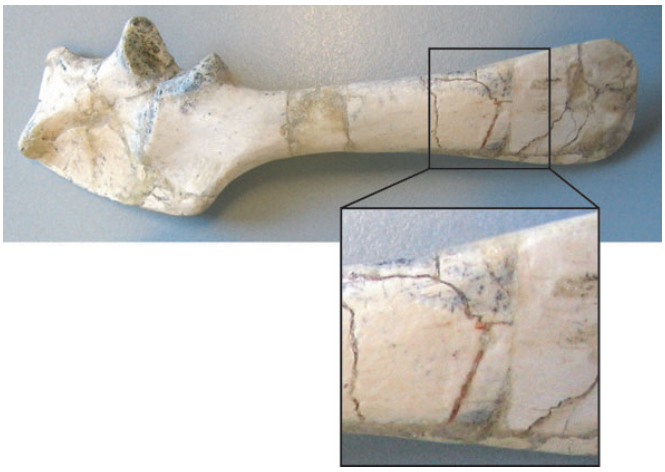

Figure 1. Forged assembled *Psittacosaurus* scapulocoracoid based on genuine bone. Note the gap refilled by wax. The middle part of the shaft is slightly darker and the cracks are reddish, in contrast with the brownish cracks seen on other aspects of the specimen. The crack shown in the inset is also unnatural: it stops abruptly where the bone is completed by wax (specimen from private collection).

Forgeries are often smoothed with sandpaper to blur the interface between true bone surface and filler materials. Whereas fossil bone surface texture tends to be coarse and rough, fossil bones treated in this manner take on a polished surface texture, devoid of natural imperfections. Excessive sanding may also reveal the internal cortical bone texture. In figure 2, the premaxillae were sanded flat.

Figure 2. Forged assembled *Psittacosaurus* skull based on genuine bone, in anterior view. The original bone was sand-papered.

Sutures between bones, especially in the skull, are difficult to falsify and are often absent in forgeries. Forgers often use parts of real cranial bones in combination with other bone fragments (cranial or not) to create a skull-shape, often quite realistic at first glance. To complete the picture, forgeries are often encased in mixtures of sand and the actual rock matrix encasing true fossils. For example, mosasaur bones and teeth from Morocco have been falsely assembled to create a tooth bearing jaw. Cementing matrix around such forgeries often makes them look more authentic, and teeth can even be prepared out of the matrix without it being obvious that the encasing "rock" is artificial. The false rock matrix has a more plastic consistency, and the interstices may retain wax or glue remains, which may be detectable during the regular preparation process with airscribe.

A simple chemical analysis can easily detect such frauds. Several acids, including formic acid (HCOOH, diluted to 20%), hydrochloric (HCl, diluted to 33%), acetic acid (CH_3COOH, diluted to 20%), can be applied to differentiate natural from artificially cemented matrix. True rock matrix and bone often reacts to the HCOOH and HCl, with small bubbles appearing on reactive surfaces upon application. In contrast, most waxes, glues and artificial infill substances do not react to these acids. This convenient and inexpensive test can provide nearly instantaneous detection of false materials. In addition, because many glues and waxes are inflammable, a simple lighter test can be used to detect the use of such materials in suspected forgeries. In these cases, glues and waxes often burn or melt when exposed to flame. Finally, acetone and other powerful organic solvents can be useful in the detection of artificially cemented material associated with a suspect specimen. These can easily reveal any paints, in

addition to glue and wax that can be combined with matrix silt or powder, to provide a natural-looking finish on forgeries. Applying to the bone just a few acid drops or exposing to fire locally and during just a few seconds is, in most of the cases, sufficient to detect frauds and keep integrity of the fossil, without damaging it.

Computed Tomography (CT) and X-ray analyses are effective techniques to detect hoaxes, and the use of such medical tools has been increasingly common in every day scientific research. Radiographic analyses detect differential densities of bone, rock, and other materials. Fossil bone and rock matrix are most of the times higher in density, which is normally depicted in the X-ray or CT film by a lighter colour. CT and plain film x-rays can reveal areas of low density on a given specimen (in darker colour) as potential areas of artificial wax or glue infill that are less apparent to the naked eye. The figure 3A shows the example of a *Psittacosaurus* skull X-ray in lateral view where the true bone is mainly white, the rock in pale grey and the wax and glue is invisible or dark grey under the x-ray. The figure 3A and 3B shows respectively a femur and a sacrum where the bone gaps seen under the X-ray represent the parts filled artificially not easily detected by a naked-eye surface examination.

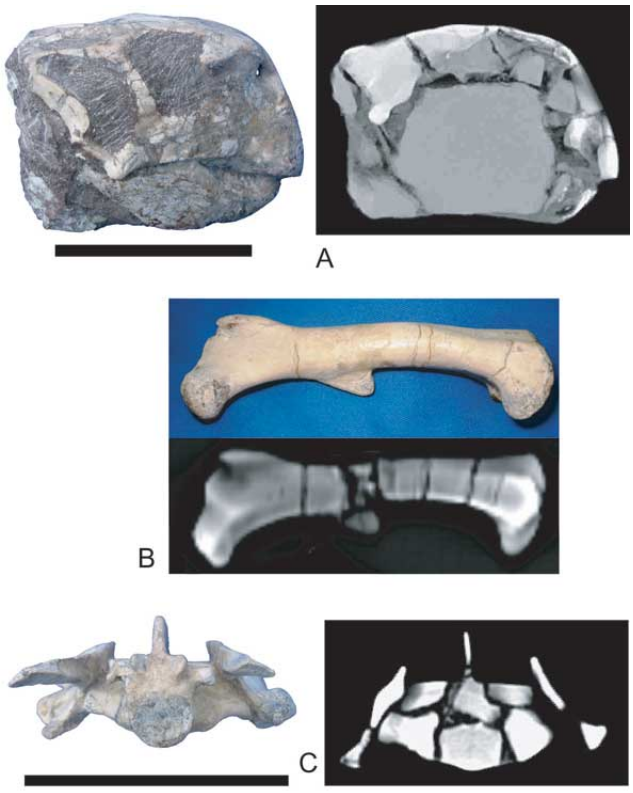

Figure 3. CT-scan of assembled skull (A), femur (B) and sacrum (C) of *Psittacosaurus*. Most of the bone is real, but gaps between fragments were filled with wax that is not visible in the scan due to their low density. The core of the "skull" is comprised of a rectangular stone, with genuine bone fragments glued around it. CT-scanning was conducted at the Clinic Cedima, in Caldas da Rainha, Portugal.

Because of different material reflection under ultraviolet light (UV), also known as black light, a composite specimen will glow with different colour and tonalities when seen under UV light because the mineral composition fluoresces differently under short wave ultraviolet versus long wave ultraviolet. Such technique is useful to distinguish original bone from the false matrix and to distinguish the bones from different proveniences. The figure 4 the colour of the bones of the psittacosaur skull in dorsal view are pinkish and green, which may represent true bone collected in different localities (therefore different mineral composition and dissimilar UV fluorescence) or larger concentration of waxes and glues. In this case the true dinosaur bone fluoresces in pink. Although effective in most cases, this technique does not always works because in dependent on the differential composition of the minerals.

This is a general overview of techniques. More details about these techniques should be found and experts consulted about them, if needed.

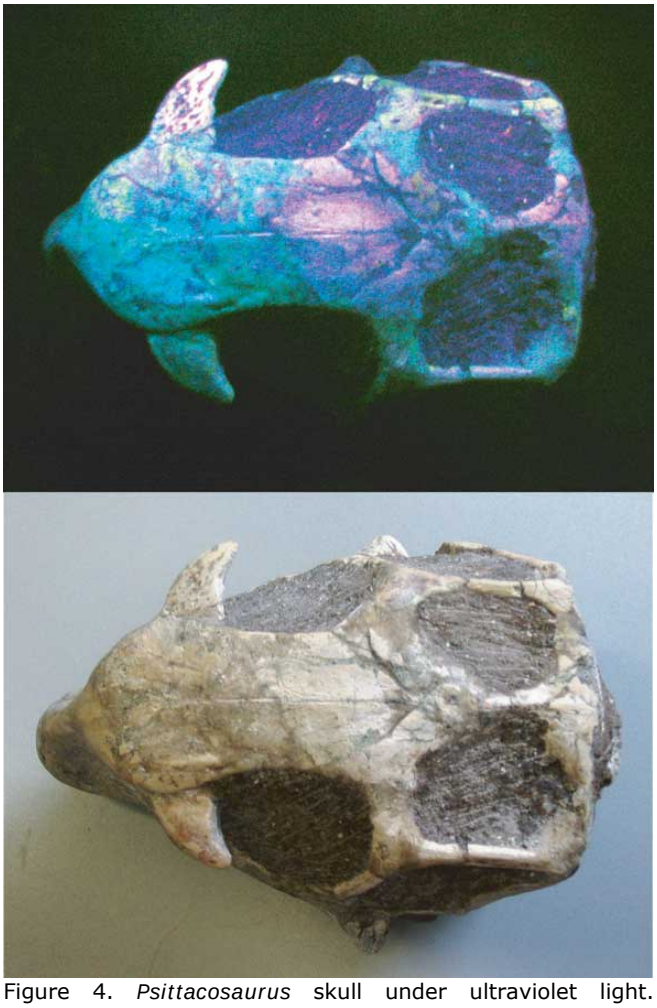

Figure 4. *Psittacosaurus* skull under ultraviolet light. Different colours indicate different bone origins and filler materials.

The purchase context is also relevant to understand the veracity of fossils. Fossils have a high likelihood of being forgeries when they are available at low prices in tourist shops and local markets where professionals are unlikely to visit.

RECOMMENDATIONS AND DISCUSSION

Paleontological hoaxes have implications for science. When incautious researchers and museums expend their limited resources to acquire fraudulent specimens of limited value, this diverts the use of those fund from the acquiring of authentic specimens. Moreover, such scandals can be exploited to discredit evolutionary scientific inquiry (see, for example, the pseudoscientific article by Harrub and Thompson, 2001).

We underscore that it is imprudent for paleontological researchers and institutions to purchase and/or trade in fossils lacking clear provenience information. Techniques for detection of forgeries described herein are to be viewed as a last resort and/or safety precaution in verifying specimen integrity. A second opinion from a trained paleontologist or fossil preparator may also give a valuable contribution to detect frauds.

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