PROMETHEUS PRESS/PALAEONTOLOGICAL NETWORK FOUNDATION (TERUEL)

Journal of Taphonomy

2003

VOLUME 1 (ISSUE 2)

Available online at www.journaltaphonomy.com

Observations on the Release of Gastroliths from Ostrich Chick Carcasses in Terrestrial and Aquatic Environments

Oliver Wings*

Institut für Paläontologie, Nußallee 8, D-53115 Bonn, Germany

Journal of Taphonomy 1 (2) (2003), 97-103.

Manuscript received 28 July 2003; revised manuscript accepted 6 August 2003.

The decomposition of two ostrich (*Struthio camelus*) chicks (body masses 2.1 kg and 11.5 kg) was observed in a terrestrial and an aquatic setting, respectively, in a hot and arid climate with temperatures ranging from 25-40°C. Special attention was given to the observation of the release of gastroliths from the body cavity. The results show that the gastroliths can be set free from carcasses with a body weight <12 kg after relatively short periods (3-6 days), and that a separation in an aquatic environment is likely because of prolonged floating of the carcass.

Keywords: AQUATIC, BIRDS, DECOMPOSITION, DISINTEGRATION, GASTROLITHS, *STRUTHIO CAMELUS*, TERRESTRIAL, VERTEBRATE TAPHONOMY

Introduction

Gastroliths, stomach stones, are known to occur in many fossil and extant vertebrate clades including some birds (Whittle and Everhart, 2000; Wings in prep.). Despite this common occurrence, the taphonomy of fossil skeletons associated with gastroliths has received little attention in the past and the release processes of gastroliths from recent carcasses are largely unstudied. Furthermore, only a small number of taphonomic studies has concentrated on recent bird bone assemblages and none of them discussed gastroliths (Bickart, 1984; Oliver and Graham, 1994; Davis and Briggs 1998).

This is unfortunate because there are many interesting questions concerning the taphonomy of gastroliths, for example: How long does it take until the stones are released? Can the gastroliths exit an articulated carcass? What are the different effects of terrestrial and aquatic environments on gastrolith deposition? During a research project on ostrich gastroliths in cooperation with the Klein Karoo Co-operative Ltd. in Oudtshoorn,

* E-mail: oliver.wings@web.de

South Africa, I conducted a preliminary experiment on freshly dead ostrich chicks to address these issues.

Experimental setting

The carcasses of two ostrich chicks were deposited in Oudtshoorn (Klein Karoo, Republic of South Africa) on the same day they died from bacterial infections beginning an experiment that ran for six days. The daily temperature during the duration of the experiment ranged from 25 to 45°C. Both carcasses were exposed to dry heat in direct sunlight for most of the day and no rainfall occurred during the experiment. The smaller carcass with a body mass of 2.1 kg was placed on the ground (Figure 1a). On the third day, this carcass was lifted at the right leg, resulting in a disruption of the carcass and exposure of the body cavity (Figure 1b). This was done in order to study the condition of the internal organs and stomach contents at this stage of decomposition.

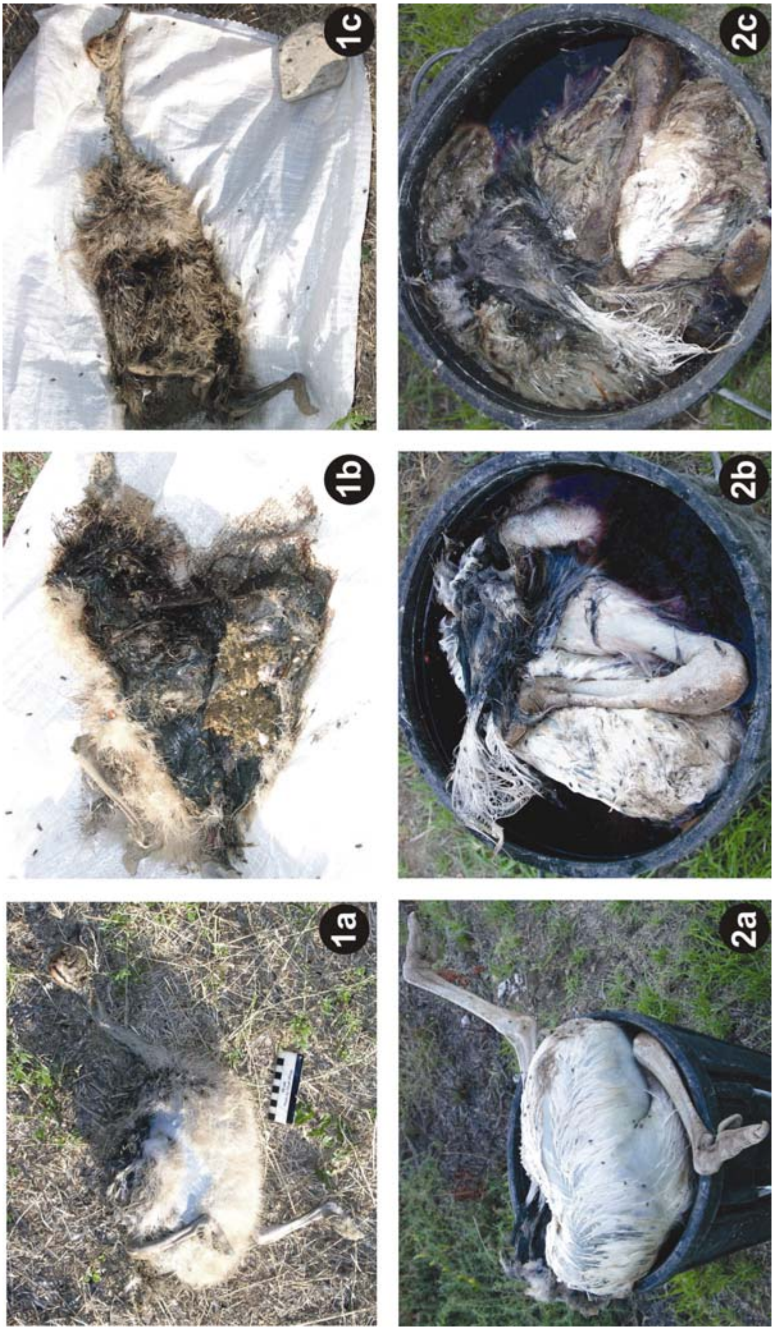
The second carcass with a body mass of 11.5 kg was deposited in a 200 liter barrel of freshwater with the ventral side oriented upwards (Figure 2a). The carcass was turned sideward after three days (Figure 2b) in order to place the complete carcass in the barrel.

On the second day, a white woven plastic bag was placed under the smaller carcass to increase the ability to distinguish it from the ground and for easier removal of the remains after the experiment was terminated. Admittedly, this was an unnatural situation, but the effect of this bag on the distribution of invertebrate scavengers on the carcass was considered to be negligible since most maggots derived from flying insects and the bag caused no barrier for terrestrial insects. Since the experiments were merely concerned with the taphonomical behavior of gastroliths, no special attention was given to the species or size of the maggots in the carcass.

Observations

The decay of the smaller chick progressed more rapidly than that of the larger one. Most of the flesh of the smaller chick was

Figure 1. (1a) Terrestrial setting, first day of the experiment. The small ostrich chick carcass with swollen body cavity is lying on the ground.
(1b) Terrestrial setting, fourth day of the experiment. Most of the flesh has already been consumed by maggots. Note the visible stomach contents including gastroliths as brown mass in the centre of the picture.
(1c) Terrestrial setting, sixth day of the experiment. The carcass had completely dried out, forming a solid mass and preserving the gastroliths *in situ*.
(2a) Aquatic setting, second day of the experiment. The large ostrich chick carcass floating with the ventral side up in the water barrel. Note the swollen body cavity, filling most of the barrel's diameter. The carcass had easily fit in the barrel the day before.
(2b) Aquatic setting, fourth day of the experiment. The carcass was turned to a lateral position (left leg is visible) in order to place all body parts in the barrel. Until then, the legs were still situated beyond the barrel margin and could have potentially stopped the carcass from sinking. The carcass is still intact and floating.
(2c) Aquatic setting, sixth day of the experiment. The carcass started to macerate, but all bones are still connected and floating. The experiment was ended on this day, the barrel was emptied and all the gastroliths were found separated from the carcass on the bottom of the barrel.


1a
1b
1c
2a
2b
2c

consumed by maggots after three days. Decomposition gases were rather limited. The thin neck dried out during the first day, and would have prevented any oral exit of stomach contents had the carcass been moved. The remaining flesh “liquidized” to some extent, permitting a potential release of the stomach contents through other “exit” sites. When the right leg of the carcass was lifted at after three days, all internal organs had been disintegrated and were almost completely consumed by maggots. However, the stomach contents, including the gastroliths, were still arranged in a cluster and not dispersed over the entire body cavity. Because of the high temperatures, the remaining soft tissues dried out very quickly during the next days of the experiment, mummifying the carcass and preserving the gastroliths in the gastric cavity (Figure 1c). At the end of the experiment, the carcass showed the phenomenon of adherence to the ground (respectively to the underlying bag) observed by Bickart (1984).

The larger chick carcass floated in the water until the experiment was terminated (Figure 2a-2c). Few maggots were observed, and they seemed to have been restricted to that part of the carcass above the water line. Unfortunately, the gizzard position could not be controlled visually during the experiment because of wet feathers that covered most of the carcass skin. The esophagus and anus were swollen and therefore did not permit the exit of decompositional gases, which expanded the body and facilitated carcass floatation. While the amount of the gases decreased during the next days, (visible as less tension of the skin), there was still a considerable amount of gas left in the carcass at experiment´s end (Figures 2b, 2c). When the experiment was terminated and the barrel emptied, all gastroliths were found in isolation at the bottom of the barrel and detached from the carcass, while all skeletal remains were still articulated and floating.

Discussion

Experiment in terrestrial environment

In general, there tends to be an overall increase in rate of decay with rising temperature (Swift et al. 1979). However, the rapid disintegration of the smaller carcass used in these experiments was not only due to the environmental setting. Disintegration also depended on body size: smaller animals contain less flesh, warm up faster and are more quickly consumed by maggots. In a less arid and cooler environment, the carcass would not have been mummified but rather would have completely disintegrated. An already mummified carcass would probably be transported in water in one piece. The stones would therefore remain in the carcass until it was soaked with water again and disintegrated. After that, the heavy gastroliths would sink to the bottom.

It is likely that carcasses buried autochthonously in a terrestrial environment (e.g., by wind-transported sediments) would have any existing gastroliths preserved *in situ*. The same pattern is predicted to occur if “terrestrial” carcasses are embedded by water-transported sediments without prior transport by water. This is the case if water velocity is too low to transport the carcass or the gastroliths.

Experiment in aquatic environment

Gastroliths are the densest and heaviest parts of a carcass and therefore tend to be the first parts to separate from a floating body. As discussed by Schäfer and Craig (1972), bird carcasses do not initially sink to the bottom, as do the carcases of fish, reptiles, and mammals. This is because air stored in bird quills, between the down feathers and in their pneumatized long bones prevents sinking. In addition, their skin probably largely prevents their guts from falling out quite some days after death. Nevertheless, as soon as a breach in the body cavity appears, the heavy gastroliths will exit the carcass and drop to the bottom. Schäfer and Craig (1972) reported that many bird carcasses found on beaches and in dunes still have gastroliths *in situ*. This is an indication of short transportation times or death in the terrestrial environment.

Without specific information about the environment and the temperatures, the decay process of a herring gull (*Larus argentatus*) was described by Schäfer and Craig (1972): four days after death, maggots were visible in the parts above the water line; after 13 days, all skeletal elements above the water were bare of musculature and connective tissue; after 27 days, the carcass was still afloat but the hind limbs and the sternum had fallen off; after 38 days, the carcass sank to the bottom; and after 65 days, the carcass remained articulated on the bottom, without any parts floating up again. A broadly similar pattern of disarticulation was reported for some of the coot (*Fulica americana*) carcasses observed by Oliver and Graham (1994)

General discussion

Neither of the carcasses reported on here, or those in previous experiments on birds (Bickart 1984; Oliver and Graham 1994; Davis and Briggs 1998), burst due to extensive generation of decompositional gases. Thus, it is likely that strong "explosion-like" disruptions of carcasses, with a potential for propulsive transport of body contents beyond the carcass, are rare in birds, and are probably restricted to much larger carcasses.

During previous examinations of other ostrich carcasses, I observed that the koilin lining layer of the gizzard can be separated from the stomach muscles after several minutes to hours. Thus, I assume the same for the two carcasses observed in this experiment. This detachment of the koilin layer is probably caused by the acidic environment in the stomach. Yet, the large muscles around the gizzard still protect the gastroliths for a considerable period before release of its contents. In the absence of maggots, the stomach is very resistant to putrification, as shown for ranids and bufonids (Wuttke, 1983), which do not even have muscular stomachs. In such cases, the gastroliths would either exit the body cavity with the stomach, or, if the opening in the carcass is too small, remain in the body cavity until the stomach is putrefied and itself eventually sets the isolated stones free. However, the stomach muscles represent valuable nutrition for maggots and are therefore rapidly consumed within a few days, allowing the fast separation of gastroliths.

Conclusions

Although the results presented here are very preliminary, they still allow a few generalizations about different taphonomic patterns of gastrolith release in terrestrial and aquatic environments.

Generally, the release of gastroliths in small animals in hot climates is very fast, both, in aquatic and terrestrial environments. In aquatic environments there is a greater chance that the stones will be separated from the skeleton due to prolonged floating of the decaying carcass without the already detached gastroliths. However, numerous well-preserved skeletons with gastroliths are known from aquatic fossil deposits, such as the marine Cretaceous formations in North America (plesiosaurs, e.g., Welles and Bump 1949; Darby and Ojakangas 1980; Taylor 1993) or the Eocene lake sediments of Messel in Germany (crocodilians, e.g., Keller and Schaal 1992; Koenigswald 1998). At these fossil sites, vertebrates are mostly articulated, indicating a short drifting time of the carcasses. It is plausible that a tougher skin or, in the case of the crocodiles, osteoderms delayed the release of the gastroliths. This idea is further corroborated by the very rare occurrence of gastroliths in fossil birds from the lacustrine deposits of Messel (G. Mayr, pers. comm. 2003) as opposed to crocodiles from the same locality, which generally have gastroliths preserved *in situ* (own observations and W. v. Koenigswald, pers. comm. 2003).

All observations and conclusions are only valid for finds lacking indications of scavenging. Scavengers are a primary agent of carcass degradation (Davis and Briggs 1998) and scavenging animals often commence consumption of a carcass on its abdomen (e.g., Weigelt 1989), thus altering the position of the gizzard with the potential of complete removal of the gastroliths. With this in mind, a comprehensive discussion of the taphonomical and sedimentological processes altering the fossil record of gastroliths is forthcoming (Wings, in prep.).

Acknowledgements

I would like to thank Dr. Adriaan Olivier from the Klein Karoo Co-operative Ltd. in Oudtshoorn, Republic of South Africa, for supplying the carcasses and permitting the experiments on the property of the Co-operative. Annalisa Gottmann, Dr. Martin Sander, and Lars Schmitz commented on earlier drafts of the manuscript and considerably improved the manuscript. The Graduiertenkolleg "Evolution and Biodiversity in Space and Time" in Bonn is gratefully acknowledged for funding the research in South Africa.

References

Bickart, K. J. (1984). A field experiment in avian taphonomy. *Journal of Vertebrate Paleontology*, 4: 525-535.

Darby, D. G. & R. W. Ojakangas. (1980). Gastroliths from an Upper Cretaceous plesiosaur. *Journal of Paleontology*, 54: 548-556.

Davis, P. G. & D. E. G. Briggs. (1998). The impact of decay and disarticulation on the preservation of fossil birds. *Palaios*, 13: 3-13.

Keller, T. & S. Schaal. (1992). Crocodiles: large ancient reptiles. In (S. Schaal & W. Ziegler, eds.) *Messel. An Insight into the History of Life and of the Earth.* Oxford. Clarendon Press, pp. 109-118.

Koenigswald, W. v. (1998). Magensteine eines Krokodils. In (W. v. Koenigswald & G. Storch, eds.) *Messel - Ein Pompeji der Paläontologie*. Sigmaringen. Thorbecke Verlag, pp. 40-41.

Oliver, J. S. & R. W. Graham. (1994). A catastrophic kill of ice-trapped coots: time-averaged versus scavenger-specific disarticulation patterns. *Paleobiology*, 20: 229-244.

Schäfer, W. & G. Y. Craig. (1972). *Ecology and Palaeoecology of Marine Environments*. University of Chicago Press, Chicago.

Swift, M. J., O. W. Heal & J. M. Anderson. (1979). *Decomposition in Terrestrial Ecosystems*. University of California Press, Berkeley.

Taylor, M. A. (1993). Stomach stones for feeding or buoyancy? The occurrence and function of gastroliths in marine tetrapods. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences*, 341: 163-175.

Weigelt, J. (1989). *Recent Vertebrate Carcasses and their Paleobiological Implications.* University of Chicago Press, Chicago.

Welles, S. P. & J. D. Bump. (1949). *Alzadasaurus pembertoni*, a new elasmosaur from the Upper Cretaceous of South Dakota. *Journal of Paleontology*, 23: 521-535.

Whittle, C. H. & M. J. Everhart. (2000). Apparent and implied evolutionary trends in lithophagic vertebrates from New Mexico and elsewhere. In (S. G. Lucas & A. B. Heckert, eds.) *Dinosaurs of New Mexico* - New Mexico Museum of Natural History and Science Bulletin pp. 75-82.

Wings, O. (in preparation). Identification, Distribution, and Function of Gastroliths in Dinosaurs and Extant Birds with Emphasis on Ostriches (*Struthio camelus*). Ph.D. University of Bonn, Bonn.

Wuttke, M. (1983). Aktuopaläontologische Studien über den Zerfall von Wirbeltieren. Teil I: Anura. *Senckenbergiana Lethaea*, 64: 529-560.