Investigation for the Fossil Embryo using Neutron Tomography at HANARO, KAERI

TaeJoo Kim[a*], CheulMuu Sim[a], Dong Hee Kim[b], Gerald Grellet-Tinner[c]
[a]*KAERI, Deonjindong, Yuseonggu, DaeJeon, 305-600, Korea*
[b]*National Science Museum, 511 Daedeogdaero, Yuseong-gu, Daejeon, 305-705, Korea*
[c]*The Field Museum, Chicago, Il, USA*
[*]*Corresponding author: tj@kaeri.re.kr*

1. Introduction

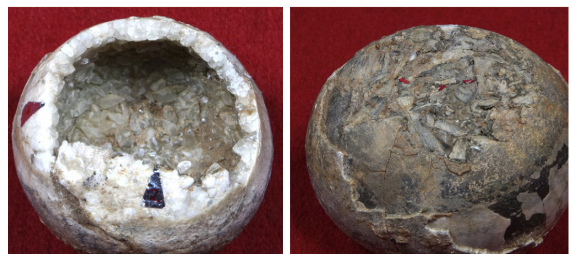
Neutron imaging technique is one of non-destructive method. It is similar to X-ray and γ-ray methods in using the different attenuation characteristics depending on materials. However, there is great difference between them. The mass attenuation coefficients of X-ray and γ-ray monotonically increase with the atomic number since they interact with electrons. Thus X-ray image method does not supply sufficient contrast between similar atomic numbers. On the other hand, that of thermal neutrons depends much on the nucleus not electrons. Especially thermal neutrons easily penetrate most of metals, while they are attenuated well by such materials as hydrogen, water, boron, gadolinium and cadmium[1]. Because of these unique characteristics of neutron, neutron imaging technique has been utilized for NDT or researches for next power sources (fuel cell or Li-Ion battery).

Recently, dinosaur egg was found at the Aptian–Albian Algui Ulaan Tsav site, Mongolia. In this study, we applied the neutron imaging technique to investigate dinosaur embryo at Neutron Radiography Facility of HANARO, KAERI.

2. Material and Method

In 2008, the Public Procurement Service of South Korea denoted to the National Science Museum of Korea a dinosaur egg with a few surfacing embryonic bones, specimen NSM60104403-20554450, as shown at Figure 1. It was diagenetically altered into a hollow calcite geode with embryonic bones partially condensed on the egg surface and within a thin layer below that same surface. One section is eroded away and opens a window into the hollow egg that reveals a calcite geode. The eggshell present on the egg surface is not fractured suggesting that little or no compression had occurred after the egg was buried.

The small size and extreme fragility of the skeleton remains precluded physical preparation of the embryo. At the first time, noninvasive X-ray computed tomographic procedure was applied to obtain a 3-dimensional visualization and characterization of the specimen. However, because of density similarities between the specimen and its matrix, it is difficult to distinguish the specimen from the surrounding materials. Therefore, neutron was chosen becaue neutron just interacts with atomic nuclei via very short-range energy with minimal attenuation. And neutron yielded interesting images of the specimen as shown at Figure 2[2].



a) **b)**

Figure 1. Photo of egg with a) calcite crystals and b) embryo skeleton surfaces.

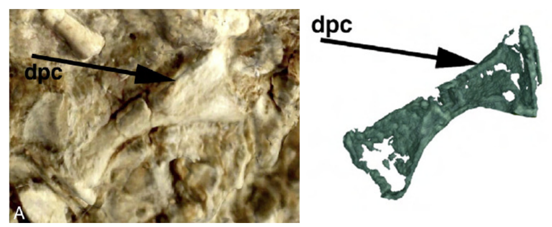


Figure 2. Comparison between photos and neutron images for the right humerus. Dpc is deltopectoral crest.

Neutron tomography(NT) was performed at the Neutron Radiography Facility(NRF) at HANARO, KAERI with a spatial resolution of 70 μm/pixel to examine the specimen. The detector system consists of a Li based neutron scintillator screen with a thickness of 50 μm that converts the thermal Neutron beam with energy of ~14 MeV in visible light with a wavelength of 440 nm. The resulting images were recorded by a CCD camera at Andor-Ikon-L DW936N-BV with an exposure time of 110 s per projection image. The tomographic volume for the egg was reconstructed by filtered back-projection algorithm and visualization by VG Studio Max 2.0 software. The scan resulted in a total of 600 sequential images at rotation of 180° with scanning parameters of 0.2279 mm for slice thickness. The field of reconstruction was 100 mm×100 mm and resulting images are 2048×2048 pixels. These parameters yielded an inter-pixel spacing (i.e., x-spacing and y-spacing) of 70 μm, a limitation related to the spread of the scintillation flash on the neutron scintillator screen.

3. Description

The dinosaur egg was reconstructed by using neutron images and method described at section 2 as shown at Figure 3 and 4. The relatively small spherical egg averages is an 87.07 by 91.1 mm diameter spherical egg and an estimated volume of 362–378 cm^3. The embryonic skeleton has settled down at the unopened pole of the egg and is preserved within a thin 7.6 ~ 8.6 mm layer of calcite.

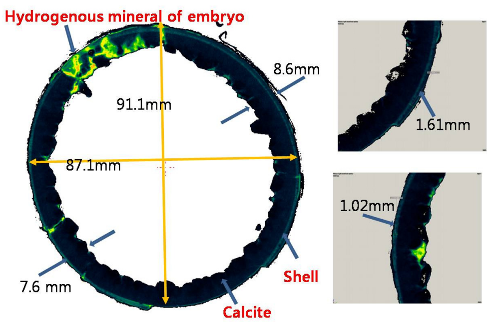


Figure 3. Dimension of dinosaur egg by neutron image

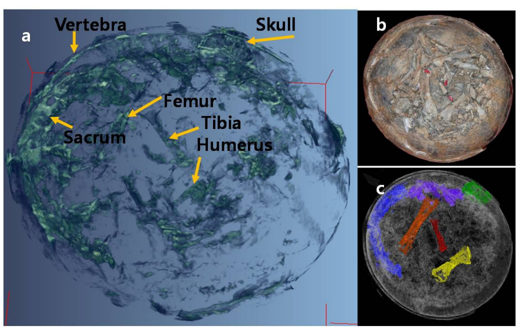


Figure 4. Neutron image on dinosaur embryo, (a)Skull, sacrum, limbs and vertebra preserved in the layer identified by neutron tomography (X-Z view), (b)Embryonic skeleton settled down at the unopened pole of the egg (red arrows on limbs), (c)Pseudo coloring Skull, sacrum, limbs and vertebra preserved in the layer identified by neutron tomography (X-Z view)

The most diagnostic bone, among those visible on surface (Figure. 1) and with neutron imaging (Figure 4), is a partially surfacing right 18.90 mm humerus. The anterior surface of this element is partly exposed revealing 3/4 of its entirety and extends diagonally into the calcitic matrix but is entirely visible with NT characterization. Although the proximal head is moderately eroded, it is relatively well preserved and the size of the proximal and distal ends appears sub equal, a feature shared with Diamantinasaurus matildae.

The other conspicuous bone is the right 29.17 mm femur in posterior view, which alike the humerus, is partially encased in the thin calcitic matrix. The proximal section of the femoral head is missing and this bone is best observed in NT imaging. The forth trochanter seems limited to a ridge distal to the missing proximal head, that ismatched in length and thickness by a lateral bulge distal to the greater trochanter that runs parallel to the trochanteric ridge. A conspicuous fossa lays mid shaft between the bulge and the ridge ends, where the shaft is at its narrowest. The fibular condyle bulges laterally and with the pronounced tibial condyle defines a long and deep fossa in the distalmost section of the femur[3]. The presence of these two pronounced fossa is reminiscent with the condition exhibited in D. matildae[4]. A proportionally slender and 18.22 mm long left tibia, representing 62% of the femur length, a larger ratio than O. skarzynskii (58%), is lodged between the femur and humerus[5]. In lateral view, the cnemial crest bulges out and tapers down at 1/3 of the shaft. Both distal processes have been eroded away and the mid section of the shaft is relatively constricted giving a slender appearance to this skeletal element like that of the lithostrotia Malawisaurus dixeyi.

Table 1. Dimension of bone by neutron tomography

Name	Length [mm]	Shaft [mm]
Femur	29.17	end: 5.90, middle: 3.23
Humerus	18.90	end: 7.22, middle: 2.92
Tibia	18.22	end: 2.98, middle: 1.87

3. Conclusions

Fossil embryos are not common in the fossil record as their preservation result from unique and specific taphonomic and diagenetic processes. Moreover, their small size and fragility make them difficult to study, which is only feasible with neutron tomography. Although there is just a few skeletal elements and lack of knowledge for the zoology, it is difficult to identify this fossil embryo. But, much information can be extracted from neutron images and it is helpful to fossil research.

REFERENCES

[1] G. F. Knoll, Radiation Detection and Measurement, John Wiley & Sons, New York, pp.612-613, 1999.

[2] D. Schwarz, P. Vontobel, E. H.Lehmann, C. A. Meyer, and G. Bongartz, Neutron tomography of internal structures of vertebrate remains. Palaeontologia Electronica, 8 Issue 2, 30A, 11p, 800KB, 2005.

[3] Hocknull, S.A., White, M.A., Tischler, T.R., Cook, A.G., Calleja, N.D., Sloan, T., Elliott, D.A., 2009. New Mid-Cretaceous (Latest Albian) dinosaurs from Winton, Queensland, Diversity Evolution,4: 166-173, 2004

[4] Curry Rogers, K., Titanosauria: a phylogenetic overview. In: Curry Rogers, K., Wilson, J.A. (Eds.), The Sauropods, Evolution and Paleobiology. University of California Press, Berkeley and Los Angeles, CA, pp. 50–103, 2005.

[5] Borsuk-Bialynicka, M. A new camarasaurid sauropod Opisthocoelicaudia skarzynskii gen.n., sp. n. from the Upper Cretaceous of Mongolia. Palaeontologia Polonica, 37, 5–64, 1977