Mongolian Journal of Paleontology

Cite this article: Saneyoshi. M, H. Asai, B. Mainbayar, T. Tanabe, Sh. Ishigaki, Kh. Tsogtbaatar 2021. Reconstruction of sedimentary environments in the Djadokhta Formation, Udyn Sayr, Gobi desert, Mongolia6 Mongolian Journal of Paleontology: 4, 24-30

Received: 10 September 2019
Accepted: 20 November 2020

Subject Category:
Geology and paleontology

Subject Areas:
paleontology

Keywords:
Paleoenvironments, Djadokhta Formation, Udyn Sayr, Mongolia

Author for correspondence:
Mototaka Saneyoshi
e-mail: saneyoshi@big.ous.ac.jp

INSTITUTE OF PALEONTOLOGY
Mongolian Academy of Sciences

Reconstruction of sedimentary environments in the Djadokhta Formation, Udyn Sayr, Gobi desert, Mongolia

Mototaka Saneyoshi[1], Hitomi Asai[2,3], Buuvei Mainbayar[4], Tomohiro Tanabe[2], Shinobu Ishigaki[1], Khishigjav Tsogtbaatar[4]

[1]Faculty of Biosphere – Geosphere Science, Okayama University of Science , Ridai-cho, Kita-ku, Okayama, 700-0005, Japan
[2]Graduate school of Biosphere – Geosphere Science, Okayama University of Science, 1-1 Ridai-cho, Kita-ku, Okayama, 700-0005, Japan
[3]Wesco Inc., 2-5-35 Shimadahonda-cho, Kita-ku, Okayama, 700-0033, Japan
[4]Institute of Paleontology, Mongolian Academy of Sciences, P.O.B 46/650, S. Danzan Street 3/1, 4th khoroo, Chingeltei district, Ulaanbaatar – 15160, Mongolia

The Djadokhta Formation in Udyn Sayr in the southwestern part of the Gobi desert, Mongolia, is described based on sedimentary facies. The succession is composed of eolian and fluvial facies, with interfingering stratigraphic intervals. The fluvial association is indicated by the presence of caliche, suggesting seasonally wet and dry conditions. The eolian deposits contain the most fossils of vertebrates such as Protoceratopsidae, reptiles and Mesozoic mammals, which form a rich part of the succession in the fossil locality. This suggests that eolian environments were the main habitat for vertebrates during the sedimentation period.

INTRODUCTION

The paleoenvironments in the Upper Cretaceous Djadokhta Formation have been studied by many researchers (Berkey and Morris, 1927; Lefield, 1971; Jerzykiewicz et al., 1993; Dashzeveg et al., 1995; Dashzeveg et al., 2005; Dingus et al., 2008), and a number of models have been proposed. These models predict the existence of contrasting environmental conditions including arid, subaerial or eolian,

and water-laid, subaqueous or fluvio-lacustrine (Ebarth et al., 1993; Fastovsky et al., 1997; Saneyoshi et al., 2011). The sedimentary succession and characteristics indicate that environmental changes occurred either gradually or rapidly (Jerzykiewicz, 2000; Watabe et al., 2010). This formation has yielded many vertebrate bone fossils from dinosaurs, reptiles, and mammals, in addition to ichnospecimens of dinosaurs, insects, and mammals (Gradzínski et al., 1977; Norell et al., 1994; Johnston, et al., 1996; Clark et al., 1999; Kielan-Jawarowska, 2003; Kirkland and Barder, 2010; Saneyoshi et al., 2010; Saneyoshi et al., 2011; Tsuihiji et al., 2014; Chinzorig et al., 2017). To develop a better understanding of the relationship between the vertebrate fossils and the paleoecology, we undertook a detailed reconstruction of the paleoenvironments based on the sedimentary succession in the formation. Udyn Sayr is located in the central part of the Gobi desert, Mongolia, approximately 50 km west of Bulugan Somon (Saneyoshi et al., 2010), and is characterized by widely distributed Upper Cretaceous sediments (Figure 1).

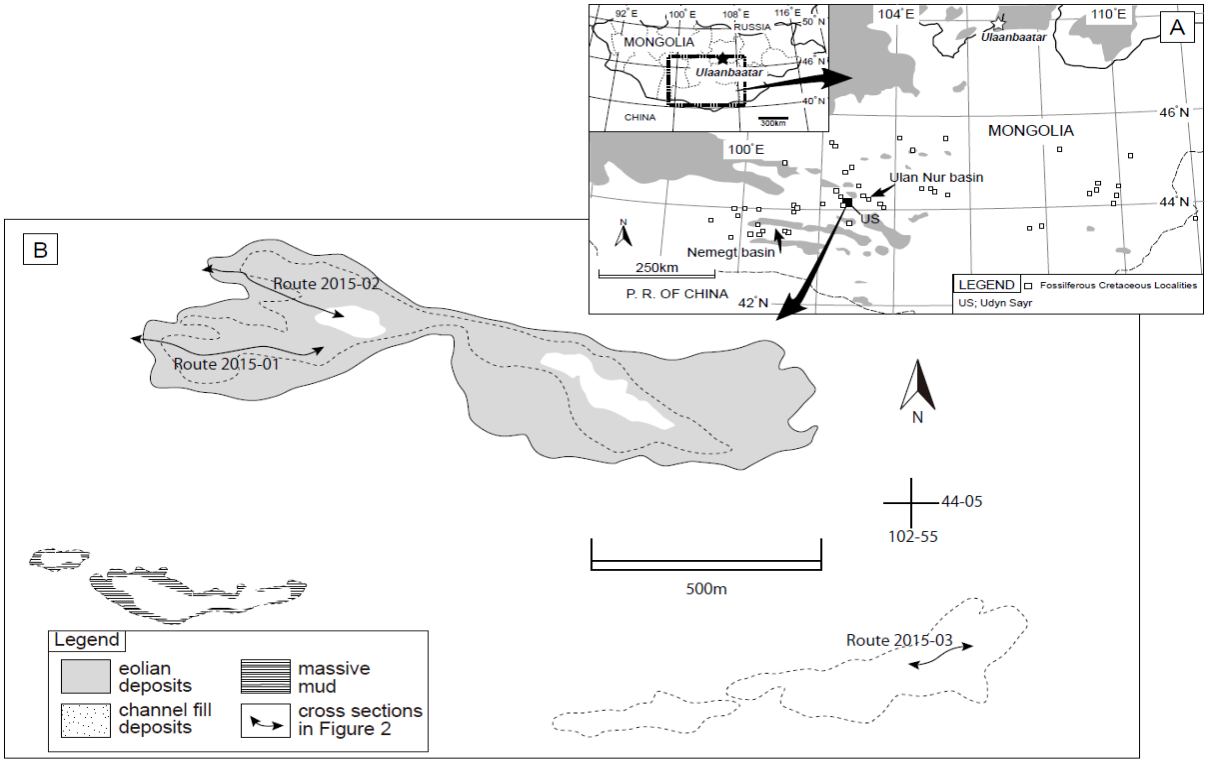

Figure 1. A) Map showing the location of the fossiliferous Cretaceous localities, fossiliferous localities of Djadokhta Formation, and Undy Sayr (modified from Jerzykiewicz, 2000; Watabe and Suzuki, 2000c; Watabe et al., 2010). B) Geological map of eolian and fluvial deposits in the Udyn Sayr. Routes show the location of columnar sections in Figure 2.

The sedimentary succession is about 40 m thick, and consists predominantly of sandstone with minor mudstone beds (Saneyoshi et al., 2010). Watabe et al. (2010) showed that the sedimentary succession comprises eolian and fluvial deposits. These sediments have yielded many fossils of dinosaurs, reptiles, and mammals, including protoceratopsid and *Udanoceratops tschizhovi*, as well as dinosaur footprints and eggshells (Kuruzanov, 1983; Watabe et al., 2010; Saneyoshi et al., 2015). Finding protoceratopsid and *Pinacosaurus* fossils indicates that the succession in the locality was deposited in the Djadokhtian age of the mid-Campanian (Jerzykiewicz, 2000; Watabe et al., 2010).

DESCRIPTION

The size of the study area is 1.5 km from north to south, and 2 km from east to west. Many vertebrate fossils have been discovered in the area. The main outcrop shown in Figure 1 is described in detailed below. The sedimentary succession was characterized by facies analyses and by previous studies (Brookfield, 1977; Fritz and Moore, 1988; Walker and James, 1992; James and Dalrymple, 2010) which identified eolian facies and fluvial association (Figure 2).

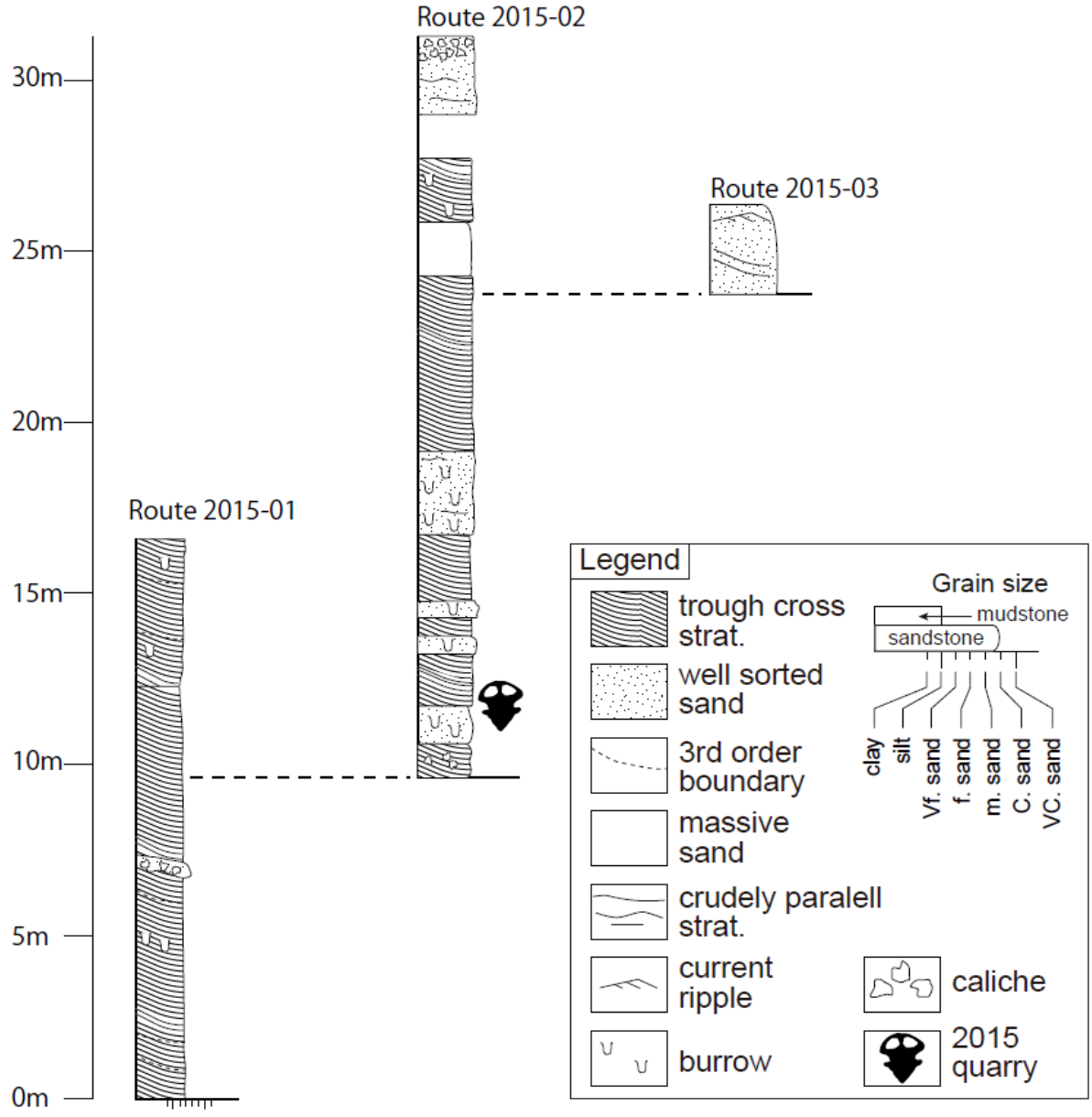

Figure 2. Clumunar cross-sections of the Udyn Sayr. Juvenile Protoceratops sp. have been discovered from 2015 quarry at stratigraphic horizon.

Eolian facies

Description: These beds are composed mainly of well-sorted fine sand with lenticular coarse sand (Figure 3A). This facies is 0.1-2.0 m thick, and exhibits trough cross-stratification, tabular cross-stratification, and current ripple lamination (Figure 3B). These sandstone beds generally have

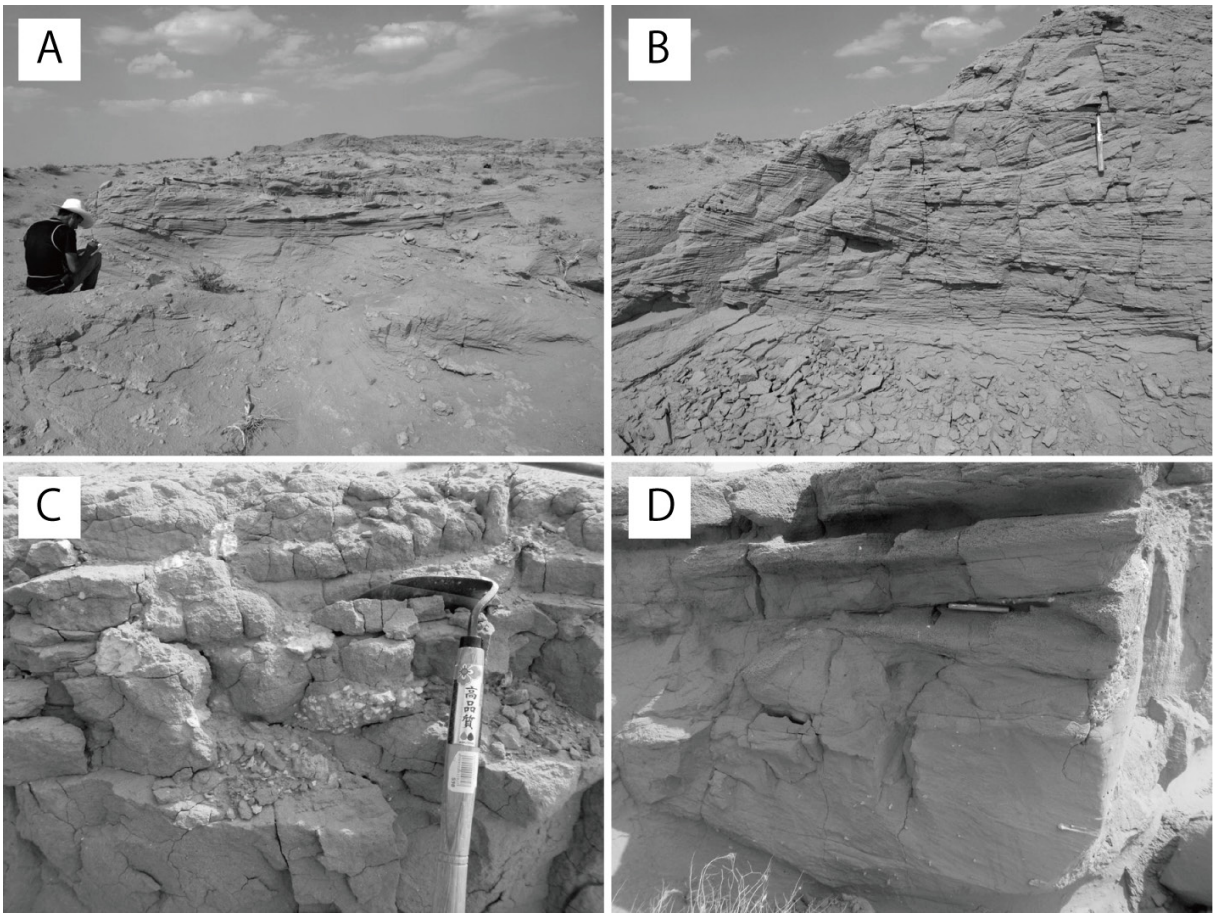

Figure 3. Photographic of outcrop of sediments in the Udyn Sayr, central part of Gobi desert. A) Trough cross-stratifications in eolian deposits of northern part of the locality. B) Cross section of trough cross-stratification of A. C) Caliches in the eolian deposits. These caliches shows a rounded and stratified position. D) Fluvial channel deposits in the top of the main outcrops. Reworked caliches are concentrated (white arrows).

flat bases, exhibit a sheet-like geometry, and can be traced for up to 150 m laterally in the northwestern part of the main locality. Some show ripple lamination at the top of the bed. This type of sandstone is widely distributed in the main outcrop, and is overlain by a fluvial facies (see below). In the 2015 summer joint expedition by the Institute of Paleontology and Geology, the Academy of Science and Okayama University of Science, a juvenile *Protoceratops* was discovered in this facies (Figure 2; Saneyoshi et al., 2015).

Interpretation: These beds are interpreted as being eolian deposits, as the well-sorted fine and coarse sand and sedimentary structure indicate unidirectional sediment transportation as bed load. The predominance of the structures throughout this facies is indicates the presence of a similar environment over a wide area. The absence of gravel and mud beds, which are important indicators of environmental changes, implies that this facies is of erg origin.

Fluvial association

This facies association consists of (1) well-sorted trough or planar cross-stratified sandstone beds intercalated with gravel beds (2) trough or planer cross-stratified reworked caliche beds and (3) massive, reddish mudstone beds.

(1) Well-sorted trough or planar cross-stratified sandstone beds intercalated with gravel beds

Description: These beds are main-

ly composed of very coarse to medium sand with granules scattered near the bottom of the beds. The granule clasts are commonly rounded. This facies is 0.1-1.0 m thick, and the beds have local concave-up erosional bases. Trough cross-stratification, tabular cross-stratification, and current ripple lamination have also been observed (Figure 3). In the southeastern part of the locality, these strata strike east-west and dip towards the north by up to 20° (typically 5-10°). Trough or planer cross-stratified beds with reworked caliche are rounded, and crop out mainly in the northern to northeastern part of the locality. These beds have a sheet-like structure, and generally overlie eolian facies.

Interpretation: These sandstone beds with erosional bases are thought to have accumulated under unidirectional flow, and are interpreted as being fluvial channel fill deposits. The strike and dip of the facies imply that they consist of meandering channels forming a lateral accretion pattern.

(2) Reddish massive mudstone beds

Description: These mudstone beds, which are typically reddish to pale yellow, are very well sorted. They are generally overlain by sandstone beds. This facies is 0.5-3.0 m thick, and contains burrows 0.1 cm in diameter and up to 10 cm in length. These mudstone beds are observed in the southwestern part of the locality.

Interpretation: The existence of channel deposits above and below this facies indicates a floodplain environment. The presence of massive mudstone also provides strong support for this interpretation (Saneyoshi et al., 2006).

Reconstruction of the paleoenvironments based on the observed succession

In the area of the Djadokhta Formation under study, eolian and fluvial facies are dominant. Eolian sandstone beds appear in the northern part of the locality, and are capped by fluvial facies characterized by channel fill deposits with reworked caliche (Figure 2). Thick floodplain deposits are observed in the southeastern and southwestern regions. These lateral and vertical changes suggest interfingering of sedimentary successions in the north-south cross section. Previously, based on the dip of the sandstone beds, we identified the bottom layer of the succession in the southern region as a fluvial channel fill deposit (Saneyoshi et al., 2010; Watabe et al., 2010).

However, these beds have flat or bended structures with a dip towards the north of up to 20°. Based on our interpretation of the lithostratigraphy and the sedimentary facies, these fluvial channel deposits are lateral accretion structures with meandering channels, and Eolian and fluvial facies are interfingered.

Previous studies on the Djadokhta Formation have indicated that it was deposited under semiarid conditions, based on the presence of eolian dunes, intermittent fluvial and lacustrine sediments, and caliche horizons (Jerzykiewicz et al., 1993; Fastovsky et al., 1997; Jerzykiewicz, 2000). The existence of similar facies at Udyn Sayr in the present study suggests that semiarid conditions also prevailed there. However, fluvial deposits are present, and eolian outcrops are not found over wide areas. The succession of the facies implies that regions with fluvial conditions were located close to those with eolian conditions. This suggests the presence of arid conditions, and the possibility that the fluvial conditions originated from another area and passed through this locality. We therefore believe that during deposition of the formation, arid and wet conditions existed in adjacent regions. This should be carefully considered in the analysis of paleoenvironments, and in particular, dinosaur habitats during the Djadokhtian age.

ACKNOWLEDGEMENTS

This research was greatly facilitated by the Institution of Paleontology and Geology, Mongolian Academy of Sciences (IPG, Mongolia). We thank stuff and students of IPG for valuable suggestions and discussion. Our thanks are extended to Okayama University of Science and Museum of Hokkaido University research group for their support in field and laboratory. This study was supported by JSPS KAKENHI Grant Number 15K21541, and Private University Research Branding Project from Ministry of Education, Culture, Sports, Science and Technology (2016-2020).

REFERENCES

Berkey, C. P., and F. K. Morris. 1927: Geology and Mongolia Reconnaissance Report Based on the Investigations of the Year 1922-1923 (Natural History of Central Asia, Volume II), 475p. Central Asiatic Expeditions, American Museum of Natural History, New York.

Brookfield, M. E., 1977. The origin of bounding surfaces in ancient eolian sandstones. Sedimentology, 56, 283-300.

Chinzorig, Ts., Y.Kobayashi, Kh. Tsogtbaatar, P. J. Currie, M. Watabe, and R.Barsbold. 2017. First Ornithomimid (Theropoda, Ornithomimosauria) from the Upper Cretaceous Djadokhta Formation of Tögrögiin Shiree, Mongolia. Scientific Report, Doi https://doi.org/10.1038/s41598-017-05272-6.

Clark, J. M., M. A. Norell, L. M. Chiappe. 1999: An oviraptorid skeleton from the Late Cretaceous of Ukhaa Tolgod, Mongolia, preserved in an avian-like brooding position over an oviraptorid nest. American Museum Novitates, no. 3265, 36 pp.

Dashzeveg, D., L. Dingus, D. B. Loope, C. C. Swisher, T.Dulam, and M.R.Sweeny. 2005: New stratigraphic subdivision, depositional environment, and age estimate for the Upper Cretaceous Djadokhta Formation, southern Ulan Nur Basin, Mongolia. American Museum Novitates, no. 3498, p. 1-14.

Dashzeveg, D., M. J. Novacek, M. A. Norell, J. M. Clark, L. M. Chiappe, A. Davidson, M. C. Mckenna, L. Dingus, C. Swisher, and P.Altangerel. 1995: Extraordinary preservation in a new vertebrate assemblage from the Late Cretaceous of Mongolia. Nature, vol. 374, p. 446-449.

Dingus, L., D. B. Loope, D. Dashzeveg, III. C. Swisher, Ch. Minjin, and M. Nocacek. 2008. The geology of Ukhaa Tolgod (Djadokhta Formation, Upper Cretaceous, Nemegt Basin, Mongolia). American Museum Novitates, 3616, 1–40.

Fastovsky, D. E., D. Badamgarav, D, H. Ishimoto, M. Watabe, and D. B. Weishampel. 1997: The paleoenvironments of Tugrikin Shireh (Gobi Desert, Mongolia) and aspects of the Taphonomy and Paleoecology of Protoceratops (Dinosaurian: Ornithishichia). Palaios, vol. 12, p. 59-70.

Fritz, W. J., and J. N. Moore. 1988. Basics of Physical Stratigraphy and Sedimentology, 337 p. John Wiley & Sons, Inc., Canada.

Gradzínski, R., Z. Kielan-Jaworowska, and T. Maryánska. 1977. Upper Cretaceous Djadokhta, Barun Goyot and Nemegt Formations of Mongolia, including remarks on previous subdivisions. Acta Geologica Polonica, 27, 281–318.

James, N. P., and R. W. Dalrymple. 2010. Facies Models 4. 586 P. Geological Association of Canada, Memorial University of Newfoundland.

Jerzykiewicz T., P.,J. Currie, D. A. Eberth, P. A. Johnston, E. H. Koster, and J. J. Zheng. 1993: Djadokhta Formation correlative strata in Chinese Inner Mongolia: an overview of the stratigraphy, sedimentary geology, and paleontology and comparisons with the type locality in the pre-Altai Gobi. Canadian Journal of Earth Sciences, vol. 30, p. 2180-2195.

Johnston P. A., D. A. Eberth, and P. K. Anderson. 1996. Alleged vertebrate egg from Upper Cretaceous redbeds, Gobi Desert, are fossil insect (Coleoptera) pupal chambers: Fictovichnus new ichnogenus. Canadian Journal of Earth Science, 33, 511-525.

Kirkland, J. I., and K.Barder. 2010. Insect trace fossils associated with Protoceratops carcasses in the Djadokhta Formation (Upper Cretaceous), Mongolia. In: Ryan, M.J., Chinnery-Allegeier, B.J., Eberth, D.A., (Eds.), New Perspectives on Horned Dinosaurs, Indian University Press, Bloomington, pp. 509-519.

Kuruzanov, S. M., 1983. New data on the pelvic structures in Avimimus. Paleontologicheskiy Zhurnal, no. 1983, 115-116. (in Russian)

Lefield, J., 1971. Geology of the Djadokhta Formation at Bayn Dzak (Mongolia). Paleontologica Polinica, vol. 25, p. 101-127.

Norell M. A., J. Clark, D. Dashzeveg, R. Barsbold, L. M. Chiappe, A. R. Davidson, M. C. Mckenna, A. Perle, and J.Novacek. 1994. A theropod dinosaur embryo and the affinities of the Flaming cliffs dinosaur eggs. Science, 776-782.

Saneyoshi, M., K. Nakayama, Y. Sawada, K. Sakai, and H. Ishida. 2006. Half graben filling processes in the early phase of continental rifting: The Miocene Namurungule Formation of the Kenya Rift. Sedimentary Geology, 186, 111-131.

Saneyoshi, M., M. Watabe, T. Tubamoto, Kh. Tsogtbaatar, Ts. Chinzorig, and S. Suzuki. 2010: Report on the HMNS – MPC joint paleontological expedition in 2007. Hayashibara Museum of Natural Sciences Research Bulletin, vol. 3, p. 19-28.

Saneyoshi, M., M. Watabe, S. Suzuki, and Kh. Tsogtbaatar. 2011. Trace fossils on dinosaur bone from Upper Cretaceous eolian deposits in Mongolia: Taphonomic interpretation of paleoecosystems in ancient desert environments. Paleogeography, Paleoclimate, Paleoecology, 311, 38-47.

Saneyoshi, M., S. Ishigaki, Kh. Tsogtbaatar, B. Mainbayar S. Ulziitseren, Ch. Bayanrdouji, B. Otogonbat, Kh. Amarbaysglan, H. Asai, and T. Tanabe. 2015. Report of the OUS-IPG Joint Expedition in 2015. Bulletin of Reseach Institite of Natural Sciences, Okayama University of Science, no. 41, 35-44.

Tuihiji, T., R. Barsbold, M. Watabe, Kh. Tsogtbaatar, Ts. Chinzorig, Y. Fujiyama, and S. Suzuki. 2014. An exquisitely preserved troodontid theropod with new information on the palatal structure from the Upper Cretaceous of Mongolia. Naturwissenschaften, 101, 131-142.

Walker, R. G., and, N. P. James. 1984. Facies Model; Response to Sea Level Change, 554 p. Geological Association of Canada, Newfoundland.

Watabe, M., Kh. Tsogtbaatar, S. Suzuki, and M. Saneyoshi. 2010: Geology of dinosaur fossil-bearing locations (Jurassic and Cretaceous, Mesozoic) in the Gobi desert: results of the HMNS − MPC Joint Paleontological Expedition: Hayashibara Museum of Natural Sciences Research Bulletin, vol. 3, p. 41-118.