Early evolution of non-avian dinosaurs during the pre-Jurassic episode

Ahmad Reza Noruzi*

[1] Department of Biochemistry, Faculty of Medicine, Tabriz University of Medical Sciences, Tabriz, Iran
E-mail: ahmadrezanowrouzifard@gmail.com

ABSTRACT

Dinosauria represents an effective group of Mesozoic terrestrial vertebrates which experienced the exceptional evolutionary processes to establish a diverse, widespread faunal lineage across nearly 160 million years of the Earth's geologic history. Early evolution of non-avian dinosaurs has been continuously focused by recent paleontological research, showing a complex and even sometimes confusing type of biological developments. This study presents a brief report on early evolution of non-avian dinosaurs at the pre-Jurassic geologic episode. The methodology process was performed by comparative analyses on the current publications to provide a descriptive summery of organized data. Fundamentally, it is demonstrated that the main concepts of early dinosaur developmental history have focused on major biological and environmental constraints which forced the group to a complex route of evolution and biodiversification. As the keystones of relevant paleontological approaches, stratigraphic analyses and continuous biological investigations are crucial items in order to access the supportive information on pre-Jurassic non-avian dinosaurs.

Keywords: Evolution, Dinosaur, Triassic, Fossil analysis, Paleontology

---

1. *INTRODUCTION*

Evolutionary history of non-avian dinosaurs has been a constant point of paleontological research since the first scientific discoveries were made [1] and [2]. This ancient subgroup of archosaurian reptiles occupied nearly every corner of the Mesozoic world for approximately 60 million years of Earth's history until the End-Cretaceous mass extinction event [3]. Early evolution of non-avian dinosaurs is a common, but poorly understood subject in vertebrate paleontology, reflecting the fact that there are still many unanswered questions about dinosaur evolution from deep time of Mesozoic era. Importantly, it is suggested that primitive dinosaurs began to thrive around the earliest Late Triassic interval when there was only one gigantic continental landmass on the entire Earth's surface [4]. In fact, current research from nearly all around the world has already allowed us to envisage well-supported evolutionary hypotheses and efficient biological models for early dinosaur history at the Triassic period [5] to [7]. Additionally, as the abundant fossil records have already made by many workers during the recent decades of paleontological exploration, more evidences on the origin and early evolution of Triassic dinosaurs helped to establish well-documented aspects in historical biology. However, this chapter of Mesozoic paleobiology still remained as a complex and debatable topic which may reveal some paradox estimations or unexpected relationships between the extinct and modern taxa, deep in the Triassic macroevolution [8]. Hence, it is important to apply for both fossil analysis and biological modeling in order to investigate the main prospects of pre-Jurassic non-avian dinosaur origins and macroevolution. In addition, the relevant natural scientific approaches of other fields of study play a key role in efficient documentation, including geochemistry, geophysics, and *paleoclimatological investigations which are used to perform more comprehensive studies in developmental biology of these early-diverging dinosaurs. In this way, more reliable evolutionary explorations can be performed to approach the potential models of the subject.*

1.1 Aims

This study's aim is to provide a summarized report on the early evolution of non-avian dinosaurs during the pre-Jurassic geological episode based on the current research to reveal the potential paleobiological models for early dinosaur developmental history.

2. METHOD

This study was performed by systematically searching the main scientific databases such as Google Scholar, Scopus and national libraries to access the current literature published in this field of dinosaur paleontology, to ensure the comprehensive and comparative analyses The key terms were searched to find the related literature, considering the symptom terms to maximize the documented information. The methodology was continued by collecting original papers, reviews, and also the scientific books in the field of early dinosaur paleobiology. Then the saved data were analyzed and classified to cover the main implications and prospects, before the paper was written at last.

3. RESULT AND DISCUSSION

3.1. Dinosaur originate

At the early Late Triassic (~ 230 Ma), Pangaea basin was intensively influenced by extreme environmental and climatic fluctuations which made the continent a harsh, unexpected place for all of the inhabiting terrestrial vertebrates [9]. This vast, hostile landmass was primarily dominated by the diversified archosaurian reptiles from the scorching deserts of low-paleolatitudinal regions to cooler environments in higher paleolatitudes of the basin [10] and [11]. Particularly, the dinosauriform archosaurs formed an early diverging subgroup of these Triassic reptilians which were forced by both environmental and faunal constraints at the very first episode of their evolution [12] and [13]. Given the Late Triassic biostratigriphic explorations from several localities in South America and Africa, it is suggested that the earliest true dinosaurian archosaurs primarily emerged in few restricted parts of southern Gondwana basin, being away from harsh circumstances of Panaean paleotropics [14]. Importantly, a family of these early diverging dinosaurs known as the herrerasaurians, are recognized from several stratigraphic localities in South America, Africa, and India, suggesting a southern Gondwanan origin hypothesis (SGOH) for Mesozoic non-avian dinosaurs around the Carnian age (~235-230 Ma) [15] to [18]. In special, the Ischigualasto Formation of Argentina represents a potential source for these Triassic herrerasaurs such as Herrerasaurus ischigualastensis (shown in Figure 1) and Sanjuansaurus gordilloi, while the Santa Maria Formation in Brazil shows other relevant species such as Staurikosaurus pricei and Gnathovorax cabreirai [19] and [20]. More recently, an additional herrerasaurian taxon has been described from Upper Maleri Formation of India which has been already named as Maleriraptor kuttyi [18]. Significantly, these continuous discoveries from the Late Triassic Gondwanan strata have indicated a similar geographic position with other early diverging dinosaurs (e.g., the basal sauropodomorph Eoraptor luensis) [21]. On the other hand, major environmental constraints of the Pangaean paleotropical zones during the Carnian-Norian geologic interval, are considered as another evidence to support the SGOH as a potential concept for early evolution of non-avian dinosaurs [22]. Nevertheless, a study performed by Health et al., has explained that early dinosaurs probably emerged in low-paleolatitudinal regions of the vast Gondwana basin, suggesting that SGOH may need further modifications by continuous research in the future [23]. As the consequent, it is essential to apply for additional paleobiological and geological approaches to provide more reliable explanations on early dinosaur origin and biogeography.

Fig 1. *Illustration of Late Triassic Herrerasaurus ischigualastensis*

3.2. Biodiversifications

As the dinosaurs began to diversify and become more widespread during the Norian age (~ 220-215 Ma), their ecological and biogeographical ascendancy started to grow and rapidly influenced the whole paleoecology of the Pangaean supercontinent [24] and [25]. It is recently suggested that early theropod dinosaurs possibly occupied a broad range of paleogeographical environments, whereas basal sauropodomorphs existed in more restricted, moderate habitats of Pangaea basin, during the Norian-Rhaetian geologic interval [12] and [26]. As an early desert specialist theropod dinosaur, Coelophysis bauri shows a significant range of evolutionary novelties which were potentially transformed to later theropod taxa towards the earliest Jurassic episode. Importantly, this early theropod dinosaur and its later Triassic descendants developed many biological adaptations and innovations which allowed them to cope with new environmental constraints and to take advantage of the increasing ecological opportunities [17], [27], and [28]. Specification played an important role in Triassic dinosaur biodiversification and ecological evolution, allowing the group to develop the essential skills and abilities to compete with the dominant non-dinosaurian archosaurs as well as to survive the hostile low-paleolatitudinal environments. Honestly, while the theropod dinosaurs remained fundamentally bipedal towards their further macroevolution, their saurischian cousins, the sauropodomorphs, shifted to both quadrupedalism and gigantism as they were continuously diversifying during the Late Triassic epoch [29] and [30]. In addition, as the dinosaur specification and biodiversification were going ahead, theropods mostly remained on their traditional diet, indicating a parallel pattern with their potential bipedalism. In the opposite, sauropodomorphs gradually shifted to herbivorous diet which is highly supported by their developed teeth and even coprolites, confirming the fact that this lineage of saurischian dinosaurs reveals powerful forces of pre-Jurassic vertebrate evolution across the ancient supercontinent [21]. On the other hand, the Triassic non-avian dinosaurs were fiercely being influenced by a high-level competition with large non-dinosaurian archosaurs (Figure 2), included both herbivorous and predatory taxa that widely dominated the Late Triassic ecosystems [11]. It has been described that some predatory archosaurian genera (e.g., Postosuchus, Batrachotomus, and Riojasuchus) potentially preyed on small contemporary dinosaurs, being considered as major faunal threat for these earlier components of Late Triassic biota. Towards the beginning of Rhaetian age, however, dinosaurs experienced many physical and biological developments that allowed them to establish an efficient, successful lineage of Mesozoic terrestrial vertebrates [31]. This fact is even getting more recognized than before, as the increasing fossil discoveries are providing new paleontological aspects in non-avian dinosaur evolution and paleobiology.

Fig 2. *Illustration of non-dinosaurian archosaur, Batrachotomus*

4. CONCLUSION

This study showed that early evolution of non-avian dinosaurs primarily began with a potential impact of major biological and environmental limitations, driving them to a special pathway of macroevolution and ecological ascendancy. Current paleobiological research alongside the continuous fossil records had a certain role in determinations and biostratigraphic estimations for Triassic dinosaur history. Hence, it is necessary to apply for both fossil record and paleobiological investigations to approach further views on the evolution of early dinosaurs.

REFERENCES

[1] *Klein, H., Lucas, S. (2025). Early evolution of dinosaurs: indications from the Triassic footprint record. Italian Journal of Geosciences, vol. 144, no. 3, p. 436-459.*

[2] *Sander, P.M., Christian, A., Clauss, M., Fechner, R., Gee, C.T., Griebeler, E.-M., Gunga, H.-C., Hummel, J., Mallison, H., Perry, S.F., et al. (2011). Biology of the sauropod dinosaurs: the evolution of gigantism. Biological Reviews of the Cambidge Philosophical Society, vol. 86, p. 117–155.*

[3] *Fassett, J.E. (2009). New geochronologic and stratigraphic evidence confirms the Paleocene age of the dinosaur-bearing Ojo Alamo Sandstone and Animas Formation in the San Juan Basin,New Mexico and Colorado. Palaeontologica Electronica, vol. 12: p. 1–155.*

[4] *Langer, M.C., Ezcurra, M.D., Bittencourt, J.S., and Novas, F.E. (2010). The origin and early evolution of dinosaurs. Biological Reviews of the Cambidge Philosophical Society, vol. 85, p. 55–110.*

[5] *Baron, M.G., Norman, D.B., and Barrett, P.M. (2017). A new hypothesis of dinosaur relationships and early dinosaur evolution. Nature, vol.543, p. 501–506.*

[6] *Alcober, O.A., and Martı´nez, R.N. (2010). A new herrerasaurid (Dinosauria, Saurischia) from the Upper Triassic Ischigualasto Formation of northwestern Argentina. ZooKeys, vol. 63, p. 55–81.*

[7] *Martinez, R.N., Sereno, P.C., Alcober, O.A., Colombi, C.E., Renne, P.R., Montan˜ ez, I.P., and Currie, B.S. (2011). A Basal Dinosaur from the Dawn of the Dinosaur Era in Southwestern Pangaea. Science, vol. 331, p. 206–210.*

[8] *Brusatte, S.L., Benton, M.J., Ruta, M., and Lloyd, G.T. (2008). Superiority, Competition, and Opportunism in the Evolutionary Radiation of Dinosaurs. Science, vol. 321, p. 1485–1488.*

[9] *Brusatte, S.L. (2017). The Rise and Fall of the Dinosaurs: A New History of a Lost World. Mariner Books.*
[10] *Benton, M.J. (2016). The Triassic. Current Biology, vol. 26 p. R214-8.*
[11] *Schultz, C.L., Martinelli, A.G., Soares, M.B., Pinheiro, F.L., Kerber, L., Horn, B.L., Pretto, F.A., Müller, R.T., Melo, T.P. (2020). Triassic faunal successions of the Parana Basin, southern Brazil. Journal of South American Earth Sciences, vol. 104, p. 102846.*
[12] *Dunne, E.M., Farnsworth, A., Greene, S.E., Lunt, D.J., Butler, R.J. (2021). Climatic drivers of latitudinal variation in Late Triassic tetrapod diversity. Palaeontology, vol. 64, p. 101-117.*
[13] *Garcia, M.S., Müller, R.T., Da-Rosa, A.A.S., Silva, S. (2019). The oldest known co-occurrence of dinosaurs and their closest relatives: A new lagerpetid from a Carnian Upper Triassic) bed of Brazil with implications for dinosauromorph biostratigraphy, early diversification, and biogeography. Journal of South American Earth Sciences, vol. 91, p. 302-19.*
[14] *Marsola, J.C.A., Ferreira, G.S., Langer, M.C., Button, D.J., Butler, R.J. (2019). Increases in sampling support the southern Gondwana hypothesis for origin of dinosaurs. Palaeontology, vol. 62, p. 473-482.*
[15] *Langer, M.C., Ramezani, J., Da Rosa, A.A.S. (2018). U-Pb age constrains on dinosaur rise from south Brazil. Gondwana Research, vol. 57, p. 133-140.*
[16] *Novas, F.E., Agnolín, F.L., Ezcurra, M.D., Temp Müller, R.T., Martinelli, A.G., Langer, M.C. (2021). Review of the fossil record of early dinosaur from South America, and its phylogenetic implication. Journal of South American Earth Sciences, vol. 110, p. 103341.*
[17] *Griffin, C.T., Wynd, B.M., Munyikwa, D., Broderick, T.J., Zondo, M., Tolan, S., Langer, M.C., Nesbitt, S.J., Taruvinga, H.R. (2022). Africa's oldest dinosaur reveal early suppression of dinosaur distribution, Nature, vol. 609, p. 313-319.*
[18] *Ezcurra, M.D., Garcia, M.S., Novas, F.E., Müller, R.T., Agnolin, F.L., Chatterjee, S. (2025). A new herrerasaurian dinosaur from the Upper Triassic Upper Maleri Formation of south-central India. Royal Society Open Science, vol. 12, p. 250081.*
[19] *Martínez, R.N., Apaldetti, C., Alcober, O.A., Colombi, C.E., Sereno, P.C., Fernandez, E., Malnis, P.S., Correa, G.A., Abelin, D. (2012). Vertebrate succession in the Ischigualasto Formation. Journal of vertebrate Paleontology, vol. 32: p. 10-30.*
[20] *Colombi, C., Martínez, R.N., Césari, S.N., Alcober, O., Limarino, C.O., Montañez, I. (2021). A high-precision U-Pb zircon age constraints the timing of the faunistic and palynofloristic events of the Carnian Ischigualasto Formation, San Juan, Argentina. Journal of South American Earth Science, vol. 111, p. 103433.*
[21] *Hallett, M., Wedel, M.J. (2016). The Sauropod Dinosaurs: Life in the Age of Giants. Johns Hopkins University Press.*
[22] *Witheside, J.H., Lindström, S., Irmis, R.B., Glasspool, I.J., Schaller, M.F., Dunlavey, M., Nesbitt, S.J., Smith, N.D., Turner, A.H. (2015). Extreme ecosystem instability suppressed tropical dinosaur dominance for 30 million years. Proceedings of National Academy of Sciences of the United States of America, vol. 112, p. 7909-7913.*
[23] *Health, J.A., Cooper, N., Upchurch, P., Mannion, P.D. (2025). Accounting for sampling heterogeneity suggests a low paleolatitude origin for dinosaurs. Current Biology, vol. 35, p. 941-953.*
[24] *Tykoski, R.S., Rowe, T. (2004). Ceratosauria. In The Dinosauria (eds DB Wieshampel, P Dosdson, H Osmolka), pp.47-70,2nd edition. Berkeley (A: University of California Press.*
[25] *Upchurch, P., Chiarenza, A.A. (2024). A brief review of non-avian dinosaur biogeography: State-of-the-art and prospectus. Biology Letters, vol. 20, p. 240429.*
[26] *Brusatte, S.L., Butler, R.J., Niedzwiedzki, G., Sulej, T., Bronowicz, R., Satkúnas, J. (2013). First record of Mesozoic terrestrial vertebrates from Lithuania: phytosaurs (Diapsida: Archosauriformes) of probable Late Triassic age, with a review of phytosaur biogeography. Geological Magazine, vol. 150, p. 110-122.*
[27] *Dunne, E.M., Farnsworth, A., Benson, R.B.J., Godog, P.L., Greene, S.E., Valdes, P.J., Lunt, D.J., Butler, R.J. (2023). Climatic controls on the ecological ascendancy of dinosaurs. Current Biology, vol. 33, p. 206-214.*
[28] *Kent, D.V., Clemmensen, L.B. (2021). Northward dispersal of dinosaurs from Gondwana to*

Greenland at the mid-Norian (215-212 Ma, Late Triassic) dip in atmospheric pCO2. Proceedings of National Academy of Sciences of the United States of America, vol. 118, p. e2020778118.

[29] *Apaldetti, C., Pol, D., Ezcurra, M.D., Martínez, R.N. (2021). Sauropodomorph evolution across the Triassic-Jurassic boundary: body size, locomotion, and their influence on morphological disparity. Scientific Reports, vol. 11, p. 225334.*

[30] *Apaldetti, C., Martínez, R.N., Cerda, I.A., Pol, D., Alcober, O. (2018). An early trend towards gigantism in Triassic sauropodomorph dinosaurs. Nature Ecology & Evolution, vol. 2, p. 1227-1232.*

[31] *Allen, B.T., Stubbs, T.L., Benton, M.J., Puttick, M.N. (2019). Archosauromorph extinction selectivity during the Triassic-Jurassic mass extinction. Palaeontology, vol. 62, p. 211-24.*