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THE LINK BETWEEN DINOSAUR GEOCHEMISTRY AND SUSTAINABLE DEVELOPMENT IN LIBYA

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Abstract

Dinosaur fossils are found in many Mesozoic rocks in Libya such as the Zarzaitine, Cabao, Mesak, Kiklah, and Mizdah formations. Dinosaur geochemistry in Libya is relevant to the fields of scientific investigation, geotourism, and sustainable development, as it contributes to the preservation and promotion of the country's fossil heritage. Although the relevance of dinosaur geochemistry is increasing worldwide, very few studies have been conducted regarding the geochemical aspects of dinosaurs from Libya. The scientific potential and possible avenues for future studies of dinosaur geochemistry in Libya are highlighted in this work.

Keywords: Dinosaur Geochemistry, Sustainable Development, Libya.

1. Introduction

The dinosaurs are a varied group of reptilian species that thrived on Earth during the Mesozoic Era. Dinosaurs first emerged some 230 million years ago in the Late Triassic and lasted until their extinction in the Late Cretaceous around 66 million years ago (Wicander, and Monroe, 2000; Erickson, 2002). The Triassic period was characterized by the dominance of small dinosaurs, while the Jurassic period was marked by the rapid diversification of large dinosaurs. The greatest diversity in dinosaurs was seen during the Cretaceous period; however, its end was marked by their extinction. Various factors led to the extinction of most non-avian dinosaurs, such as volcano eruption, meteorite collision, climatic change, and environmental disruption. Most of the dinosaurs were oviparous animals, including herbivores, carnivores, and omnivores. (Benton, 2019). Bones (e.g., Pyzalla et al., 2006; Britt et al., 2009; Kremer et al., 2012; An et al., 2016; Cerda et al., 2019; Garilli et al., 2023; Aureliano et al., 2026), teeth (e.g., Dyke and Malakhov 2004; Amiot et al., 2010; Montanari et al., 2013; Torices et al., 2018; Averianov et al., 2022; Michailow et al., 2025), footprints (e.g., Avanzini and Lockley, 2002; Lockley et al., 2006; Xing et al., 2011; Li et al., 2015; Liard et al., 2019; Antonelli et al., 2023; Jacobs, 2026), eggs (e.g., Codrea et al., 2002; Grellet-Tinner et al., 2006; Liang et al., 2009; Sellés et al., 2013; Tanaka et al., 2016; He et al., 2020; Xing et al., 2023; Kim et al., 2026), skin impressions (e.g., Kim et al., 2010; Rothschild and Depalma, 2013; Fondevilla et al., 2016; Hendrickx and Bell, 2021; Apesteguía et al., 2023; Ralls, 2026), and coprolites—fossilized excrement— (e.g., Ghosh et al., 2003; Chin et al., 2009; Eriksson et al., 2011; Souto and Fernandes, 2015; Mancuso et al., 2018; Dridi, 2022; Dino et al., 2026) are examples of dinosaur fossils. The major groups of dinosaurs are presented in Fig. 1.

Dinosaur geochemistry refers to the process by which geochemical techniques are used to analyze dinosaurs and the conditions under which they existed millions of years ago (e.g., Montanari et al., 2013; Vajda et al., 2016; Fanti et al., 2018; Ferrante et al., 2021). This field involves the use of geology, geochemistry, and paleontology to reconstruct past environments. The isotopes found in dinosaur fossils enable researchers to comprehend the depositional settings. Some of the most commonly used isotopes include those of carbon ($\delta^{13}C$), oxygen ($\delta^{18}O$), nitrogen ($\delta^{15}N$), and strontium ($^{87}Sr/^{86}Sr$). Major and trace elements in dinosaur fossils give information regarding their preservation, diagenesis, and depositional environment. The most important major elements are iron (Fe) and manganese (Mn), whereas rare earth elements (REE), uranium (U), and thorium (Th) are the significant trace elements. Biomarkers, proteins, lipids, and soft tissues are examined through the analysis of organic compounds found in fossils. Taphonomy provides insights into mineralization, bone preservation, fossil coloration, and burial settings. Geochemical analysis of rock strata containing dinosaur fossils is utilized in determining paleoclimatic conditions, ocean geochemistry, and volcanic eruptions. It aids researchers in understanding dinosaur evolution and extinction episodes. Conclusively, dinosaur geochemistry is an area that bridges paleontology and geochemistry and allows scientists to quantitatively establish how biological systems operated in the past using chemistry. This science forms a significant aspect of earth's evolution during the Mesozoic Era.

2. Objective

Reviewing the dinosaur geochemistry in Libya and connecting it to sustainable development is the goal of this study. In order to enhance knowledge of the geochemical importance of dinosaur fossils in Libya, the review entails the compilation and synthesis of preceding studies.

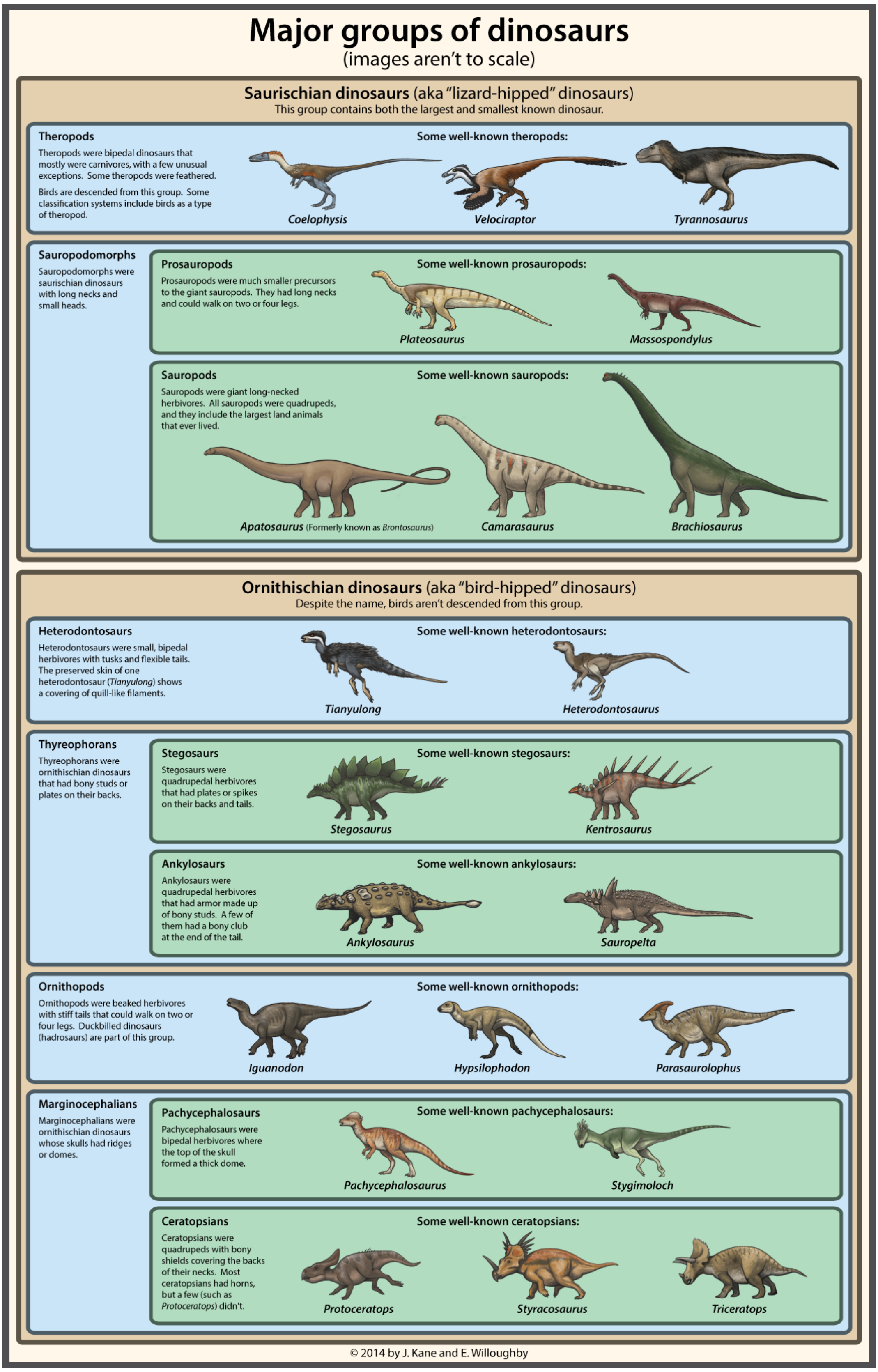

Fig. 1: Dinosaur classification simplified (after Kane and Willoughby, 2014).

3. Dinosaur Geochemistry in Libya

3.1. Dinosaur-Bearing Formations in Libya

The Cabao Formation (Early Cretaceous) which is located around Nalut (NW Libya) is the site of Libya's most significant dinosaur findings (Le Loeuff et al., 2010). There have been reports of further dinosaur fossils from the Triassic Zarzaitine Formation (Hallett, 2002), the Early Cretaceous Mesak Formation (Abdullah et al., 2024), the Early Cretaceous Kiklah Formation (Smith and Vecchia, 2006) and the Late Cretaceous Mizdah Formation (Nessov et al., 1998). Fossils and replicas pertaining to Libyan dinosaur finds are preserved at the Nalut Dinosaur Museum (Fig. 2).

3.2. Sustainable Development Applications

3.2.1. Geotourism Development

One of the primary cornerstones of Libya's geoparks and sustainable tourism initiatives might be dinosaur fossils.

3.2.2. Scientific Research

Academic geosciences curricula are strengthened by dinosaur geochemistry. Fossil geochemistry research is becoming more and more important at Libyan universities.

3.2.3. Water and Environment

Depositional settings of dinosaur fossils may provide valuable insights into aquifers, paleoclimate, and desertification. This is consistent with the geosciences' role in sustainable development in Libya, particularly groundwater conservation and environmental surveillance.

3.2.4. Geoheritage Conservation

Many areas where dinosaur fossils have been found in Libya are still under-recorded, along with the illicit exploitation of such fossils. To achieve sustainable development, it is necessary that (1) There should be legal protection of the fossil-bearing sites; (2) Geoparks and museums should be established; (3) Digital documentation of the geosites; and (4) Awareness among local communities should be initiated.

Fig. 2: Nalut Dinosaur Museum (after Temehu, 2006).

4. Conclusions

Dinosaur geochemistry in Libya plays a very crucial role from a scientific perspective in explaining the paleoclimate, depositional settings as well as the geological history of the Mesozoic strata in Libya. To properly assess dinosaur fossils in Libya, more research is required because dinosaur geochemistry in Libya has not yet been well studied, despite the field's scientific significance. Dinosaur geochemistry is of paramount importance to sustainable advancement, geotourism, and heritage preservation. The documenting, preservation, and international acknowledgment of Libya's fossil legacy can be improved via ongoing study and international cooperation.

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