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# The Vital Role of Archaeological Geochemistry in Supporting Sustainable Development in Libya

Osama Rahil Shaltami[1,*], osama.rahil@yahoo.com , https://orcid.org/0009-0006-0890-9093 ,
Abobakar E. Algomati[2], Abobakar.algomati@bsu.edu.ly , https://orcid.org/0009-0004-4572-5117 ,
Hamza Al Matoni[3], desert201255@gmail.com , https://orcid.org/0000-0002-4748-065X ,
Ramzi Salem[4], ferganiramzi@gmail.com , https://orcid.org/0000-0003-1539-1596
[1]Department of Earth Sciences, Faculty of Science, University of Benghazi, Libya
[2,3,4]Department of Engineering Geology, Faculty of Engineering, University of Bright Star, Libya
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* Corresponding author osama.rahil@yahoo.com

***Index Terms***

Archaeological Geochemistry, Sustainable Development, Libya.

***Abstract***

Archaeological geochemistry in Libya is extremely significant in helping us understand past activities of humans, their environment, and resource use in crucial cultural areas such as Cyrene, Leptis Magna, and Sabratha. The application of geochemical methodologies in the study of soil, sediment, ceramic, and metallurgy samples helps uncover information about elemental composition and isotopes related to trading, agriculture, and technology. The subject of geochemistry in archaeology involves a number of methods from different fields including Geochemistry, Archaeology, and Environmental Science used to answer questions about the process of site formation, pollution, and paleoenvironments in arid and semi-arid environments. The use of archaeological geochemistry is especially relevant in Libya since this method will help shed light on water management, mineral resource exploitation, and the impact of human activity on the environment in arid and coastal zones. Finally, the analysis of geochemical properties is used in heritage conservation, which allows one to study material degradation in order to find ways of restoring UNESCO world heritage sites.

# الدور الحيوي لجيوكيمياء الأثار في دعم التنمية المستدامة في ليبيا

أسامة رحيل الشلطامي[1،*]، أبوبكر عز الدين القماطي[2]، حمزة الماطوني[3]، رمزى سالم[4]
[1]جامعة بنغازي، كلية العلوم، قسم علوم الأرض، بنغازي، ليبيا، osama.rahil@yahoo.com، https://orcid.org/0009-0006-0890-9093
[2،3،4] جامعة النجم الساطع، كلية الهندسة، قسم هندسة الجيولوجيا، البريقة، ليبيا،
Abobakar.algomati@bsu.edu.ly , https://orcid.org/0009-0004-4572-5117 [2]
desert201255@gmail.com , https://orcid.org/0000-0002-4748-065X [3]
ferganiramzi@gmail.com , https://orcid.org/0000-0003-1539-1596 [4]
DOI: https://doi.org/10.36602/jsras.2026.3.2.4
osama.rahil@yahoo.com * المؤلف المراسل

***الكلمات المفتاحية***

جيوكيمياء الأثار، التنمية المستدامة، ليبيا.

***الملخص***

تعد جيوكيمياء الأثار في ليبيا أساسا لإعادة بناء النشاط البشري التاريخي، والظروف البيئية، واستخدام الموارد عبر المناظر الطبيعية الثقافية الهامة. يستطيع الباحثون تحديد التركيبات العنصرية والبصمات النظائرية التي تكشف أنماط التجارة، والممارسات الزراعية، والتقدم التقني، وذلك باستخدام تقنيات الجيوكيمياء على التربة، والرواسب، والفخار، والمخلفات المعدنية. كما تتيح جيوكيمياء الأثار في ليبيا فهم أنظمة إدارة المياه القديمة، واستغلال الموارد المعدنية، والآثار البيئية للحضارات السابقة في المناطق الصحراوية والساحلية. علاوة على ذلك، تسهم التحليلات الجيوكيميائية في دعم حماية التراث التاريخي من خلال تقييم تدهور المواد وتوجيه خطط ترميم المواقع التاريخية العالمية التابعة لليونسكو. ويستند تخطيط استخدام الأراضي الحديث وحماية البيئة في ليبيا إلى دمج جيوكيمياء الأثار مع أطر التنمية المستدامة، مما يساعد أيضًا في الحفاظ على الأصول الثقافية.

## 1. INTRODUCTION

Archaeological geochemistry is a powerful interdisciplinary field that examines past human behaviors, materials, and environments using the science of geochemistry and archaeology (e.g., Hughes and Smith, 1993; Jacobson et al., 1995; Palmer and Finkelman, 2006; Oonk et al., 2009; Moffat, 2014; Degryse and Alexander Bentley, 2018; Bintliff and Degryse, 2022; Scott et al., 2024).

Libya is home to 63 archaeological sites (Archiqoo, 2017). There are three main categories of archaeological sites in Libya: (1) Historical sites; (2) Heritage sites; and (3) Monuments (Figure 1). Application of geochemical methods in archaeology of Libya is necessary because it will help to reveal trade networks, understand the adaptation to desert conditions of the ancient people and protect the sites from destruction by natural and man-made causes. There have been numerous research on archaeological geochemistry in Libya (e.g., Bader, 2014; Abdel Rahim, 2016; Duckworth et al., 2016; Leitch et al., 2016; Castorina et al., 2023; Barich, 2024). The feasibility of rejuvenating Al-Aziziya Palace into a viable model for economic growth is considered by Farajallah et al. (2025). The historical and architectural value of this place is highlighted in order for it to regain its status as an area of cultural and economic significance.

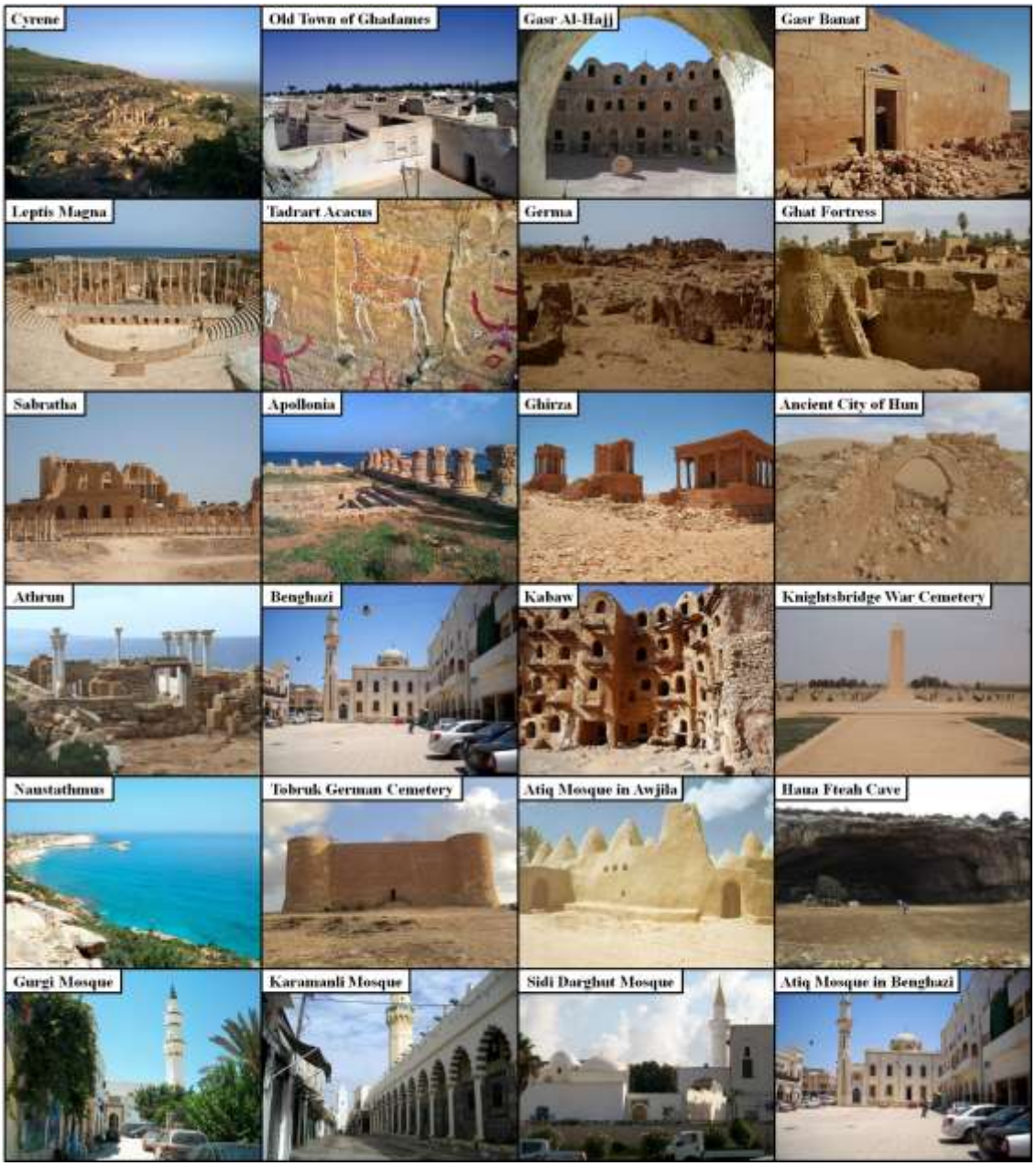



Figure 1. Photos of several archaeological sites in Libya (after Archiqoo, 2017).

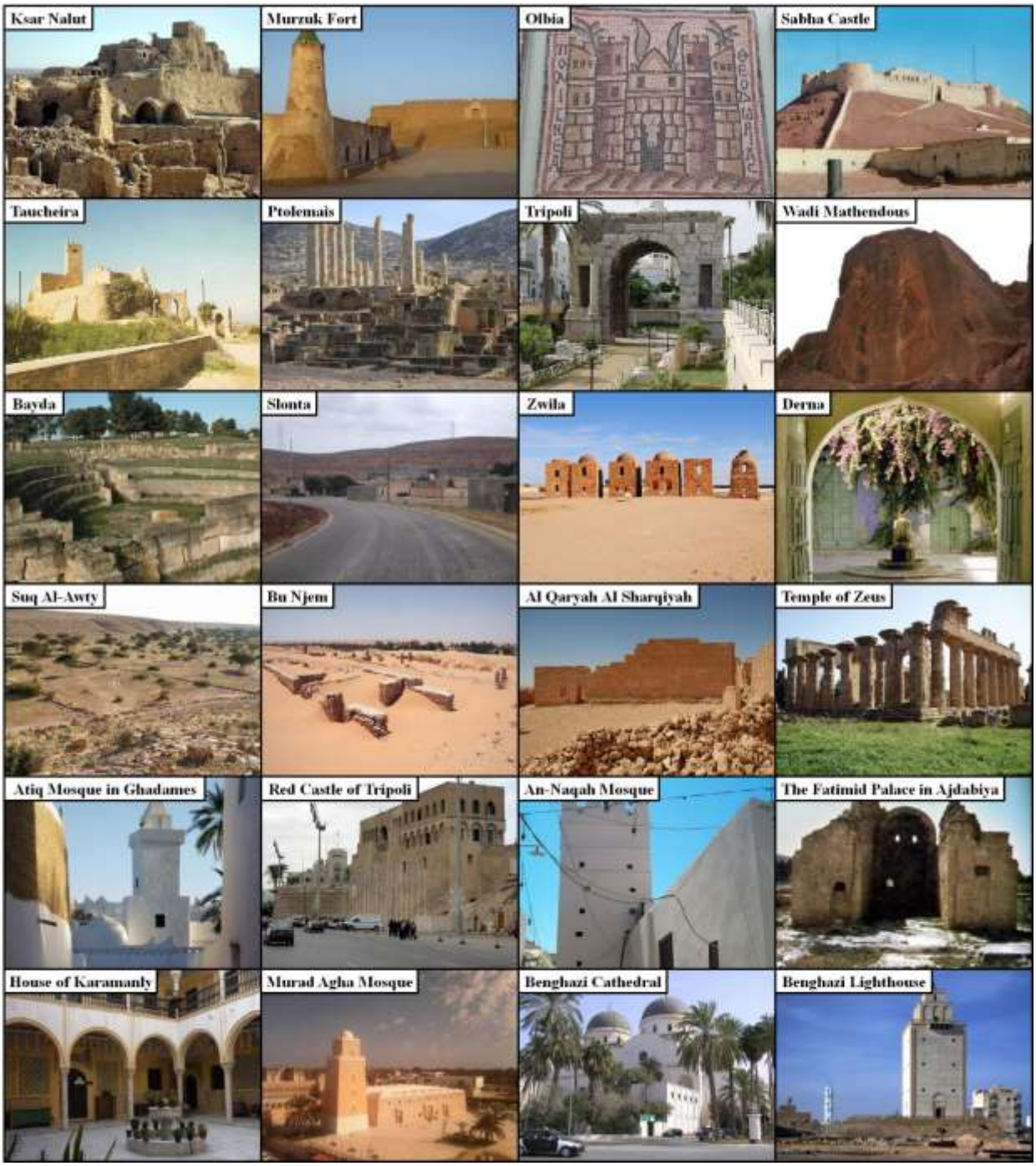



Figure 1: Continued.

## 2. OBJECTIVE

The objective of this writing is to bring into focus the crucial importance of geochemistry in archaeology in relation to sustainable development in Libya. Geochemistry in archaeology and sustainable development have a common point in understanding past human behaviors as far as solving today's environmental and social problems are concerned. Geochemistry helps in determining the exact location of the settlement, detecting signs of human presence in the soil and identifying the origin of an object. Sustainable development means meeting current requirements without compromising future needs.

## 3. KEY APPLICATIONS OF ARCHAEOLOGICAL GEOCHEMISTRY IN LIBYA

**(1) Provenance studies:** Locating the origins of pottery and raw material forms one of the most important uses of provenance studies.
**(2) Analysis of metallic objects:** Old metallic objects are often analyzed through geochemistry.
(3) Environment reconstruction: The transformation of Sahara from its lushness to its present-day deserts is

attributed to the geochemistry of archaeology. It helps in interpreting patterns of prehistoric human settlements.

**(4) Geoarchaeology:** Geochemistry and remote sensing are merged in large projects. The geochemical signature of soils and sediments can help in locating endangered sites.

**(5) Maritime settings:** Geochemistry assists in understanding issues of harbors, coastline erosion, and conservation of sites.

## 4. Importance of Libya in Archaeological Geochemistry

**(1) Environmental diversity:** Some examples of environmental diversity are ancient lakes, deserts, volcanic environment, and coastal areas. Such diversity enables comparing the different preservation environments.

**(2) Continuous cultural sequence:** Ancient cultures of Sahara, Garamantians, Greek settlement, Roman settlements, and Islamic-Ottoman periods have existed in Libya. The material signatures of each one of them geochemically differ from others.

**(3) Preservation environments:** Organic and inorganic objects are usually well-preserved in arid conditions. Nevertheless, sabkha environment can accelerate deterioration processes.

## 5. Link between Archaeological Geochemistry and Sustainable Development in Libya

**(1) Cultural heritage conservation:** It helps in knowing the composition of materials and their mode of degradation, restoring the objects to help in preserving them, and in detecting real from fake objects. Historical preservation becomes easier using these techniques, and this constitutes part of sustainability.

**(2) Sustainable tourism:** Through archaeological geochemistry, creation of geoparks and heritage routes, economic stimulation, and improved interpretation and attractiveness of sites is achieved.

**(3) Environmental reconstruction and climatic insight:** Information on ancient climatic conditions, interaction between humans and their environment, and evidence on ancient water usage and desertification is gained through geochemistry. This plays an important role in Libya considering that the country faces issues of climate change and water shortages.

**(4) Resources management:** The process is used to know ancient mining practices and raw material utilization, present day exploration of minerals, and connecting ancient mining practices with present geo-resource management.

**(5) Urban planning and risk management:** Geochemistry assists in discovering buried archaeological features before construction work begins, and in reducing destruction of heritage in case of urban expansion.

**(6) Socio-economic development:** Geochemistry plays an important role in creating national unity, cultural identity, job opportunities, and scientific capacity.

## 6. Major Challenges of Archaeological Geochemistry in Libya

The influence of archaeological geochemistry in Libya is constrained by a number of challenges: (1) Instability in politics; (2) Illegal excavations and looting; (3) Urbanization and infrastructure expansion; (4) Inadequate resources and infrastructure for research; and (5) Inadequate mapping and database integration. Numerous sites are already at risk due to these concerns.

## 7. Conclusions

Archaeological geochemistry in Libya revealed that: (1) The prehistoric communities in the country were interlinked worldwide and technologically advanced; (2) Environmental conditions play an important role in preservation and understanding of archaeological sites; and (3) Historical and heritage sites require scientific investigation to understand and protect. Besides providing knowledge about the past, the study of archaeological geochemistry helps create sustainable development. The following points demonstrate the contribution of archaeological geochemistry to sustainable development in Libya: (1) The implementation of conservation efforts based on evidence is facilitated by archaeological geochemistry, ensuring the sustainable preservation of cultural heritage—an essential element of sustainability; (2) Sustainable management of natural resources is facilitated by the examples of efficient use and adaptation provided by the ancient Libyans; (3) Archaeological geochemistry contributes to environmental conservation policies by acting as an environmental monitoring mechanism; (4) Effective planning for climate resilience is facilitated by knowledge about ancient climate variability, which enables prediction of future threats in desert environments such as Libya; (5) Sustainable tourism is achieved through the integration of geochemical studies in the management of archaeological sites, generating economic profits while minimizing environmental degradation; (6) Groundwater conservation and sustainable land-use management are achieved through the application of archaeological geochemistry, especially in desert environments; (7) Archaeological geochemistry integrates global sustainability objectives with heritage conservation; and (8) Archaeological geochemistry integrates scientific principles, heritage conservation, and sustainability, and is an integral part of national development strategies.

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## BIOGRAPHIES



**Osama Rahil Shaltami** is a professor in the field of geochemistry and a senior researcher. His most important works are publications related to geochemistry of sedimentary rocks, industrial geology, economic geology, petroleum geochemistry, gas geochemistry, hydrogeochemistry, nuclear geochemistry, environmental geochemistry, and sustainable development.



**Abobakar E. Algomati** is a faculty member in the Department of Engineering Geology at University of Bright Star, specializing in geochemistry. His most important works are publications related to geochemistry of sedimentary rocks, industrial geology, economic geology, petroleum geochemistry, hydrogeochemistry, and sustainable development.



**Hamza Al Matoni** is a faculty member in the Department of Engineering Geology at University of Bright Star, specializing in geochemistry. His most important contributions are articles on geochemistry of sedimentary rocks, petroleum geochemistry, hydrogeochemistry, and sustainable development.



**Ramzi Salem** is a faculty member in the Department of Engineering Geology at University of Bright Star, specializing in geochemistry. His articles on geochemistry of sedimentary rocks, petroleum geochemistry, hydrogeochemistry, and sustainable development are among his most significant works.