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Research

"Comprehensive Review of Kuwait's Fossil Record and Geological History"

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Abstract

Kuwait, situated in the northeastern corner of the Arabian Peninsula, holds a significant paleontological record that provides insights into its ancient environmental and climatic conditions. The fossil record in Kuwait is diverse and spans multiple geological periods, reflecting the region's dynamic geological history.

Fossils can provide valuable information concerning general depositional processes, characteristics of currents, substrate consistency, and, in some instances, causes of sediment sorting. A study of ancient depositional environments is of interest in and of itself and should be concerned with reconstructing them. All the fossils, found in Kuwait are of recent ages; there are few studies that do not highlight any accurate ages. The oldest was found

There are many sites where rocks containing fossils of different ages, shapes, and types appear, indicating different sedimentary environments. The fossils are mainly found among the outcrops and rocks that were deposited in Coastal and shallow marine environments, such as tidal channel complexes, Barrier islands, Shorefaces, Estuaries, evaporitic shallow marine sabkhas, and coastal aeolian depositional settings.

The evidence of sea level fluctuations is clearly presented in the Khiran ridges. The oldest ridge was located south of Al Khor Al Muftah and was removed due to urbanization. The remaining outcrop of the oolitic limestone ridge is located now at least 500 meters away from the current beach.

Many fossils in the marine rock layers of the Pleistocene appear in the outcrops of the southern part of the State of Kuwait, and there are also layers of rocks containing marine fossils of shells and shellfish in the Jal Al-Zour region, which is the northern highlands region that rises today 50 meters above the current sea level. These fossils can be used for the analysis of paleoenvironments, life and evolutionary relationships of organisms, and to understand paleo-ecologies.

key words

Marine fossils - Khiran ridges- sedimentary environments- Jal Al-Zour – paleoenvironment.

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ملخص البحث

تقع الكويت في الزاوية الشمالية الشرقية من شبه الجزيرة العربية، وتحتفظ بسجل حفريات مهم يوفر رؤى حول الظروف البيئية والمناخية القديمة. السجل الأحفوري في الكويت متنوع ويمتد على فترات جيولوجية متعددة، مما يعكس التاريخ الجيولوجي للمنطقة.

يمكن أن توفر الحفريات معلومات قيمة حول العمليات الترسيبية العامة، وخصائص التيارات، واتساق الركيزة، وفي بعض الحالات، أسباب فرز الرواسب. إن دراسة البيئات الترسيبية القديمة أمر مثير للاهتمام في حد ذاته ويجب أن تهتم بإعادة بنائها. جميع الحفريات الموجودة في الكويت تعود إلى أعمار حديثة؛ هناك دراسات قليلة لا تذكر أي أعمار دقيقة للحفريات.

هناك العديد من المواقع حيث تظهر الصخور التي تحتوي على حفريات من أعمار وأشكال وأنواع مختلفة، مما يشير إلى بيئات رسوبية مختلفة. توجد الأحافير بشكل رئيسي بين الصخور والنتوءات الصخرية التي ترسبت في البيئات البحرية الساحلية والضحلة، مثل قنوات المد والجزر والأرصفة الرملية والشواطئ والمصطبات والسبخات البحرية الضحلة وبيئات الترسيب الريحية الساحلية.

إن أدلة تقلبات مستوى سطح البحر واضحة في سلسلة جبال الخيران حيث كانت أقدم سلسلة جبال تقع جنوب الخور المفتح وتم إزالتها بسبب التوسع الحضري. وتقع بقية سلسلة جبال الحجر الجيري الصخري الآن على بعد ٥٠٠ متر على الأقل من الشاطئ الحالي.

تظهر العديد من الأحافير في طبقات الصخور البحرية من العصر البليستوسيني في نتوءات الجزء الجنوبي من دولة الكويت، وهناك أيضًا طبقات من الصخور تحتوي على أحافير بحرية من الأصداف والرخويات في منطقة جل الزور، وهي منطقة المرتفعات الشمالية التي ترتفع اليوم ٥٠ مترًا عن مستوى سطح البحر الحالي. يمكن استخدام هذه الحفريات لتحليل البيئات القديمة والحياة والعلاقات التطورية للكائنات الحية، وفهم البيئات القديمة.

الكلمات الافتتاحية :

الحفريات البحرية – مرتفعات الخيران – البيئات الرسوبية – جال الزور – البيئات القديمة

Introduction

Marine fossils offer invaluable insights into ancient marine ecosystems, geological history, paleoenvironment, and biodiversity. In recent years, the study of marine fossils has become increasingly important for understanding regional and global environmental changes, particularly in areas with complex geological histories like the Arabian Peninsula. Among the less explored regions for

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paleontological research is Kuwait, located at the northwestern edge of the Arabian Gulf, where marine fossils are abundant but understudied.

Despite Kuwait's rich potential, the majority of fossil studies in the Arabian Gulf have focused on countries like Saudi Arabia and the United Arab Emirates, leaving a significant gap in the understanding of Kuwait's paleontological record. This paper aims to address this gap by presenting a comprehensive overview of marine fossils from key formations in Kuwait. It examines the taxonomic diversity, paleoecology, and stratigraphic context of the fossil assemblages, offering new interpretations about the region's paleoenvironments and sedimentary history.

Fossils serve as essential tools for understanding evolutionary history and patterns of biodiversity. Marine fossils, in particular, provide crucial insights into speciation processes, extinction risks, and spatial diversity distribution. The fossil record reveals that significant taxonomic groups exhibit unique diversification patterns and show varied, often unpredictable, responses to mass extinction events (Alroy, 2010). However, interpreting this fossil data requires careful consideration of biological and geological influences (Allmon & Smith, 2011). Fossilized marine gastropods offer essential insights into patterns and processes of speciation; however, the limitations of the fossil record necessitate thorough and cautious analysis (Warren D. Allmon & Ursula E. Smith, 2011). The fossil record offers the potential to identify traits and environmental conditions linked to extinction risks, thereby aiding in the development of conservation strategies in the context of global environmental change (Finnegan et al., 2023). Studies examining marine fossil diversity indicate that environmental factors, especially the extent of reef habitats, significantly shape biodiversity patterns over time and space (Close et al., 2020). Although fossils are fundamental for reconstructing phylogenetic relationships and evolutionary classifications, it is important to acknowledge the fossil record's inherent incompleteness and geographic variability (Donoghue et al., 1989). Recognizing these limitations is crucial for accurately interpreting fossil data and its implications for both historical and contemporary marine ecosystems.

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This study also highlights the implications of these findings for regional paleogeographic reconstructions. By comparing fossil assemblages from Kuwait with those from neighbouring regions, we can better understand marine transgressions, regressions, and broader climatic and environmental shifts that influenced the Arabian Gulf. The research contributes to palaeontology and regional geological studies by providing a clearer picture of Kuwait's ancient marine ecosystems, helping to fill a critical gap in Middle Eastern fossil records. Carbon dating suggests that the most recent phase of this sea level drop occurred approximately 1,800 years ago (Tanoli, 2015).

This research advances scientific knowledge and has potential implications for the petroleum industry, which heavily relies on understanding sedimentary rock formations and the fossil record for oil exploration. Therefore, the findings presented in this paper contribute to academic discourse and hold practical significance for the region's ongoing economic development.

Method of study

To achieve the objectives of the present study, a literature review of previous studies and research, site visits, and field data collection were conducted for the three sites and their surroundings. The study area's geological, paleontological, and geomorphological aspects were reviewed.

The field work was conducted from 2022-2023. Many images and samples were taken at different times before 2022. Samples were not collected, only photographed and left at the site according to Environment Law 42 for the year 2014. Article 100 in section five of the law specifies collecting and harming the habitats and the organisms in them alive. The study depends on the literature and a review of the studies depending on the geographical location to create a record of the presence and abundance of the fossil assemblage.

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Study Area:

Kuwait is situated at the north-western end of the Arabian Gulf within the latitudes of 28º N and 30º N and longitudes of 47º E and 49º E. Kuwait has a coastline of over 500km spanning nine islands, extending from the northern islands of Warba and Boubyan to the Nuwaiseb and Al-Khiran in the south. Marine and estuarine waters are highly productive coastal habitats, including tidal flats, wetlands, mudflats, algal beds, mangroves, and coral reefs. These habitats support a range of important ecological, social, and economic benefits such as critical to maintaining human well-being and global biodiversity' (Machava-Antonio et al, 2022). Kuwait's climate is typically arid, characterized by a dry desert environment with extreme summer temperatures that can reach up to 50°C, along with minimal annual rainfall, generally under 110 mm (Almutawa & Alfraih, 2023; Alkandari, 2024).

While much of Kuwait's surface is covered by Quaternary deposits, there are notable outcrops from the Oligo-Miocene and Pleistocene epochs. The geomorphology of Kuwait is broadly categorized into four main zones, shaped by both tectonic activity and climatic changes (Al-Sarawi, 1995). Key stratigraphic exposures can be found in areas such as the Jal Az-Zor escarpment, Al-Subyiah (Bahrah), Ahmadi Quarry, the Khiran Ridges, and Enjefa Beach. The oldest visible rock formations belong to the Middle Eocene Dammam Formation, exposed in the Ahmadi Quarry, while the youngest deposits cover much of the surface, overlaying the Kuwait Group's formations.

Kuwait's surficial deposits reflect two primary depositional environments: desert and coastal. These deposits have been categorized into distinct physiographic regions, including the Al-Dibdibba gravel plains in northern Kuwait, the sand flats in the south, the coastal flats also in the south, and the coastal hills at Jal Az-Zor in the north and the Ahmadi Ridge in the south (Khalaf et al., 1984). Notably, flooding events have influenced the formation of certain areas, including Wadi Al-Batin in southern Kuwait. Additionally, the southern coastal regions are marked by modern

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carbonate sediments, such as oolite, dolomite, and microbial mats, particularly around areas like Al-Khiran and Azzor (Gischler & Lomando, 2005).

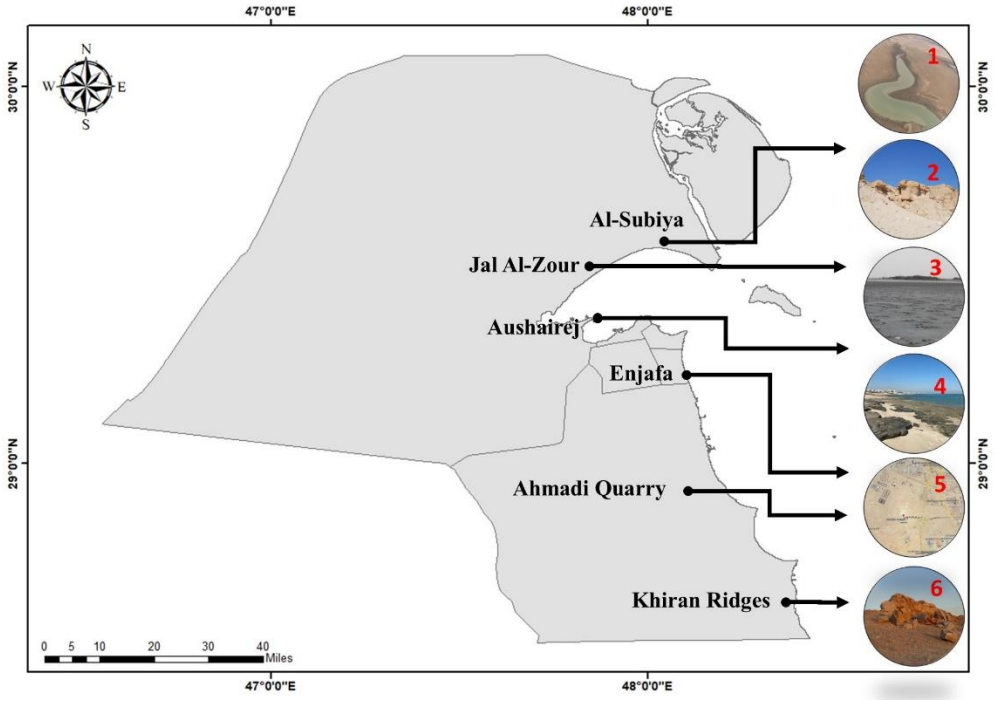

Figure (1): Location map of the study area.

Sampling areas:

Jal AlZour Escarpment

The Jal Az-Zor escarpment is located on the northern side of Kuwait Bay and rises to a height of approximately 145 meters in hilly terrain (Abd El-Aal et al., 2023). This natural geological exposure is the best site for observing the Kuwait Group sedimentary sequence. The area provides an invaluable window into the region's geological past, showcasing layers of sedimentary deposits that form part of the Kuwait Group. In terms of age, Jal Al Zour is dominated by clastic deposits ranging from the Early Oligocene to the Pleistocene. These sediments offer important insights into the evolutionary processes that shaped Kuwait's landscape over millions of years. Notably, a 1–2-meter-thick fossiliferous layer is present at the escarpment base, containing species such as Ostrea lamellimaginula and Clausinella.

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These fossils serve as vital markers of the region's paleontological history(Abd El-Aal et al., 2023), offering clues about the environmental conditions during their time. The lithology is diverse, featuring cross-bedded sandstone, cross-bedded conglomerate, calcareous poorly sorted sandstone, red sandstone, and yellowish-green claystone with root traces and fossiliferous sandstone. These rock types reflect a range of depositional environments, including tidal channels, estuarine complexes, and barrier island systems, suggesting a dynamic coastal and marine environment during the formation of these sediments (AlRefaei et al., 2023). The presence of sedimentary structures such as cross-bedded sandstone and conglomerates and evidence of bioturbation further illustrates the complex geological processes that have shaped the escarpment. Human activities in the area are notable, especially during the camping season when the escarpment experiences high levels of recreational use. While part of the area is legally protected as a natural reserve, much of it remains unmanaged and unprotected, leaving it vulnerable to human impact. In addition to its geological and paleontological significance, Jal Al Zour holds ecological and conservation value. A portion of the escarpment is designated as a national park, with both coastal and desert zones. This area has been recognized as an Important Bird and Biodiversity Area (IBA) because it is a breeding ground for various bird species. The region’s biodiversity highlights the importance of continued conservation efforts to preserve both its geological and ecological heritage.

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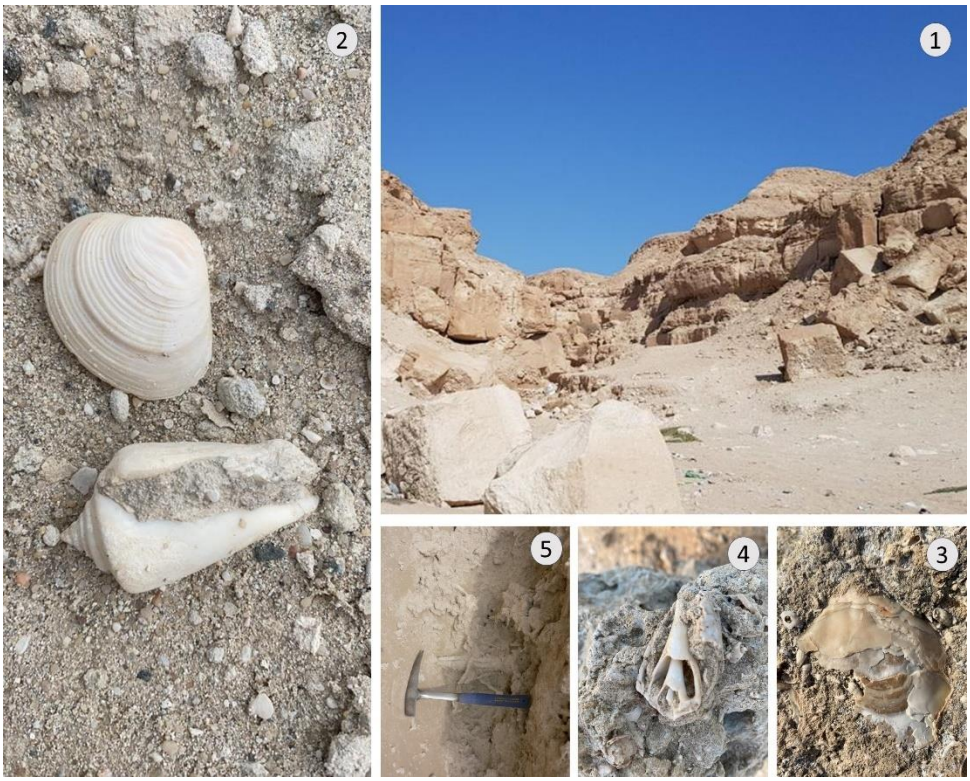

Figure (2):
1- View of Jal Al-Zour
2- Gastropods and bivalves from Aushairej
3- Bivalves in Coquina rocks
4- Deformed gastropods in the sandstone of Aishairej
5-Bioturbation from Jal Al-Zour

Anjafa Beach

This area is located approximately 20 kilometers from Kuwait City, extending over a length of around 900 meters, with an elevation of less than 3 meters above sea level. This coastal region has been shaped by a mid-to-late Holocene drop in sea level, which led to the deposition and progradation of coastal facies along the beach. These processes have contributed to the development of distinct stratigraphic and sedimentary features that make the area valuable for scientific study. This site

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contains evidence of Ophiomorpha vertical burrows and various species of gastropods and bivalves, which vary in size (Al-Awadi et al., 1997). These fossils provide important clues about the ecological conditions and biodiversity of the region during the Holocene. The stratigraphy of the site is marked by several distinct units, including horizontally laminated facies, trough cross-bedded facies, and planar wedge-shaped cross-bedded and bioturbated facies. These stratigraphic units reflect a range of depositional environments, including tidal inlets, tidal channels, shallow tidal channels, foreshore beach zones, tidal deltas, and coastal dunes. The sedimentary structures within the site, such as grain size distribution (notably lacking clay) and the size and direction of upper shoreface trough cross-bedding, offer further insights into the area's dynamic coastal processes (Abd El-Aal et al., 2023). There is a large amount of human activity throughout the year, with many beach visitors, water sports enthusiasts, and recreational vehicle users using the area. Despite the high level of human interaction, the area remains unmanaged mainly in terms of conservation. A formal conservation plan has not been implemented to protect the site's natural or geological features even though it falls under the jurisdiction of the local municipality. A unique combination of stratigraphic features, paleontological evidence, and depositional environments makes. This site is an important site for understanding coastal evolution during the Holocene. However, the absence of active conservation efforts highlights the need for increased management to preserve its geological and environmental integrity.

Al-Khiran Three Ridges:

The Khiran Ridges are located along the southern coast of Kuwait and form a sequence of coastal ridges that extend in a North-Northwest to South-Southeast orientation, running parallel to the Arabian Gulf coastline. This geographical arrangement positions the Khiran Ridges as significant coastal landforms within the region. The exact age of the Khiran Ridges remains uncertain, with estimates suggesting they date from the Pleistocene to the Holocene epoch (Abd El-Aal et al., 2023). The more recent sediments found on the surface of these ridges are predominantly from the Holocene. Over time, many of the region’s natural

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geomorphological features have been altered or replaced by human activity. For example, natural tidal creeks (khors) have been transformed into artificial inlets, and tidal flats along the coastline have been substituted by artificial beaches, where sand from desert sources has been deposited (Hassan, 2018). Paleontological evidence from the Khiran Ridges indicates a marine depositional setting. A thin, fossil-rich layer at the base of the ridges contains various species of bivalves and gastropods, which provide insight into the ancient environments that once existed in this area. The lithology of the Khiran Ridges is diverse, ranging from oolitic marine sandstone to calcareous coastal aeolian sandstone. The geological composition includes Oolitic-Quartzose Sandstone, Quartz-Oolitic Sandstone, Oolitic Limestone, and sediments from the Holocene epoch, all reflecting the ridges' complex depositional history . The depositional environments represented by the Khiran Ridges include shallow marine barriers, ancient and recent beach formations, as well as coastal dune systems. These environments indicate a history of fluctuating sea levels and shifting coastal dynamics that have shaped the ridges over time. In terms of sedimentary structures, the ridges are composed of coarse, cross-bedded sandstone that is only slightly cemented. This sandstone contains well-rounded quartz grains, skeletal fragments, and oolites, pointing to active depositional processes that occurred in a dynamic coastal environment. Human activities have significantly impacted the Khiran region. Extensive land development has destroyed much of the coastal ridges and Sabkha deposits, and year-round human activity, including tourism and residential development, continues to affect the landscape. Management and conservation efforts in the Khiran Ridges are limited. While most of the region is unprotected, the Quartz-Oolitic Sandstone formation is part of a heritage area managed by the National Council for Culture, Arts, and Literature (NCCAL). However, beyond this, no formal conservation strategies are in place to preserve the area's natural and geological features.

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Figure (3): 1- Al-Khiran sandstone-rich ridge
2- The Oolitic-Quartzose Sandstone
3- microspcopic image of the oolitic sandstone showing smaller fragments of fossils.
4- Al-Khiran ridge, mold of gastropod.
5- Gastropod from the subsurface area around the ridges (Khiran-Nuwaiseeb)
6- The older ridge is located inland and was destroyed by the Khiran residential project

East Doha (Aushairej):

The Aushairej area is located approximately 35 kilometers southwest of Kuwait City along the southwestern side of Kuwait Bay. This coastal site features a mixed shoreline, characterized by bedrock platforms and a surface covered with soft sediments and boulders. The beach itself is notably narrow and has been impacted

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by extensive construction activities. The beach also contains a sediment barrier that has been created through the relocation of sediments, which contains a lot of allocated marine fossils. Despite its distinct geomorphological features, the Aushairej area has not been the subject of significant geological studies. Current research in the region has primarily focused on the mudflats and marine organisms, leaving the geological aspects of the site largely unexplored.

Results and discussion:

The fossil assemblages are summarized in table (1). The study of fossil evidence offers crucial insights into the historical sea-level fluctuations that have shaped Kuwait's coastline and surrounding environments. Marine fossils preserved in Kuwait's sedimentary formations provide a record of sea-level changes over geological time, reflecting the dynamic interaction between marine transgressions and regressions.

Kuwait's geological history was shaped by the tectonic activity of the Arabian Plate and global climatic changes, leading to repeated fluctuations in sea levels throughout the Cenozoic Era. These sea-level changes are recorded in the region's sedimentary layers and are reflected in the fossil record. The key geological formations that document these changes include the Dammam Formation and the Kuwait Group, both of which span crucial periods from the Miocene through the Pliocene and into the Quaternary epochs. These formations provide valuable insights into the region's evolving landscape and environmental conditions.

Marine fossil assemblages, including corals, mollusks, and echinoderms, are frequently discovered within sedimentary layers formed during periods of marine transgressions. Fossilized remains of bivalves and gastropods indicate extended phases of marine transgressions. These fossils are often located in regions that were once positioned along ancient shorelines, where sediment deposition helped preserve these organisms as sea levels rise. The evidence of sea level fluctuations is clearly presented in the Khiran ridges. The oldest ridge was located south of Al Khor Al

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Muftah and was removed due to urbanization. The remaining outcrop of the oolitic limestone ridge is located now at least 500 meters away from the current beach.

There is a 1-2-meter thick fossiliferous layer at the base of the Jal AlZour escarpment that dates from the early Oligocene to the Pleistocene, and reflects a wide range of depositional environments, including tidal channels, estuaries, and barrier island systems, which suggests a dynamic coastal and marine environment. These layers stand now over 145 meter high above the current sea level.

Further research into Kuwait's fossil record and its connection to sea-level fluctuations could involve detailed stratigraphic analysis and radiometric dating of fossil-bearing formations to establish a more precise timeline of transgressions and regressions.

No.	Fossil's Scientific Name	Stratigraphy / Facies	Area	Approximate Age	Depositional environment	References
1.Enjefa Beach Outcrop						
1	Gastropods	Fine-to-medium-grained sands			Tidal channel (Channel fill/abandonment facies)	(Abd El-Aal et al., 2023)
2	Bivalves	Fine-to-medium-grained sands			Tidal channel (Channel	(Abd El-Aal et al., 2023)

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			900 m length, 3 m thickness	Late Holocene 2300 years	fill/abandonment facies)	
3	Coral fragments	Fine-to-medium-grained sands			Tidal channel (Channel fill/abandonment facies)	(Abd El-Aal et al., 2023)
4	Extensive bioturbation (Thalassinoides)	Trough cross-bedded fine-grained sands			The middle shoreface facies (low tide water line)	(Abd El-Aal et al., 2023)
5	Ophiomorpha burrows	Trough cross-bedded fine-grained sands			Tidal facies: The middle shoreface facies (low tide water line)	(Abd El-Aal et al., 2023)
2. Jal Alzour Escarpment						
1	Echinoderms (uncommon)	Cross-bedded sandstone	60 Km length,			(Abd El-Aal et al., 2023)

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2	Bioturbation (ophiomorpha burrows, Thalassinoides burrows)	Large scale cross bedded conglomerate	135m above sea level	Early Oligocene to Pleistocene	Terrestrial complex Estuarine central bay (Point bars)	(Abd El-Aal et al., 2023)
3	Bioturbation (ophiomorpha burrows, skolithos burrows)	Calcareous poorly sorted sandstone			Estuary mouth bar/shoreface	(Abd El-Aal et al., 2023)
4	Bioturbation (ophiomorpha burrows, Thalassinoides burrows)	Large scale cross bedded conglomerate			Estuarine central bay (point bars) and channel fill	(Abd El-Aal et al., 2023)
5	Bioturbation (ophiomorpha burrows, skolithos burrows)	Fine grained sandstone			Barrier island complex (Backshore berm and intertidal to supratidal	(Abd El-Aal et al., 2023)

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					complex – back barrier)	
6	skolithos burrows	Red cross bedded sandstone			Barrier island complex (tidal channel)	(Abd El-Aal et al., 2023)
7	Bivalves	Yellowish green claystone with rootles			Barrier island	(Abd El-Aal et al., 2023)
8	Gastropods	Yellowish green claystone with rootles			Barrier island	(Abd El-Aal et al., 2023)
9	Bioturbation (ophiomorpha burrows)	Yellowish-green siltstone / clay			Barrier island	(Abd El-Aal et al., 2023)
10	Thalassinoides burrows	Large scale ccross bedded conglomerate/bioturbation			Barrier island	(Abd El-Aal et al., 2023)

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11	skolithos burrows	Latteral accretion sandstone				(Abd El-Aal et al., 2023)
12	skolithos burrows	Red cross bedded sandstone			Tidal channel complex (tidal channel)	(Abd El-Aal et al., 2023)
13	Ostrea Lamimaginula	fossiliferous layer				(Fuchs et al., 1968)
14	clausinella fasciata	fossiliferous layer				(Fuchs et al., 1968)
15	Bivalves	fossiliferous sandstone				(Fuchs et al., 1968)
16	Gastropods	fossiliferous sandstone				(Fuchs et al., 1968)
17	oyster shells	fossiliferous sandstone				(Fuchs et al., 1968)

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3.Alsubiya (Bahra) Outcrop						
1	Gastropods	reddish colored Cross-Bedded Sandstone	16 × 6 km of a topographically low coastal plain land on the north coast of Kuwait Bay.	Oligo-Miocene	shallow marine environment	(Abd El-Aal et al., 2023)
2	Bivalves	reddish colored Cross-Bedded Sandstone			shallow marine environment	(Abd El-Aal et al., 2023)
3	Borrows	reddish colored Cross-Bedded Sandstone			shallow marine environment	(Abd El-Aal et al., 2023)
4	gastropod	on top of mud volcano outcrop;		lower Miocene	evaporitic shallow marine sabkha	(Alibrahim et al., 2021)
5	bivalve shells	on top of mud volcano outcrop;			evaporitic shallow marine sabkha	(Alibrahim et al., 2021)
6	bioturbation network of Thalassinoides	mud volcano outcrop;			evaporitic shallow marine sabkha	(Alibrahim et al., 2021)

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7	Ophiomorpha (decapoda) showing thick pelletoidal walls	evaporitic sandy matrix			evaporitic shallow marine sabkha	(Alibrahim et al., 2021)
8	fossilized crustaceanfeces (coprolite).	mud volcano outcrop;			evaporitic shallow marine sabkha	(Alibrahim et al., 2021)
4.Ahmadi Quarry Outcrop						
1	shell fragments of Gastropods	chalky dolostone with thin chert bands and lenses	10 Km², 100 m height	Middle Eocene	shallow marine/marginal environments	(Al-Awadi et al., 1997)Bergstrom & Aten, 1965; Burdon & Al-Sharhan, 1968)

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2	Pelecypods	chalky dolostone with thin chert bands and lenses			shallow marine/marginal environments	(Al-Awadi et al., 1997; Bergstrom & Aten, 1965; Burdon & Al-Sharhan, 1968)
5. Khiran Ridge Outcrop						
1	Gastropod shells	The Oolitic-Quartzose Sandstone	100 Km², 450-4000 m length, 5-15 m height	Late Pleistocene To Holocene	Marine tidal-influenced depositional	(Abd El-Aal et al., 2023)
2	RRoot structure (e.g., rhizocretion)	The Oolitic-Quartzose Sandstone			coastal aeolian depositional setting	(Saleh, 1975)
3	Bivalves	Oolitic limestone			marine depositional setting	(Abd El-Aal et al., 2023)
4	Gastropods	Oolitic limestone			marine depositional setting	(Abd El-Aal et al., 2023)

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5	Undefined in the reference	Cross bedded sandstone			deposited in terrestrial to marginal-transitional marine depositional settings	(Abd El-Aal et al., 2023)
6. Ushairej						
1	gastropod	Lose beach sand	area of 6377 m^2	Recent	Shallow marine environment	This study
2	Coral branches	Lose beach sand			Shallow marine environment	
3	Mixed species of bivalves, most of them in deformed	Lose beach sand, saved in sandstone.			Shallow marine environment	

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	shapes (broken),					

Conclusion and recommendations

This is the first paper that has gathered all fossil-valued sites on one map for conservation consideration. Kuwait does not have a fossil atlas that compiles all fossils in one document. Kuwait's fossil record offers important insights into past sea-level fluctuations and their influence on the region's coastlines and environment. Using fossil evidence along with sedimentological data, researchers can reconstruct detailed paleogeographic evidence for Kuwait's sea-level fluctuations during various periods of sea level rise and fall. In addition, these maps will enhance our understanding of the evolution of marine ecosystems as well as terrestrial ecosystems over time. More data is required to confirm the present state of relative sea levels in Kuwait's coastal areas. There is no legal framework for the protection of these geological sites, and protective regulations are essential to their preservation. Promoting these areas as critical attractions could also support eco-tourism, raising awareness of Kuwait’s natural heritage while ensuring its conservation for future generations.

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