

**Title:** First documented record of the ammonite *Turrilites costatus* LAMARCK, 1801 from the Cenomanian of northern Saudi Arabia: Implications for Arabian Plate paleogeography

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**Version Information:** This is **Version 2** of the manuscript.

**Reason for Update:** This version has been significantly expanded to include new field data from two additional localities (Localities B and C) south of Ar'ar. These findings extend the geographic distribution of *T. costatus* to over 30 km.

## Abstract

This study presents the first documented occurrence of the heteromorph ammonite genus *Turrilites* LAMARCK, 1801, from the Cretaceous strata of the Kingdom of Saudi Arabia. In-situ fossil assemblages, identified as *Turrilites costatus* LAMARCK, 1801, were discovered and documented in **three separate outcrops** of the Aruma Formation, located south of the city of Ar'ar in northern Saudi Arabia. The geographic distribution of these localities spans a distance of over **30 kilometers**, suggesting a regional phenomenon rather than an isolated anomaly.

Historically, the published record of this genus on the Arabian Peninsula has been restricted to the Natih Formation of Oman, on the southeastern margin of the Arabian Plate. The presence of *Turrilites*, a well-established index fossil for open-marine, outer-shelf environments, in the interior of the Arabian Plate presents new paleontological data. These findings **suggest the possibility** that environmental conditions in the northern plate interior during the Cenomanian were more conducive to open marine connections than previously thought. This discovery **proposes a need for a reassessment** of the region's paleogeographic models and **supports the hypothesis** of an open seaway connected to the Neo-Tethys Ocean.

## **1. Introduction**

### **1.1 Biostratigraphic and Paleocologic Significance of *Turrilites***

The heteromorph ammonite genus *Turrilites* LAMARCK, 1801, characterized by its distinctive turreted, screw-like shell, is a cornerstone of Middle Cretaceous biostratigraphy. Species within this genus, particularly *Turrilites costatus*, serve as crucial index fossils for defining and correlating the Cenomanian Stage on a global scale (Kennedy, 1971). The relatively short stratigraphic range and wide geographic distribution of *T. costatus* make it an invaluable tool for high-resolution chronostratigraphic subdivision, specifically for identifying the Middle Cenomanian substage.

Beyond its biostratigraphic utility, *Turrilites* is also a powerful paleoenvironmental indicator. Like many ammonoids, especially the heteromorphic forms, *Turrilites* is interpreted as having been a stenohaline organism, intolerant of significant fluctuations in marine salinity (Westermann, 1996). Its fossil occurrences are overwhelmingly associated with outer-shelf to upper-slope marine facies, characterized by normal salinity, stable oxygen levels, and direct connection to the open ocean. The genus is conspicuously absent from strata representing restricted, brackish, or hypersaline depositional environments. Consequently, the discovery of *Turrilites* provides important evidence for the former presence of a fully marine, open-shelf setting.

### **1.2 Cretaceous Paleogeography of the Arabian Plate: Prevailing Models**

The paleogeography of the Arabian Plate during the mid-Cretaceous was dominated by the vast, warm, and shallow Neo-Tethys Ocean to the northeast. The plate itself formed a massive carbonate platform, with depositional environments largely controlled by eustatic sea-level fluctuations (Sharland et al., 2001). Prevailing geological models for the Cenomanian depict the interior of the Arabian Plate, including the region of modern-day northern Saudi Arabia, as a broad, shallow epeiric (or inland) sea comprising extensive shallow-water carbonate platforms (see palaeogeographic reconstruction in Scotese, 2014, Fig. 2). This setting, often referred to as the Wasia-Aruma platform, is generally characterized by shallow-water carbonate deposition, with models suggesting that circulation could be restricted in areas far from the open-ocean margin (Sharland et al., 2001). Such restricted circulation can lead to environmental conditions, including elevated salinity and temperature, that would be inhospitable to stenohaline oceanic fauna like cephalopods.

### 1.3 The Knowledge Gap: Absence of *Turrilites* Records in Saudi Arabia

In accordance with these paleogeographic models, the known distribution of *Turrilites* on the Arabian Peninsula has, until now, been exclusively confined to its southeastern margin. Rich assemblages of *Turrilites costatus* and other Cenomanian ammonites are well-documented from the open-marine deposits of the Natih Formation in the Oman Mountains (Kennedy & Simmons, 1991). These occurrences in Oman represent the paleoenvironment of the continental shelf edge, directly facing the Neo-Tethys Ocean. In contrast, a comprehensive review of the paleontological literature for the Kingdom of Saudi Arabia reveals a complete absence of any prior documented records of the genus *Turrilites*. This conspicuous biogeographic gap has reinforced the interpretation of an environmentally restrictive barrier separating the plate interior from the open ocean.

### 1.4 Aims of the Present Study

The aims of this study are: (1) To formally document this discovery at its **three localities** and provide a systematic paleontological description supported by comparisons; (2) To establish the precise geological and stratigraphic context of the fossil-bearing localities; (3) and to discuss the paleoenvironmental and paleogeographic implications of these **regional** findings for our understanding of the Cenomanian seaway across the Arabian Plate.

## 2. Geological Setting and Localities

The fossil specimens described herein were discovered within the Aruma Formation. Based on the presence of the index fossil *Turrilites costatus*, the age of this specific horizon is confidently assigned to the Middle Cenomanian. The host rock at the discovery site is a whitish to yellowish, bioclastic limestone, which is consistent with the known lithologies of the lower part of the Aruma Formation in the region.

The fossils were documented in-situ at **three separate localities (A, B, C)** south of the city of Ar'ar (**Figure 1**):

- **Locality A:** (Coordinates: **30° 52' 52.84" N, 40° 55' 0.80" E**). The primary site, featuring a dense fossil assemblage (>9 specimens) in a concentrated area of approx. 2 sq. meters. Preservation consists of high-fidelity external molds and partially dissolved original shell material (Figures 2, 3).

- **Locality B:** (Coordinates: 30° 52' 50.45" N, 40° 56' 10.85" E). Located 1.9 km from Locality A. Specimens at this site, though of poorer quality, show key diagnostic features including dextral coiling and a subquadrate whorl section (Figure 4).
- **Locality C:** (Coordinates: 31° 6' 58.36" N, 40° 45' 54.63" E). Located 30 km from Locality A. Specimens at this site clearly exhibit dextral coiling, and a mold of a juvenile specimen clearly preserves the three characteristic rows of tubercles (Figure 5).

The presence of these environmentally sensitive fossils at three geographically separate in-situ localities is a primary finding of this study.

### 3. Systematic Paleontology

The classification follows the scheme presented in the *Treatise on Invertebrate Paleontology, Part L* (Arkell et al., 1957).

Phylum MOLLUSCA Cuvier, 1795

Class CEPHALOPODA Cuvier, 1797

Order AMMONOIDEA Zittel, 1884

Suborder ANCYLOCERATINA Wiedmann, 1966

Superfamily TURRILITOIDEA Gill, 1871

Family TURRILITIDAE Gill, 1871

\*\*Genus *Turrilites* Lamarck, 1801

\*\*Species *Turrilites* (*Turrilites*) *costatus* Lamarck, 1801

(Figures 2, 3, 4, 5)

Material:

Specimens documented from the three localities (A, B, C) as detailed in Section 2.

Description:

Shell is a high-spired, tightly coiled turricone with dextral coiling. This is consistent with all known Cenomanian Turrilites species, which are exclusively dextral (Chirat et al., 2021). The whorl section is subquadrate to subpolygonal, matching classic descriptions of the species (Callapez et al., 2018).

Ornamentation is the key diagnostic feature, consisting of strong, oblique ribs bearing **three distinct rows of tubercles** (Arkell et al., 1957). 1. The lowest row (at the lower whorl suture) consists of small tubercles. 2. The middle row (mid-flank) comprises the most prominent, sharp, conical tubercles. 3. The uppermost row (at the upper whorl suture) consists of small, sometimes clavate, tubercles.

Due to the preservation state (external molds and partial shells), the **internal suture lines are not preserved**.

Taphonomic and Ontogenetic Remarks:

A variation in tubercle expression is noted, depending on preservation and ontogeny. On larger specimens, notably at Localities A and B, preserved as eroded external molds or internal casts, the middle (largest) row tends to dominate, while the upper and lower rows become very weak or disappear. Significantly, a specimen discovered at Locality C, which is a well-preserved external mold of a juvenile (small-sized) individual (Fig. 5), clearly shows all three tubercle rows. This phenomenon aligns with taphonomic studies of related genera, where smaller tubercles (features of the outer test) are not prominently preserved on the internal cast (Wright, 1963; Cobban & Scott, 1972). The discovery of all three rows on the juvenile specimen (Locality C), coupled with the dominance of only the middle row on larger specimens (Localities A and B), provides an integrated taphonomic and ontogenetic explanation supporting the identification of all specimens as *T. costatus*.

Differential Diagnosis:

*T. (T.) costatus* is distinguished from contemporaneous species based on ornamentation.

- It is distinguished from *T. (T.) acutus* Passy, 1832, as the latter possesses more prominent tubercles (especially the lowest row) which create a strongly crenulated suture line, a feature not observed in the present material.
- It is distinguished from *T. (Euturrilites) scheuchzerianus* Bosc, 1801, as the latter lacks prominent tubercles and possesses only simple (non-tuberculate) ribs.

- The presence of three (not four) tubercle rows excludes other species within the genus (Arkell et al., 1957).

Based on this combination of features—dextral coiling, subquadrate whorl section, three tubercle rows with a dominant middle row, and the observed taphonomic/ontogenetic variation—the material from all three localities is confidently assigned to *Turrilites* (*Turrilites*) *costatus*.

## 4. Discussion

### 4.1 Biostratigraphic Implications

The discovery of *Turrilites costatus* provides a precise age determination for the host strata of the Aruma Formation at these localities. *T. costatus* is the index species for the Middle Cenomanian substage of the global chronostratigraphic scale (Kennedy, 1971). This finding therefore establishes a **key biostratigraphic tie-point** for the Late Cretaceous succession in northern Saudi Arabia, a region where high-resolution **index macrofossils** have historically been rare.

### 4.2 Paleoeological Reconstruction: Evidence for an Open Marine Setting

The paleoecological significance of this discovery is profound. As established, *Turrilites* ammonoids were stenohaline inhabitants of open-marine, normal-salinity environments (Westermann, 1996). The presence of a single specimen could potentially be explained by post-mortem drift. However, the documentation of **in-situ** fossil assemblages at **three separate localities (A, B, C)** spanning a geographic distance of over **30 km** (Fig. 1), provides important evidence. This wide geographic extent **suggests** these were not isolated anomalies.

Instead, we **propose** that these findings represent a stable, persistent marine environment capable of supporting thriving populations of these environmentally sensitive cephalopods. This conclusion **presents new data** that differs from some prevailing models that depict the Arabian Plate interior as a restricted, shallow epeiric sea, where conditions could potentially become hypersaline and inhospitable to such fauna.

### 4.3 Paleogeographic Implications: A Proposed Trans-Arabian Seaway

Based on the paleoecological evidence for a persistent, open-marine environment extending over 30 km, a **re-evaluation** of some paleogeographic maps of the Arabian Plate during the Middle Cenomanian is warranted (e.g., Sharland et al., 2001).

We **propose** that these three localities (A, B, C) represent the first macrofossil evidence supporting the hypothesis of an "**open marine corridor**" or "Trans-Arabian Seaway." Such a seaway would have provided the necessary oceanic circulation and connection to the Neo-Tethys Ocean, maintaining the stable, normal-salinity conditions required to sustain stenohaline fauna. This finding also establishes a new biogeographic link. Whereas *T. costatus* was previously documented on the plate margin in Oman (Natih Formation) (Kennedy & Simmons, 1991), its discovery now deep in the plate interior in northern Saudi Arabia **suggests** that the faunal exchange pathway between these two regions was perhaps more open than previously thought.

#### 4.4 Limitations and Future Work

We acknowledge that these results are based on a single ammonite genus. Mapping the full geographic and stratigraphic extent of this open-marine facies requires further fieldwork. Future research focusing on associated microfossils (e.g., planktonic foraminifera) or other oceanic faunal elements within these strata will be crucial to **confirm or refute** the hypothesis proposed here and to delineate the geometry of this ancient seaway.

#### 5. Conclusion

This paper presents the first documented evidence of the ammonite *Turrilites costatus* from the Cenomanian Aruma Formation of northern Saudi Arabia, based on discoveries at three separate localities spanning over 30 km. This discovery has three principal scientific contributions:

1. **Taxonomic and Biogeographic:** It extends the known geographic range of *T. costatus* significantly onto the Arabian Plate interior, filling a gap in the fossil record.
2. **Biostratigraphic:** It provides a precise Middle Cenomanian age for the lower part of the Aruma Formation in this region, serving as a critical new tie-point for stratigraphic correlation.

3. **Paleogeographic:** It provides macrofossil evidence, based on a regional extent, that supports the hypothesis of an open-marine, oceanic environment in the northern interior of the Arabian Plate, **suggesting** a need to re-evaluate existing paleogeographic models.

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### **Declarations**

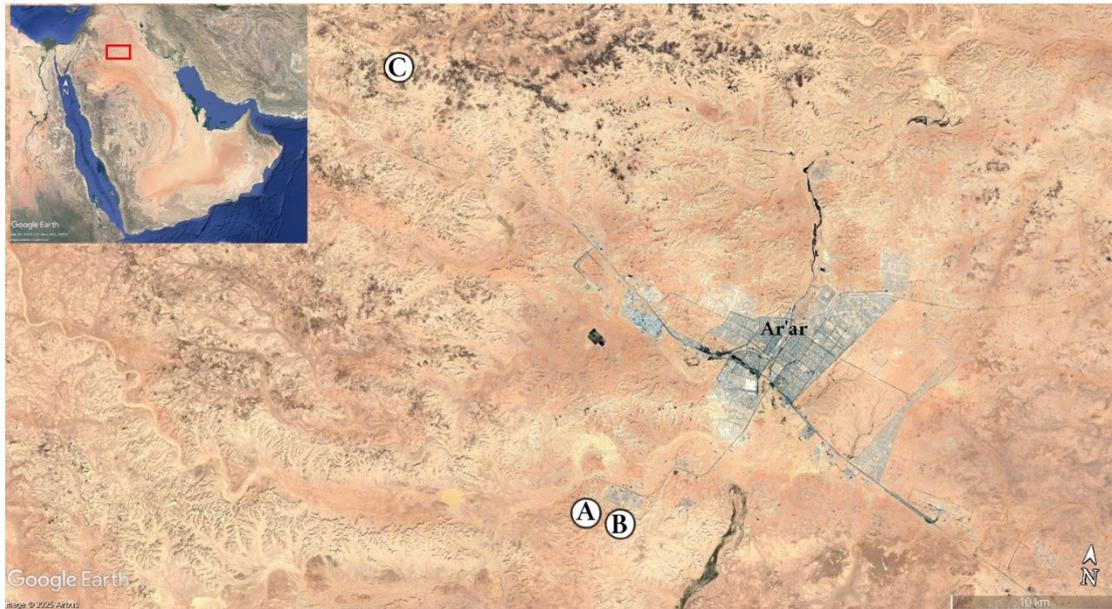
Conflict of Interest: The author declares that he has no conflict of interest.

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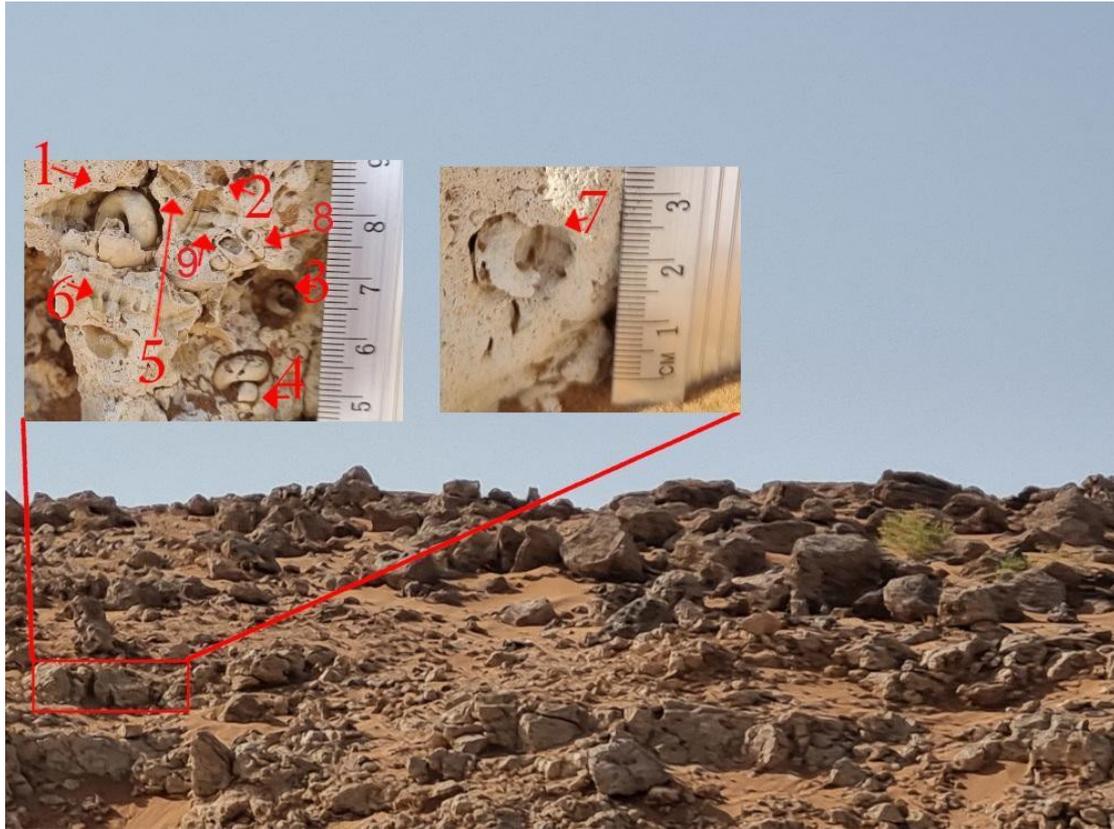
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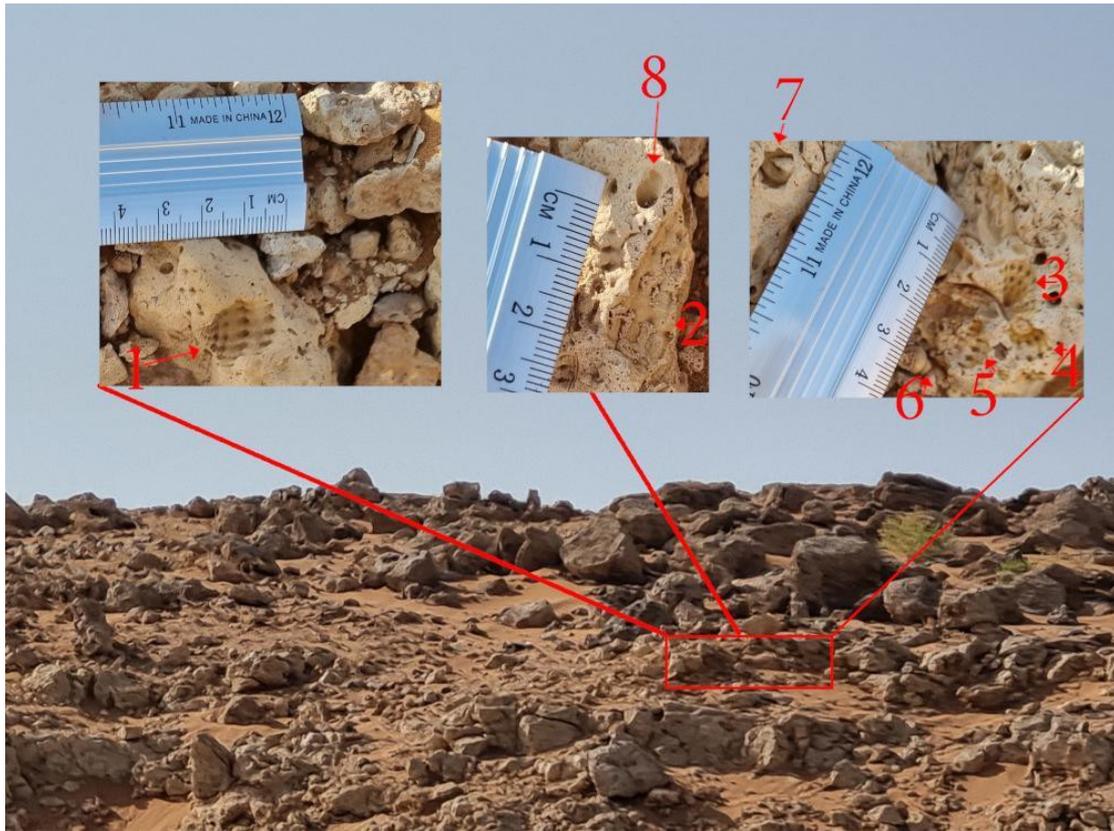
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**Figure 1:** Map of the study area, showing the three in-situ fossil localities (A, B, C) south of the city of Ar'ar, northern Saudi Arabia. (Inset map shows the location of Ar'ar within the Arabian Peninsula). (Source: Google Earth Pro, modified by the author).



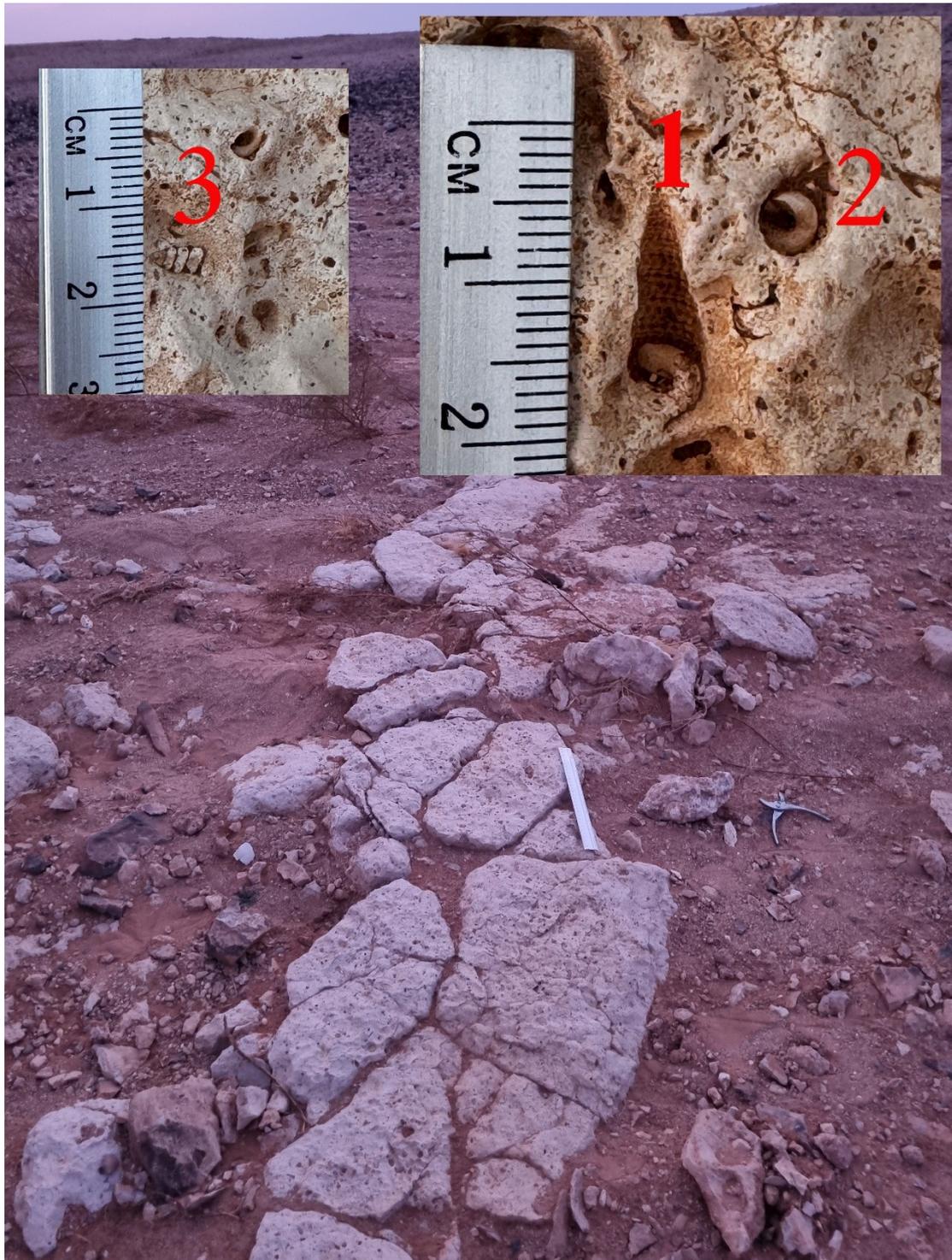
**Figure 2:** An *in-situ* fossil assemblage of *Turrilites costatus* LAMARCK, 1801 on the surface of a limestone slab from the Cenomanian Aruma Formation, Ar'ar locality, northern Saudi Arabia. Note the high density of specimens preserved as both partial shells (e.g., 1, 4, 7) and high-fidelity external molds (e.g., 2, 3, 5, 6, 9). The concentration of individuals suggests a life assemblage with minimal post-mortem transport. Scale is in centimeters.



**Figure 3:** Additional specimens of *Turrilites costatus* LAMARCK, 1801 from an adjacent block at the Ar'ar locality. Note the excellent preservation of external molds, clearly showing the characteristic oblique ribs and three rows of tubercles (e.g., specimen 2). Specimen 8 is an unidentified fossil fragment, possibly a bivalve. Scale is in centimeters.



**Figure 4:** *Turrilites costatus* from Locality B (1.9 km from Locality A). **1.** Apical view of a specimen, showing clear dextral coiling and the external mold of the tubercle row. **2.** Longitudinal section of a specimen, showing the characteristic subquadrant whorl section. **3.** Lateral view of a specimen showing dextral coiling, with impressions of tubercles preserved on the flanks. **\*\*4.** **\*\*** A high-fidelity external mold clearly showing the tubercle ornamentation.



**Figure 5:** *Turrilites costatus* from Locality C (30 km from Locality A). **1.** A high-fidelity external mold of a juvenile specimen, showing clear preservation of all three diagnostic tubercle rows. An adjacent specimen (right) shows dextral coiling. **2.** A partially preserved coil, possibly *T. costatus*. **3.** An eroded specimen of *T. costatus*, clearly showing dextral coiling; tubercles are obscured by weathering.