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Stratigraphic Setting and Lithology of Mount Scopus Chalk Quarry Cave

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This article describes the geological setting of the Mount Scopus chalk-vessel production and quarry cave. This artificial cave was manually quarried in chalk of the middle of Menuḥa Formation, which consists of tiny calcitic skeletons of micro-organisms living in the open sea. Due to its clay content, this rock unit was easier for quarrying, but also caused stability problems and the breakage of stone vessels during manufacture.

Keywords: bedrock stratigraphy, lithology, depositional paleoenvironment

Introduction

The Mount Scopus cave is artificial, manually quarried in chalk in the middle of the Menuḥa Formation of the Senonian Mount Scopus Group (Fig. 1). It is located on the eastern flank of the Judean anticline, which is also the western flank of the Judean Desert syncline. The syncline was a submarine basin in the Upper Cretaceous period. The Menuḥa Formation chalk consists of tiny calcitic skeletons of pelagic (plantic) micro-organisms, living in the open sea (depth over 100–150 m). This paleo-ecological setting probably reached below the photic zone, as suggested by the near lack of larger invertebrates (especially bottom dwellers) that prefer the shallower productive zone. Therefore, the pure chalk part of the formation is assumed to have accumulated far from the continental influence in a rather deep sea.

In many places in Israel, an argillaceous (marl) layer appears within the Menuḥa chalk. In northern Israel, the argillaceous unit was distinguished as the Kabri Marl member, whereas in central Israel, the marl unit separates the Menuḥa Formation into the Lower (first) and Upper (second) chalk members. The marl was formed by the addition of clay to the chalk during deposition, and it is associated with an increase in the amount of phosphate grains, some quartz grains, fish bones, oyster (bivalve) shells and their fragments and ferruginous

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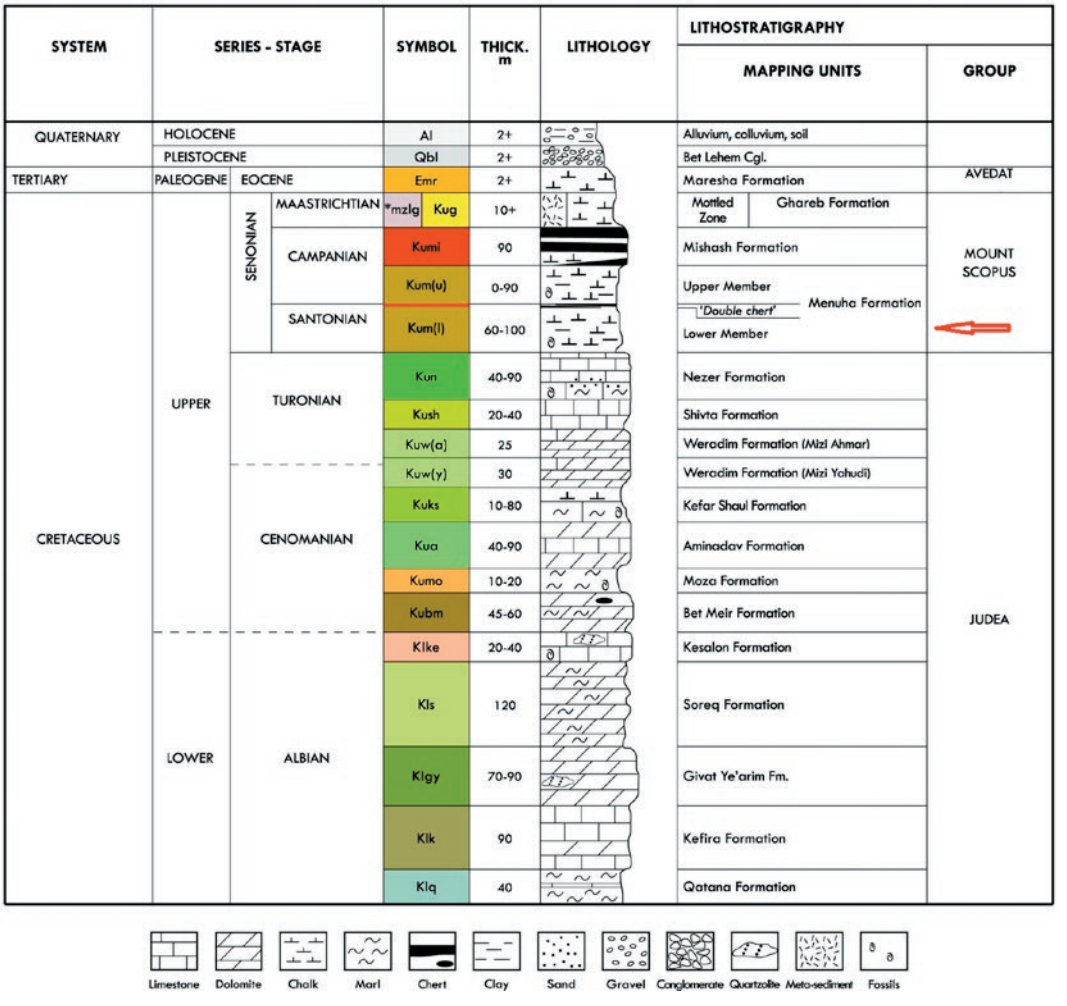

Fig. 1. Regional stratigraphic section, arrow pointing to cave location (after Sneh and Avni 2011).

impregnation. The nature of this marly unit suggests an increase in detrital marine and terrestrial components, such as clay and quartz grains. This may be the result of a relative sea-level drop (shallowing), and/or an increase of seaward influx of terrestrial detritus. Age-indicative fossils provide similar chronology to the argillaceous-detritic unit in the middle of the Menuḥa Formation throughout the country.

Accordingly, this unit represents a rather simultaneous ecological sedimentary event in the latest Santonian (84 million years BP) to earliest Campanian (83 Ma) times. This period is evidenced in samples taken from the ceiling of the Mount Scopus cave that yielded the Late Santonian foraminifer *Dicarinella asymetrica* Sigal. In addition, several (c. 10 specimens) well-preserved ammonites were found on the ceiling of the cave (Fig. 2), probably belonging to *Reginaites reymenti* Klinger and Kennedy, known from the

Fig. 2. Cave ceiling with ammonite fossil.

same period and previously described from the Menuḥa Formation of Jerusalem, related to *Protexanites planatus* Lasswitz.

The Bedrock Stratigraphic Position Selected for the Cave

The argillaceous unit of the Menuha chalk was analyzed in detail for the construction of the nearby Mount Scopus road tunnel (Mimran 1995). The argillaceous unit in the middle of the Menuḥa sequence is distinguished from the white chalk above and below by its grayish to light brown color (Fig. 3). The rock consists mainly of chalk, mostly containing 15–20% clay, and in extreme cases reaching almost 30%. The smectite content in the fine fraction is between 20–70%. The geotechnical parameters of the rock (Table 1) indicate very low strength (Mimran 1995).

Due to its clay content (mostly insoluble residue), this unit is lithified (cohesive) and easier to excavate than the white chalk above and below. The mechanical properties of the argillaceous unit rendered it easier for quarrying, but these properties may have caused stability problems of the cave ceiling, as well as breakage of stone vessels during manufacture (Fig. 4; see Seligman, Amit and Zilberbod, this volume). The cave has two main levels of quarrying which may well be associated with the bedrock qualities. The quarry workers started to cut the stone in the soft argillaceous unit, and later extended the

Fig. 3. Argillaceous chalk, top of quarry.

Table 1. Geotechnical Parameters of the Menuḥa Chalk at Mount Scopus (after Mimran 1995)

Drill Hole No.	Sample	ρ, g/cm3	Depth (m)	Pc, MPa	Δδ max, MPa	E, GPa	ν
2	2A	2.23	42.30	1.0	19.7	2.80	0.17
				3.0	21.7	3.30	0.21
				5.0	28.3	3.80	0.22
	2B	2.13	46.25	1.0	19.3	5.10	0.22
				3.0	24.0	6.00	0.20
				5.0	29.5	6.00	0.20
4	4A	2.07	22.50		21.6	5.70	0.21
	4B	2.34	23.50–24.00	2.4	38.0	6.00	0.11
	4C	2.17	25.00	4.3	37.5	8.30	0.18
	4D	2.09	26.00	6.0	37.9	7.30	0.19
6	6A	1.55	33.15–33.50		4.7	0.51	0.31
	6B	1.53	33.15–33.50	1.0	7.3	0.58	0.12
	6C	1.9	34.20–34.45	2.0	10.0	1.00	0.29

Fig. 4. The ceiling of the lower cave.

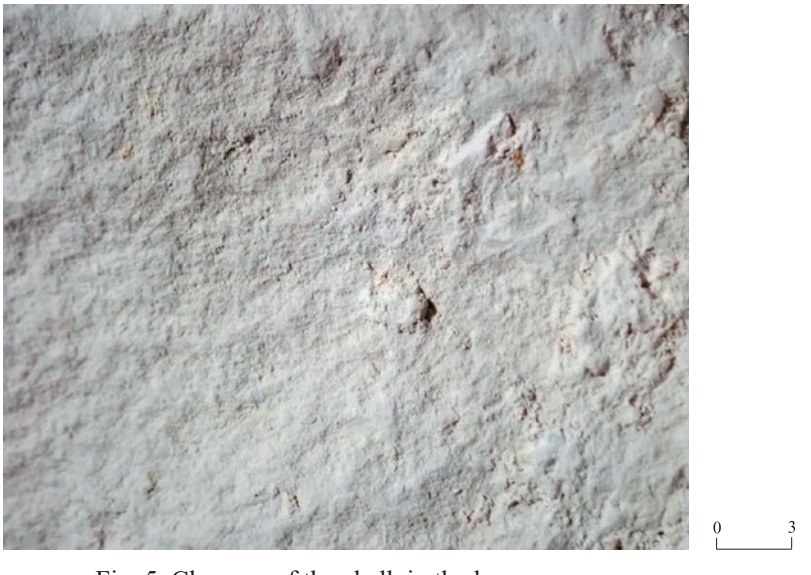

Fig. 5. Close-up of the chalk in the lower cave.

cave into the underlying chalk that is better suited for chalk vessels (Fig. 5). The cave served as a protected, shaded, cool and moist site for the quarry and chalk vessel workshop, the moisture being an important factor for avoiding dry, brittle rock which breaks easily.

Fig. 6. A broken mug discarded in the cave.

The chalk vessels and cores were not examined in this study, but they may have come from the argillaceous chalk, which is easier to shape, or from the cleaner and harder chalk above and below, as both units at this site are cohesive enough to allow easy quarrying and vessel shaping. This is not the case with most limestones and dolomites of the Judea Group at Jerusalem, which are harder. Naturally, the chalk vessels were easily broken during manufacturing and usage (Fig. 6).

Epigenetic Bedrock Structures and Voids

Natural features, such as fractures and bedding planes, served as boundaries for removing large blocks of rock, economizing stone-cutting effort. The main fracture strike is 135°, and the secondary direction is 20°, these directions aligning with the known Syrian Arc strain in this region (Eyal 1996; Eyal and Reches 1983); some sub-horizontal fractures also appear. The fractures affected the stability of the ceiling, necessitating supports to prevent ceiling collapse. Conchoidal fracture surfaces, typical of chalk, are common. The fractures commonly show ferruginous impregnation and manganese oxides, indicating some infiltration of water through the fractures. Some fractures were invaded by plant roots prior to quarrying; whilst the organic matter is not extant, the root's path is observed through their typical fossils, termed rhizofossils. They probably reflect a wetter period than today, such as the last glacial period, which supported denser vegetation in the presently semi-arid desert border (Danin, Wieder and Magaritz 1987; Frumkin, Ford and Schwarcz 2000).

In a few places, the tectonic features were enlarged by karstic dissolution, prior to the excavation of the cave. A few small karst cavities, up to tens of centimeters, were encountered during the quarrying of the cave. A vertical micro-shaft (diam. 30 cm) visible in the ceiling was cut by the quarrying; a larger karst cave (depth 7 m) was encountered in a nearby borehole (Mimran 1995).

The Sediments in the Cave

Sedimentation within the cave is mostly associated with human activity within the cave chambers. The larger stones (diam. up to few tens of centimeters) were chalk fragments,

either collapsed from the ceiling or detached during the stone-cutting process; several collapse spots were observed, particularly close to the cave entrances. Hundreds of chalk-vessel cores and defective chalk vessels were found inside the cave (e.g., Fig. 6; see Seligman, Amit and Zilberbod, this volume), and thousands of smaller chalk chips (diam. a few centimeters) resulted from the quarrying process. Silt to clay-size detritus comprised the chalk powder originating from the chalk-vessel manufacturing process, only a small portion of the fine sediment attributable to wind-transported dust from outside the cave. Natural fine sediments of dark to light brown color were observed near the main entrance. These sediments originated from rendzina soils of the mountain slope south of the cave, which were borne into the cave by water runoff and colluvial processes. Several such thin rendzina layers were observed within the chalk fragment heaps at the cave entrance. Most of the rendzina-type sediment appeared within the top of the sediment sequence at the cave entrance, probably resulting from sediment entering the cave after it ceased to function, but before the entrance was completely covered and blocked.

Conclusion

Sediment layers are often oblique due to debris accumulating in heaps at points of chalk-vessel production. Large concentrations of chalk-vessel cores rolled down the heaps from the manufacturing sites. It seems that some debris was manually moved from one place to another within the cave, possibly for flattening the working surface or for cleaning purposes. The distribution of the fine material seems to be more uniformly spread across the cave than the stone debris.

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