Khushaym Matruk (Jordan)

Description: Khushaym Matruk (Central Jordan, about 80 km south-east of Amman), is a site on which a direct contact between an upper-cretaceous biomicrite (Muwaqqar Formation) and natural cements, i.e. thermally metamorphosed biomicrite, can be observed (see also Maqarin). The interest for this site is motivated mainly by the fact that on this specific location the clay content of the biomicrite is significantly higher than in other sites previously explored in Jordan (Maqarin, Daba, Siwaqa, Suweileh). The Khushaym Matruk site is thus an interesting site on which the behaviour of clay minerals in the presence of alkaline fluids can be explored. A first sampling of this site was done within the Maqarin Phase IV project (1999-2004) in cooperation between Andra, CEA, JNC, Nagra, Nirex, SKB and Jordan University.

Geological setting

The metamorphic rocks (natural cements) and the associated biomicrite and travertines are widely distributed in two areas: Daba (Khan Az-Zabib) and Siwaqa (Figs 1). The northern boundaries of the first and second areas are located 25 km and 60 km south of Amman. The first area lies between 36° 00' to 36° 15' longitude E, and 31° 15' to 31° 30' latitude N and the second area lies between 35° 00' to 36° 15' longitude E, and 31° 15' to 31° 30' lalitude N. Khan Az-Zabib covers 662 sq. km and Siwaqa covers about 660 sq. km.

The Daba-Siwaqa area was situated during the Late Cretaceous to Early Eocene time (≈ 90 - ≈ 50 My ago) in a shallow marine, stable shelf environment of the Tethys sea. Transgression took place during Cenomanian times, and marine sedimentation took place until the Late Eocene, despite the fluctuations in sea level. Uplifting took place and gentle folding and faulting is mostly related to the continued tectonic movement along the Jordan Rift which is located ≈ 60 km to the west of Daba – Siwaqa area. The exposed rocks in this area of Jordan are thus mainly sedimentary and range in age from Upper Cretaceous (Turonian) to Tertiary (Eocene). Travertines and superficial deposits are Pleistocene to Recent in age. The travertine deposits are probably linked with episodes of wet climate during which significant alteration of metamorphosed rocks are thought to have occurred. The general chronological sequence of lithological units in central Jordan is given in Table 1.

The Khushaym Matruk area (N 31°16' 570 ; E 36°14' 775) belongs to the southern extension of the Daba Marble Zone (see Maqarin Phase II Report (1998), Linklater Ed., p. 38). The site itself is located at the western end of a low range of hills and the contact between the biomicrite and the thermally metamorphosed rocks is clearly visible (Fig. 2). At the present day, the groundwater table lies some 150-200 m deep and the site is therefore totally desaturated. The mean annual precipitation (which occurs in winter) is at present 110 mm ; however, periods of pluvial climate have been identified in this region during the last 0.5 My (personal communication of Prof. Khoury).

Table 1: List of lithological units in Central Jordan (after Khoury, Maqarin Phase IV reports)

Lithological Units	Age	Thickness (m)
Alluvium and gravel	Holocene – Recent	-
Fluviatile and lacustine gravel	Pleistocene – Recent	-
Travertine	Pleistocene – Recent	-
Um Rijam Chert Limestone Formation (B4)	Eocene	30-80
Muwaqqar Chalk Marl Formation (B3)	Paleocene – Tertiary	70-150
Al-Hisa Phosphorite Formation (B2)	Maestrichtian	25-70
	(Upper Cretaceous)	
Amman Silicified Limestone Formation (B2a)	Campanian	15-80
	(Upper Cretaceous)	
Wadi Umm Ghudran Formation (B1)	Campanian – Santonian	3
Wadi Es – Sir Limestone Formation (A7)	Turonian	30

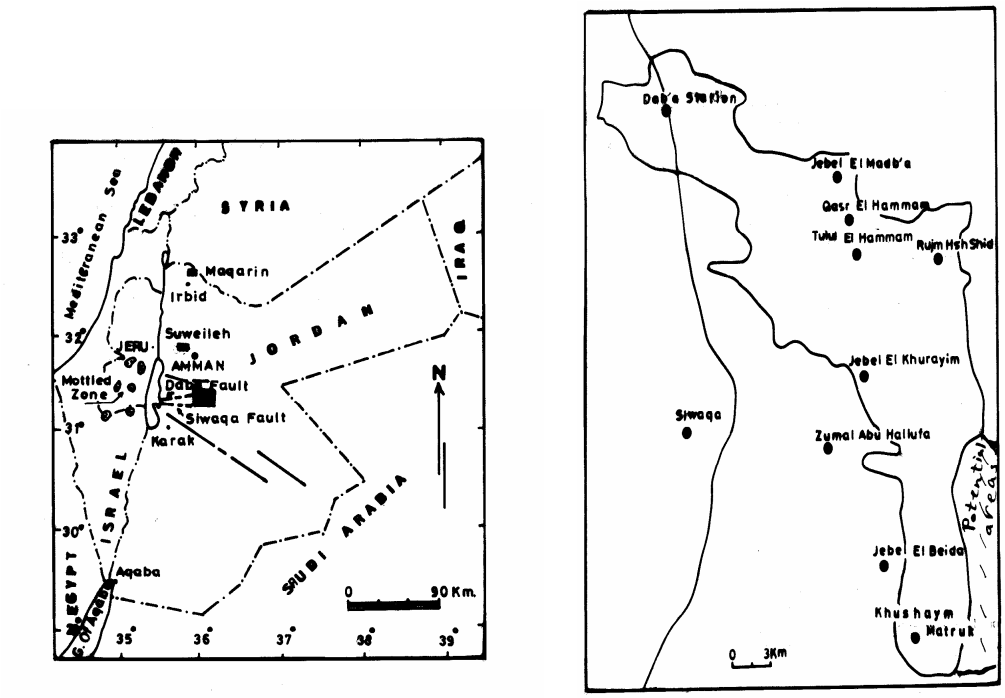


Figure 1: Maps showing the location of Khushaym Matruk and other sites of Central Jordan where natural cement bodies are found (after Khoury, Maqarin Phase IV reports, to be published

Figure 2: The Khushaym Matruk site in 2004. At the top of the hill, a cap of high temperature grade cement is preserved. The grey layer at the basis of the hill shows the outcrop of the Muwaqqar biomicrite. The discontinuous travertine layer can be recognized as a small ridge just above the biomicrite/cement interface (Photograph L. Trotignon)

Results obtained so far during Maqarin Phase IV project on the KM site are presently synthesized and will be published in 2005. Most investigations have focused on a vertical

sampling of about 10 m extension across the interface. The sampling was done along a trench that was dug in order to avoid potential surface alteration and weathering effects.

A discontinuous travertine layer (about 1 to 2 m thick) covers at the surface the interface between cement and baked biomicrite. Green Cr-rich minerals are associated with this travertine body. A zone of strongly baked and perturbed biomicrite, about 2.5 to 3 m thick, is observed between the cement zone and the apparently unperturbed underlying biomicrite (see Fig. 3). This baked zone contains both hard and soft micro horizons, with different colours, suggesting a pervasive transformation by heat and/or chemicals of the biomicrite. Information obtained from magnetic investigations and the study of organic matter shows that this layer of baked micrites corresponds to the spatial extension of the thermal gradient from the cement zone (T > 900°C) down to temperatures of about 150°C. Mineralogical and petrographic investigations show that :

– the texture of the rock in the baked zone is perturbed, a lot of fractures filled with gypsum or zeolite minerals are found. Foraminifera tests are often filled with zeolites. Some horizons are enriched in clay minerals (up to 23 wt%)

– quartz and K-feldspar, initially present in the biomicrite, have disappeared ; amorphous silica has precipitated

– smectitic clay minerals in this baked layer have a lower crystallinity than in the original biomicrite

– a significant increase in cation exchange capacity is associated with the interface between the baked zone and the less perturbed biomicrite

– the clays below the baked zone are more beidellitic in nature, with a lower I/S content (60 %) near the baked zone than at depth (80 %).

– large vertical fractures crosscut the whole section (Fig. 3). These large fractures are mainly filled with gypsum.

In contrast with the Maqarin site, no pyrite was detected in the biomicrite. It is not known whether this is due to surficial oxidation of the rock mass, pyrite beeing present at greater depths, or if this is effectively a specificity of the Khushaym Matruk site.

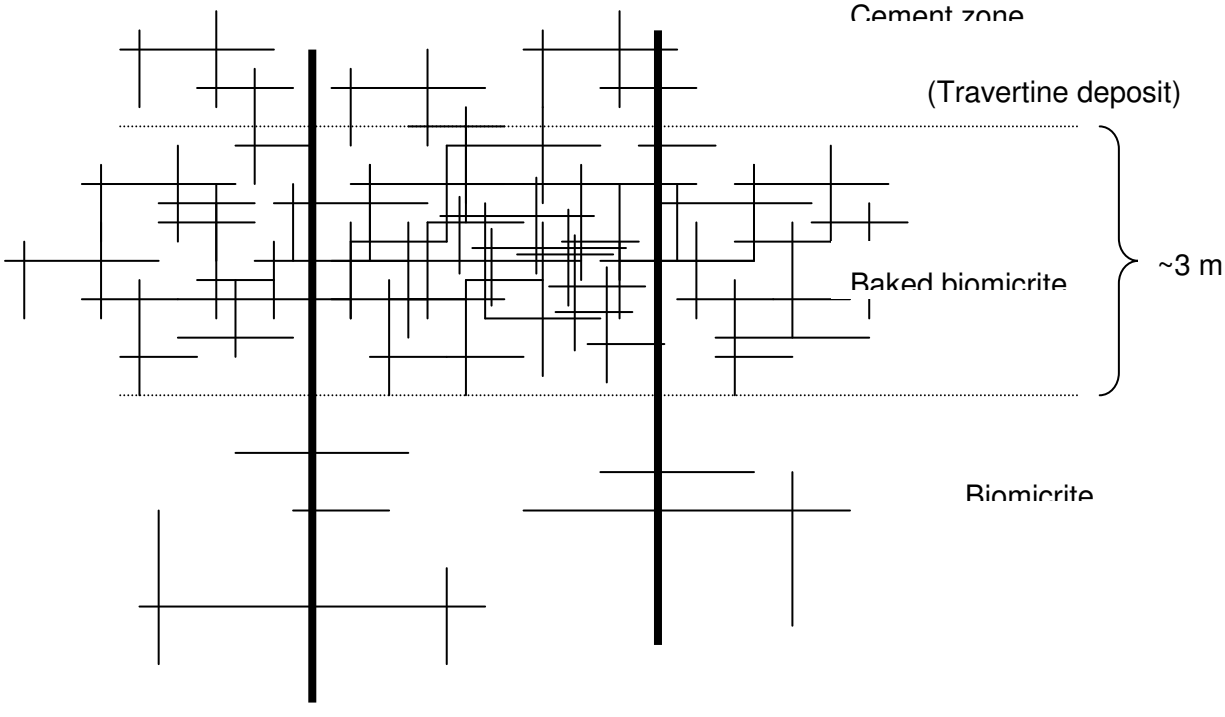
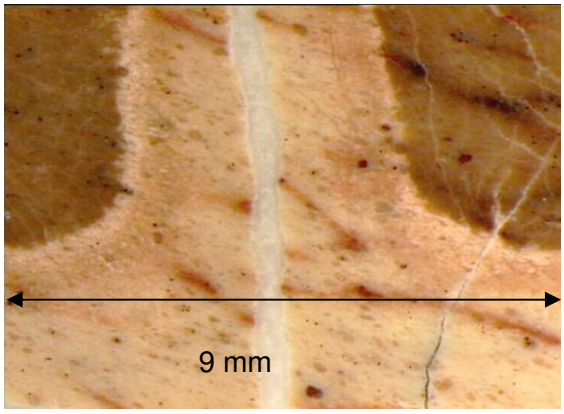


Figure 3: Schematic representation of the Khushaym Matruk trench profile. The cement zone (> 50 m thick) is fractured. CSH minerals (jennite, afwilite) are found in fractures of the cement zone. Discontinuous travertine deposits are found at the basis of the cement body. A 3 m thick zone of strongly baked biomicrite is found below the travertine deposits. This zone corresponds to temperatures greater than 150°C and has undergone important textural and chemical transformations and pervasive fluid circulation. The underlying biomicrite has been affected by high pH fluids only by circulation of these fluids along large vertical fractures.



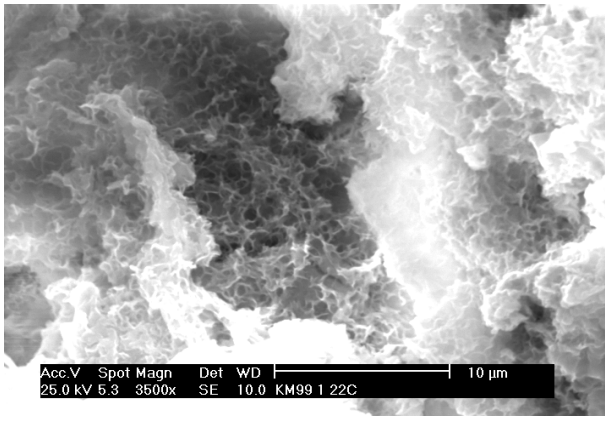


Figure 4: Left : fracture accross a cement sample from Khushaym Matruk. The inside filling of the fracture is jennite and calcite. In the discoloured cement, spurrite has been replaced by CSH and afwillite. Right: smectitic clay minerals observed in a clay enriched horizon of the baked biomicrites of Khushaym Matruk (Photograph by L. Trotignon)

The age of the combustion process is believed to be less than 1 My (possibly around 800 ky, considering isotope data obtained on travertine in another Central Jordan site, magnitude of erosion having affected the KM site and preliminary paleomagnetic results). Techer et al. (2004) have evidenced that in Khushaym Matruk high pH solutions have circulated in the sedimentary pile between 110 and 130 ky ago.

Relevance: The site of Khushaym Matruk has relevance for three subsystems in a waste disposal :

– cement alteration : observation of fractures in the cement zone
– impact of temperature on sediments : 3 m thick zone of baked biomicrite
– interactions between high pH fluids and clay minerals : observations at the vicinity of large fractures crosscutting the biomicrite at some depth.

Position(s) in the matrix tables: Cement, near field, argilite, clays, thermal effect, alkaline perturbation

Limitations: including:

– Difficulties to separate thermal and chemical effects on a large part of the profile
– Dating is incomplete
– Some of the clays have been formed in connection with the thermal perturbation, in particular in the baked biomicrite. These clays may have strongly hampered further ingress of high pH fluids but it is not easy to demonstrate (deserves further investigations).

Quantitative information: At the present state of investigation, mostly qualitative information on possible interaction scenarios. Modelling is needed.

Uncertainties: Mostly on the age and duration of processes. Influence of organic matter on the high pH fluids may be underestimated

Time-scale: The duration of episodes during which high pH fluids percolated in the fracture network is not known. One of such episodes was dated by Techer et al. (2005) around 110-130 ky bp.

PA/safety case applications: Gaucher et al. (2004) quote the Khushaym-Matruk analogue in connection with simulations of the diffusion of an alkaline plume in a clay barrier. However, because the understanding of the site is presently not complete, it is not certain that the quotation is completely appropriate.

Communication applications: None known at present.

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Added value comments: Note that in KM, CSH phases seem to be located only within the cement zone, whereas in Maqarin, CSH minerals can be found along distant fractures. This could mean that calcium migration has been hampered, perhaps due to the higher clay content in the baked zone.

Potential follow-up work: Work is till in progress in the framework of Maqarin Phase IV project. The investigations have shown where interactions between high pH fluids and clay minerals could be studied without too much interference with other processes : in the zone below baked marls, along major fractures.

The site presents also several other interesting features, in particular for understanding cement hydration, organic matter transformations, migration of transition metals, temperature effects on materials.

Keywords: Khushaym Matruk, Jordan, cement, biomicrite, temperature gradient, high pH fluids, zeolites, clays,

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