Significance of Palygorskite in the Drilling and Production of Hydrocarbon in the Neogene of North Kuwait*

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Abstract

Palygorskite is a fibrous authigenic clay mineral with the chemical composition of $(Mg,Al)_2Si_4O_{10}(OH).4(H_2O)$, which forms mainly in coastal, schizohaline environments, under arid to semiarid climates. Recent studies have revealed that it occurs within the Neogene clastic rocks of the North Kuwait fields (Figure 6), where its fibrous pore-filling and dense mat-like grain-coating habit has previously been sometimes misinterpreted as a variation of fibrous illite. SEM images of core plug samples from Neogene clastic reservoirs in the study area show the presence of abundant thin fibres within the pore systems, extending in all directions and locally blocking pore throats. EDX results have confirmed these as authigenic palygorskite. It is likely that these precipitates have a detrimental effect on the production from the affected reservoirs. The palygorskite is frequently associated with corroded authigenic dolomite, which may have provided magnesium for the palygorskite formation, whilst the dissolution of detrital feldspar grains may be the source of silica and aluminum. Although palygorskite appears to occur within most sedimentary facies associations of the arid to semiarid coastal environment, and is present within all reservoir layers, petrographic results suggest that its vertical distribution is partly controlled by the presence of flooding and erosive sedimentary surfaces.

Besides other expandable clay minerals, such as smectite and illite-smectite which occur primarily within detrital clay throughout the Neogene succession, palygorskite is also believed to have some swelling potential. All these clays are thought to have the ability to swell as a result of contact with pore water, water-based drilling mud or during thermal production methods, resulting in potential formation damage. The authigenic palygorskite occurs both within micro and macropore networks throughout the studied succession.

The finely crystalline web-like and the fibrous pore-bridging habit displayed by this mineral is likely to reduce the permeability of the pore systems and can result in fines migration during production. The potential problems resulting from swelling and fines migration are more likely to be an issue in the southern part of the studied area where the overall content of the smectite, illite-smectite and palygorskite is higher compared to the northern areas. Considerable attention should be paid to the presence of palygorskite during the planning of field development techniques to avoid potential production problems.

Introduction

Palygorskite is a fibrous clay mineral found to be commonly occurring with the Neogene sediments of the wells drilled in the northern fields of Kuwait. It is best illustrated in the SEM pictures of the core pieces shown in the text (Figure 1, Figure 2, Figure 3, Figure 4, Figure 5). This mineral commonly forms either by chemical sedimentation as authigenically formed minerals in lagoons and evaporitic basins or by transformation from former clays during early diagenesis in epicontinental and inland seas and lakes (Millot, 1970; Weaver, 1989). In the present work, the close occurrence of this mineral with the dolomitic facies and occlusion of the pore paces with the dense fibrous network is studied to understand its impact in the drilling and production of hydrocarbon. It has fibrous pore-bridging and a dense mat-like grain-coating habit and it is being illustrated through the SEM and XRD data.

Higher Temperature Testing of the Core Samples

Selected core trims were subjected to 450 deg F to ascertain the changes occurring on the clay minerals, including the palygorskite.The pre- and post-test SEM images were compared along with the XRD data. For a group of 10 samples, the following significant changes were observed in the clay mineral distribution in the post-test data.

- Higher concentration of smectite.
- Lack of mixed layer illite/smectite.
- The increased smectite concentration will expect to cause permeability damage during fresh steam injection due to the swelling nature of smectite.
- Lack of palygorskite and filamentous illite in the post-test samples.
- From SEM and XRD results, the steam exposure at 450° F has destroyed most filamentous texture (fibrous clay) of palygorskite and illite crystals.

Observations

Palygorskite is commonly associatiated with dolomite and the dolomite dissolution could provide the Mg, while K-feldspar and plagioclage are seen as partial or complete dissolved mineral through the Neogenes of the study area, providing a source of Al and Si that resulted in the formation of palygorskite.

Considerable changes are seen in the clay mineral alterations after being subjected to 450 deg F, perticularly the smectite and palygorskite. The destruction of the fine threads of this mineral are a matter of concern that can bridge/block the pore space during production.

Summary and Conclusions

1. In the studied area, palygorskite occurs more commonly with the flooding and erosive surfaces, which may form the requisite diagenetic conditions to form the mineral. Abundant dolomitic matrix assiciated with the stratigraphic surfaces could provide the necessary Mg source required for palygorskite formation.

2. When subjected to elevated temperature of 450 deg F, the fibrous material of the mineral are found to be destroyed, which may move away and block the pore space if accumulated with sufficient concentrations at a place.

3. Palygorskite creates web-like fibrous habit that partially bridges macropores and coated grain of quartz and/or dolomite.

Recommendations

It is recommended to conduct steam flood tests of core samples with and without chemical treatments under different PH to determine the residual oil saturation and changes in porosity and permeability due to clay swelling/dispersion and also to establish the remedial measures for prohibiting the destruction of palygorskite.

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Weaver, C.E., 1989, Clays, Muds and Shales: Developments in Sedimentology, v. 44, Elsevier, New York, 819 p.

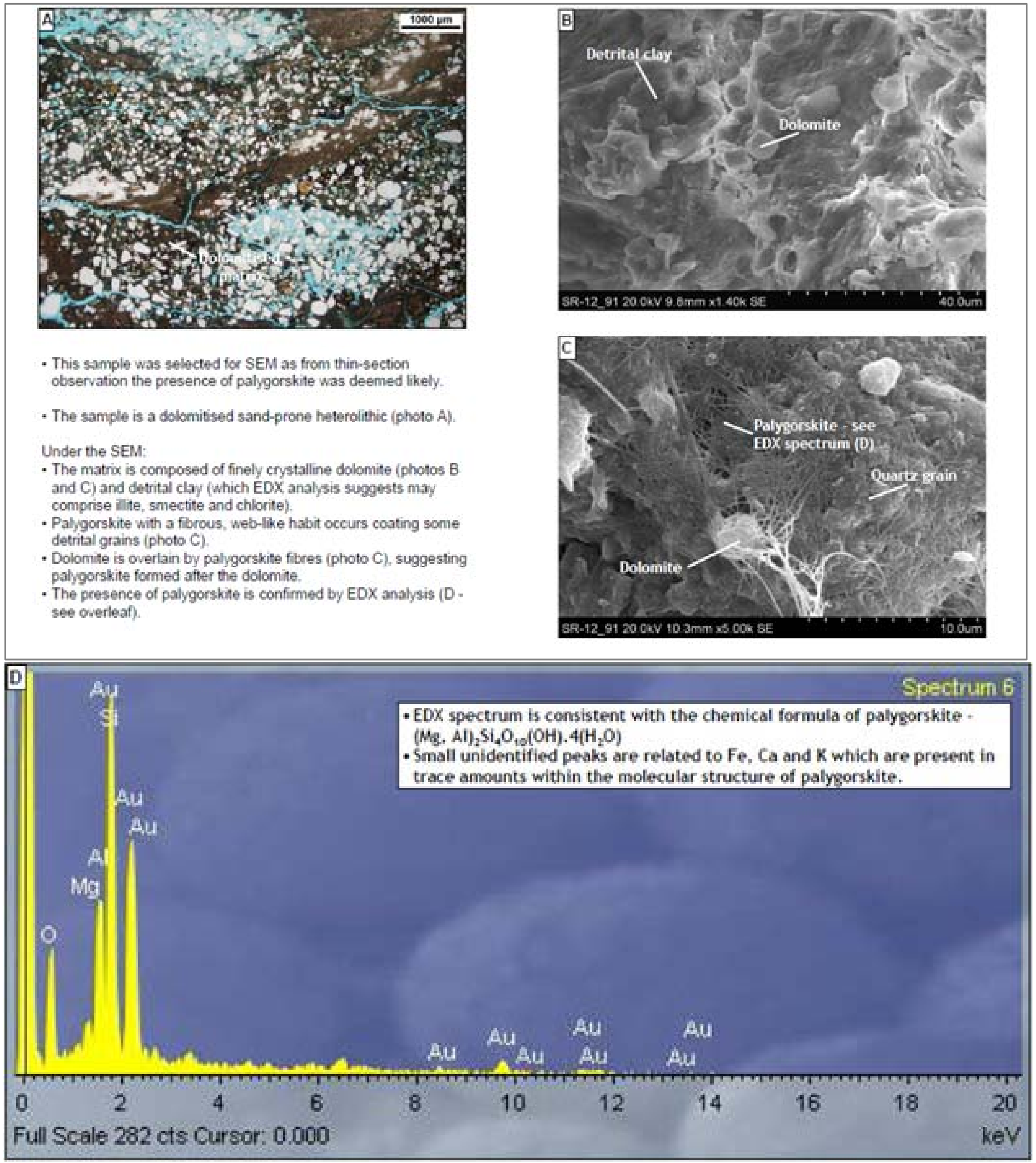


Figure 1. Case study 1.

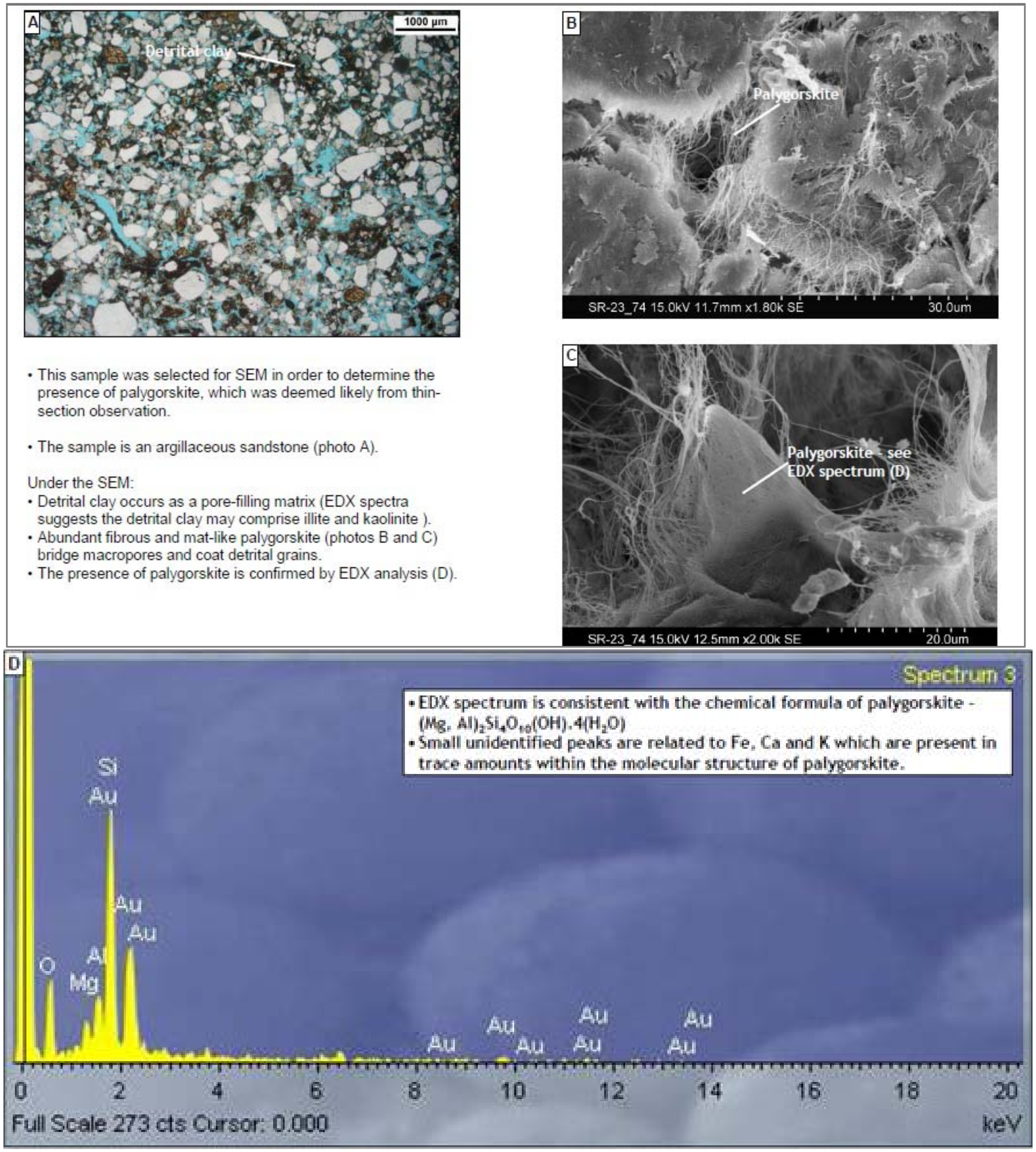


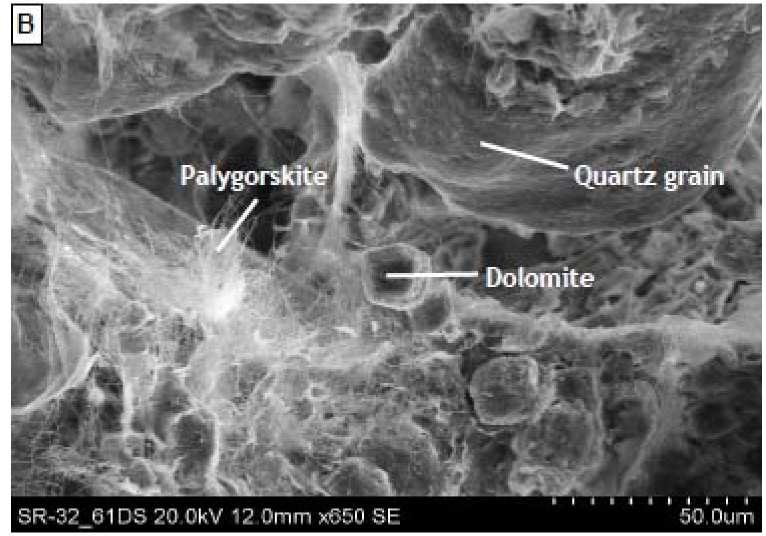
Figure 2. Case study 2.

- This sample was selected for SEM in order to investigate the presence palygorskite, composition of the detrital clay and carbonate dissolution.

- The sample is a dolomitised argillaceous sandstone (photo A).

Under the SEM:

- The matrix is composed mainly of finely crystalline dolomite (photo B), with very minor illitic/illite-smectitic detrital clay and isolated patches of finely crystalline calcite (photo C).
- Abundant palygorskite (photos B and C) occurs with a fibrous web-like habit, which bridge macropores in cleaner parts of the sample.
- There has been some minor dissolution of dolomite and calcite, which show etched surfaces to crystals *(eg.* photo C).



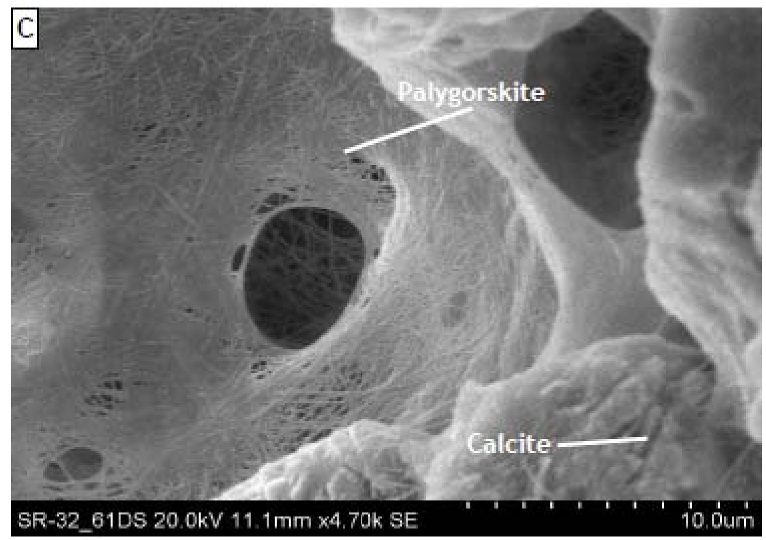
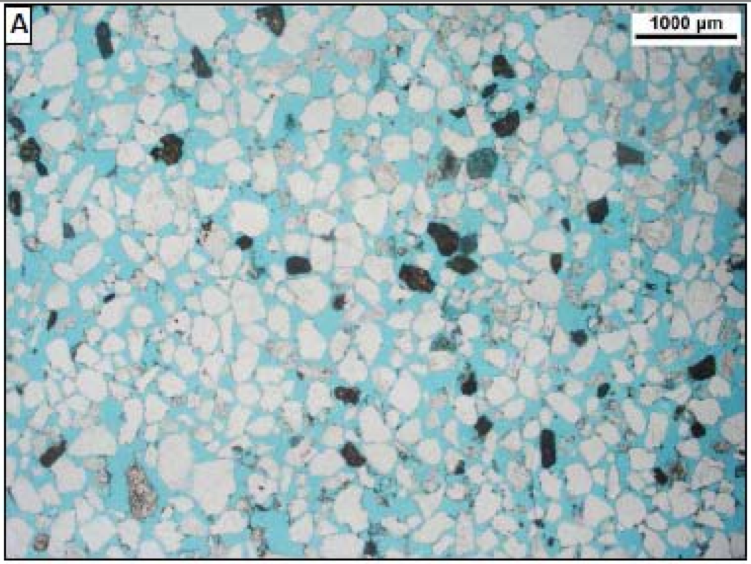
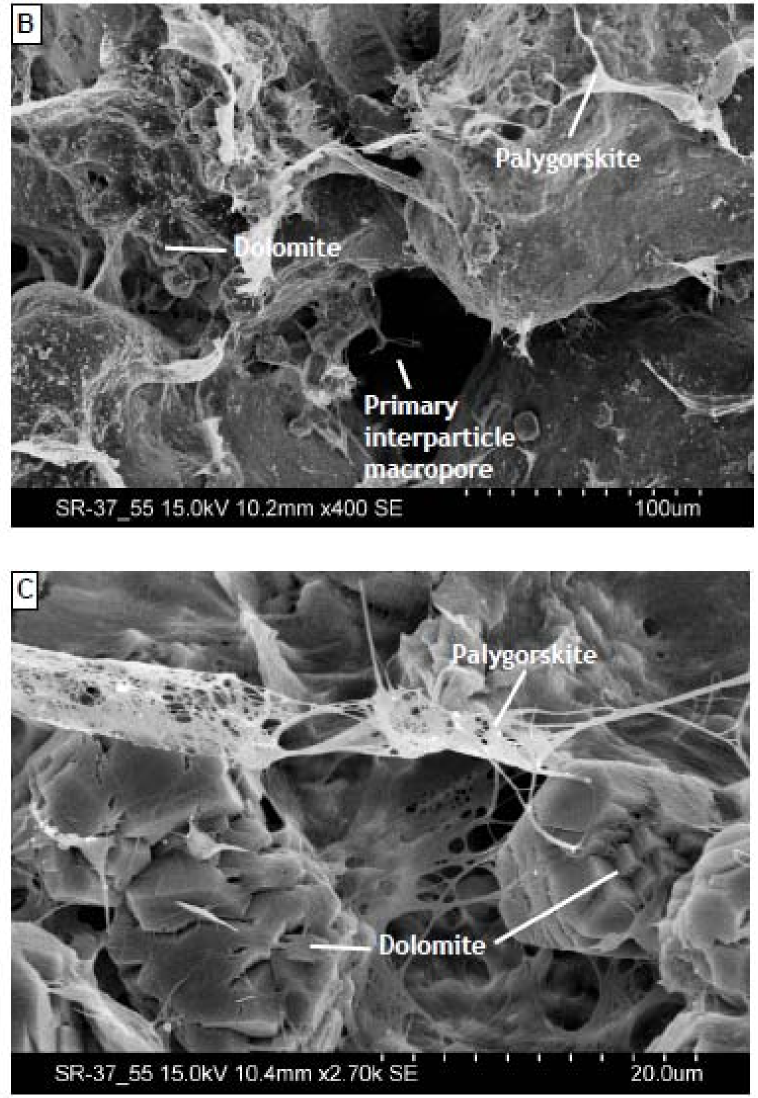


Figure 3. Case study 3.



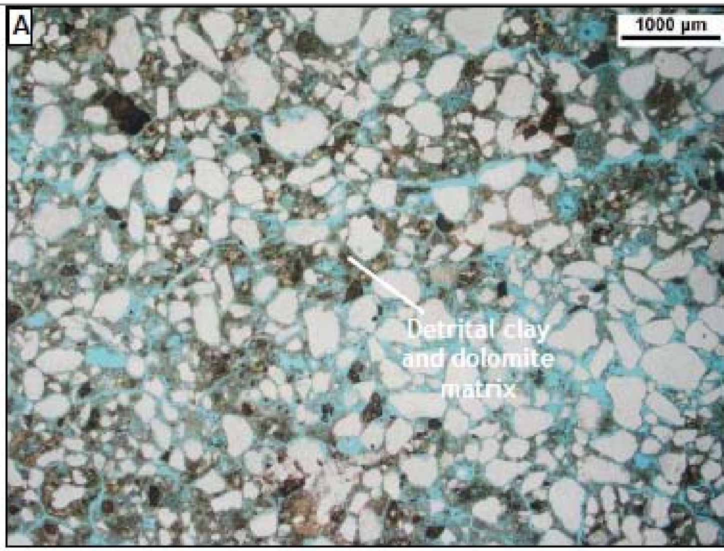


- This sample was selected for SEM as from thin-section observation the presence of palygorskite was deemed very likely.

- The sample is a relatively clean sandstone (photo A and B).

Under the SEM:
- The sample is relatively clean, with abundant primary macropores (photo B).
- The sample contains moderately abundant palygorskite (photos B and C), which primarily occurs with a web-like fibrous habit that partially bridges macropores and coats grains.
- Finely crystalline dolomite is present on grain surfaces (photo B) and is commonly partially dissolved and overlain by palygorskite (photo C).
- Palygorskite was visually identified, but due to its finely fibrous nature and proximity to dolomite crystals the EDX results are inconclusive.

Figure 4. Case study 4.



- This sample was selected for SEM as from thin-section observation the presence of palygorskite was deemed likely.

- The sample is a dolomitised argillaceous sandstone (photo A).

Under the SEM:
- The matrix comprises a mix of detrital clay (which EDX analysis suggests may be composed of illite) and finely crystalline dolomite (photo B), which replaces the detrital clay.
- Minor palygorskite (photo C) occurs as very fine, web-like fibres that can bridging macroporosity.
- Palygorskite was visually identified, but due to its finely fibrous nature and limited abundance the EDX results are inconclusive.

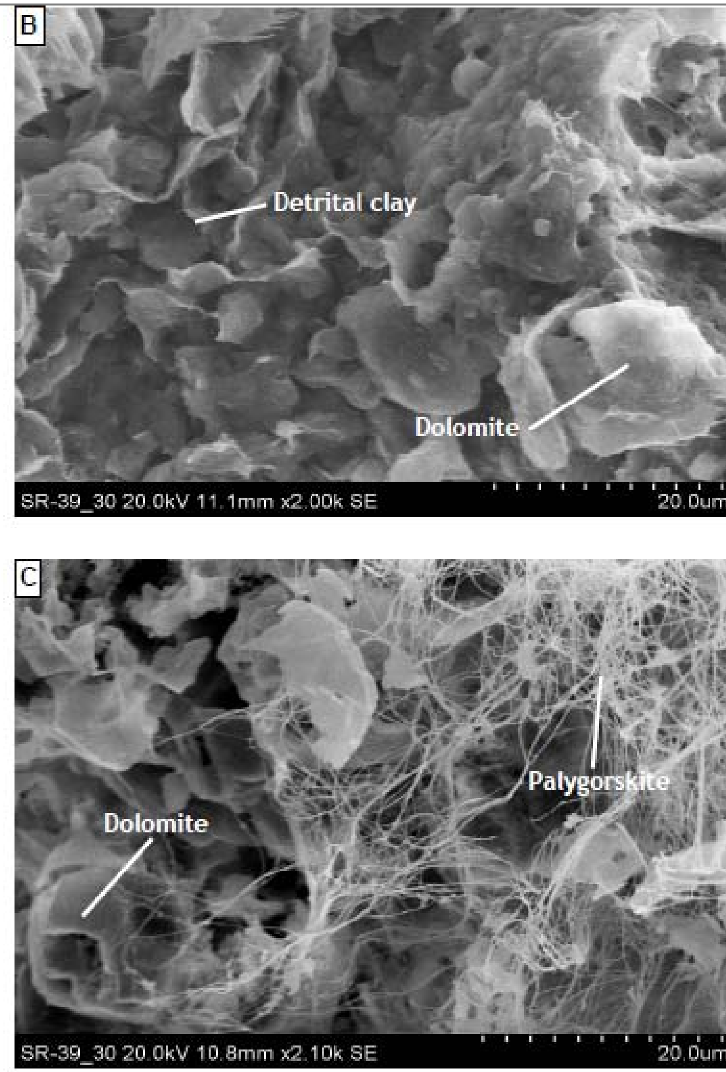


Figure 5. Case study 5.

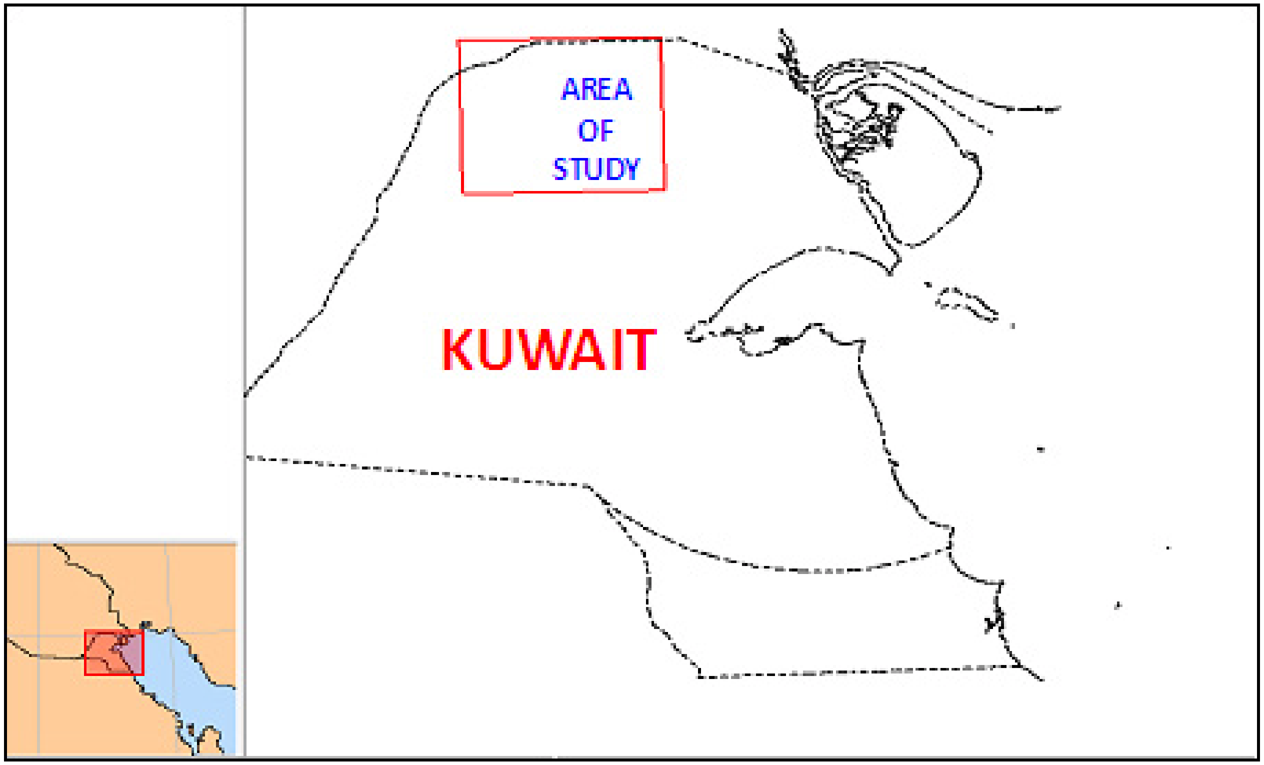


Figure 6. Location map of study area.