# Travertine-Tufa Deposition in Relation with Gafsa-Jeffara Fault System: Implication on Fluid-Flow (Southern Tunisia)

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**Abstract**

Travertine and Tufa are continental carbonate deposits that originate from deep geothermal systems supersaturated by bicarbonates. These non-marine carbonates are characterized by complex interactions between biological, chemical and physical processes that make them interesting recorders of climatic and environmental changes. Previous works have shown that exhumed travertine affected by active tectonics could be an ideal tool in understanding the relation in a fault-fluid flow. The principal purpose of this work is to carry out for a the first time a detailed study on representative rock samples of Jebel El Mzar (Southern Tunisia, province of Kirchaou): "a thermogene travertine and tufa" related study to the Gafsa-Jeffara fault system activity which is characterized by diverse facies. Geochemical, microstructural, petrological and petrophysical studies of Travertine/Tufa samples were carried out.

**Keywords**

Travertine-Tufa • Active faults • Fluid flow
Petrophysical • Geochemical

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## 1 Introduction

Travertine refers to all non-marine carbonate precipitation formed at or near terrestrial springs, rivers, lakes, and caves and divided into two categories: Meteogene and Thermogene [7]. The meteogene travertine is usually referred to as "tufa", especially when it contains remains of micro and macrophytes, invertebrates and bacteria. Thermogene deposits of $CO_2$ have a deeper origin as their source is either magmatic degassing or a decarbonation processes. Such deposits are typical of tectonically active areas related to active faults [4, 6]. In this work, travertine-tufa deposits are related to the Gafsa-Jeffara fault system. The Gafsa fault is an active NW-SE strike slip fault. It passes through different lithostratigraphic formations. It extends to the SE called Tunisian south accident [5] or Jeffara fault [3] (Fig. 1).

The main objective of this work is to highlight the relationships between faults and their associated features (e.g. banded calcite veins, fractures), and fluid flow (travertine deposits) and to characterize the geochemical feature of parental fluids deposited during tectonic activity.

## 2 Geological Setting and Methods

### 2.1 Geological Setting

Located in Southern Tunisia (Government of Tataouine, Province of Kirchaou), Jebel El Mzar is an isolated massif in the plain of Touazine. Consisting essentially of tufa and travertine with white banded calcite and traces of iron and manganese. Its thickness is about 50 m. The presence of vegetal print "Sabal Major" ages it to the Aquitanian era [2]). The position of this massif at the intersection of E-W and NW-SE, highlights the existence of hydrothermal activities [2] (Figs. 1, 2).



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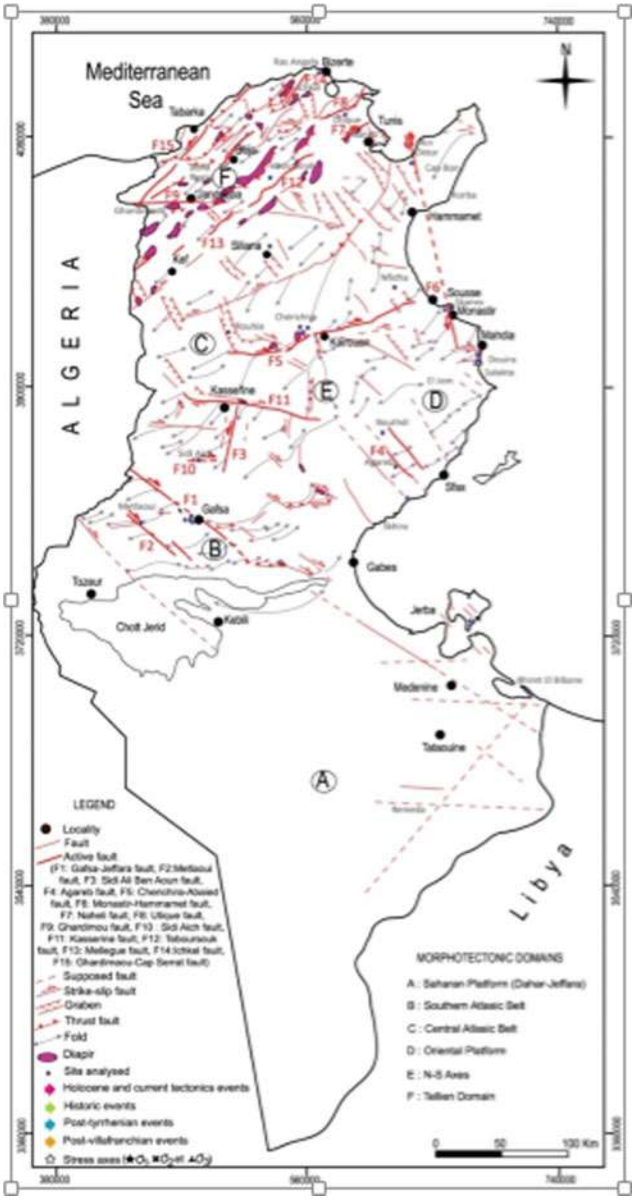


**Fig. 1** Structural map of Tunisia [1]

## 2.2 Methods

In order to characterize these Travertine and Tufa deposits, XRD analyses were done to determine their mineralogical composition. Textural features, microfacies, diagenetic phases, and deformation microstructures were investigated by optical and scanning electron microscopes (ESEM, FEG-SEM). Trace element concentration tests were carried out based on semi quantitative analysis using X-ray fluorescence. Some samples were selected for fluid inclusion microthermometry based on the presence of sufficient number of fluid inclusions to determine the temperature and salinity of fluid precipitation. Stable C-O isotopic analysis of veins allowed the identification of the $CO_2$ source. Raman Spectroscopy was used for the assessment of mineral composition, fluid inclusion composition. The facies reservoir properties (porosity and permeability) were studied by 4D X-ray computer tomography (XRCT) on large slabs.

# 3 Results

## 3.1 XRF

See Table 1.

## 3.2 Petrography, Diagenesis, Paleontology, Deformations Microstructures, Fluid Inclusion and Raman Spectroscopy

See Fig. 3.

## 3.3 X-Ray Computed Tomography (XRCT)

See Fig. 4.

# 4 Conclusion

The mineralogical compositions of the total travertine samples mainly consists of calcite with varying amounts of quartz (i.e., detrital quartz). Fluid inclusion and Raman spectroscopy studies show that three-phase inclusion present $H_2O$ (l), $CO_2$ (l) and $CO_2$ (g), varying in size, shape and chronology.

Fieldwork combined with a microstructural deformation study highlighted a brittle deformation due to the presence of micro-faults, cracks, joints, veining, stylolites, deformation twins etc. This confirms that the travertine-tufa deposition in Jebel El Mazar is highly controled by the fault activity and that the calcite veins act as feeding conduits.

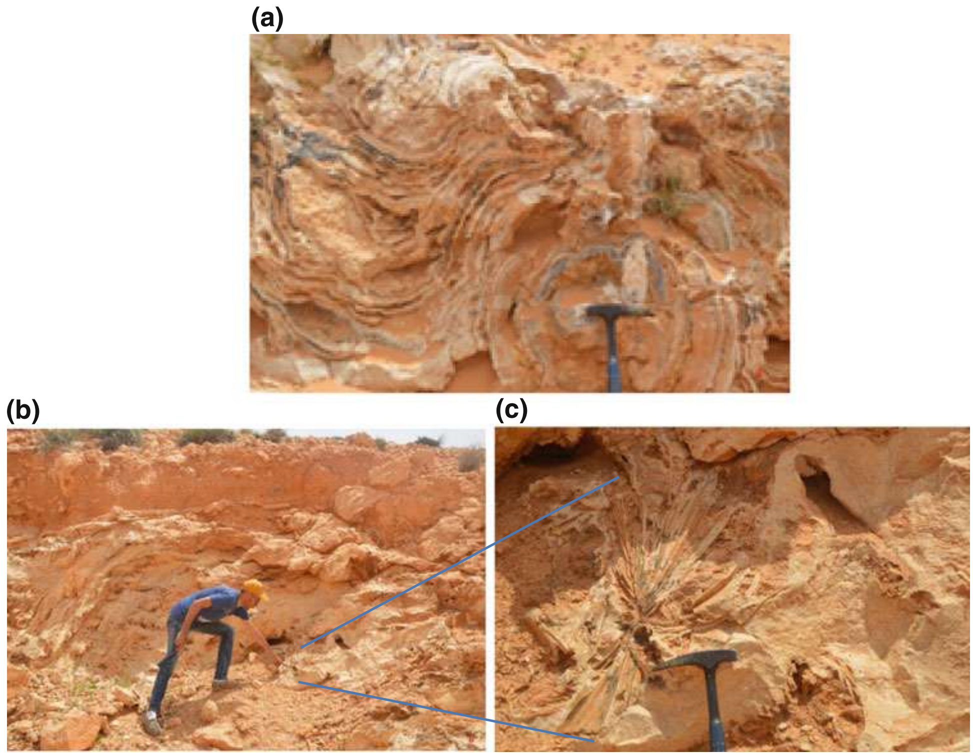

**Fig. 2** **a** Circular central veining surrounded by undulated banded veins developed in Consequence of repeated episodes of Carbonate deposition within the same fracture playing as conduits, **b** and **c**: 'Sabal major': Aquitanian (Miocene) in Age

**Table 1** X-ray fluorescence results of major and minor elements of sample 6 (wt%)

| $Na_2O$ | $MgO$ | $SiO_2$ | $P_2O_5$ | $Cl$ | $K_2O$ | $SO_3$ | $Al_2O_3$ |
|---|---|---|---|---|---|---|---|
| 0.0928 | 0.437 | 6.28 | 0.0596 | 0.0938 | 0.268 | 0.161 | 2.72 |
| $CaO$ | $TiO_2$ | $MnO$ | $Fe_2O_3$ | $NiO$ | $CuO$ | $ZnO$ | $SrO$ |
| 87 | 0.191 | 0.160 | 2.50 | 0.0107 | 0.0104 | 0.0072 | 0.0287 |

Petrography combined with a petrophysical study show different facies associations with dominant components of micrite, sparite and microsparite, and a variety of porosity types: inter and intra particle, channel, fenestral, vugs, moldic, shelter etc. The presence of fossil fauna and flora, and diagenetic processes (cementation, dissolution, recrystallization, fracturing etc.) was also revealed by the aforementioned study.

XRCT provided informations about the reservoir characteristics of travertine-tufa (porosity, permeability, interconnectivity etc.). The comparison between the XRCT results of different samples showed the impact of diagenesis and microstructure deformation on porosity and permeability (e.g., Stylolitisation causes decreases in the porosity, permeability).

The presence of fauna, flora, and the repetitive alternation of colors confirm that the travertine-tufa deposition is controlled by the biota and climate.

The travertine-tufa of Jebel El Mazar is an exhumed hydrothermal system and could be a reservoir analog for active hydrothermal systems and a key for future hydrothermal exploration.

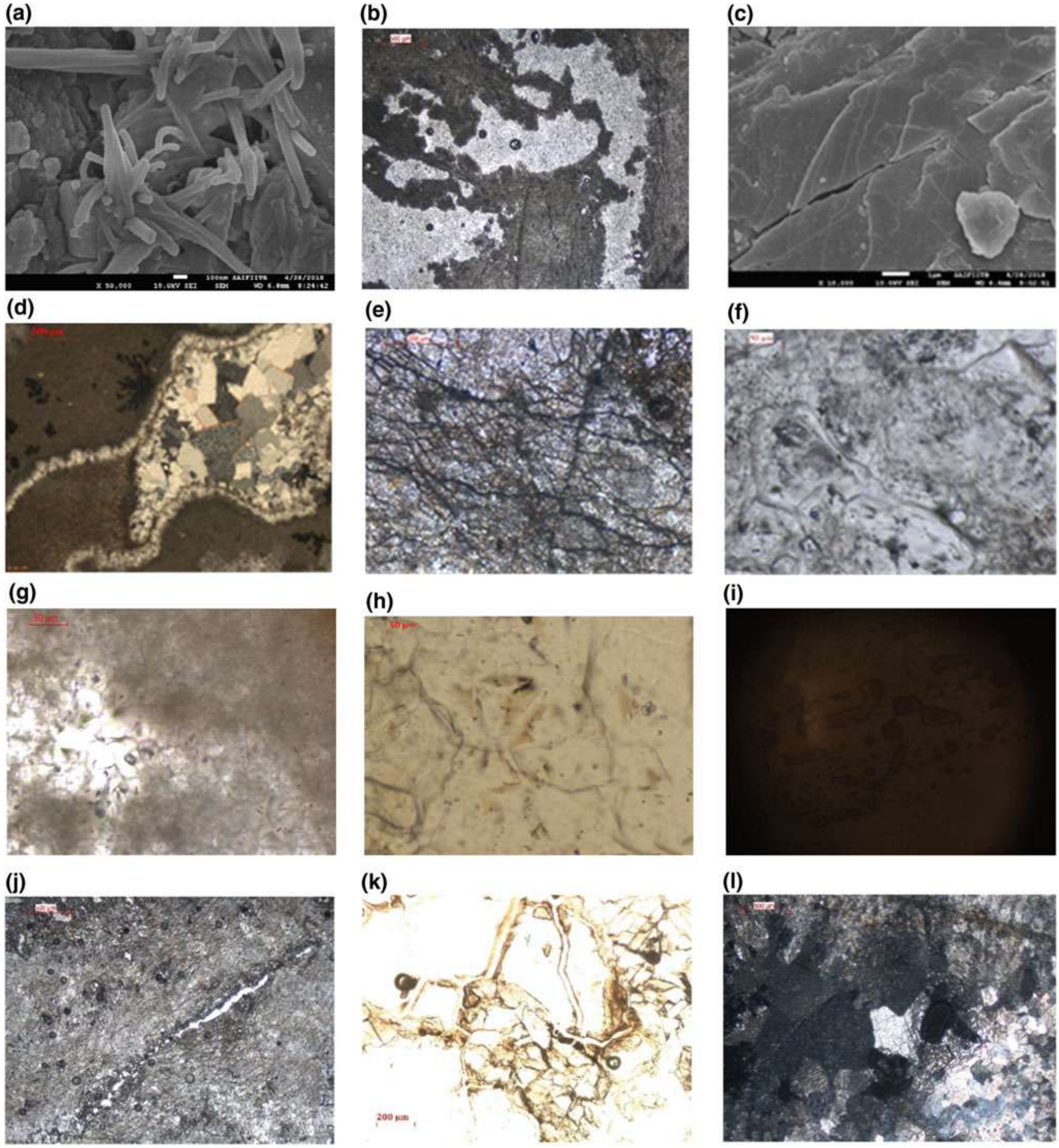


**Fig. 3** **a** A SEM image of Shrub Travertine displaying bacterial rods encased within calcite crystals. **b** Micrograph showing fenestral fabric with elongated spar-filled pores in micritic sediment (PPL). **c** SEM image showing the geometry and shear sense of Riedel Y-S shears. **d** Micrograph showing calcite cement (the size of the crystals increases away from the initial substrate of the sparry mosaic, The intercristalline boundaries in the mosaic are made up of plane interfaces and a high percentage of enfacial junctions among the triple junctions (XPL). **e** Thin-section photomicrograph showing solution seam stylolite with residue accumulation. **f**, **g**, **h** Examples of Fluid inclusion in Calcite (Vapour-Liquid inclusion), **i** Photomicrographs of Fluid inclusion in Calcite, during Raman Spectrometry analysis. **j** A thin section of photomicrograph showing stylolite-associated porosity (PPL). **k** A thin section of photomicrograph showing inter-particle, intra-partice and channel porosities (PPL). **l** A thin section of photomicrograph showing deformation twins in calcite (XPL)


**Fig. 4** **a** Picture shows the sample 8, cut into 2 cm cube for XRCT scanning. **b** Sample 8 in three-dimensionality illustrate fabrics, pores, and overall structure. **c** XRCT image gives information about the pore shapes, volumes and connections. *Note* darker gray (or Black) shades represent lower optical densities (porous phase) and lighter gray shades represent the solid phase

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