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Petrography and mineralogy of Roman mortars from buildings of the ancient city of Jerash, Jordan

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HIGHLIGHTS

- We obtained the structural data about Roman mortars of ancient buildings of Jerash.
- We studied the mineralogy, petrography and geochemistry of cementing materials.
- We compared the composition of these mortars with other Roman mortars.
- We covered the archaeological buildings of Roman Jerash city in Jordan.

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ABSTRACT

Roman mortars (cementing materials) from the archaeological site of Jerash have been studied by means of petrography, mineralogy, microstructure and geochemical analysis. They are mainly composed of lime with differing in the type and proportion of aggregates used, including crushed carbonate rocks (limestone), gypsum, and siliceous sand. The samples were studied in order to identify their mineralogical composition using thin section, XRD and SEM and their chemical compositions were analysed using XRF. The results showed that two types of natural aggregate sources were used: the first was composed of calcite, gypsum and quartz while the second was composed of calcite gypsum, clay minerals and crushed pozzolan. One sample of the first type showed fine particles with micrite matrix and clay minerals. Petrographic analysis showed the strong binder cohesion and perfect binder bond of aggregate and high reactivity for of the lime, and these agree with soft burning of the raw limestone.

1. Introduction

Jerash is one of the Roman Decapolis and representing one of the greatest and most important archaeological sites in Jordan. As ancient classical city, it was called Gerasa during the classical period. It was the Roman city in 63 B.C. and become part of the Roman province of Arabia in A.D. 90 [1].

Jerash is characterized by impressive Roman architecture. Buildings of the city includes, Hadrian's arch, Temples of Zeus and Artemis, Oval Plaza which is surrounded by Corinthian columns of a fine Ionic order and opened onto Colonnaded street, Hippodrome the Southern theater and North theater (Fig. 1). The Roman architecture of the city is one of the most boasted, valuable and remarkably well-preserved remains of the ancient civilizations lived in this region. Therefore, Roman architectural designs have been present days in buildings and homes throughout the modern world. However, Roman mortars used in constructions of the ancient city of Jerash are the focus of this study. They have been attracting the attentions of researchers concerning their chemical composition that reflects their distinctive durability [2].

Despite of the cultural importance of this city, compositional characterization of Roman mortars, used in the constructions of this city, has never been investigated. This preliminary study however, fuscous on obtaining structural information about Roman mortars (cementing materials) used in archaeological buildings of Jerash by studying the mineralogy, petrography and geochemistry

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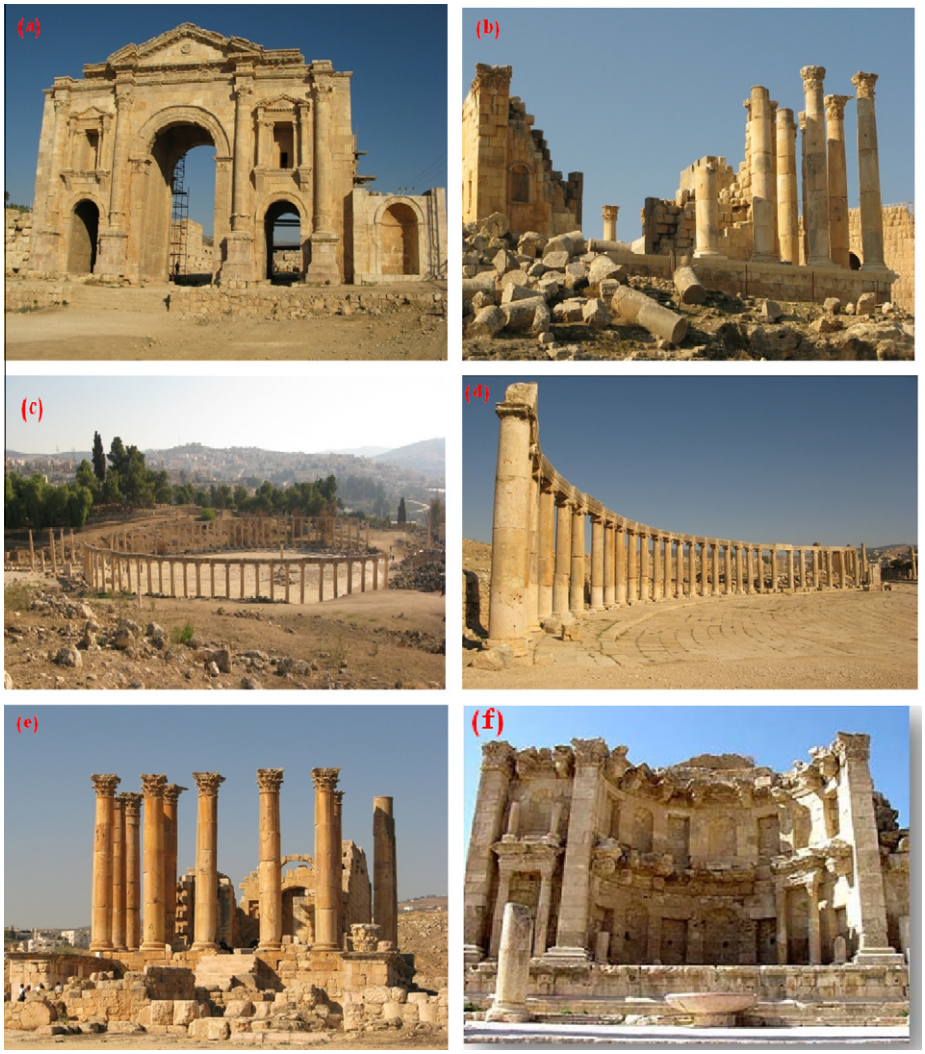

Fig. 1. Location site study of the ancient Jerash City, (a) Hadrian's arch at the south end of the city, (b) the Temple of Zeus, (c) a view of the Oval Piazza, (d) the ionic columns surrounding the Oval Piazza, (e) the Temple of Artemis, and (f) Nymphaeum.

of the cementing materials. The composition of these mortars will be compared with other Roman mortars described in the archaeological record.

2. Methodology

2.1. Sampling and analytical techniques

Nine samples of Roman cementing materials (CM1–CM9) were collected from the boundaries between stones (Fig. 2) found at different locations in the ancient buildings (Fig. 1) at the city of Jerash. Scanning Electron Microscope (SEM)-FEI, Model: Quanta-600 was used for studying the microstructure and investigating the nature of mortar particles and texture relationship. The mineralogical composition was evaluated by X-ray Diffraction (XRD) using a Phillips difractometer with Cu Kα radiation. The chemical analysis of the major elements of the whole samples was carried out using Phillips X-ray Florescence (XRF) Majex PW-2424 model, a valuable at the University of Al al-Bayt (Water Environment and Arid Regions Research Center). Thin sections were prepared via vacuum impregnation with an epoxy resin/hardener for each sample and cut with oil to avoid damaging water-soluble minerals in the mortars. They were polished to the standard thickness of 30 μm, covered with a glass slip and examined with polarizer microscope available at the University of Jordan. Microphotograph of samples was used Leitz Labrlux IZ Pols Polarizer Microscope and Olympus OM-4 Ti Camera in petrography unit at Natural Resources Authority.

3. Results and discussion

3.1. Petrography

The preliminary observations of petrographic analyses of samples CM2, CM3, CM6, and CM7 show that the mortars contain rounded nodules of lime (CaO), which may indicate that the lime was slacked with minimum amount of water in order to convert lime into calcium hydroxide $Ca(OH)_2$. The presence lime carbonate ($CaCO_3$) in these mortars however, indicates that the decarbonation of calcareous rocks during the production of lime was incomplete, possibly due to the use of low temperature, or insufficient time of heating [3–5]. Sample CM9 shows that the mortar contains mafic minerals with brownish to black color with pozzolan sources. This mixing of materials is a characteristic to the Roman mortar (concrete), which is formed when lime carbonate ($CaCO_3$) is mixed pozzolan to produce strong durable material used on the construction of buildings [6].

Optical microscopy for the mortar composition of samples CM1, CM2, CM3, CM5, CM7 and CM9 are shown in Fig. 3. The analyses