The quarryscapes of Gerasa (Jarash), Jordan

Nizar Abu-Jaber, Ziad al Saad and Nihad Smadi

Yarmouk University, Irbid, Jordan.
E-mail: abujaber@yu.edu.jo

The quarry landscapes of Jarash offer an important opportunity to understand ancient Gerasa in its natural environment as well as its building materials. A number of quarry sites have been documented in the Jarash area as part of the QuarryScapes project, including four major locations at Asfur, Al Shawahid, Wadi Suf and Majar. The quarries were used to extract building stone from the Upper Cretaceous Naur, Fuheis and Wadi As Sir Formations of the Ajloun Group. The limestone from the quarries is easily correlated with most building stone used for the construction of Gerasa using petrographical analysis. The quarry sites include intriguing evidence of the extraction techniques. Tool marks, evidence of chiselling, dressing and extraction planning, as well as unfinished blocks and columns, are commonly seen at the quarries. These quarry sites should be considered an integral part of Gerasa as cultural heritage sites that can give visitors a chance to better appreciate the ancient city in its natural setting, at a distance from the modern city of Jarash. Unfortunately, urban expansion poses a threat to these sites and endangers their existence and undermines their protection. The situation is exacerbated by inadequate legislation and lack of an effective conservation strategy.

Introduction

Background

The ancient Graeco–Roman city of Gerasa is a magnificent example of a large provincial capital from the period. It attracts visitors from all over the world to admire its majestic architecture. However, due to the proximity of the modern city of Jarash, and the impingement of this city on the archaeological site, it is difficult to visualise the ancient city in its true natural environment. The reason why this site was chosen for early settlement can easily be appreciated if the environment is understood (strategic location, availability of water, building materials and agricultural resources). While it is a shame that the setting is obscured by the modern city, little can be done to alter this reality.

The quarries from which stone was extracted to build the ancient city provide an excellent opportunity to allow visitors to better appreciate the hinterland of Gerasa. A number of excellent examples of Roman quarrying sites in the area

Abu-Jaber, N., al-Saad, Z. and Smadi, N. (2009) The quarryscapes of Gerasa (Jarash), Jordan. *In* Abu-Jaber, N., Bloxam, E.G., Degryse, P. and Heldal, T. (eds.) *QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean*, Geological Survey of Norway Special Publication,**12**, pp. 67–75.

can be seen and appreciated. These sites deserve documentation and protection both for their archaeological value, as they record ancient technology adopted for stone extraction, and for their tourism attraction potential. Current legislation and land-use practices will offer no long-term protection for these sites. If this situation is to be changed, the decision makers should be convinced of the high significance and value of these sites. This can only be done through full documentation and analysis. Interpretation and presentation of these sites, as well as any attempt to convince decision makers of their value will only be convincing when all relevant information is readily available. Detailed assigning of significance, as articulated by Bloxam (2009) is beyond the scope of this paper. However, it is clear that some aspects of quarry significance can be easily identified in the Gerasa quarry landscapes (i.e., stone sources and production), while others such as logistics and social context are difficult to recognise.

Few previous studies have been made on the quarries of Gerasa (Utoum 2003). The focus of these studies was on the building materials used in terms of their nature and characteristics and not on the ancient quarrying and quarrying techniques. The various aspects of the ancient quarrying as a process have not been dealt with.

The QuarryScapes project was initiated to highlight the importance of stone sources and their extraction locales and techniques in the eastern Mediterranean. While ancient monuments are well protected and presented, the quarries from which the monuments were built often receive little recognition or protection.

As part of QuarryScapes, Yarmouk University undertook the study of the Early Bronze chert quarries of Al Jafr, the Nabatean sandstone quarries of Petra and the limestone quarries associated with the Graeco–Roman city of Gerasa. The purpose of this paper is to report and document some of the most significant examples of quarry sites related to ancient Gerasa, with respect to geology, landscape, notable features and potential threats. How the various quarries contributed different stone for different uses will also be explored based on petrographical analysis.

Location

Jarash is situated about 40 km north of Amman and about 30 km south of Irbid (Figure 1). The topographical map sheet of the region covers an area of 660 km^2, located between coordinates 35°45`–36°E and 32°15`–32°30`N. It lies within the drainage basin of Wadi Jarash, which in turn drains into the Zerqa River to the south of the city of Jarash. The upper reaches of the Wadi Jarash drainage basin are relatively steep, and are covered by a mixture of forests, planted orchards and fallow lands. This area was where most Roman quarrying activities took place. Downstream, the ancient city of Gerasa is located. Gerasa is one of the most complete examples of a provincial Roman city to be seen anywhere. The site now lies on a modern highway that links Amman with the north of the country. The topography of the area is illustrated in Figure 2.

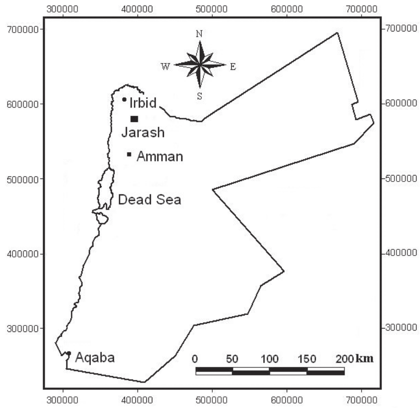

Figure 1. Location map of study area of Jarash.

Climate

The majority of the area is within the mountainous part of the northern highlands of Jordan. Winters are cold with a mean daily temperature of less than 10°C, and it receives a relatively high mean annual rainfall exceeding 500 mm. Summers are fairly hot and dry, with a mean monthly and yearly temperature of 20°C, and practically no precipitation.

The geology of Jarash

The geology of the Jarash area was described and mapped by Abdelhamid (1995). The sheet area, which lies in close proximity to the Jordan valley rift located about 15 km to the west, is dominated by sedimentary rocks, mainly of Late Cretaceous age. These include in upward

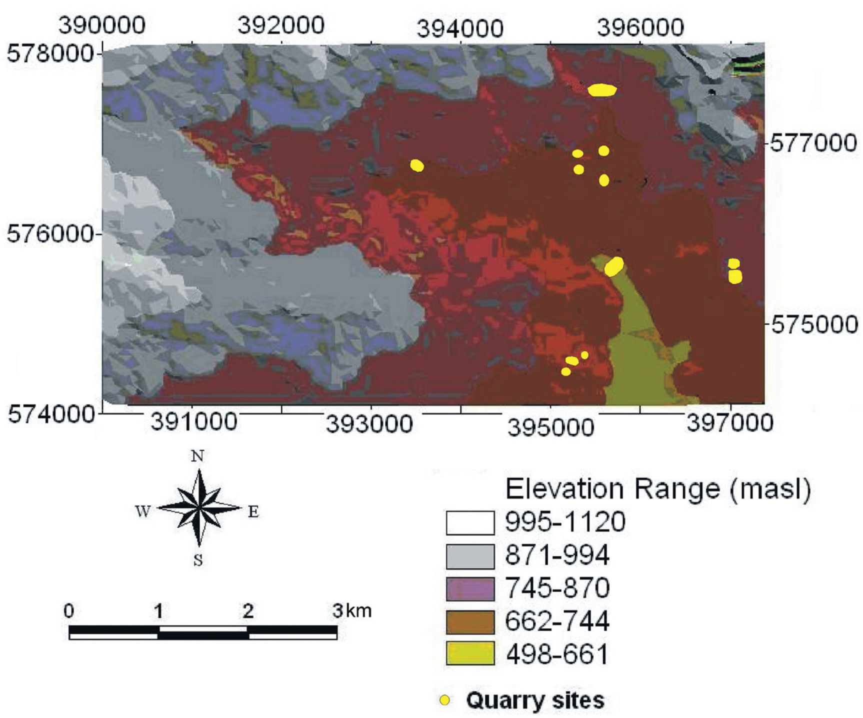

Figure 2. Elevation map of the landscape.

sequence the Kurnub Sandstone Group (Lower Cretaceous), the Ajloun Group (Cenomanian–Turonian) comprising the Naur limestone, Fuheis, Hummar, Wadi Shuayb and Wadi As Sir formations, the Belqa Group comprising the Wadi Um Ghudran and Amman Silicified formations (Coniacian–Campanian), and small outcrops of the Muwaqqar and Um Rijam chert limestone formations (Maastrichtian–Eocene). The characteristics of these formations as described by Bender (1974) and Abed (1982a, b) are summarised in Table 1. Figure 3 is a simplified geological map of the area.

Quaternary sediments and soil consist of brown to red and pale brown soil of varying thickness found throughout the study area. Thick caliche layers reflecting weathering in arid conditions are also found throughout the area. This caliche is easily mined and devoid of joints, making it ideal for extracting large building stones. Caliche was used in the building of Jadara as well, specifically in some of the columns of the main temple (Bashaireh 2003). The ancient quarry sites described in this paper are largely coated with thick caliche, often obscuring the original stone that was extracted at the site, and sometimes making determination of the formation from which the stone was quarried difficult.

The area contains an E–W fault system, a NNE and a NW fault, possibly of Late Tertiary age. Gentle folds are present, and are subparallel and mainly characterise the central and western parts of the sheet area. The rest of the regional structure, the Ajloun Dome, is centred near Ibbin a few kilometres NE of Ajloun to the west of Jarash. Landslides are common along the steep wadi sides in the western and southern part of the sheet area, where marly formations such as the Naur and Wadi Shuayb formations crop out.

Limestone, mainly from the Wadi As Sir Limestone Formation in the western and central parts of the sheet area, has been quarried for many years for good-quality building stone and aggregates. The majority of old sand mines in the Kurnub Sandstone in the central southern part have been abandoned. Building stones are well known historically and archaeologically due to the presence of ancient Roman and Islamic settlements, which stand as evidence of the use of limestone for building purposes. While the ancient quarry sites described herein are from the older Naur and Fuheis for-

Table 1. The major stratigraphy found in the Jarash area (summarised from Bender (1974) and Abed (1982a, b)).

Group	Formation	Description	Thickness (m)	Has it been quarried?
Belqa	Amman Silicified Limestone	Medium- to thin-bedded, locally thick chert, silicified limestone, limestone and phosphatic chert, and a few thin phosphatic beds at the top		No
	Wadi Um Ghudran	Yellow to white grey or pink grey fossiliferous chalky limestone. Upper part typically pink to yellow grey, hard, medium- to thin-bedded, fossiliferous to coquinoidal, and with chert concretions and bands towards the top		No
Ajloun	Wadi As Sir	Thick-bedded to massive limestone with steep distinctive rocky slopes. Hard, partially dolomitised.		Yes
	Wadi Shuayb	Yellow to yellow grey thin- to medium-bedded marly limestone, commonly nodular, fossiliferous to locally shelly and coquinoidal		No
	Hummar	Hard limestone, mainly of pink to yellow grey, partly dolomitised, locally marly limestone	75	Yes
	Fuheis	Marls and marly nodular limestone	50	Yes
	Naur	Marly limestone, marl and clay, commonly grey to yellow grey limestone. It is nodular and marly, fossiliferous, medium to thick bedded	180	Yes, in a few horizons near the top.
Kurnub	Kurnub	Medium- to coarse-grained quartz arenite with a few marine intercalations of dolomite and shale		No

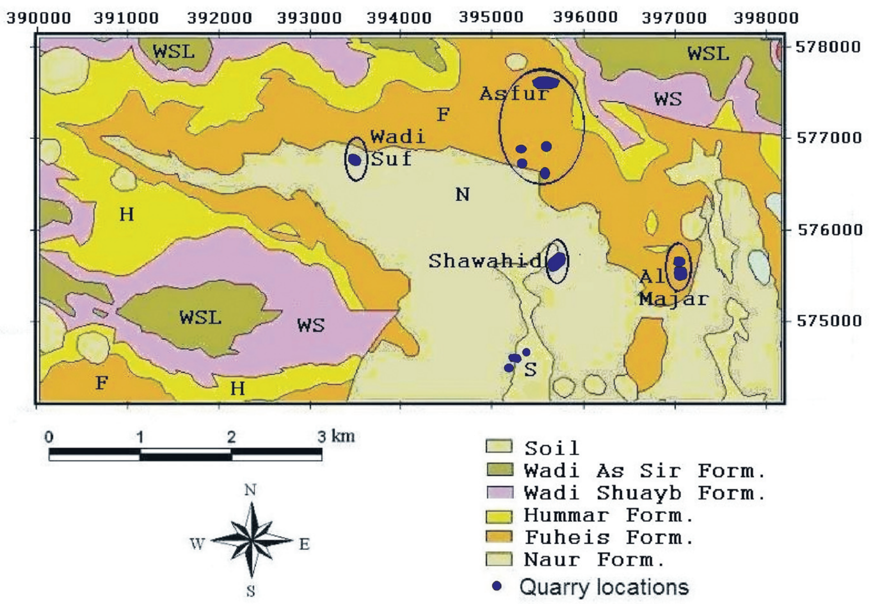

Figure 3. Simplified geological map showing the major quarry sites.

mations, more recent extraction has been focussed on the Wadi As Sir Formation.

Good quality micritic to spary-micritic limestone from the Wadi As Sir limestone and, locally, the Naur limestone and Hummar formations have been quarried for a long time as decorative building stones and for use as aggregates. Part of the thick-(>30 cm) to medium-(5–30 cm) bedded, milky to light grey micritic limestones of the upper Wadi As Sir formation, in the western part of the study area, could be used for ornamental purposes. Additionally, caliche has been quarried at some locations. To the west, near the Jordan valley, travertine is also mined for building and ornamental purposes (El Radaideh and Mustafa 2008). Some examples of travertine are found in Gerasa, and it is possible that the Romans used the same source as is currently extracted near Dair Abu Said.

History and archaeology of Jarash

Known as the 'Pompeii of the East', Jarash (known as Gerasa in the Classical time) is considered to be one of the best preserved and most complete Roman cities in the world. The ancient town of Gerasa, located 48 km north of the Jordanian capital of Amman, is one of Jordan's most famous archaeological and tourist sites, and visited by thousands of sightseers every year. Founded in the Hellenistic Period (332–63 BC), probably on the site of an earlier Iron Age settlement, the city was transformed in the Roman Period by the construction of an urban grid featuring paved and colonnaded streets and major monuments. Included among these are huge temples, theatres, and open public spaces, especially the famous 'Oval Piazza' in front of the Zeus temple.

From the middle of the 5th century, Christianity was the major religion and the construction of churches proceeded apace. Under the Byzantine emperor Justinian (527—565 CE) seven churches were built, mostly out of stones pillaged from the earlier Roman temples and shrines (Clark 1986).

At the time of the Islamic expansion into Syria–Palestine (635–640 CE), Gerasa conceded to Islamic leaders without any destruction being inflicted on the city. Social and economical life continued unabated, and a large mosque was built in the centre of the city.

With the destruction of the city by a devastating earthquake in 747, Gerasa's glory days passed into shadow and its population shrank to about one-quarter of its former size (Kraeling 1938, Pierobon, 1983–1984, Meyer 1988).

Apart from a brief occupation by a Crusader garrison in the 12th century, the city was completely deserted until the arrival of the Circassians from Russia in 1878, after which the site's archaeological importance was realised and excavations began.

The archaeological park at Jarash encapsulates the western half of the Graeco–Roman city as defined by the ancient city walls. Within it the remains are protected. The eastern half of the ancient city has been largely overbuilt beginning in the late 19th century when the modern town of Jarash was established.

The quarries of Jarash: current investigations

As part of the QuarryScapes project, ancient quarries in the Jarash region are documented and described by the Yarmouk University team through surveys in and around Jarash. Many quarries are found in the surrounding areas including the Asfur, Al-Shawahed, Wadi Suf and Al-Majar.

Methodology of the study

Preliminary field surveys and literature studies were conducted to locate the quarry sites and to contextualise them in the landscape. Following this, air photo, topographical, geological and archaeological data were used to construct a GIS database of the region. Later, more detailed surveys of the quarry sites were conducted using standard surveying techniques. Samples from the quarries and rubble from the archaeological site at Gerasa were collected for comparison. The materials examined in this study consisted of samples from the ancient city of Gerasa, as well as samples from the Wadi Suf, Al Shawahed, Al Majar and the Asfur areas of Jarash, where the ancient quarries were studied and documented. Limestone samples were collected and described based on their colour, mineralogy, texture and use. These samples were analysed in order to define criteria for provenance determination of ancient stone in Jarash and nearby areas.

Thin sections of the samples were made at the workshops of Yarmouk University and were investigated using a standard petrographical polarising microscope. This work aimed to define a series of parameters of significance, notably the mineralogy and texture of the rock and their value for provenancing.

Asfur quarry

This quarry was largest in terms of area. It currently lies on both sides of the street from Jarash to the Suf Refugee Camp. This area is known as 'Rubwat Al-Jundi'. This quarry shows much evidence of quarrying processes such as incomplete columns (Figure 4), traces of cutting blocks in quarries (Figure 5), and traces of industrial grooves (Figure 6). The Fuheis Limestone Formation crops out at Asfur quarry, and consists mainly of dolostone. The elevation of Asfur ranges from 746 to 871 m asl, and other nearby small quarries range from 622 to 746 m asl (Figure 2). The slope of Asfur is between 0 to 20°, but other near small quarries are 0 to 10°. Aspect of Asfur is south (112.5–247.5°) and is nearly flat (~1°).

The dimensions of Asfur quarry 77 m in width and 175 m in length, over a relief of 34 m. These dimensions show that the area is 13,475 m^2, and that ap-

Figure 4. Incomplete quarrying and transporting columns from the Asfur quarry landscape.

Figure 5. Traces of cutting blocks from the Asfur quarry landscape.

Figure 6. Traces of industrial grooves of column from the Asfur quarry landscape.

proximately 26,000 m^3 of stone was removed, assuming an average removal of 2 m in thickness. Unfortunately, no evidence of the logistical infrastructure for quarrying has been identified.

Al-Shawahed quarry

Another major quarry site is known as the Al-Shawahed quarry, which is set to the east of Wadi Suf. It consists of the hill faces surrounding the Suf Refugee Camp, northwest of Jarash. Evidence of the quarrying process is borne out by the many traces of cutting blocks and man-made grooves in the quarry faces. The soft and easy-to-quarry marly Naur Limestone Formation crops out at the Al-Shawahed quarry. Building blocks from this formation have been observed at Gerasa, mostly used for non-ornamental functions. The proximity and ease of extraction probably made Al Shawahid one of the more important extraction sites in the region for low-quality stone.

The elevation of Al-Shawahed ranges from 373 to 497 m asl, the slope is 0 to 10° and the aspect is flat (~1°) to southwest (202.5–247.5°). The disseminated nature of the quarrying activities here makes it difficult to determine its dimensions or estimate how much stone was removed.

The quarry site here is in danger of encroaching urbanisation, and there are no legal or practical barriers to its ultimate removal from the landscape.

Wadi Suf quarry

The elevation of Wadi Suf quarry northwest of Jarash ranges from 622 to 746 m asl, the slope is 0 to 10°, and its aspect is south (157.5–202.5°). This quarry is damaged because of natural factors (biological and chemical weathering) as well as from reclamation of agricultural lands. Farmers removed some rocks under this quarry at the northeast end, where there is a Roman cemetery cut into the rock. This was presumably for land reclamation, extraction of stone for later buildings and possibly as a byproduct of treasure hunting. In Wadi Suf there are many small quarries and damaged cut rocks. This quarry includes traces of cutting blocks, and industrial grooves as well as incomplete and unmoved columns.

Caliche covering the upper part of the Naur Limestone Formation crops out here. This is a particularly massive caliche, that seems to have been quarried for itself, and used for massive objects such as columns. Caliche enjoys the benefit of having few fractures and joints.

Al-Majar quarry

Another quarry is at Al-Majar, west of Jarash and south of the Asfur quarry. The trace blocks cut from the quarry are evidence of the quarrying process. The dimensions of Al-Majar quarry are: width 27 m, length 35 m, and height 5 m. Thus the exposed quarry area is 945 m^2, and the extracted volume is approximately 4725 m^3.

The elevation of Al-Majar ranges from 746 to 871 m asl, the slope is 0 to 10°, and aspect is southwest (202.5–247.5°) to west (247.5–292.5°). The Fuheis Formation crops out at Al-Majar quarry, and consists mainly of dolostone.

An assessment of the state of preservation and threats

Jarash quarries and quarry landscapes are under threat, chiefly from modern human activities that erase all traces of ancient use. These quarries have not been properly studied or documented, and once modern exploitation starts, there is very little chance to recover any archaeological evidence.

The greatest problem seems to be the total lack of appreciation of the value of this ancient landscape not just by the locals but even by the decision makers who are responsible for the protection and safeguarding of the country's cultural legacy. This led to damage of the ancient quarries by human activities and to lack of any initiatives from the responsible government agencies to protect these important cultural remains. The sites are not legally protected by the Antiquities Law and therefore are under the threat of urban and agricultural expansion.

The encroaching agricultural activities within the sites have been going on for ages. The fields have expanded all around the sites with the consequence of covering a substantial part of ancient stone-quarrying remains and debris.

The rapid population growth results in uncontrollable urban expansion in the area. The threat of modern buildings within and near the sites is also helping in destroying the archaeological data and the environment. The foundations of the buildings required the levelling of the bedrock with the consequence that any rock cut features were obliterated.

Petrographical study

Due to variations in depositional environment and diagenetic history of limestone, variations in texture result and can be used to differentiate limestone from different sources. Herein, petrographical characteristics of limestone from the different sources and from the archaeological sites are studied and compared in order to ascertain how useful this approach may be for provenance studies for determining which stone came from which quarry. Both the Folk (1959) and Dunham (1962) classifications for textural classification are used to describe the microtexture of the limestone samples. It is recognised that petrographical study can give a great deal of information on grain fabric, texture and mineralogy, including grain size and shape, grain distribution, sorting lithology, sedimentary and organic structure, colour variation and cement.

Sample collection

Ten limestone samples were collected and grouped according to their colour and texture from the various quarry locations. In addition, four samples of the caliche were collected, including six samples from Gerasa.

Experimental methods

Experimental methods can be divided into field methods and lab methods. Field methods include the geological surveys and sampling.

Geological surveys

Geological surveys were made in order to identify the variety of rocks present in Jarash. Areas such as Asfur to the northeast, Al-Shawahid to the north, Al-Majar to the northeast, and Wadi Suf to the northwest where surveyed, as they are believed to have been used in the construction of the ancient city.

Lab methods

Thin sections were prepared for standard petrographical analysis (Kerr 1977). The thin sections were made in the workshop of Earth and Environmental Sciences at Yarmouk University. All of the thin sections were studied using polarising microscope for the identification of the minerals, and their textures for classification of the samples. Thin sections were stained with alizarin reds to reveal dolomite present.

Results and discussion of ancient limestone quarry sources

Macroscopical analyses

Sample numbers 1, 4 and 5 show nearly identical macroscopical features. These are grey to yellow grey colour, hard, locally fossiliferous, medium-bedded to locally thin and massive dolomite and dolomitic limestone with a distinctive dark grey to grey weathering colour. These rocks belong to the upper unit of the Fuheis Formation, and the samples were taken from the Asfur quarry landscape (Table 2).

Sample numbers 2, 3, 6, 14, 15 and 16 come from the upper unit of the Fuheis Formation. These samples are light grey to white and yellow grey, hard limestone, mainly micritic to locally marly. These samples were taken form the Asfur and Al-Majar quarry landscape (Table 2).

Sample numbers 10, 11 and 17 are grey to yellow grey, frequently marly, fossiliferous, medium- to thick-bedded, locally massive sparry micrite to micrite alternating with yellow to white grey marls. These came from the lower unit of Naur Limestone Formation, taken from the Wadi Suf and Al-Shawahed quarry landscape (Table 2).

Samples 12 and 13 show features that suggest that they come from the upper unit of Naur Limestone Formation, that consists of yellow grey to pink, hard, medium- to thick-bedded, locally dolomitic, mainly micritic limestone. These samples come from the Wadi Suf quarry landscape.

Petrographical analyses

Nomenclature for the microtextural analyses of the samples described above are shown in Table 3. Samples 1, 4 and 5 are composed mainly of pelloids, intraclasts and fossil fragments (burrows, echinoids, grastropods and bivalves); generally this microfacies is character-

Table 2. Macroscopical description of the limestone and caliche samples from ancient limestone quarries context.

Sample no.	Source	Grain size	Colour
1	Asfur	Fine–Medium	Yellow grey
2	Asfur	Fine	White to light grey
3	Asfur	Fine	White and yellow grey
4	Asfur	Fine–Medium	Yellow grey with light and dark grey
5	Asfur	Medium	Yellow grey with light grey
6	Asfur	Fine–Medium	White with light and dark grey
10	W. Suf	Fine–Medium	Grey to yellow grey with grey
11	W. Suf	Medium	Grey with light grey
12	W. Suf	Fine–Medium	Grey to pink
13	W. Suf	Fine	White with light and dark grey
14	Majar	Medium	White with light grey
15	Majar	Fine–Medium	White with grey
16	Majar	Fine–Medium	White to grey
17	Al-Shawahed	Medium	Grey with white grey

Table 3. Petrographical nomenclatures and classification of rocks in ancient quarries.

Sample no.	Allochems					Petrographical classification	
	Peloids (%)	Fossils (%)	Intraclast (%)	Mud supported	Grain supported	Folk (1959	Dunham (1962)
1					*	Biosparite–biomicrite	Wackstone–packstone
2	30	70		*		Poorly-washed pelbiomicrite	Wackstone
3	50	40			*	Poorly-washed biopelsparite	Packstone
4					*	Biomicrite	Grainstone
5		50	50		*	Sparse biointramicrite	Packstone
6	20	30		*		Poorly-washed pelbiomicrite	Wackstone–packstone
10					*	Biosparite	Packstone
11		40	10		*	Packed biomicrite	Packstone
12	60	40		*		Packed biopelmicrite	Wackstone–packstone
13	30	20		*		Biomicrite	Wackstone
14					*	Poorly-washed biopelsparite	Wackstone–packstone
15	10	30		*		Pelbiosparite	Wackstone
16	30	10			*	Biopelmicrite	Packstone–wackstone
17		30	10		*	Poorly-washed biosparite	Packstone

ised by a high percentage of allochems, dominance of primary micritic matrix and diagenesis that involved recrystallisation followed by dolomitisation. This microfacies consists of fossiliferous pelloidal wackstone–packstone–grainstone. Figure 7 is a micrograph of this facies.

Samples 2, 3, 6, 14, 15 and 16 consist of a micritic matrix with bioclasts and sparite cement, with recrystalisation of calcite spar. This microfacies consists of fossiliferous (bivalves and plecypods) pelloidal wackstone–packstone.

Samples 10, 11 and 17 are composed mainly of fossil fragments (foraminifera and ostracoda), inraclasts, micritic matrix and sparite cement. This microfacies consists of fossiliferous packstone.

Samples 12 and 13 consist of fossiliferous (echinoids) with biomicrite and pelloids. This microfacies consist of fossiliferous pelloidal wackstone–packstone.

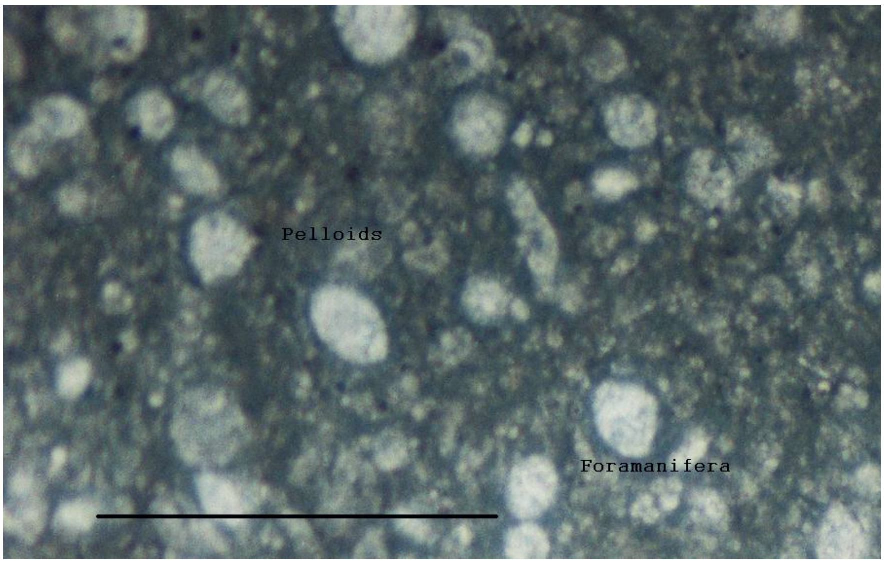

Figure 7. Photomicrograph of the Hummar Formation source rock from the area. It shows abundant pelloids and a few fossil foraminifera in a micritic matrix. Bar length is 2 mm.

Results and discussion of archaeological context

Macroscopical analyses

Sample number 27 is from upper North Theater, and is yellow grey to pink, hard, locally dolomitic, mainly micritic limestone (Table 4).

Samples 28 and 40 are from South Theatre and Colonnaded Street, respectively. These consist of light grey to white and yellow grey, hard limestone, mainly micritic and locally marly (Table 4).

Sample number 29 is from lower North Theatre, and consists of grey to yellow grey, hard limestone, with a distinctive dark grey to grey weathering colour (Table 4).

Sample numbers 38 and 39 are from the South Theatre and Colonnaded Street, respectively. These show identical features which are grey to yellow grey, marly, sparry micrite to micrite alternating with yellow to white grey marls, these samples from (Table 4).

Petrographical analyses

Petrographical characteristics of samples from the archaeological site are summarised in Table 5. Sample number 27 consists of pelloids and fossil fragments (echinoids) with biomicrite. This microfacies consists of fossiliferous pelloidal wackstone.

Sample number 28 and 40 are composed of peloids and fossils (bivalve and pelecypods), and micritic martrix with bioclasts and sparite cement. This microfacies consist of fossiliferous pelloidal wackstone–packstone.

Sample number 29 consists of pelloids, fossilliferous (echinoid spines) and intraclasts with biomicrite. This microfacies consist of fossiliferous pelloidal packstone.

Samples number 38 and 39 are composed of fossil fragments (foraminifera and ostracoda) and micritic intraclasts, matrix and sparite cement. This microfacies consists of fossiliferous packstone.

Correlation

It is clear that that there are obvious similarities between the samples taken from the quarries and those from the ancient

Table 4. Macroscopical description of the limestone samples from an archaeological context..

Sample no.	Source	Grain size	Colour
27	Upper North Theater	Medium	Grey with light red
28	South Theater	Fine	White to light grey
29	Lower North Theater	Medium	Grey to yellow grey
38	South Theater	Fine–Medium	Grey with light and dark grey
39	Colonnaded street	Medium	White to light grey
40	Colonnaded street	Fine–Medium	White and yellow grey

Table 5. Petrographical nomenclatures and classification of rocks in the archaeological context.

Sample no.	Allochems					Petrographical classification	
	Peloids (%)	Fossils (%)	Intraclast (%)	Mud supported	Grain supported	Folk (1959	Dunham (1962)
27	60	40		*		Packed biopelmicrite	Wackstone
28	30	70		*		Poorly-washed pelbiomicrite	Wackstone
29		50	50		*	Sparse biointramicrite	Packstone
38		30	10		*	Poorly-washed biosparite	Packstone
39		40	10		*	Packed biomicrite	Packstone–wackstone
40	50	40			*	Poorly-washed biopelsparite	Packstone

city. These similarities suggest that direct correlations can be made between the sources of the stone and the sites of their ultimate consumption.

For example, sample number 5 from Asfur and sample number 29 from the lower North Theater are very similar in macroscopical and petrographical characteristics. Also, samples 2 and 3 from quarry of Asfur sites are similar in macroscopical and petrographical characteristics to samples 28 and 40 taken from the South Theater and the Colonnaded Street.

The group of samples numbered 10, 11 and 17, particularly samples 11 and 17 from quarry locations at Wadi Suf and Al-Shawahed, extracted from the Naur Limestone, are similar to samples 38 and 39 from the archaeological location, respectively. No recognisable differences can be seen between sample number 12 from the Wadi Suf quarry and sample number 27 from the upper North Theater.

The previous results suggest that the provenance of stones used as building materials in ancient Jarash is the surrounding area, and can be attributed to the ancient quarry landscapes in Asfur, Al-Shawahed, Wadi Suf, and Al-Majar locations. Therefore most building materials in ancient Jarash are local. Variations between the local sources are not great enough to assign stones at the archaeological site to specific sources at the quarries.

Conclusions

The geological-petrographical study of the quarrying sites of the ancient city of Jarash, combined with the study of the rock-cut surfaces and their tool marks, has given preliminary information about the characteristics of the main building stone of Jarash monuments and of the quarrying techniques applied there.

The volume of stone masonry acquired and the absence of material waste at the many quarries surveyed indicate exceptional stone management skills and productivity as well as the shear accuracy for calculating stone consumption with minimal waste.

It is hoped that the information granted in this paper can be of great profit for archaeological and architectural research that may provide further comprehension to the history of man's achievements of stone extraction, and share new interpretations to the ancient workings of Jarash stonemasons.

The results of this research highlight the value and significance of ancient stone quarries as a rich source of invaluable information about ancient technological achievements and socioeconomical aspects of ancient Jarash. Specifically, data on sources and extraction technology can be gleaned directly from these results. It is hoped that these findings will bring more attention and raise awareness among locals and government responsible officials about the significance and vulnerability of such sites. So far, these sites have largely gone unrecognised due to poor documentation, which has consequently led to their current indiscriminate destruction mainly by human activities such as urbanisation and agriculture. This study will be extended through further and more detailed investigation to further reveal the significance and value of these sites and to devise the necessary legal and conservation measures to ensure sustainable management of these important sites.

Acknowledgments

We would like to thank Mr. Shafeeq Badarneh for his help in preparing the thin sections and Mr. Abdallah Rawabdeh for working with the figures. This work was funded under the EU Sixth Framework Programme though the QuarryScapes project.

References

Abdelhamid, G. (1995) The Geology of Jarash Area, Map Sheet No. 3154-I, Bulletin 30, Natural Resources Authority, Amman, Jordan.

Abed, A.M. (1982a) Depositional environments of the Kurnub (Lower Cretaceous) sandstones, North Jordan. *Sedimentary Geology*, **31**, 267–279.

Abed, A.M. (1982b) Microfacies and paleoenvironments of Wadi Sir Formation (Upper Cretaceous), North Jordan. *Facies*, 7, 229–236.

Bashaireh, K., (2003) Provenance of marble and caliche used in the building of Um Qais (Gadara), NW Jordan. Unpublished M.Sc., Department of Earth and Environmental Sciences, Yarmouk University, Irbid, Jordan, 111 pp.

Bender, F. (1974) *Geology of Jordan*, Borntraeger, Berlin, 196 pp.

Bloxam, E.G. (2009) New directions in identifying the significance of ancient quarry landscapes: four concepts of landscape. *In* Abu-Jaber, N., Bloxam, E.G., Degryse, P. and Heldal, T. (eds.) *QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean,* Geological Survey of Norway Special publication,**12**, pp. 165–183.

Clark, V.A., (1986). The Church of Bishop Isaiah at Jerash. In Zayadine, F. (ed.) Jerash Archaeological Project, Vol. 1, Amman, Department of Antiquities, pp. 303–318.

Dunham, R.J. (1962) Classification of carbonate rocks according to depositional texture. *In* Ham, W.E. (ed.) *Classification of carbonate rocks*, American Association of Petroleum Geologists Memoir, pp. 108–121.

El-Radaideh, N. and Mustafa, H. (2008) Petrographical and mineralogical study of the travertine in Deir Abu Said area, NW Jordan. *Abhath al Yarmouk (Basic Science and Engineering)*, **17**, 565–584.

Folk, R.L. (1959) Practical petrographic classification of limestones. *American Association of Petroleum Geologists Bulletin*, **43**, 1–38.

Kerr, P.F. (1977) *Optical mineralogy*, Fourth edition, McGraw-Hill, New York, 492 pp.

Kraeling, C.H. (1938) Gerasa: City of the Decapolis. American Schools of Oriental Research, New Haven, USA, 616 pp.

Meyer, C. (1988) Glass from the North Theater Byzantine church, and soundings at Jerash, Jordan, 1982–1983. Preliminary Reports of ASOR-sponsored excavations from 1982–1985. Baltimore.

Pierobon, R. (1983–1984) Gerasa, 1. Sanctuary of Artemis. Soundings in the Temple-Terrace, 1978–1980. *Mesopotamia*, **18–19**, 85–111.

Utoum, M. (2003) *A Study of the Architectural Roman Elements in Jerash*. MSc Thesis, University of Jordan, Amman, Jordan (In Arabic), 228 pp.