



# GEOMORPHOLOGICAL AND GEOLOGICAL CONSTRAINTS ON THE DEVELOPMENT OF EARLY BRONZE CHERT INDUSTRIES AT THE NORTHERN RIM OF THE AL JAFR BASIN, SOUTHERN JORDAN

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## ABSTRACT

The northern rim of Al Jafr basin was the focus of a massive quarrying effort during the late Neolithic and Chalcolithic periods. At that time, massive volumes of chert were extracted from the Muwaqqar Chalk Marl and the Umm Rijam Formations that crop out in the Umm Rijam, Khuzayma and Al Athriyat mountains.

The landscape of the region is marked by a 100 km long escarpment marking the hydrological divide between the Al Jafr and Al Hisa basins. This escarpment and associated buttes were the exposures from which the chert was extracted. This was done from the nodules of the Muwaqqar Chalk Marl Unit beds and from the beds of the Umm Rijam Formation. Various patterns of extraction were developed based on the nature of the geological formation. The soft marl and chalk of the MCM led to narrow and deep digging into the exposures. The hard limestone of the Umm Rijam formation led to wide and shallow extraction patterns.

Hilltops on the plateau served as sites for stone workshops. These sites were readily accessible and apparently defensible. They probably served dual purposes; a place to work stone and as observation posts defending the stone extraction activities in the lower areas.

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**KEYWORDS:** Geomorphological, chert, neolithic, chalcolithic, quarry, climatic, Al jafr basin, Jordan, Umm Rijam Chert Limestone, Muwaqqar chalk marl

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## INTRODUCTION

Massive, industrial scale extraction of flint for the production of cortical flake blanks in the Al Jafr Basin region has been recently documented (Quintero *et al.*, 2002). Seventy nine sites with areas reaching 12 hectares have been documented, with an estimate that millions of cortical flake blanks were extracted and exported from the area during the Chalcolithic and Early Bronze ages. The scale of this quarrying suggests that the flint blanks were being used across large areas of the Levant during that period.

The choice of this region for such an intensive extraction effort is interesting. Current climatic conditions in the area are inhospitable, with less than 100 mm of rain falling per year, and hot dry summers and cold winters. Chert-bearing strata are readily available in many areas in the southern Levant, raising questions as to why this area in particular was chosen for this massive quarrying enterprise. The quality of the available chert is clearly one aspect of this choice, with other factors including defensibility, ease of quarrying and access to markets being important as well.

While the factors dissuading from choosing this area for large scale Human settlement and economic activity are obvious, the factors that compelled them to choose this area are less so.

The purpose of this paper is to examine the geological and geomorphological nature of this landscape with a view towards understanding what positive elements led to this choice. Herein, an analysis of the landscape and geology is presented in order to better understand these issues.

## NATURE OF THE STUDY AREA

### *Chronology and Climate*

The chronology of the massive extraction described by Quintero *et al.* (2002) is based solely on the flint blanks and tool typologies. Based on these typologies, the timing of the quarrying activities has been set at the Chalcolithic and Early Bronze periods. According to established chronologies, these periods in the Levant extended from 6000 to 5000 years before the present. While the area is currently arid, with no readily accessible water resources, this may have not been the situation when the massive quarrying activities were being conducted.

The region during the Pleistocene and Holocene has seen a number of climatic fluctuations, ranging from pluvial times in the Late Pleistocene correlatable with glacial periods at higher latitudes in the northern hemisphere to dry interpluvials, the most notable of which marked the termination of the Pleistocene and the beginning of the Holocene about 12000 years ago. The Early Holocene (Versilian) was extremely dry; while a more humid pluvial period prevailed from 7000 to 4500 before the present (the Atlantic) prior to the current interpluvial (Horowitz, 1979). The Late Pleistocene and Holocene pluvial periods have been cited as periods where various groundwater basins in Jordan were nourished (Bajjali and Abu-Jaber, 2001), while fluctuations in the level of the Dead Sea have been used to determine changes in climatic conditions during the Holocene (Migowski *et al.*, 2006). It is possible that the repeated dry interfluvial periods led to the erosion of the Acheulian sites described by Rech *et al.* (2007).

Thus, the period of extensive mining coincided with the Middle Holocene At-

lantic pluvial stage, when climatic conditions saw lower temperatures and increased rainfall (Horowitz, 1979; Bajjali and Abu-Jaber, 2001), making the region much more hospitable to human habitation and activity. The end of the Middle Holocene pluvial has been well correlated with cultural declines in the area (Migowski et al., 2006).

### Geomorphology

The Al Jafr basin is a large internally draining catchment area in southern Jordan. It has an EW extension of around 150 km and a NS extension reaching 100 km. During previous climatic events, this basin was a freshwater lake (Moumani, 2006), although there is little evidence of standing water during the Mid Holocene, possibly due to wind induced deflation (Davies, 2005).

The elevation at the center of the playa is about 850 m above sea level and about 1030 m above sea level at the northern boundary of the depression. The northern boundary is witnessing slope retreat. These slopes are dissected by a number of ephemeral streams that cut through the older Cretaceous and Tertiary marine sedimentary sequences.

The northern boundary of the basin is divided into three hill ranges, which are, from west to east: Umm Rijam, Khuzayma and Al Athriyat (Figure 1). These hilly ranges are generally of moderate slopes and rolling hills, except on the retreating slopes facing the Jafr depression and along the ephemeral streams that feed into the depression. The nature of the slopes and the hills is largely determined by the stratigraphic units which outcrop there, as will be described later.

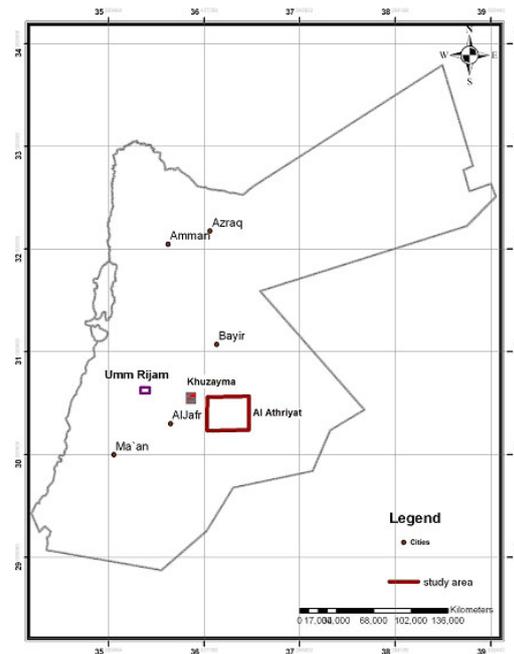


Figure 1. Location map of the area.

The surface sediments covering the area consist of desert pavement on the non active surfaces. The wadis and wadi outflows consist of coarse grained fluvial sediments and sediment outwashes that appear as the ephemeral streams enter into the depression.

### Geology and stratigraphy

The stratigraphic sequence of greatest significance to this work is that of the Late Cretaceous and Tertiary that are exposed on the hilly areas on the northern margin of the basin, as opposed to the Pleistocene and Holocene sediments in the center of the depression. These recent sediments have been described by Davies (2005), and are not relevant to the question of the nature of the chert quarrying industry that thrived in the Middle Holocene.

The Campanian to Maastrichtian Al Hisa Phosphorite formation crops out to the north of the study area, and frag-

ments from it are found in the alluvium of the area.

It consists of alternating layers of phosphorite, chert, phosphatic chert, coquinooidal limestone, limestone and marl. The thickness of this formation has been reported to reach 42 m in the Jurf al Darawish area.

This formation is currently mined for phosphate to the north of the study area (Wadi al Abiad and Hisa mines) and at the southern margin of the Jafr basin (Ash Shidiya mines).

The Al Hisa Phosphorite formation is overlain by the Maastrichtian Muwaqqar Chalk Marl formation (MCM). This formation consists of soft marl and chalky marl, with thin beds of chert near the base.

The formation in the area has been reported to be 27 m thick, and the formation contains prominent bands of chert and limestone concretions. The chert concretions reach over a meter in length and were the target of some of chert extraction activities, although most of the concretions are in the decimeter range in length.

The 40 m thick Eocene Umm Rijam Chert Limestone formation (URC) overlies the Muwaqqar Chalk Marl formation. The Umm Rijam formation consists of hard bedded limestone and chert. The contrast between this formation and the underlying MCM is stark.

The hard nature of the URC leads to the formation of steep cliffs that sharply contrast with the more gentle erosion pattern seen in the soft underlying MCM.

The 20 cm thick chert beds were the target of quarrying activities at some locations. A general view of the stratigraphic column can be seen in figure 2.



**Figure 2. The stratigraphic sequence in the study area.**

Faulting in the area had led to different exposures of the various formations to appear in different areas. The Salawan fault in the north is a right lateral EW extending fault with a horizontal displacement of about 7 km and a vertical displacement of about 100 m of the southern downthrown block. The NW trending Al Karak Al Fayha fault system is a tensional feature defines the exposure of the Umm Rijam formation, which is found on the southwestern downthrown blocks, and that of the MCM, which is exposed on the upthrown northeastern block. Total vertical displacement on this system is estimated to be about 50 m (Bender, 1974). The north trending Kubayda fault and the NE trending Al Jafr fault are of no interest in this context, as they are not expressed in the chert extraction sites.

### ***Lithic Industry***

Reconnaissance surveys conducted by the Al Jafr Basin archaeological Project reported that seventy nine of the one hundred and eleven recorded archaeological sites in the Al Jafr basin have evidence of highly developed lithic industry. The lithic industry at these sites centered on the production of cortical flake blanks for tabular scrapers. The sites also document a significant industry devoted

for the production of large percussion blades. The sites represent an enormous industry that included huge quarries as well as open-trench mine sites (Quintero et al, 2002).

Archaeological evidence strongly suggests that tabular scraper manufacturing at Al Jafr basin was a very well-organized industry. This included quarrying and mining of the flint at many sites, production of cortical flake blanks on an enormous scale and transportation of these blanks to specialized fan scraper production workshops. It is believed that enormous quantities of these blanks were exported to other production centers in Jordan and the Levant (Quintero et al, 2002).

Large tabular flint implements with a cortical back dated to the Chalcolithic and the Early Bronze Ages have been found in many sites in Jordan such as Teleilat Ghassul (Hennessy, 1969), Wadi Ziglab (Siggers, 1997), Magass (Eichman and Khalil, 1999) and Tell Abu Hamed (Egan and Bikai, 1999). The trade links between these sites and Al Jafr need to be investigated.

## APPROACH AND METHODOLOGY

The purpose of this work is to document the geomorphological and geological attributes of the quarry locations documented by Quintero et al. (2002). These attributes show clear, deliberate decisions made by the people involved in the extraction of the cortical flake blanks in this region.

### *Geological and archeological field surveys*

The first step was to find the locations of the quarries, and to document these locations. The positions of the quarries

were recorded using a Global Position System (GPS). The locations are given in Universal Transverse Mercator (UTM) units.

After this, three stratigraphic profiles by length, two in Khuzayma, one in the up land, and the second in the lowland, and one on upland of Umm Rijam, and by width, were taken using a tape meter.

A width profile was taken along the mountain, the profile as length passes all of beds on one point. Four columnar sections were made, one at Al Athriyat, two at Khuzayma, and one at Umm Rijam for correlation. Tape measures were used to determine length, width and height of the quarries and beds.

### *Post-survey*

After the collection of the readings and location values, topographic maps from the Royal Jordanian Geographic Centre and geologic map from Natural Resource authority were obtained and integrated into a GIS database. Location values were converted to JTM grid, and digital maps were made by using arc view GIS 3.2. With these, contour maps, slope maps, elevation maps, and aspect maps and Triangular Information Networks (TIN) were constructed.

## RESULTS

Topographic maps of the three mountains and the quarries and workshops were produced. Closely spaced contour lines of the escarpment are seen in Umm Rijam, Al-Athriyat and Khuzayma. The quarries are found behind the flanks of these escarpments in Al-Athriyyat, as well as in wadis such as Wadi Al-Ghwier.

Figure 3 is a geological map of the Khuzayma. A map for Umm Rijam was

also prepared, but the Natural Resources Authority of Jordan has not completed mapping of the Al Athriyat Mountain. Based on the topographic map and the columnar section drawn from that area

(Figure 4), the Umm Rijam Formation is limited to the top of the mountain. Chert nodules exist at the base and were extracted from the Muwaqqar Formation.

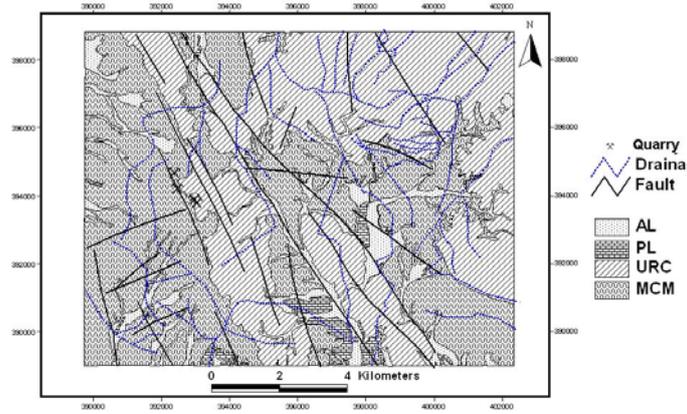


Figure 3. Geological map of Khuzayma. AL: Alluvium; PL Pleistocene sediment; URC Umm Rijam Chert; MCM Muwaqqar Chalk Marl.

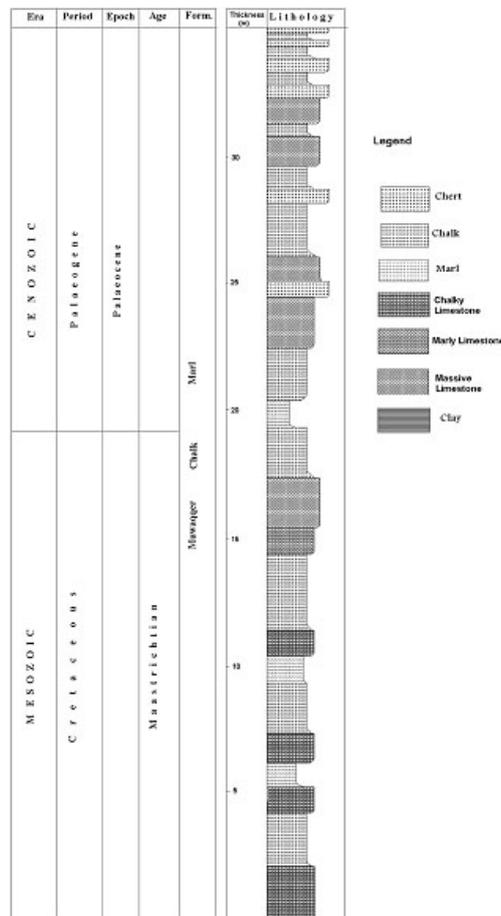


Figure 4: Al Athriyat columnar section showing chalk beds containing limestone, and chert nodules.

At Umm Rijam Mountain, all of quarries' settings are in the Umm Rijam Chert Formation, except of one quarry that extracted from the Muwaqqar Chalk Marl Formation. The geological map of Khuzayma shows intensive quarrying in the Muwaqqar Formation. A few small quarries are found in the northern side from the Umm Rijam Formation.

Drainage in the upland plateau is opposite in direction to the escarpment direction, indicating that the mountains represent drainage divides. This can be seen clearly in the aerial photographs of the study area (Figure 5).

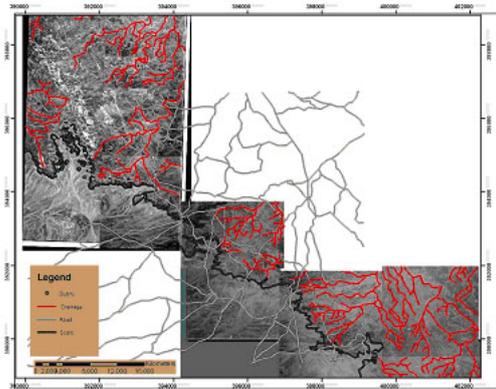


Figure 5. Aerial photograph of Al Athriyat.

These show the scarp and the drainage system. All of mountains have a same escarp and drainage system. They all have two slope types according to elevation; up land and low land, and bound by cliffs. The escarpment is jagged and forms many trenches and valleys that cut into it. The drainage basin in the low land is marked by alluvial fans. These are not triangular; as sometimes they consist of semi-circles. There are many mesas and buttes scattered behind the escarpment, many of which contain ancient quarries. In one case (at Khuzayma) this is distinctive in that it extends to more than 5 km.

More detailed information is needed to determine the sections within the Muwaqqar Formation that would have been suitable for extraction of chert nodules for tool manufacturing in ancient times.

An E-W geologic cross section is given in figure 6, through the Umm Rijam, Khuzayma and Al Athriyat Mountains. This figure shows that the Umm Rijam Formation crops out exclusively in the Umm Rijam Mountain, while the Muwaqqar Formation dominates in Al Athriyat areas, where the Umm Rijam Formation crops out at the tops of these mountains.

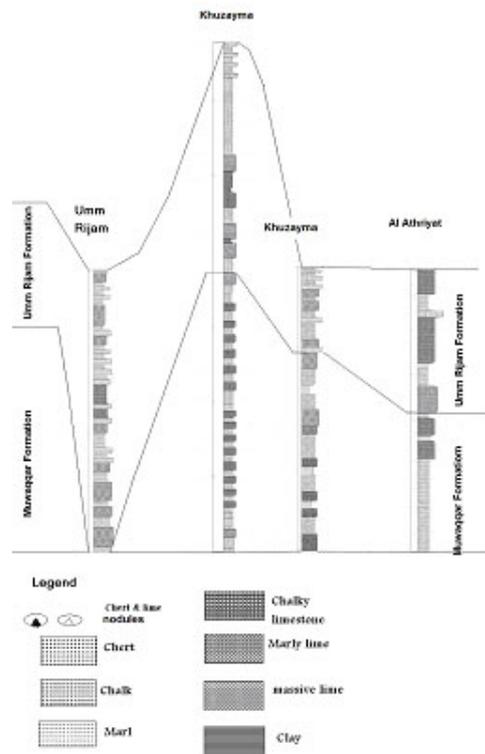


Figure 6. Correlation between columnar sections between Umm Rijam in the west to Al Athriyat in the east has been correlated.

Conversely, the extension of the exposed section of Muwaqqar Formation is limited in the western part of the area, and is more exposed in the eastern side of the Umm Rijam Mountains. The

Khuzayma Mountain in the central area has both formations. The Al-Hisa Formation is exposed on the northern side of this mountain, while the chert quarries are found on the southern side of this mountain.

Detailed columnar sections show that chert beds are indicative of the Umm Rijam Formation. Nodules, however, are scattered in horizons of both the Umm Rijam and Muwaqqar Formations. The columnar sections, from Al-Athriyat show that the chalk beds are present throughout the section. At the lower parts, these are interbedded with marl and chalky limestone and near the top they are capped by chalky and massive limestone. In the lower parts, the chalk has limestone nodules, whereas at the top, chert nodules become more intensive. At Khuzayma, a similar pattern is present but with an absence of marl beds. The nodules are present in the chalk beds (Figure 6).

In the Umm Rijam Formation, the lower parts of the section have limestone nodules within chalk and chalky limestone. In the middle and upper parts, the chalk is interbedded with chert and limestone nodules, as well as with chert beds.

Quarries in the Khuzayma area occur on isolated hills beyond the escarpment. These were excavated into exposures of the Umm Rijam formation. The slopes in quarry sites ranged from 60 to 85 degrees. There are a number of segments of the slopes at this site. From bottom to top, there is a convex slope, containing chalk and marly limestone at the base, followed by a vertical limestone cliff, followed by a second convex slope, topped with a limestone cliff, after which the beds become thicker, with convex slopes due to the presence of chalk beds that contain chert nodules and a segment

that is vertical due to thin sequence of chert and limestone beds.

All of the quarries are similar in the eastern part of the landscape are dominated by the Muwaqqar Formation. This is seen at Al-Athriyat, Wadi Al-Ghwier, and the Khuzayma areas.

In general, there is grading in natural slopes, this grading is discrete in the two crests and contained fractured nodules from Umm Rijam in these crests. Weathering and erosion of the tops of the crests conceal parts of these structures. The tops of the mountains contain of chert and chalk and limestone, its obvious transport chert beds, then removed it to the low land, then eroded chalk beds and extra.

Two segments of concave curves are present; every one has a clear length dimension, whereas width and depth are not as distinctive. The existence of an ancient path is a guide to the presence of this quarry. The first segment is about 85 as long, 85 as width and 4.5 m deep, whereas the second is 100, 85 and 4 m as long width and depth respectively with strike 30 NW and slope in usual 20 goes to 40, 55 then return 20.

In summary, the quarries seem to have been chosen based on a number of specific criteria. It seems that the chert nodules found in the upper part of the Muwaqqar Formation and the lower part of the Umm Rijam Formation were preferred over material found below or above this interval. The types of quarries (steeps and gentle slopes) depended on the formations from which they were extracted, with the Athriyat and Khuzayma, which have Muwaqqar Formation outcrops consisting of chalk and limestone having steep slopes, while in Khuzayma and Umm Rijam in the

Umm Rijam Formation, the quarries have gentle slopes.

A large number of small and large quarries are distributed in the Umm Rijam, Khuzayma, and Al Athriyat Mountains. These quarries were derived from both the MCM, and the URC Formations. Every one of these quarries is somewhat distinct in form, characteristics and extent.



Figure 7. A general view of a number of chert quarries in Khuzayma. Arch of the quarries at the lower level is about 20 m.

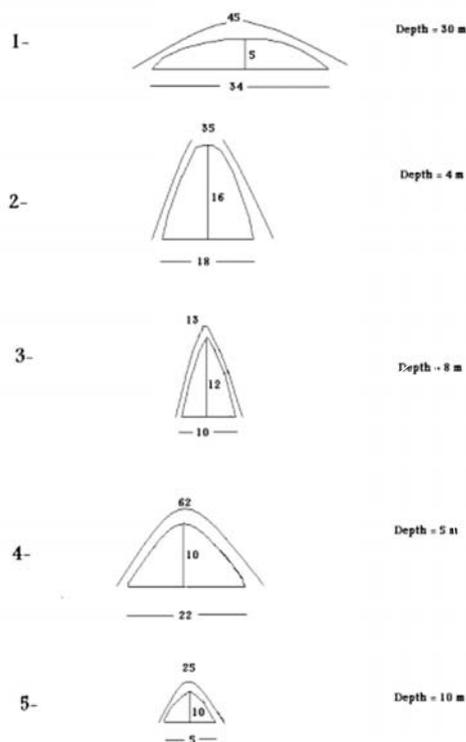


Figure 8. The dimensions of some of the quarries

Figure 7 shows a general view and figure 8 shows the dimensions of different quarries at Khuzayma. It is clear that these dimensions reflect the ease in which the stone was quarried and the abundance of material available at the site.

In the Muwaqqar Formation, the quarries are found at the flank low land of the mountains. This is especially the case in Khuzayma, Al-Ghwier and Al-Athriyat. The quarries have a half circle (ellipsoid) forms which vary in size, curvature, and depth. Quarry sites containing of great number of individual quarries, reaching up to 30 quarries at one quarry site in Khuzayma. The forms of this quarry site have trenches or half circles at the mountain flank. The lengths of these trenches reach up to 3 km consisting of three sections (in Khuzayma), every one is about 1 km long.

The dimensions of these quarries are variable (Figure 8). This figure is indicative of the quarrying technique. Generally, the largest sizes are at the top and the smallest are at the bottom. The depth too varied between 4 m to 30 m. The radius varied from 5 to 34 m. The curvature is also varied, ranging from 13-45 m. These variations depend on variation on radius, poor curvature occurs when the outer radius is greater than the inner radius, and the opposite is true. These shapes reflect the ease with which the ore could be extracted and the amount of chert at the locality.

The nature of quarrying on this formation depends on the characteristics of this formation. The soft material (chalk) is dug out to extract chert and limestone nodules, which are the raw material of the stone tools in that time. This type of quarries occurs at steep slopes, and have a nearly vertical quarry faces.

The quarries at Umm Rijam and Khuzayma are identified by changes in topography, location, slopes and dimensions. The dimensions of one of the Umm Rijam quarries are 80 by 80 m, with penetration that doesn't exceed 2 m. Two types of quarrying took place from this formation. The first was by hammering to access to the fractured beds, followed by rolling them to the lowland for transport, and the second was the extraction of nodules from the soft chalk and chalky limestone.

There are many examples showing traces of transport of chert raw materials from the quarry sites to the area of manufacturing of the tools, or from the workshops to the traditional paths. The debris on these roads varies in size from a few centimeters to tens of centimeters. The roads also vary in width, from 1.5 to 3.7 m.



**Figure 9.** An ancient stone-workshop in Umm Rijam. Note the shape. Radius is about 15 m.

There are many stone working workshops, especially in the Umm Rijam and Al-Athriyat areas (three in Umm Rijam and two in Al-Athriyat). These are rounded or ellipsoid in shape, with a void in the centre where the work took place, and waste or debitage around this center. The waste is homogenous in size in the workshop, but varied in different workshops. An example of one of the

workshops is shown in figure 9. This particular site is ellipsoid shape and of a large amount of waste, having a diameter between 5 to 35 m. No hammerstones were found in these areas. The locations of the workshops were strategic, placed in the higher areas of the plateau.

## CONCLUSIONS

The large scale extraction of chert in the northern flank of Al Jafr basin during the late Neolithic and Chalcolithic periods was facilitated by favorable climatic conditions at the time. Need, climate and geology led to massive extraction of chert along a 100 km stretch, beginning at Umm Rijam mountain in the west and ending at Al Athriyat mountain in the east. This extraction took place from the Muwaqqar Chalk Marl Unit and the overlying Umm Rijam formation. Quarries in the URC formation tend to be shallow and wide, reflecting the hardness of the accompanying limestone beds.

At Umm Rijam and Khuzayma, the Umm Rijam Formation crops out. This formation is characterized by the presence of chert beds and a few horizons of chert and limestone nodules. At Khuzayma and Al Athriyat, the MCM formation crops out, and extraction of chert nodules took place from this formation. Quarries here tend to be deep and narrow, due to the ease of digging into the chalk and marl in which the nodules are found.

High areas on the plateau served as locations for stone working. Some of these strategic locations are still visible, as are traces of roads on which the material was apparently transported.

The breathtaking landscape in the area, coupled with the archaeological

significance of these quarries warrants both attention and protection from the relevant authorities, as encroachment of

modern development may soon lead to the degradation and destruction of this unique human heritage.

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