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Quarrying Flint at Neolithic Ramat Tamar: An Experiment

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Abstract. An actualistic quarrying experiment was conducted at the PPN flint mine Ramat Tamar 1 southwest of the Dead Sea, Israel. The goal was to reach the flint bearing horizon and study potential flint quarrying techniques. At the site the limestone is loosened by a system of natural cleft planes. Using crowbars and hammers, five tons of limestone were removed from an original mining front, resulting in seven flint nodules weighing 66 kg. The experiment preliminarily indicates a combined PPN mining strategy by use of crowbars and/or wedges and heavy hammers.

Keywords. Israel, Neolithic, PPN, Flint mining, Quarrying experiment, Miner's tools.

Résumé. Une expérience grandeur nature fut réalisée à Ramat Tamar 1, une mine en silex du PPN située au sud-ouest de la mer Morte en Israël. Le but fut d'atteindre la couche contenant le silex et d'étudier les possibilités d'exploitations minières. La structure de la roche-mère constitue l'un des critères les plus importants dans le choix de la stratégie minière du silex au Néolithique et des outils d'extraction appropriés. À Ramat Tamar, la roche est fortement délitée par des pans de clivages naturels, transformant la roche en sections en forme de prismes, ce qui favorise l'emploi de leviers en pieds-de-biche et de coins. Durant la fouille de Ramat Tamar par feu Wolfgang Taute (Tübingen), un lourd marteau de basalte fut découvert, attestant l'emploi de méthodes de percussion. Durant l'expérimentation, cinq tonnes de blocs calcaires furent dégagées d'un front de carrière originel et sept rognons de silex furent extraits, équivalents à un poids de 66 kg. Les résultats préliminaires de l'expérience indiquent une combinaison de techniques minières au PPN, en dégageant des blocs à partir des prismes rocheux, déjà naturellement fendus à l'aide de coins et de pieds-de-biche et en les fracturant davantage par de lourds marteaux. Les expériences futures à Ramat Tamar s'orienteront vers l'emploi de coins en bois et en silex, ainsi que de marteaux en basalte.

Mots-clés. Israël, Néolithique, PPN, mines de silex, expériences d'extraction en carrière, outils des mineurs.

INTRODUCTION

A Neolithic flint mining complex was discovered by the late Prof. Wolfgang Taute 12 km southwest of the Dead Sea, overlooking the Arava Valley. The extraction industrial landscape described by Taute includes the Late PPNB workshop at Mesad Mazzal, situated on the Lissan Plateau in the Arava, and a series of flint mines and small workshops on the eastern edge of the Negev Plateau, some 200 m higher in elevation than Mesad Mazzal (Taute, 1985, 1994).

Ramat Tamar 1 (fig. 1), an opencast flint mine, and an associated workshop were excavated by Taute. The Neolithic miners exploited flint nodules from an outcrop at a depth of 1.5 m or less below the rocky horizon of dolomite (fig. 2). The mining waste covers the exhausted extraction surface at an area of ca. 100 m^2. A single basalt hammer, interpreted by Taute as a mining tool was discovered in the mining waste.

Hollow depressions appear under the mining waste (fig. 3). Each depression represents a negative of a flint nodule taken out by the miners. According to Taute's

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Fig. 1. Ramat Tamar 1. A general picture of the flint mine exposed by Taute.

Fig. 2. A close up at Ramat Tamar 1 with the rocky section, the flint horizon and the area exploited by Neolithic miners.

Fig. 3. A close up at the hollow depressions discovered under the mining waste at the area exploited by Neolithic miners.

calculations more than 6 tons of high quality Turonian flint were extracted from this specific locality. The extracted flint was used to produce mainly bifacial tools such as axes and adzes. A preliminary survey conducted by the authors at the quarrying complex of Ramat Tamar indicates that while indeed bifacial tools were the most dominant end product, opposed-platform "Naviform" cores and blades are also found in the workshops attached to the extraction localities.

Since the discovery of this large-scale Neolithic quarrying complex and the excavation of the locality at Ramat Tamar 1 by Taute, no field work took place at the site. Two of the authors (R.B. and A.G.) conducted an archaeological survey at Ramat Tamar during the late 1990's in order to evaluate the extent of the quarrying operation and study the complexity of the Ramat Tamar Neolithic industrial complex. This survey was part of a wider research project aimed at investigating prehistoric lithic procurement strategies practiced in the Paleolithic and Neolithic southern Levant (Barkai, Gopher, 2001, in press; Barkai *et al.*, 2002, 2006; Verri *et al.*, 2004). The results of our survey will be published elsewhere, while in this paper we will focus on a specific quarrying experiment conducted at Ramat Tamar 1, near by the quarrying locality excavated by Taute.

EXPERIMENTAL FLINT QUARRYING – A SHORT OVERVIEW

The idea of conducting a flint mining experiment arose during the field surveys at Ramat Tamar, and J. Weiner, an archaeologist well experienced with Neolithic mining technologies in Europe (Weiner, 1986, 1995) and a personal friend, joined the expedition. As J. Weiner was in mutual contact with Prof. Taute in Germany in the past he was well acquainted with the Ramat Tamar quarrying complex and was enthusiastic about the experimental project.

According to our knowledge, only very few archaeological mining experiments have been performed in the past (Lane Fox, 1876; Schmid, 1980). When dealing with prehistoric flint mining, one question among others concerns the flint extraction technology. This not only involves the geological and morphological setting of the mines, but also the miner's tools and the method of their particular handling.

One of the most detailed quarrying experiment was conducted by researchers of Neolithic pelites- quartz quarries in Plancher-les-Mines, at the Marbranche Valley, France. They employed reproductions of authentic working tools found at Neolithic flint mines in Europe and similar tools known from ethnographic records, such as antler picks, wooden digging sticks, bone tools, and other tools (Pétrequin *et al.*, 1998, p. 303).

The experimental mining showed that work in a small quarry (ten cubic meters of excavated material) required two working days of ten workers, during which the desired blocks were selected but no flaking was performed. The average number of stone (pelites-quartz) blocks that were adequate for flaking per one cubic meter was eighteen. In some cases, the workers were able to excavate stone blocks without use of special tools. By average, during a single work day, each worker would excavate approximately one and a half cubic meters and would produce about nine adequate blocks (over one kilogram each). As the quality of the raw material changed according to the different layers, some of the raw material was abandoned. The time required for the preparation of blanks or roughouts was not calculated.

It was initially estimated that about eighteen axes would be manufactured from a single cubic meter of excavated material, but the experimental flaking showed that the loss of raw material during initial flaking is immense: only four or five blocks out of each eighteen blocks that were excavated from one cubic meter of material survived the entire process to become a tool. Most of the blocks were abandoned because of cracks or flaws in the raw material (Pétrequin *et al.*, 1998, p. 307).

This experiment indicated quite clearly that mining and quarrying are difficult and extensive labors that necessitate early preparations, much experience and the ability to recruit many workers. They required a physically challenging effort that did not guarantee results. To actually produce some axes, massive quantities of raw materials had to be mined or quarried. This explains the enormous quantities of debris found in the various procurement sites.

In a middle-sized quarry at Plancher-les-Mines, France, some sixty to a hundred and twenty cubic meters were excavated. Following the experimental mining, it may be assumed that a hundred and twenty to two hundred and forty man days were required for this task. In larger quarries three to five hundred cubic meters were excavated, requiring six hundred to a thousand man days. It may be assumed, then, that mining and quarrying were performed in teams. This would not be the first team work known of, as in Neolithic Europe we know of group ventures designed to construct earth mounds and megaliths (Pétrequin *et al.*, 1998, p. 304).

It is estimated that in the Haut-Ruisseau quarries at Plancher-les-Mines, France, at least forty thousand cubic meters were excavated during four hundred years – between the years 4,100 and 3,700 BC – which required some eighty thousand man days. It may be assumed that in addition to this estimate, many more work days were required to process the raw materials and manufacture the tools. It is safely assumed, then, that this was a joint effort of the entire community (Pétrequin *et al.*, 1998, p. 304-305).

As the geological formations and lithic outcrops at Ramat Tamar are entirely different from those in Europe, the information from the very few European mining experiments presented above could not be direcetly applied to our experiment.

We were familiar with the Ramat Tamar complex and its characteristics, but had no information regarding Neolithic flint mining technologies and extraction strategies. For the reasons presented above we have applied a very basic trial-and-error approach in our flint mining experiment, gaining information and experience as the experiment continued. Our experiment is presented below as a first step towards a reconstruction of Neolithic mining technologies in the Levant.

The quarrying experiment at Ramat Tamar

Our flint quarrying experiment took place over three days during September 2000.

Three modern male "miners" carried out the extraction work. The experiment was documented by video and stills cameras. Quarrying debris were weighed and the working time was measured.

The goals of our experiment were as follows:

– to study quarrying techniques and procedures,

– to evaluate the labour investment involved in flint procurement by quarrying,

– to gain some basic insight on Neolithic flint quarrying and practice flint quarrying – an actualistic study.

Experiment location

The experiment took place next to a genuine Neolithic flint quarry, at the Ramat Tamar 1 locality (fig. 4). We have continued the quarrying operation at the extraction front left during Neolithic times, where flint nodules are covered by *ca.* 1.2 m of dolomite.

Mining tools at Ramat Tamar

The possibility to gain insight into prehistoric extraction technology is greatly improved by original mining tools. Unfortunately, in the case of Ramat Tamar, only one such artefact is known, a hammer made from a large basalt pebble showing heavy battering marks at either ends and lacking any trace of hafting (Taute, 1994; personal observation J.W.). It was found on the working floor in the very vicinity of the extraction front, covered by the waste heap.

On this basis, percussion is the only documented method being used by the Ramat Tamar miners.

Previous visits to the mine had revealed that the limestone shows a natural system of vertical up to 3 cm wide cleft planes, criss-crossing the solid bedrock from top to bottom and transforming it into individual column-like sections. Though the clefts are filled with loose dust, they strongly indicate the possibility that the miners may have deliberately used them by employing crowbars or wedges.

This observation emphasised the use of leverage as an additional potential extraction method, forcing us

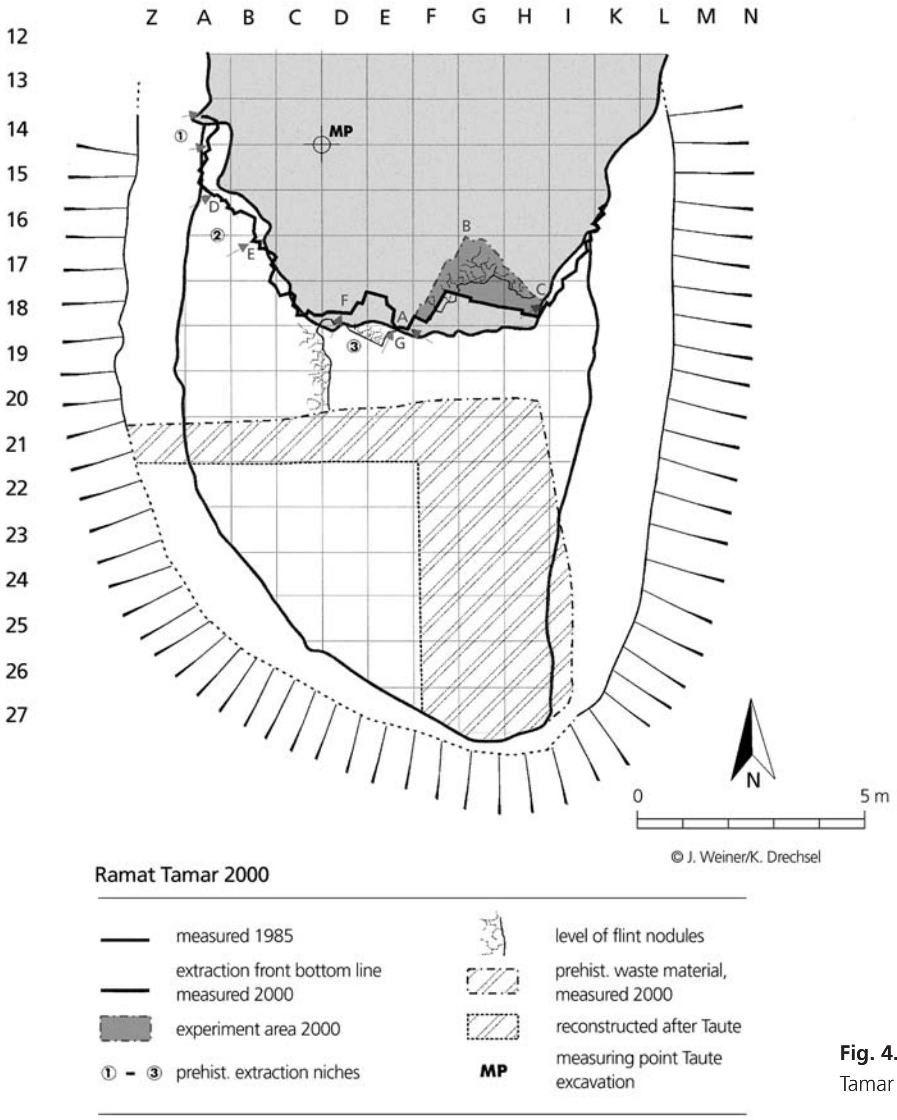

Fig. 4. The experiment location at Ramat Tamar 1 in relation to Taute's excavation.

to take appropriate leverage tools for our experiment in mind.

Experimental tools

According to the original find, we collected several basalt pebbles in the Jordan Valley to be used as hammers, while two crowbars were made of straight thicker native hardwood branches (Acacia aneura), both fresh and seasoned, the ends of which were shaped into screwdriver tips.

We decided to bring a range of modern metal hammers as well as crowbars to Ramat Tamar 1, too. But it has to be underlined that during this first experimental stage, our paramount aim was to reach the prehistorically exploited flint layer and gain as much first hand information on the shape, size, and amount of nodules and their bedding, respectively. Additionally, we personally wanted to experience the bedrock's behaviour against mechanical force, *i.e.* its density and hardness. Hence, testing of the basalt hammerstones and wooden crowbars was only a by-product, but is planned more thoroughly for a future stage of our experiment.

Practical experience

From the very beginning it turned out that the cleft system had to be taken into account in our attempt to reach the flint layer. Starting from the top, the dusty filling was removed from the clefts leaving openings wide enough to insert crowbars. While the working ends of the metal crowbars fitted perfectly, those of the wooden ones were too thick and had to be flattened. We hoped that by employing the crowbars the limestone could be pried loose and would come off in fragments. But due to the limestones' hardness and tough structure it became obvious that the already recognised columns were not internally cracked but in some cases reached solidly down to the flint layer and had to be broken gradually from top to bottom. Furthermore the flattened

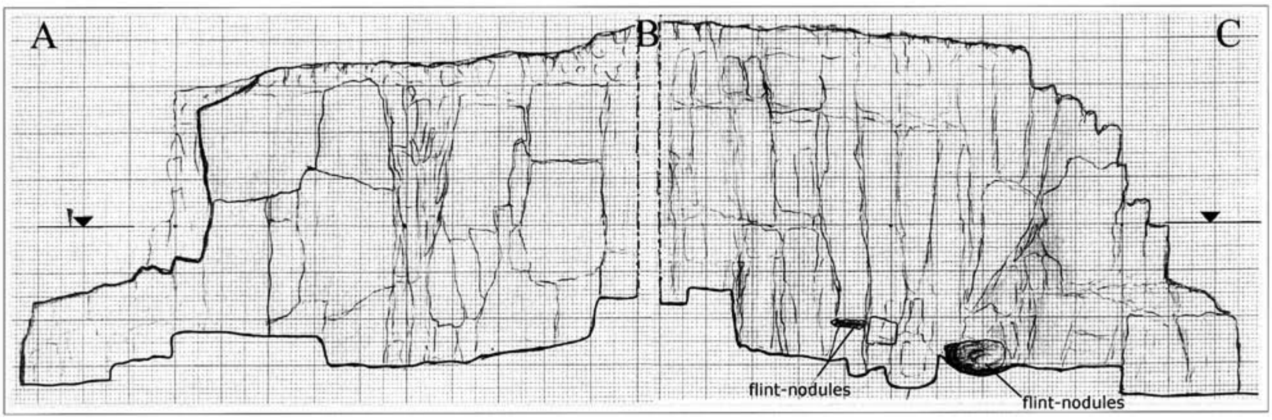

Fig. 5. Ramat Tamar experiment: a section of the extraction front with the dolomite cover and the flint horizons (M 1:20; Z: K. Drechsel, Sept. 2000).

Fig. 6. A large flint nodule immediately after extraction. Note the two of negatives and the cracked dolomite.

ends of the wooden crowbars yielded, and finally broke. An attempt with two differently shaped basalt pebble hammers was carried out to shatter the limestone. As we found this an ardous, uneffective task, it was decided to carry on with the metal crowbars.

It became clear to us that by using the natural cleft system very little force is needed in order to weaken the cracked dolomite and divide it into inividual columns. After expanding the existing cracks the metal crowbars turn out to be very useful in applying mechanical leverage and detaching the stone columns from the rock mass.

Consequently, a combination of leverage with the metal crowbars and subsequent cleaning of the clefts and cracks turned out to be very successful.

We reached a first flint layer of up to 5 cm thick flat flint nodules at a depth of *ca.* 1.25 m below the actual surface. At another 6 cm below the flat flint nodule horizon, the main layer of huge nodules is deposited (fig. 5). While the nodules could easily be detached from their bed leaving typical negatives in the underlying stratum (fig. 6), portions of the adjacent limestone still adhered to their sides and upper surface. As successful flint working can only be achieved with "clean" nodules, we attempted to remove the adhering limestone. This was solved with the aid of the basalt pebble hammers and turned out to be quite easy as this particular limestone was not very tough. So it may be possible, that the original basalt hammer could, in fact, have been used for the removal of the adhering limestone.

Preliminary conclusions

Cleft system

The natural cracks had reduced the original massy compact limestone/dolomite into individual vertical sections and thus must have played a key-role for the prehistoric extraction method. We suggest that the Neolithic miners took advantage of the existing cleft system, expanded the cracks and quarried the stone with very little force applied.

Prior to the removal of the individual columns, the clefts had to be cleaned of their filling.

As it is virtually very difficult to remove the columns in one piece, they must have been broken into fragments employing percussion tools, *i.e.* hammers.

At the same time advantage must have been taken of the clefts by either using crowbars or wedges. Though a thus achieved horizontal displacement of the columns would have been quite restricted, it served to loosen the extraction front's overall structure.

Crowbars

Due to the quite narrow clefts, it seems that wooden crowbars with thin tapering ends were not suitable for enlarging the clefts. The same holds true for bone which is too brittle. No remains of antler tools which should have been well preserved were found, and it seems that antler crowbars or wedges were not used. In case Neolithic miners used wooden crowbars they had to expand the natural cracks beforehand and adjust

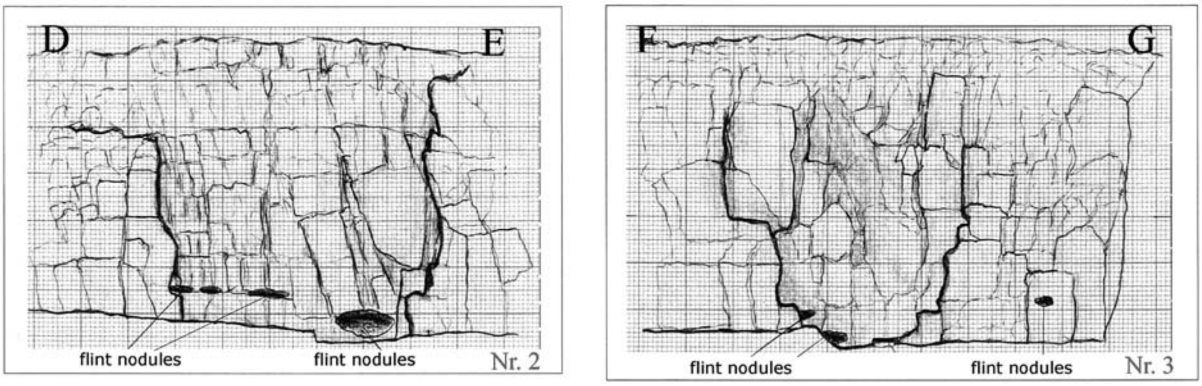

Fig. 7. Ramat Tamar: Individual extraction niches located within the Neolithic extraction front (M 1:20; Z: K. Drechsel, Sept. 2000).

Fig. 8. The flint nodules extracted in the experiment.

the thickness of their leverage tools to the designated cleavage planes.

Wedges

Wedges were not tested during this stage of the experiment. Neolithic wedges could have been made of wood, traces of which would not have been preserved. The "extending wedge technique" using dry wooden wedges and water, is only suited for clefts in solid rock. Using this method on the open "flexible clefts" at Ramat Tamar would probably not have achieved the desired effect.

Neolithic wedges could have been made of sturdy flint flakes which should bear shattering marks on their striking platform. According to information by D. Schyle, University of Cologne, who is studying Taute's collections, no such flakes were found during the excavation. Anyway, during the next stage of the experiment, this hypothesis will be tested as well.

Antler wedges are well known from European flint mines (Di Lernia, 1993; Lech, 1980; Weisgerber *et al.,* 1980). Their remains should have been well preserved, but none have been found at Ramat Tamar, and it seems they have not been used (Barkai, 2005).

No traces of fire-setting have been observed, neither in the shape of charcoal nor indirectly as discoloration of limestone.

Cleaning and dissecting the nodules

As the flint nodules are acctually connected to the immediately above limestone layer, the adhearing limestone has to be removed by pecking/knapping. Though we did not further work the nodules, the first step in the *chaîne opératoire* would, of course, be to open them systematically which would require tough hammerstones of suitable shapes, and again, due to their toughness, basalt hammers seem the most likely tools. It is clear that the Neolithic miners indeed dissected the extracted nodules in the workshops found adjacent to the extraction localities and further reduced the large nodules into carriable blanks, cores and roughouts. These were taken to the nearby workshop of Messad Mazal where bifacial tools were shaped and blades were produced.

Extraction niches

As a result of our documention of the extraction front, a feature was observed which was not described by Taute (1994). In fact, the front's face is running irregularly and can be devided into individual niches, three of which can clearly be distinguished (fig. 7). Their width is roughly 1 m while their depth can reach up to 0.5 m into the front. These niches could be interpreted as individual extraction areas where different teams of miner's worked. Creating niches makes a perfect sense as it isolates a sort of spur between them (a pronounced spur between niches 1 and 2; another wider, equally pronounced one between niches 2 and 3) which subsequently could be simultaneously attacked not only from one face (the spur's front face) but also from two additional side faces.

End note

Summing up, a combination of percussion (by hammers) and leverage (presumably by wedges and crowbars) at the moment seems to be the most likely method of flint extraction at Ramat Tamar. The Neolithic miners were familiar with the natural structure of the thick covering dolomite layer and took advantage of the existing cleft system. The rock characteristics allowed relatively easy quarrying, using mainly leverage with the aid of constant cleaning and debris removal. We would like to suggest that the combination of high quality and almost endless quantity of perfect flint nodules covered by thick but cracked limestone made Ramat Tamar a favourable extraction location during Neolithic times. This is the reason Neolithic miners kept returning to this extensive industrial landscape again and again for providing Neolithic communities with superior raw material.

During our experiment five tons of rock were quarried and seven flint nodules, 66 kg in weight were prized (fig. 8). This experiment was conducted by three unexperienced flint "miners" during 3 working days. The first two days of our experiment were mostly spent on studying the rock characteristics and practicing possible quarrying techniques. The actual quarrying work demanded only a fraction of our three days' stay.

It must be kept in mind that Neolithic miners decided to STOP their quarry operation at the place our experiment took place, and therefore our results stand for a minimum estimation of the Ramat Tamar quarry potential.

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