

Prehistoric Flint Mining at Ryckholt-St. Geertruid (Netherlands) and Grimes Graves (England).

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Introduction

During excavations at Ryckholt-St. Geertruid (1964-1972) we examined more than 60 flint mines (shafts and their galleries). Radio-carbon dates indicate these mines were in use between 3150 and 3050 B.C.

At Grimes Graves we examined (1973-1976) about 20 flint mines. Here, Radio-carbon dates gave only a general indication of a date between 2200 and 1800 B.C.

The large number of mines examined represents only a small fraction of the total number of flint mines at both locations.

We estimate that there are more than 1000 at each location. However, before I give a description of the prehistoric working-methods, it is necessary that I say something about the term mining.

Essentially, the term mining includes all types of exploitation of minerals and raw materials. In a limited sense, the term is used for exploitations by subterranean activities.

Here, I want to restrict these remarks about flint mining to mining with shafts and galleries, to a depth of more than 2 meters. Shafts shallower than 2 meters could be made by a single person and often the skilfulness of that person determined the working method rather than mining rules about safety and efficiency.

Shafts deeper than 2 meters involved more persons working together and this co-operation promoted generally efficient and safe working methods.

Basic mining rules

First I would like to outline the basic mining rules followed at both, Ryckholt-St. Geertruid and Grimes Graves.

We found a number of nearly empty galleries, running straight between two shafts. It was assumed that these galleries were kept open for safety reasons, and so we called them "escape-routes".

Sections through the galleries indicate that efficiency and safety determined their shape and size. Using a minimum of space (a safe working method) the miners efficiently extracted a maximum amount of flint. The different shapes of the galleries at Ryckholt-St. Geertruid and Grimes Graves were caused by differing lithologies, soft homogeneous chalk at Ryckholt-St. Geertruid and hard jointed chalk at Grimes Graves.

In the galleries, there is at the face only room for one quarry worker. Such a small space is, however, a basic mining rule for prehistoric flint mining.

The depth of the shaft, the length of the galleries, the horizontal area worked, the amount of flint extracted and the number of persons employed are all closely interrelated (See Fig. 1).

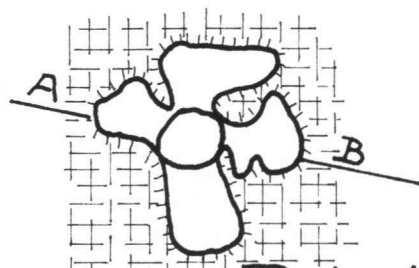
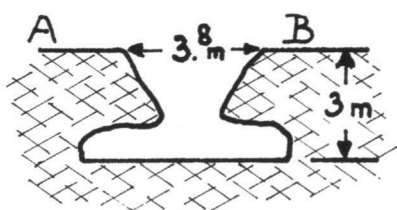
Normally it is the rule that the length of a gallery is less than the depth of the shaft. It is easier to dig a new shaft than to quarry a gallery which is longer than the shaft is deep.

This is because of the extreme difficulties associated with transportation in a narrow gallery.

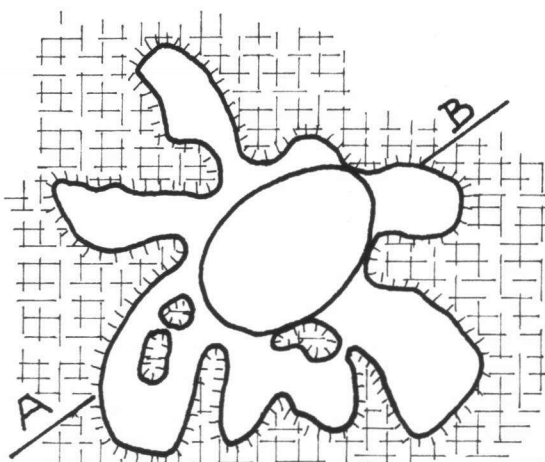
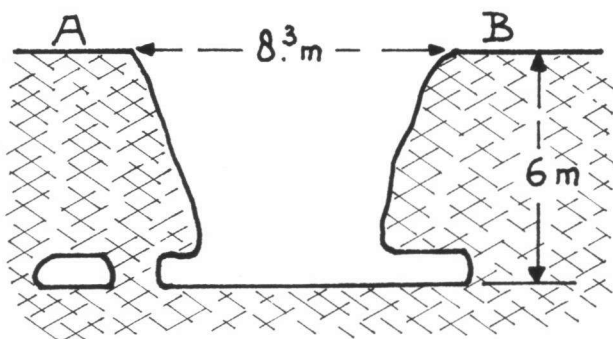
GRIMES GRAVES

Section of the shaft

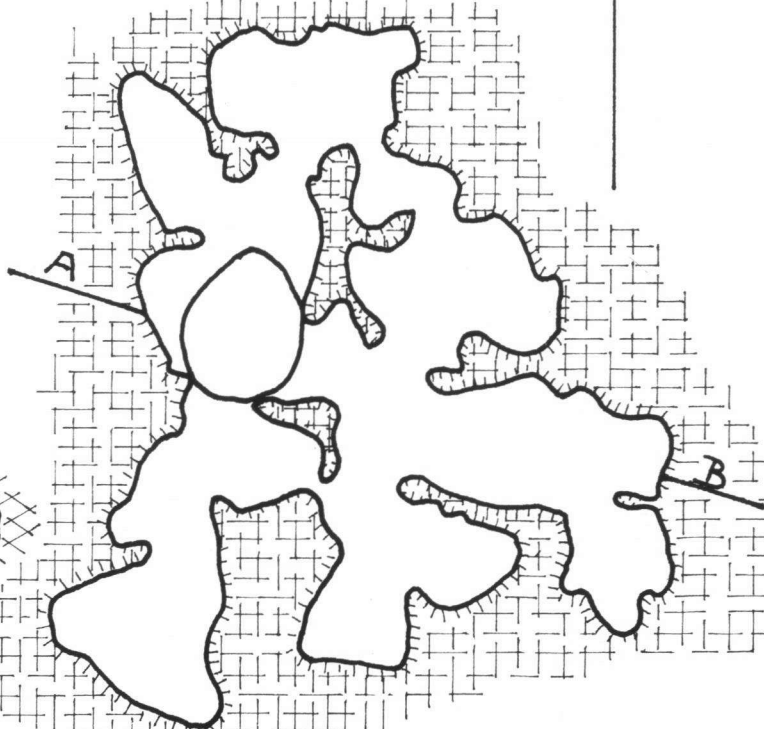
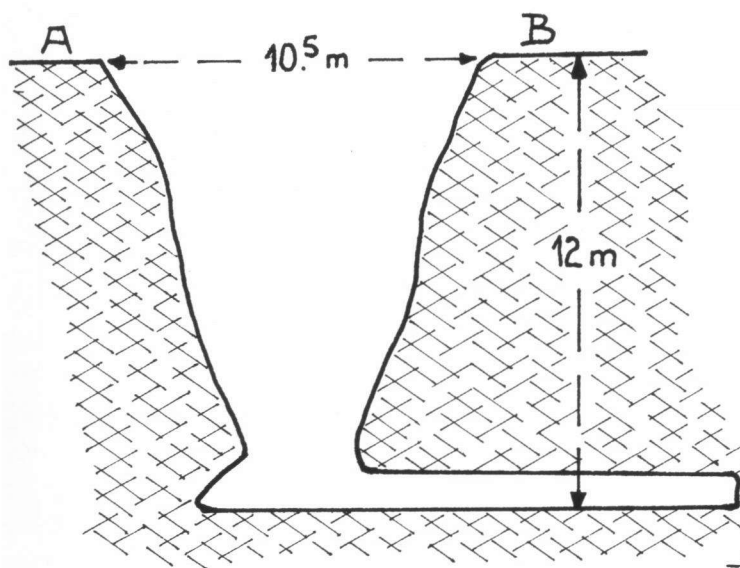
Exploited area



Pit 11



Pit 15



Greenwell's Pit

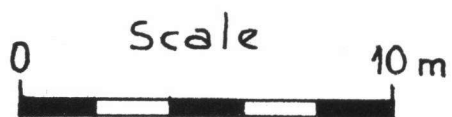


Fig. 1.

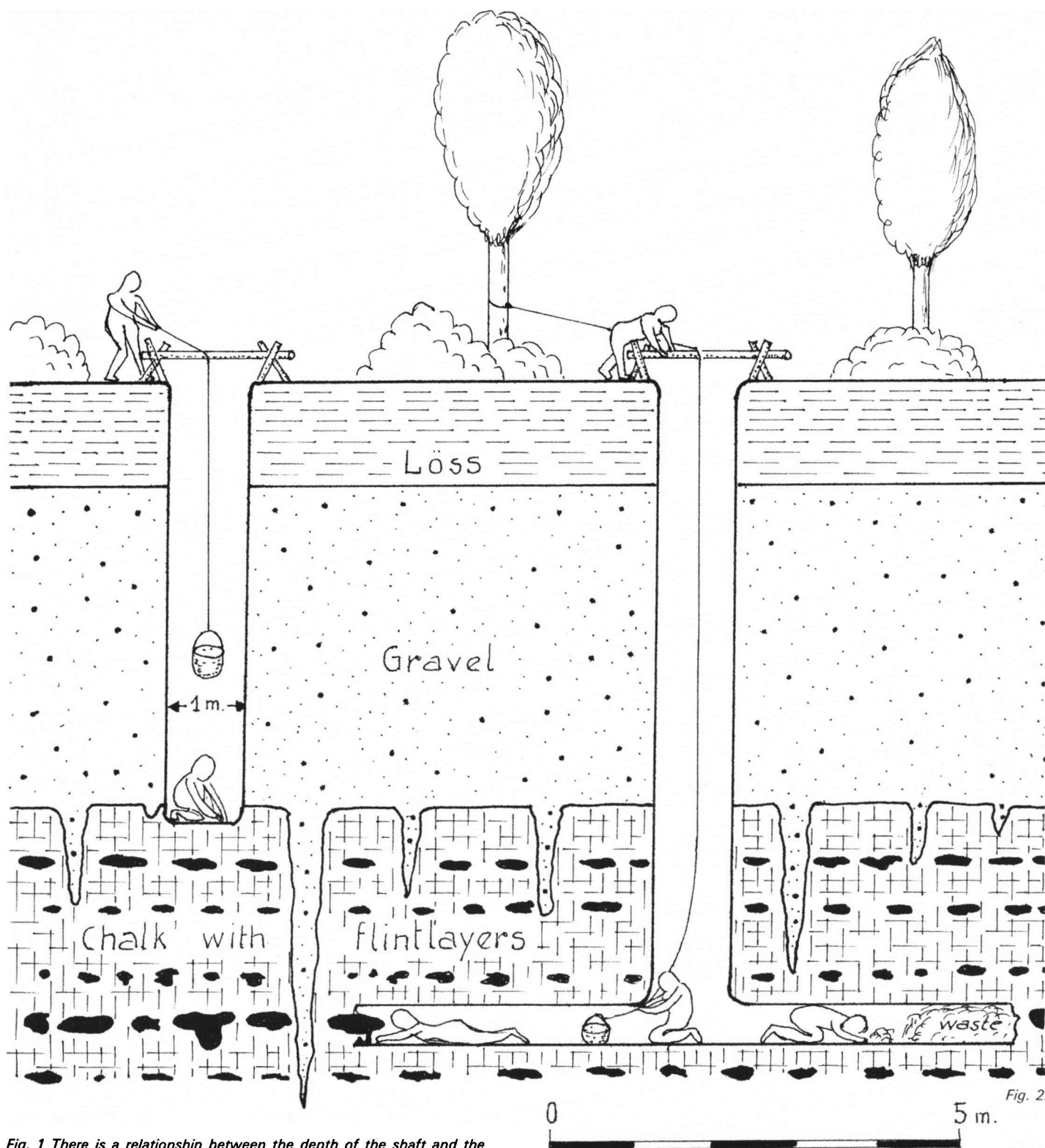


Fig. 1 There is a relationship between the depth of the shaft and the horizontal exploited area.

Fig. 2 Reconstruction of the working method at Ryckholt-St. Geertruid, vertical section.

As a rule, the horizontal area exploited by galleries and niches was larger than the square of the depth of the shaft. Thus it was necessary to obtain a larger amount of flint in the deeper shafts to compensate the additional time spent in digging the shafts.

Galleries and niches were connected to the shaft by the shortest direct distance. In this way the transportation was reduced to a minimum. For the same reason all the abandoned works (except the escape routes) were refilled with quarried waste material.

It is clear that an increase in the area exploited from a shaft would require a corresponding increase in the number of persons employed. It was impossible for one person to quarry a gallery longer than 2 meters in an efficient way.

A reconstruction of the working methods at Ryckholt-St. Geertruid

The shafts were dug out by two persons, one quarrying at the bottom of the shaft and one hoisting the quarried material to the surface. In this way they produced a shaft about 1 meter in diameter (minimum room required for one quarry worker). (See Fig. 2).

In several shafts we found grooves worn into the chalk wall of the shaft, an indication that the miners used ropes for hoisting the material.

When reaching the intended flint layer, the miner started to quarry a gallery which usually became the escape route.

Because the escape route had to be kept open, refuse had to be carried to the surface. After more galleries had been opened up, the refuse was used for refilling the abandoned works.

When the mine had been finished, two of the galleries, the escape route and the gallery last quarried, remained almost empty.

The last quarried gallery, normally was the escape route for the next shaft (See Fig. 3).

This simple, but safe and efficient working method, was generally employed in shafts of between 2 and 4 meters depth. In deeper shafts (4-8 meters) efficiency and safety required a different working method. Two adjacent shafts were dug out simultaneously and the escape route was obtained by a short gallery between the two shafts. The work at this gallery decreased, but the shafts did not lie in the centre of the exploited areas. To get the required amount of flint (greater than for the less deep shafts) the construction of longer galleries was necessary. The increased length of the galleries increased the number of employed persons involved in transportation.

The deepest shafts at Ryckholt-St. Geertruid (8-12 meters) were characterized by a third working method. The miners dug out a shaft straight above the end of an empty gallery of a previously used shaft. This meant that the escape route was ready immediately after digging the shaft. Transport-work decreased in this way because the miner could start to refill the previously abandoned works.

In this case the shaft was located at the edge of the mine and the length of the galleries had to be increased more and more, to get the required amount of flint. In a same way the number of persons required for transportation was greater. The increasing number of workers reduced the output per worker, because at any time only one person was quarrying flint.

This rough outline of flint mining at Ryckholt-St. Geertruid highlights the relationship between the depth of the shaft and the working methods.

If it is remembered that there was room for only one person quarrying flint in these mines, it is possible to calculate the number of persons employed in transportation. A maximum number would here be 2 persons at the shaft plus 1 person for every 2 meters of the longest gallery of the mine.

If the daily production of the worker quarrying flint is known, it is possible to calculate the time required for exploiting the flint in a mine. Experiments indicate that an average amount of a 1/2 m³ (or 1 m² in a gallery) was within reach of a prehistoric miner.

Taking all of above into consideration, it is possible to reach the following quantitative conclusions about prehistoric flint mining at Ryckholt-St. Geertruid.

Depth of the shaft	Number of persons	Max. length of the galleries	Total working-days for shaft + 1 st gallery
2 m	1	—	3 + — = 3
4 m	2	2 m	6 + 2 = 8
4 m	3	4 m	6 + 4 = 10
6 m	4	6 m	9 + 6 = 15
8 m	5	8 m	12 + 8 = 20
10 m	6	10 m	15 + 10 = 25
12 m	7	12 m	18 + 12 = 30

Depth of the shaft 2-4 m
The shaft lies in the centre of the exploited area
Maximum length of the galleries 2 m
Exploited area per mine 4-16 m²
Amount of exploited flint per mine 1300-5200 kgs
Number of employed persons per mine 2
Number of working days per mine 7-22
Daily output per person (flint) 118-140 kgs

Depth of the shaft 4-6 m
The shaft does not lie in the centre of the exploited area
Maximum length of the galleries 2-4 m
Exploited area per mine 16-50 m²
Amount of exploited flint per mine 5200-16250 kgs
Number of employed persons per mine 3
Number of working days per mine 22-59
Daily output per person (flint) 79-118 kgs

Depth of the shaft 6-8 m
The shaft does not lie in the centre of the exploited area
Maximum length of the galleries 4-6 m
Exploited area per mine 50-76 m²

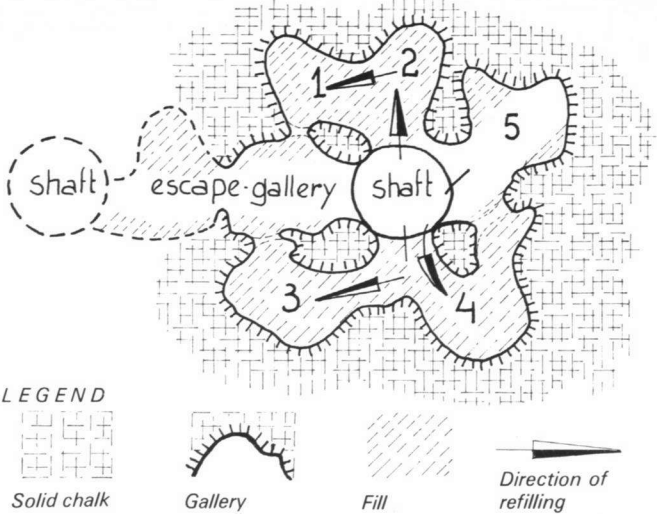


Fig. 3 Reconstruction of the working method at Ryckholt-St. Geertruid, horizontal area of shafts 2-4 meters deep.

Amount of exploited flint per mine 16250-24700 kgs
Number of employed persons per mine 4
Number of working days per mine 59-88
Daily output per person (flint) 77-79 kgs

Depth of the shaft 8-10 m
The shaft lies at the edge of the exploited area
Maximum length of the galleries 6-8 m
Exploited area per mine 76-115 m²
Amount of exploited flint per mine 24700-37375 kgs
Number of employed persons per mine 5
Number of working days per mine 88-125
Daily output per person (flint) 65-77 kgs

Depth of the shaft 10-12 m
The shaft lies at the edge of the exploited area
Maximum length of the galleries 8-10 m
Exploited area per mine 115-161 m²
Amount of exploited flint per mine 37375-52325 kgs
Number of employed persons per mine 6
Number of working days per mine 125-179
Daily output per person (flint) 65-53 kgs

The simple, but safe and efficient, working methods at Ryckholt-St. Geertruid limited the amount of flint exploited, by increasing the number of working days and decreasing the output per person. It was therefore impossible to exploit a large amount of flint in a short time from a deeper mine.

A reconstruction of the working methods employed at Grimes Graves

The wide funnelshaped shafts at Grimes Graves are 5-50 times larger than the small shafts at Ryckholt-St. Geertruid (see Fig. 4). It is impossible to attribute this large size of the shafts to geological factors. I assume that the geological situation at Grimes Graves is more favourable for the construction of small shafts.

From a mining point of view a wide funnelshaped shaft is disadvantageous in many ways. For example, the use of hoisting ropes is difficult, even impossible, in shafts which have a diameter of 10-15 m at the top, and narrow to 3-5 m at the bottom. Moreover, the miners had to remove 5-50 times the amount of material to reach the flintlayer.

To remove this large amount of material the miners had to use 5-50 times the number of working days, or 5-50 times the number of employed persons, or a combination of both. Therefore I formed the impression that the shafts at Grimes Graves were dug out by a group of persons, without use of hoisting ropes.

Quarrying a shaft at Grimes Graves

The shaft-area, at the surface, indicates the number of persons according to the basic mining rule of minimum room.

To get an idea about the minimum room for working in a group we conducted some experiments upon which the following calculations were based.

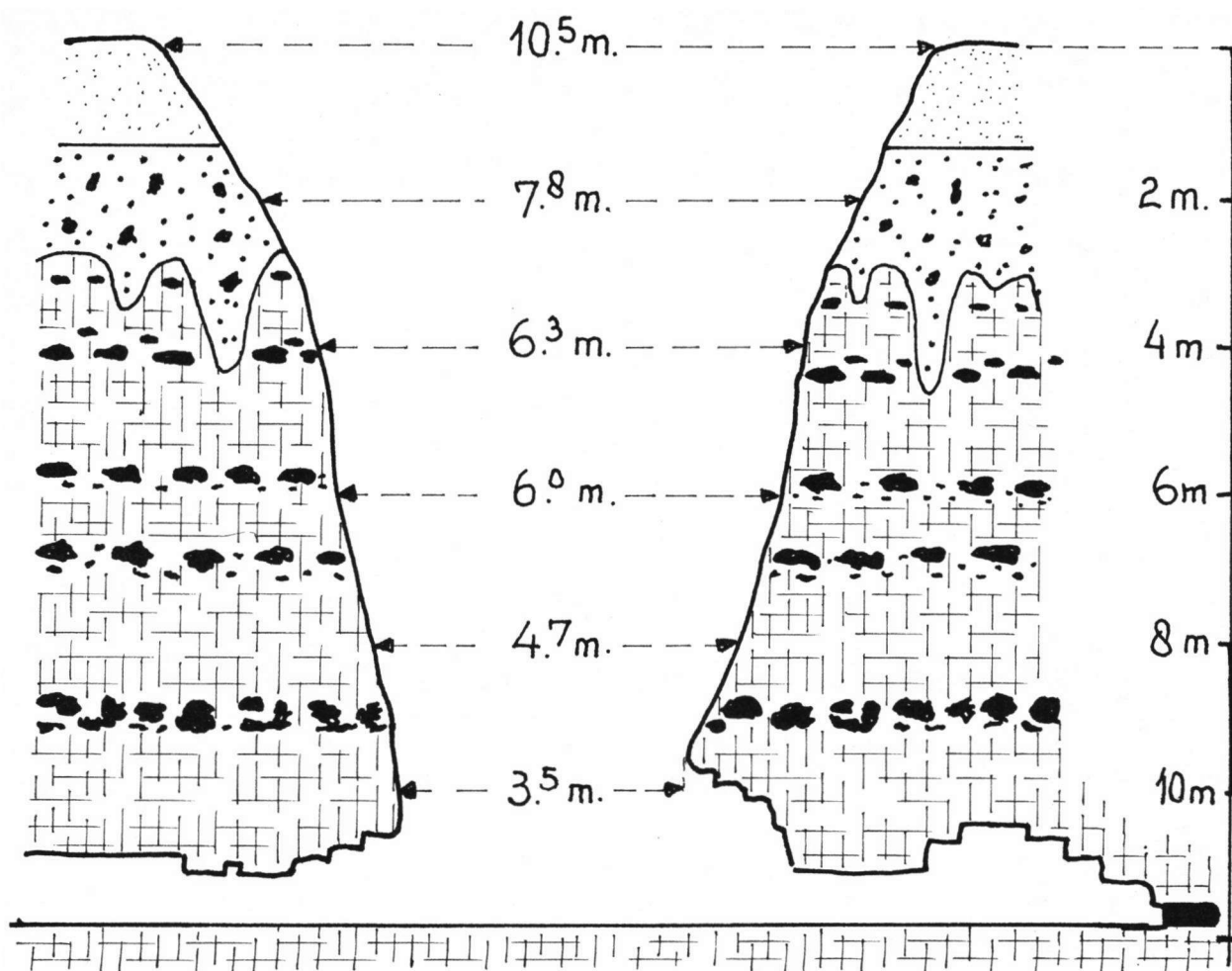


Fig. 4 Section of the shaft Greenwell's Pit, Grimes Graves.

1 persons	=	0.75 m ²	=	a shaft-area with a diameter of	1	m
2 persons	=	4.00 m ²	=	"	2.26	m
4 persons	=	10.00 m ²	=	"	3.75	m
9 persons	=	27.00 m ²	=	"	5.86	m
16 persons	=	64.00 m ²	=	"	9.03	m
21 persons	=	85.50 m ²	=	"	10.43	m

The funnel shape of the shaft indicates that the number of workers engaged in quarrying decreased with increasing depth of the shaft. However, with increasing depth of the shaft, the number of persons engaged in subsidiary work, such as carrying material and building scaffolding must have increased.

If we know the number of workers engaged in quarrying (according to the area of the shaft), we can calculate the number of working days in a same way as for Ryckholt-St. Geertruid (1/2 m³ daily per person). As an example I present the calculations of the shaft "Greenwell's Pit" at Grimes Graves (See Fig. 4).

Depth in m	Ø shaft in m	Number of persons quarrying		Amount of material removed in m ³	Number of working- days
		Max.	Min.		
0-2	10.5 - 7.8	21	- 14	133	12
2-4	7.8 - 6.3	14	- 10	78	12
4-6	6.3 - 6.0	10	- 9	59	13
6-8	6.0 - 4.7	9	- 6	45	15
8-10	4.7 - 3.5	6	- 4	26	13
10-12	3.5 - 4.5	6	- 4	25	13
12	10.5 - 3.5	21	- 4	365	78

After the miners reached the flintlayer, at a depth of 12 m, they started to exploit this layer by means of galleries.

Quarrying galleries at Grimes Graves

There is a relation between the space at the bottom of the shaft and the number of galleries. Therefore I assume that the same

number of workers at the bottom of the shaft started to quarry galleries. In this way the exploitation of the area took place much more quickly than at Ryckholt-St. Geertruid.

In Greenwell's Pit, I estimate that we can count on a total of 21 persons. Only 4 of them had room to quarry in a gallery. The rest, 17 persons, must have been restricted to transportation activities or flintknapping. Their work can be subdivided into:

4 persons for transportation in the galleries.

6 persons for transportation in the shaft.

7 persons for flintknapping or other work at the surface.

There are 4 galleries in Greenwell's Pit, and these have been refilled with quarried waste material. The fill was brought into the galleries in successive stages of the work. We can divide the work as follows: (See Fig. 5).

Stage I: Around the bottom of the shaft niches and galleries were quarried to a length of 2 meters.

Stage II: 4 galleries were quarried to a length of 4 meters.

Stage III: 1 gallery was stopped and refilled.

3 galleries were quarried to a length of 6 meters.

1 niche was quarried in a gallery.

Stage IV: A second gallery was stopped and partly refilled.

2 galleries were quarried to a length of 8 meters.

2 niches were quarried and the niche of stage III refilled.

Stage V: Gallery 3 was stopped and partly refilled.

1 gallery was quarried to a length of 11 meters.

3 niches were quarried and the niches of stage IV refilled.

Stage VI: Quarrying at the front of the galleries ceased.

4 niches were quarried and the niches of stage V were refilled.

Stage VII: Quarrying of niches continued till the moment of complete refilling of the abandoned works was achieved. Only the last quarrying sites were kept open.

The working methods employed in the galleries at Grimes Graves fit my conception of safe and efficient mining; safe because the

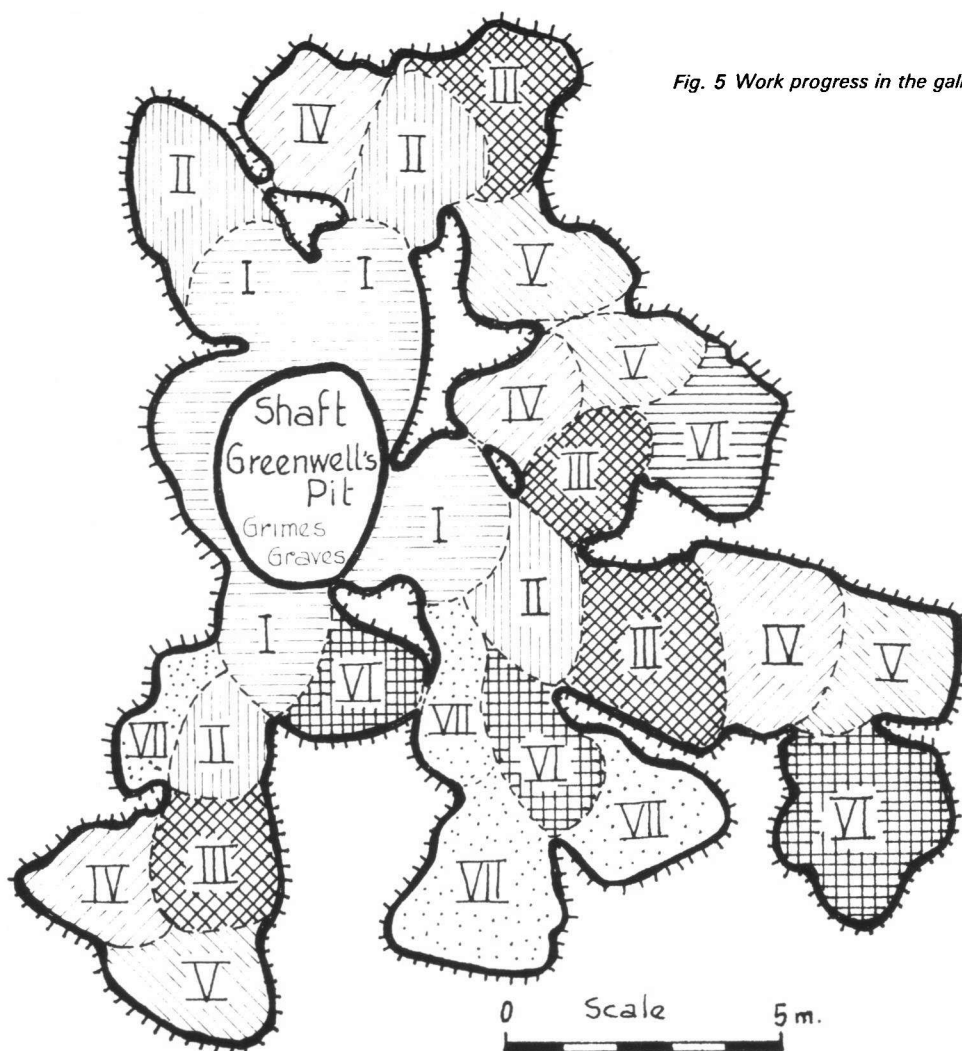


Fig. 5 Work progress in the galleries of Greenwell's Pit, Grimes Graves.

niches are made in a backward direction (backward mining) and efficient because the quarried waste material was put into the abandoned works near the place of quarrying.

At Grimes Graves there is also a relationship between the depth of the shaft, the exploited area, the length of the galleries and the number of persons employed to exploit them (See Fig. 1).

We can calculate the working days at Grimes Graves in a same way as we did for Ryckholt-St. Geertruid. The number of workers engaged in quarrying is however of great importance. Calculations, based on measurements of several excavated shafts of varying depth, are presented here.

Depth in m	Ideal group of persons	Capacity of the shaft in m ³	Exploited area in m ²	Amount of exploited flint in kgs.	Number of working-days	Daily output per person in kgs flint
2 - 3	2 - 4	1.5 - 17.5	4 - 15	1300 - 4875	7 - 19	140 - 171
3 - 4	4 - 9	17.5 - 50	15 - 30	4875 - 9750	19	71 - 62
4 - 6	9 - 12	50 - 100	30 - 50	9750 - 16250	19 - 30	62 - 50
6 - 8	12 - 15	100 - 175	50 - 76	16250 - 24700	30 - 47	50 - 39
8 - 10	15 - 18	175 - 250	76 - 115	24700 - 37375	47 - 80	39 - 30
10 - 12	18 - 21	250 - 325	115 - 161	37375 - 52325	80 - 115	30 - 24

The working days for flintknapping or various work at the surface are not included in the daily output per person.

General

It must be understood that the miners at Grimes Graves and also at Ryckholt-St. Geertruid, did not always work in a perfect way. Sometimes the mining was based on incorrect calculations of the depth of the shaft or on the number of persons required in a group. However, investigations of the mining at Ryckholt-St. Geertruid and Grimes Graves do indicate that prehistoric mining was a well organized and an efficient kind of work.

Differences in working methods depend on the depth of the shaft and the number of persons employed, but these differences in no way indicate that the working method was in any sense primitive.

The miners at Ryckholt-St. Geertruid preferred the simplest working method. Time was of little importance, but the daily output per person was the important factor.

At Grimes Graves the miners preferred a working method which favoured the exploitation of a large amount of flint in a short time. The daily output per person was of little importance.

If we summarize the calculations of daily output and the working time for both areas, the differences will be clear.

Depth of the shaft in m	Number of persons employed		Number of working days necessary		Daily output per person in kgs	
	Ryckholt	Grimes	Ryckholt	Grimes	Ryckholt	Grimes
2- 4	2	2- 9	7- 22	7- 19	140-118	140-62
4- 6	3	9-12	22- 59	19- 30	118- 79	62-50
6- 8	4	12-15	59- 88	30- 47	79- 77	50-39
8-10	5	15-18	88-125	47- 80	77- 65	39-30
10-12	6	18-21	125-179	80-115	65- 53	30-24

From a mining point of view we must assume that prehistoric mining was a temporary activity which took place during the warmer months of the year. In the colder months it is quite impossible to work in an open mine. This might explain the working method at Grimes Graves, because it was impossible to get a large amount of flint in a short time, using the Ryckholt-St. Geertruid method.

Reasons for this may be found in the society structures or in the total population of the trade area. Perhaps the distance between the living area and the mining area also played a part.

These considerations may be worth a special study in connection with what had been said here about mining.

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