VI. Interpreting the evidence

1. Planimetric areal measurements

The areas of shafts and galleries of irregular outline were measured by using a planimeter, type A. Ott/Kempten, no. 37763. We used the map 1:50, as measured by P.W. Bosch and W.M. Felder (BOSCH & FELDER 1990).

The areas of the individual mines (gross and net), external and internal pillars and the solution pipes were measured. Internal pillars are those that are positioned entirely within a single mine, while external pillars are those found between two mines or at the outer margin of a mine.

In drawing dividing lines between the mines we based our decisions on our knowledge gained during excavations at Grimes Graves (P.J. FELDER 1997). In a few cases the dividing lines were drawn only after deliberation with other experienced participants.

The individual mines were indicated on the map scale 1:50 by drawing boundary lines around an exploitation unit (most often between the latter and its neighbours). These divisions transect the centre of the breaches that were encountered, whereas external pillars were regularly distributed over adjacent mines. The same was done for solution pipes situated between two mines. Internal pillars and solution pipes were included whole in the mine concerned.
In this way the gross area of each individual mine (= shaft with corresponding galleries, pillars and solution pipes) could be determined. The net area of exploitation of each mine comprises the shaft with its corresponding galleries. By measuring the internal pillars and solution pipes individually it is possible to indicate their areas.

2. CAD, map and artefacts

At a later stage (from 1990) the excavation plan of the flint mines was digitalised using the computer assisted design program Autocad, at the State Service for Archaeological Research (Amersfoort), under the expert guidance of Paul Zoetbrood.

This enabled the transfer to the main plan in a short period of time of all measuring points on submaps drawn at different scales. Upon entering only two fixed points, the computer automatically adjusts all other measuring points entered to the right scale. This became the basis for plotting the finds, which, based on these measuring points, were plotted by triangulation. We have not yet found the time for input of these data. The most important categories on the map were referred to different 'levels' in Autocad (comparable to sheets of tracing-paper), as follows:

- chalk islands
- solution pipes
- shafts
- breaches
- limits of mines
- limits of excavation
- data such as shaft number and measuring points.

By means of this program areas and outer limits of all map entities can be computed, allowing us to produce portions of map to any scale (and at all desired levels).

Data on the surface area of mines, chalk islands and solution pipes were entered in a DBase III+ file, assigning serial numbers to all elements which are now available in two working-document versions of the map (resting with Marjorie de Grooth and P. Sjeuf Felder). The next stage, subsequent to an error analysis, will involve entering these numbers to individual levels of the computerised map.

With regard to the category 'limits of mines' we opted for the delimitation of the space cleared, exclusive of internal and external breaches, which thus differs from measurements executed by planimeter (see VI.1.). In the present paper planimeter data are used.

The files are available on request.

3. Map: interpretations

3.1. Measurements and observations

The net surface area of the excavated prehistoric mines adds up to 1525,8 m^2 (Fig. 18). Within this area 75 shafts were recognised. Of 56 shafts all mine galleries were excavated and plotted. Shafts 1, 37, 67 and 68 were excluded from

Fig. 18.1 Map of the excavated mines - Western part.

Fig. 18.2 Map of the excavated mines - Middle part.

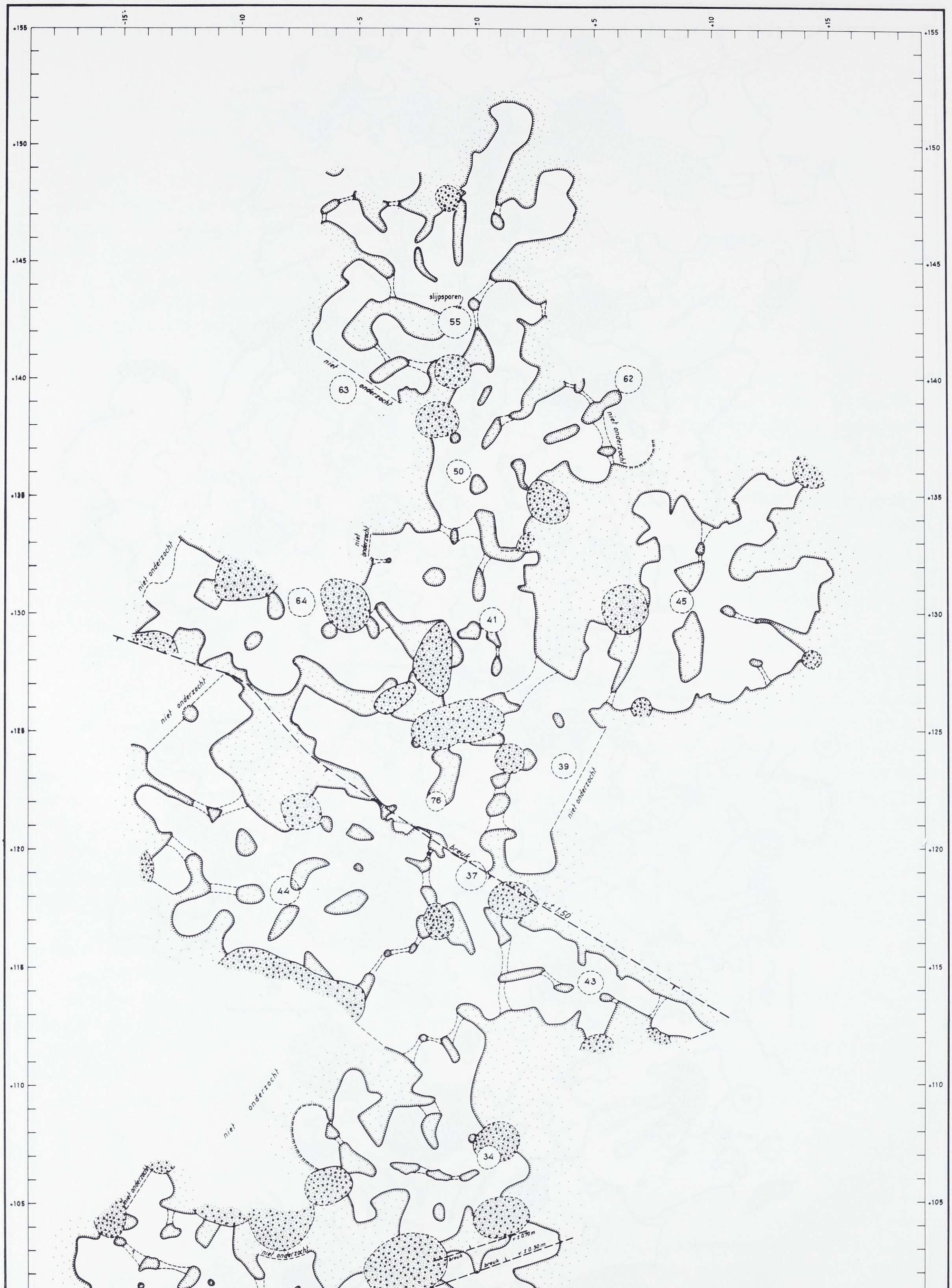

Fig. 18.3 Map of the excavated mines - Eastern part.

calculations, while we assumed shafts 30 + 37 to represent but a single shaft. In total, 51 mines were excavated completely and included in the calculations.

In Fig. 19 the excavated area is subdivided into sections (A-E) and shafts are shown with any connecting galleries. Also indicated are the number of mines excavated fully, the minimum and maximum depth below surface, the minimum and maximum as well as mean distances between the shafts, and the minimum and maximum as well as mean gross and net surface area of the mines. Finally, some contour lines are indicated (+ 116 - +124 NAP).

During the excavation a number of observations were made which are of importance for interpretation of the plan. Almost all galleries were filled with extracted chalk and other refuse. A number of galleries, however, were found to be almost empty (e.g. between shafts 14 and 15). They will be discussed in section 6.3.4. In almost all underground workings tool marks were recognised (Report 31). In various shafts marks were found which document the use of ropes.

The prehistoric miners did not dig shafts at random, but in rows, which are more or less parallel to the contour lines (Fig. 19). Taken together with the increase in size of the mines, this seems to indicate a well thought-out plan during shaft construction.

3.2. Reconstruction of prehistoric method of working

Only in part does the reconstruction of the method of working discussed herein rely on data collected from the underground workings. Other data were collected during visits to excavations in other areas of prehistoric mine fields (e.g. Grimes Graves, United Kingdom). In addition, it is based partly on experiments carried out, and, naturally, on the extensive mining experience of the participants. For the first time in history, prehistoric mines were excavated by modern mining engineers at Rijckholt-St. Geertruid.

3.3. Shaft construction

As was demonstrated above, shafts were not dug at random but in a carefully selected spot. When determining the location of the shaft problems could arise even aboveground, e.g. a large tree in the way, or hints of the presence of a solution pipe in the subsoil. In such cases, the miners simply deviated from the strict theoretical plan. Miners need to be flexible; despite all preparations there may be problems at various times. As the German mining proverb goes, *'Hinter der Hacke ist es dunkel'*, i.e. you are never certain what to expect next. In mining, it is impossible to make predictions.

Despite all preparatory work, some shafts will have been dug in the wrong places. We can definitely rule out that people intentionally dug shafts across a solution pipe; the danger of collapse would have been too great. Yet some shafts must have been dug into such pipes unintentionally (Shafts 1, 3, 4, 8, 34, 66, 70 and 77). It is quite possible that more shafts were dug in a larger solution pipe, but we cannot be certain about this, since we were unable to detect these shafts when working underground. At Shaft 29 we think we have an indication of such a large-sized pipe. The exploited area there is too extensive in comparison and some large solution pipes occur into which shafts could have been dug without 'striking' chalk.

Only two people were needed to construct a shaft, regardless of depth, provided that ropes and a kind of basket were available to draw up the extracted material. In view of the rope marks in the shaft walls the prehistoric miners did indeed have ropes and maybe even a crane.

The diameter of the shafts at Rijckholt-St. Geertruid are such (*c.* 1 metre) that it would have been impossible for two people to work there. All shafts recognised were thus dug by a single person only. This miner will of course have been assisted by another person who took care of haulage of the extracted material from the shaft. In this way, there was no need for the man in the shaft to come to the surface to dispose of small quantities.

As much as possible, the spoil from a shaft was dumped into a disused shaft. Not only were old shafts filled in this way, but portions of the gallery near the bottom of the shaft as well. This method was adopted as it was the easiest way to work there.

When digging shafts through the overburden (loam and gravel) deer antler picks especially

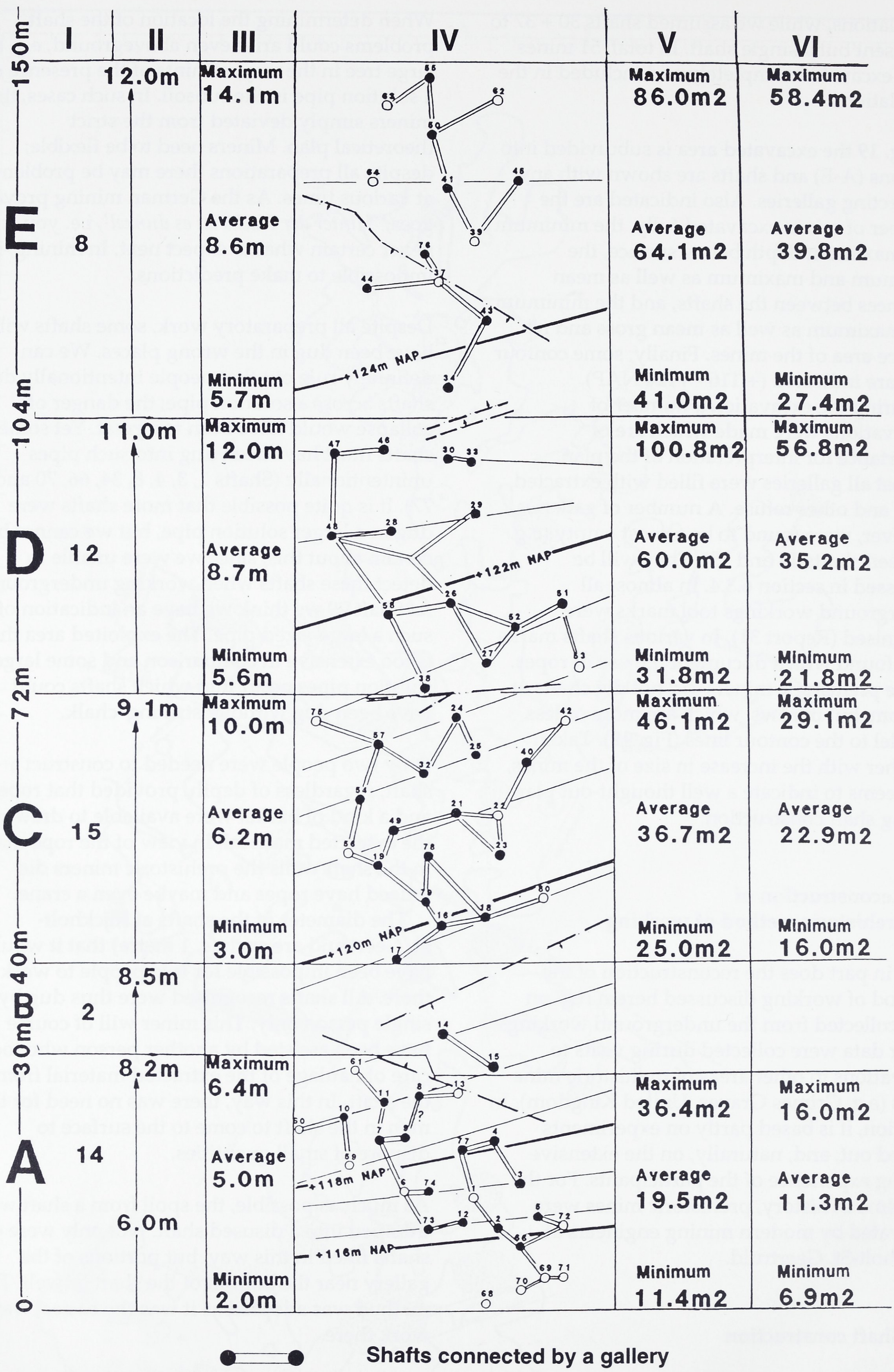

Fig. 19 Schematic overview of connections between mines.
I: number of mines; II: maximum depth of shafts; III: distance between shafts; IV: shafts in excavated area, closed symbol: completely excavated mine, open symbol: partly excavated mine; V: gross area; VI: net area.

were used. When constructing the entrance of the tunnel, we found only few antlers (not plotted), more or less resting on the surface. The largest number of antler picks were found by the Dominican friars in their shallow excavations at the 'Schoone Grubbe'.

We may assume the shaft to have been supported in one way or another in the unconsolidated overburden. We found clues in the form of voids left by split timbers (see VII.1.2.).

Antler picks (Fig. 23) were more often used as scrapers rather than as picks. Upon 'striking' chalk, stone picks were used. The indurated top of the chalk was worked with heavy stone hammers (*Kerbschlägel*), such as the ones found near the tunnel entrance. In contrast, the softer chalk layers were worked with flint picks in wooden hafts. Two types of flint heads were distinguished: narrow and broad ones. Narrow picks were used for scraping rather than for cutting, whereas the broad ones were indeed used for hacking.

The fact that people dug shafts right through several flint layers to reach flint bed 10 of the Lanaye Member clearly shows that they knew beforehand which layer had to be exploited at the bottom of the shaft.

3.4. Construction of galleries

Upon reaching the required flint layer, people began to extract flint nodules from the walls of the shaft, thus starting the first gallery. In a gallery, the flint nodules were undermined, then removed by using hafted picks (predominantly narrow ones) to scrape the surrounding chalk. After removal of flint the gallery was excavated to the required height and width (using mainly broad hafted picks). Thus originated a gallery with the greatest width at a level corresponding to the flint layer, i.e. more or less in the centre of the gallery. From a mining viewpoint this is an efficient way of exploitation, making certain that the largest possible amount of flint was mined. Chalks and flint nodules excavated in the first gallery at the bottom of the shaft would have to be brought to the surface to create room to work in. To do this, the same haulage system as employed in shaft construction could be used. As the gallery was widened, a portion of the excavated chalk could be deposited on the sides of the gallery. People used all available space underground to dump refuse. In such a gallery only a single miner could move. When the gallery was extended, a second person had to assist the first in transportation of the material excavated. In experiments we conducted it became apparent that a stretch of two metres length worked best. Transportation of materials within the gallery was easy using hands and feet to scrape (we often did this ourselves during the excavation), which explains why we did not find any scoop shovels.

It seems reasonable to assume that in some places, especially at dangerous sites, temporary timber supporting props were used. Voids left by wood found in the fill point to this.

On encountering empty galleries, generally between two shafts, we assumed these to have been left for safety reasons and referred to them as 'escape galleries'. If anything did happen within the shaft in which people were working they could always flee to the adjoining shaft. Such an escape gallery was located between shafts 14 and 15. Another example was found between galleries 50 and 55. In shaft field 55, however, two other galleries were found to be more or less empty. The explanation we came up with was that shaft 55 was originally situated at the outer margin of the mine field. For this reason no new shaft was dug here and the last galleries remained empty. Should an additional shaft have been dug later one of the galleries would have been filled and the other remained empty to be used as escape route. The discovery of these two empty galleries in one and the same shaft field reinforced our assumption that escape routes were constructed intentionally. Remarkable in any case is that almost all mines were well connected with one or more neighbours (Fig. 19), generally by means of gallery 'a' (Fig. 20).

Looking at individual exploitation units (Fig. 20), it is apparent that there is a development in the length of galleries and the area of mines. The smallest mines in fact comprise but a single gallery (see Shaft 4), while the largest mines consist of a complex of galleries (see Shaft 29). Between these extremes numerous intermediates can be recognised.

In the various ground plans a certain system may be seen. Gallery 'a' was probably dug to connect two mines. Gallery 'b' was excavated in

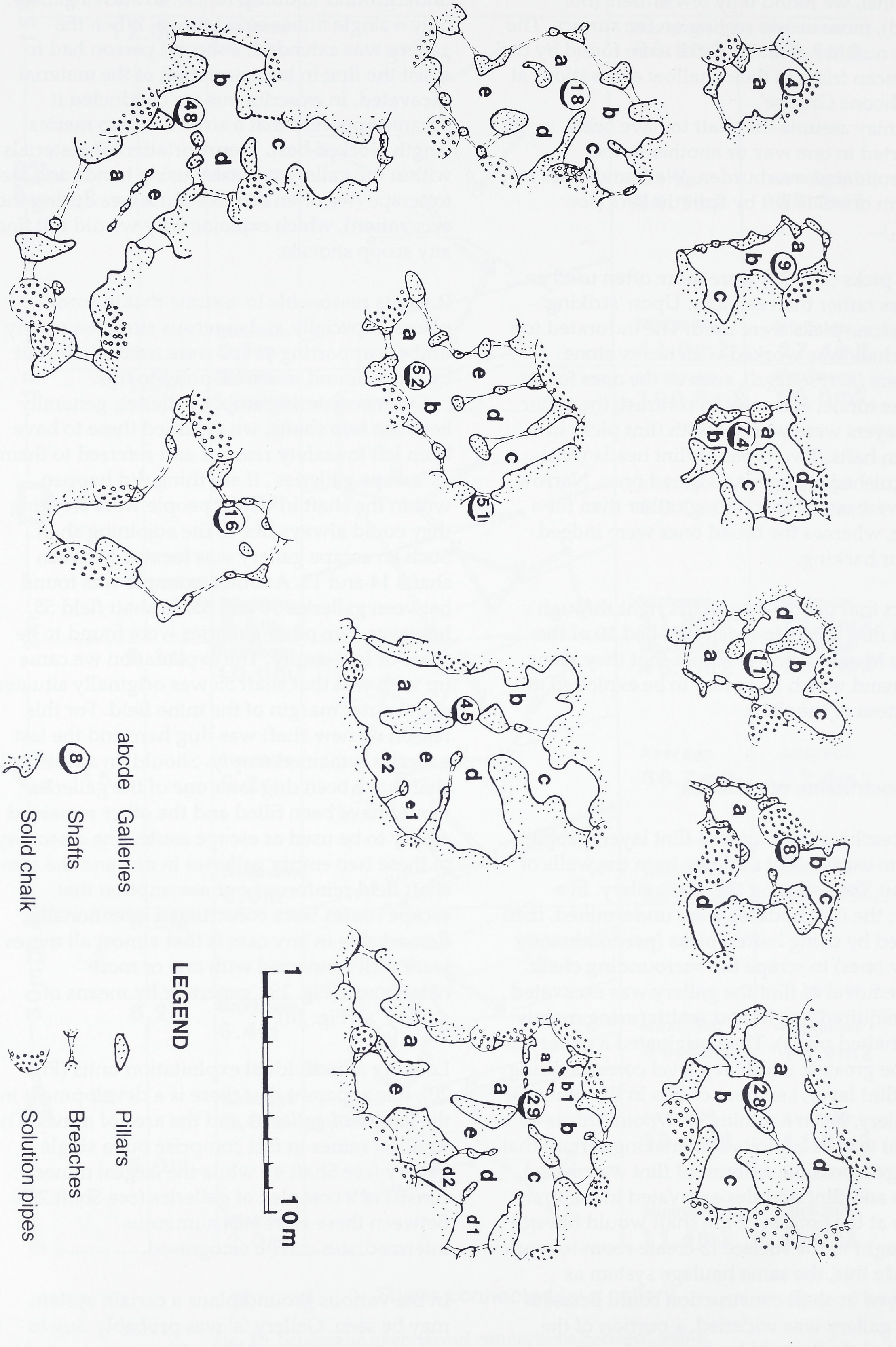

Fig. 20 Ground plans of characteristic mines.

line with gallery 'a' on the opposite side of the shaft so as to start the new exploitation. We may assume that galleries 'a' and 'b' both at first were hardly or not filled and remained open. Gallery 'a' could thus be considered to represent the escape route. Gallery 'b', however, would eventually be filled during construction of one of the other galleries.

In shafts that correspond to Shaft 9 (Fig. 20), the construction of a new gallery (gallery 'c') was started. At the start of the excavation we referred to these small galleries as niches. These often appeared to be empty, whereas gallery 'b' was largely filled.

In shafts that are comparable to Shaft 74 (Fig. 20) two more galleries ('c' and 'd') were excavated, starting from the shaft and galleries 'a' and 'b'. Refuse was used to fill as much space as possible (i.e. with excavated chalk).

As the area to be exploited increased, so did the number of galleries, resulting in a complex system as that seen in Shaft 29. The basic principle, however, remained the same: expose first (galleries 'a' and 'b'), followed by further exploiting through branching galleries until the required amount of flint had been excavated or the available room had been filled with refuse. Naturally, geological conditions played an important part in determining the method of exploitation. The form of the mines and the direction of the galleries was in part determined by these conditions, as was the width of the internal pillars. If conditions were advantageous, it was possible to have small, slender pillars, or, as seen in Shaft 16, have almost no pillars at all. The filling of the galleries in part prevented collapse. During our excavation it appeared that the fill was occasionally under pressure and so in places had a support function.

Not only did the prehistoric miners construct shafts and galleries purposefully to excavate flint, they also did this as efficiently as possible. As the shafts became deeper, they were more widely spaced (see Fig. 19). With increasing shaft depth the distance between the shafts and the surface area exploited increased. All this combined with the simple and safe method of constructing galleries demonstrates that already in prehistoric times very efficient mining took place.