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Excavations of Prehistoric Flint Mines at Rijckholt-St. Geertruid (Limburg, The Netherlands)

by the 'Prehistoric Flint Mines Working Group' of the Dutch Geological Society, Limburg Section

edited by P.J. (Sjeuf) Felder, P. Cor M. Rademakers & Marjorie E.Th. de Grooth

DGUF

In Kommission bei Dr. Rudolf Habelt GmbH Bonn 1998

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I. General information

1. Introduction

The 'tunnel excavation' of the prehistoric flint mines at Rijckholt-St. Geertruid (1964-1972) was to be the first in a series of studies of such mines in Europe. The three flint symposiums at Maastricht in particular, as organised by Working Group members, who also participated in the excavation, have contributed much to this development. Following upon the excavations in Rijckholt-St. Geertruid, this Working Group also excavated flint mines at Grimes Graves (P.J. FELDER 1977; SIEVEKING 1979; LONGWORTH & VARNDELL 1996).

In view of the fact that the excavations were carried out and the flint symposiums organised outside official working hours the participants spent much of their own time. This in part explains why the present paper took so long to complete. Other reasons include the lack of knowledge of underground flint mining, which, however, progressed during the excavation. At any rate, this lack of knowledge made it clear that some matters had to be examined in great detail before they could be written up. The study of the many hafted flint picks found (Reports 24 and 25) may serve as an example. As it turned out, these studies did not yield unequivocal results.

Beside the problems we faced during preparation of the present paper, there were difficulties of a geological nature, despite the fact that a number of participants specialised in geology. Not until 1979 could the flint layer exploited at Rijckholt-St. Geertruid be identified as layer 10 of the Lanaye Chalk Member (Gulpen Formation).

Over the years, however, a large number of reports have been written on the excavation. Therefore, it was decided to combine all these reports into a single, extensive paper and publish it in some form or other. Only then could we start with the preparation of the present volume.

The basic data on flint extraction and working at the Rijckholt mines are summarised in Chapter X.

2. Excavation reports Rijckholt-St. Geertruid 1964-1972

Results and data are recorded in the *'Rapportage Opgraving Rijckholt-St. Geertruid 1964-1972'*. This report comprises 39 interim reports which on December 7, 1993, were transferred together with all finds, original registration forms, drawings etc., to the Rijckholt Committee of the Council for Cultural Mangement.

The reports, and all associated artefacts, are lodged with the Provincial Depot for Archaeological Finds (Provinciaal Depot voor Bodemvondsten) at Maastricht.

References made in the present volume to Report (number) refer to the various interim reports.

Specification of interim reports:

01: permits and concessions
02: maps of the examined portion of the prehistoric flint mines
03: methods employed in preparation of the computerised version of the excavation area
04: map of the first galleries encountered
05: the Rijckholt 1 skull
06: three voids
07: molluscs in fill of shaft 15
08: archaeological-biological studies at Savelsbos
09: snails from shaft 15 (excursion report)
10: skeletal remains of mammals from shafts
11: vertebrate skeletal remains
12: faunal remains encountered in shafts
13: survey of areas of Rijckholt flint mines
14: announcements and proceedings of meetings of the Working Group
15: Working Group correspondence
16: C14 dating
17: Prof. Dr. A.E. van Giffen's visit
18: publications in newspapers and weeklies on the Rijckholt excavations
19: historical account
20: survey of activities, part 1: 1964-1967
21: survey of activities, part 2: 1968-1972
22: clearing and preservation of the Rijckholt-St. Geertruid mines
23: registration forms for finds and find contexts
24: measurements of finds
25: analysis of finds
26: photographs and slides
27: finds from mine 55

Fig. 1 Working Group members during a lunchbreak (the so-called *botteren*) around the stove; from left to right: Werner M. Felder, P.C.M. (Cor) Rademakers, Cees Roos, P.J. (Sjeuf) Felder, Gerrit M.J. Rademakers, Jan P.M.T. Meessen, Harry L.M. Jonkergouw, Frans H.G. Engelen and G.W. (Sjir) Hensgens.

28: survey of shafts based on Autocad maps
29: registration of finds 3766 to 6264
30: methods of plotting employed during excavation
31: tool marks in the galleries
32: survey of molluscs
33: artefacts and working methods used by the prehistoric miners at Rijckholt
34: letter to Louwe Kooymans about 'Playing with numbers' (= *Spel met getallen*)
35: flint studies in southern Limburg
36: hammerstones from the flint mines
37: annual reports 1965 to 1971
38: drafts for the full publication on the excavations of the Rijckholt-St. Geertruid flint mines
39: list of papers on prehistoric flint workshops in southern Limburg and contiguous areas

3. Members of the Prehistoric Flint Mines Working Group

During the 1964-1972 excavation campaign, the following people were members of the Working Group for the entire period or parts thereof. At the beginning of excavations, a photograph was taken of some of the members (Fig. 1).

Bless, M.J.M.
Bosch, P.W.
Bremen, J.
Dodemont, L.
Engelen, F.H.G.
Engelen, F.H.M.
Felder, P.J.
Felder, W.M.
Geel, E.A. van
Goossens, C.
Hensgens, G.W.
Hermens, J.A.
Horbach, A.J.A.B.G.
Janssens, H.J.
Jonkergouw, H.L.M.
Kessels, A.L.M.
Knol, J.
Koning, H. de
Kraaijenhagen, F.C.
Lardinois, L.G.J.
Meessen, J.P.M.T.
Neumann, A.
Nillesen, J.H.M.
Orbons, P.M.
Rademakers, G.H.J.
Rademakers, P.C.M.
Rensma, J.
Roebroeks, W.
Roos, C.
Roos, N.
Ruys v.Duchteren, J.H.
Simons, J.
Schijven, C.J.
Vegte, G. van der
Willems, J.H.

Members' addresses at the time and the period during which they were active are listed in Report 37.

4. Survey of donors

Large financial or material donations were received from the following companies and institutions. In addition, specific activities resulted in many contributions by firms, societies and private individuals (see Report 37).

We wish to extend our most sincere thanks to all of these people:

Atlas-Copco NV, Rotterdam
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Eerste Nederlandse Cement Industrie (ENCI), Maastricht
Faber, F.J. Prof. Dr., Delft
Gemeentebestuur Kerkrade
Heer, L. Drs. de, Den Haag
Hemsing-Hooge, J.A.M. Mevr. Dr., Utrecht
Ministerie van C.R.M., Den Haag
Nederlandse Aardolie Maatschappij (NAM), Oldenzaal
Nederlandse Organisatie voor Zuiver Wetenschappelijk Onderzoek (ZWO), Den Haag
Nederlandse Geologische Vereniging, Winterswijk
Nederlandse Geologische Vereniging, Afd. Limburg
NV Philips Gloeilampenfabrieken, Eindhoven
NV Oranje-Nassaumijnen, Heerlen
Prins Bernhard Fonds, Amsterdam
Provincie Limburg
Provinciaal Bestuur van Limburg
Rijksinstituut voor Natuurbeheer, Leersum
Rijksinstituut voor Veldbiologisch Onderzoek (RIVON), Zeist
Staatsbosbeheer, Maastricht
Staatsmijnen/DSM NV, Heerlen
Stichting Fonds voor Sociale Instellingen (FSI), Brunssum

5. Translations

Last, but certainly not least, we should like to thank John Jagt (Maastricht), Gillian Varndell (London), and Diane Webb (Maastricht) for turning our Dutch texts into English.

II. Geography and geology

1. Geography

The mine field is situated in the south of the Netherlands (Fig. 2), in the eastern Maas valley (Fig. 3), in the former municipalities of Rijckholt (now Eijsden) and St. Geertruid (now Margraten) (Fig. 4). For the largest part it is located in the slopes between the Middle and Upper Terraces (in the Savelsbos), the remainder being part of the Upper Terrace (St. Geertruid plateau). This area is intersected by a dry valley, the so-called 'Schoone Grub(be)'. Fig. 5 shows that the largest portion of the underground mine field is situated to the south of this valley. This limitation has been determined by a combination of geological and archaeological data (excavations and field observations). Indeed, an exploratory geophysical investigation was carried out by Technical University Delft (BUSSEMAKER 1988), but this did not yield any useful results. This was in part inherent to the geological situation, in particular to the large number of solution pipes which could not be distinguished from shafts. It is quite possible that, in the time available then, the right method of investigation could not be developed (HERBICH 1997).

The maximum distribution of the mined flint layer was mapped at the southern and eastern ends. In the east this boundary has also been noted during the excavation: at the plateau in excavation pit I of the BAI investigations of 1964 (WATERBOLK 1994, figs. 1; 5), and underground, in the Working Group's excavation.

The recess in the west, along the Schoone Grub, documents pre-war observations by Hamal-Nandrin and colleagues, van Giffen and colleagues and the Dominican friars. Over a distance of at least 500 m, they found traces of shafts and galleries on both valley slopes. The demarcation at the northern side is based mainly on field mapping by members of the Working Group during the excavation.[1] Towards the west the limit of mining activities is indicated by the natural outcrop of the flint-bearing limestone beds in the slope towards the Middle Terrace of the Meuse valley.

Demarcated in this way the area in which the underground exploitation was concentrated has an areal extent of *c.* 8 hectares (Fig. 4). This is thus but a relatively small nucleus of the total area from which, over time, flint could have been extracted by means of other techniques (12 hectares). There is no direct link either with the distribution of flint refuse, over an area of 25 hectares.

2. Geology

The prehistoric mine fields of Rijckholt-St. Geertruid are situated to the east of the Meuse River (Fig. 3), just south of the city of Maastricht. During the Quaternary, the river eroded late Cretaceous strata in a terraced valley. The late Cretaceous in this area primarily comprises chalks/limestones with flints. The strata occurring at Rijckholt-St. Geertruid belong to the following lithostratigraphical units (Table 1).

The basal portion of the present-day river valley (Oost Maarland Member [10], Fig. 6) is situated at 39 m + NAP. The terrace gravels are overlain by loamy deposits of the Betuwe Formation [11] or by deposits of the Twente Formation (loess) [9]. The upper surface of the present-day river valley lies at *c.* 48 m + NAP.

The base of the Middle Terrace (Caberg Member [8], Fig. 6) occurs at 48 m NAP. In the Rijckholt countryside, it is clearly visible as a step. Resting on the gravel deposits of the Middle Terrace are loess deposits [9], which in places are covered by brook deposits and alluvial grounds from the Upper Terrace [11]. The surface of the Middle Terrace thus gradually goes from 60 to 70 m NAP.

The base of the Upper Terrace (St. Geertruid Member [6], Fig. 6) is at 114 m + NAP. Its gravels are overlain by loess deposits [9], which, along the margins, have in part been washed away. The surface of the Upper Terrace thus gradually goes from 125 to 140 m NAP. The transition between the Middle and the Upper Terrace (a 55 m height difference) is a wooded area, *c.* 500 m in width and relatively steep. The

[1] NB from the recess at the height of the Henkeput it becomes clear that we no longer consider this pit to be a Neolithic flint mine; cf. WATERBOLK 1994.

Fig. 2 Position of southern Limburg in northwest Europe.

AGE		UNIT	LITHOLOGY	
	Holocene	Betuwe Fm	clay/sand/gravel	[10]
		Twente Fm	loess	[9]
Quarternary	Pleistocene	Oost Maarland		[8]
		Caberg	terrace deposits	[7]
		Geertruid		[6]
Tertiary	Oligocene	Tongeren Fm		[5]
		Maastricht Fm	chalk (Valkenburg)	[4]
			chalk (Lanaye)	[3]
Cretaceous	Maastrichtian	Gulpen Fm	chalk (Lixhe)	[2]
			chalk (Vijlen)	[1]

Table 1 Geological subdivision of strata at Rijckholt-St. Geertruid.

fertile loess deposits on the Middle and Upper Terraces are being used as farmland.

In places, the Cretaceous chalks with flints crop out in the steep margin of the Upper Terrace. Generally these chalks with flints are overlain by younger deposits. Only in places where marked erosion occurred (dry valley 'Schoone Grub', Fig. 7) did steep faces occasionally develop, and chalks with flint layers become exposed. Sometimes only a thin surface wash deposit covers them.

The stratigraphy of the chalks with flint in the Rijckholt-St. Geertruid area has previously been difficult to determine on account of the small exposures. The outcropping chalks were formerly assigned to the 'Maastrichtian' (van RUMMELEN in CREMERS 1923). Since in 1957 (FELDER & FELDER 1957) the boundary between the Maastricht Formation and the Gulpen Formation had been recognised in the 'Schoone Grub', the strata were referred (W.M. FELDER 1971) to the Gulpen Formation, and the Lanaye Member in particular. Difficulties in recognising the flint layers exploited, in comparison with Lanaye Member occurrences elsewhere, were also great.

Not until many years later (1979), when very detailed lithological sections had been logged and checked by using bioclast analyses, did it become possible to correlate flint layers of the Lanaye Member (W.M. FELDER 1979; P.J. FELDER 1979; RADEMAKERS 1995).

The chalks with flints, which at Rijckholt-St. Geertruid form the base of the terraced Meuse valley, are assigned a late Cretaceous, late Maastrichtian age. From the bottom to the top, the Maastrichtian deposits comprise the Vijlen [1], Lixhe 1, 2 and 3 [2], Lanaye [3], and Valkenburg members [4]. The Lixhe and Lanaye members are part of the Gulpen Formation. The Valkenburg Member is the basal unit of the Maastricht Formation.

2.1. Vijlen Member [1], Gulpen Formation, Maastrichtian

In the Rijckholt area, the Vijlen Member comprises two different subunits, the lower of which is a glauconitic chalk (25 m) with little or no flint and of an early Maastrichtian age. The late Maastrichtian portion of this member attains a thickness of *c.* 15 m and consists of fine-grained chalk with small grey flints. The flints from this member have not been exploited in prehistoric times.

2.2. Lixhe Member [2], Gulpen Formation, late Maastrichtian

The fine-grained Lixhe chalks have been subdivided on the basis of flint contents (Lixhe 1, 2 and 3), each *c.* 10 m thick. Towards the top, flint content increases. More or less distinct flint layers form the boundaries between the subunits. Generally, the Lixhe 1 and 2 flints are

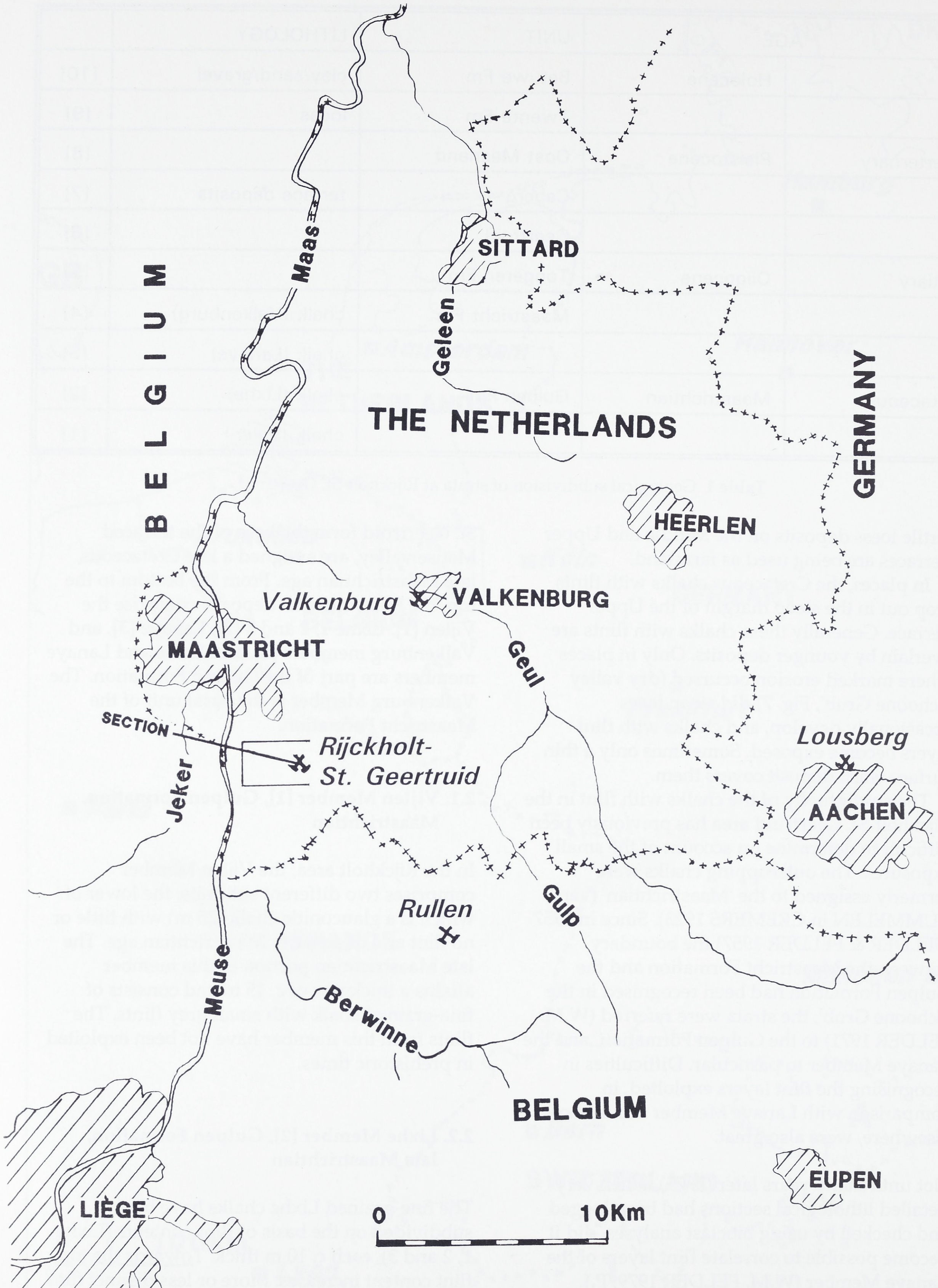


Fig. 3 Southern Limburg and contiguous Belgian and German territories.

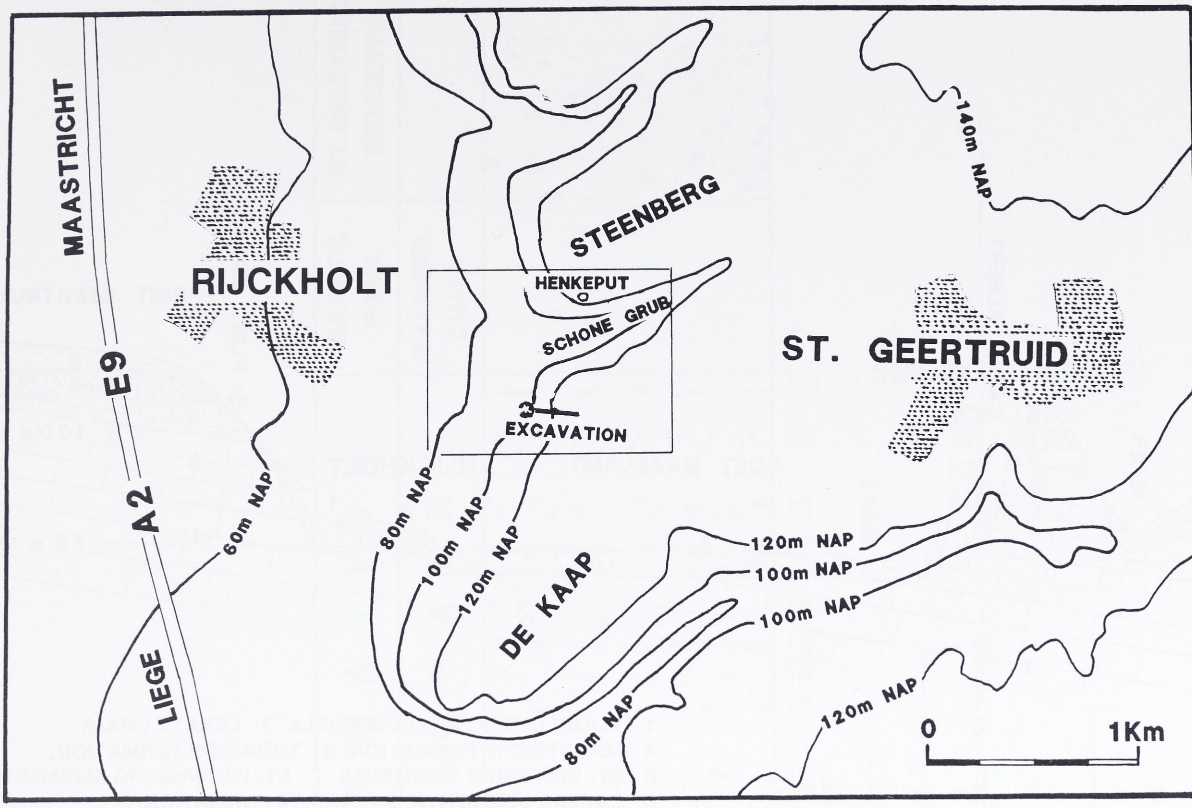


Fig. 4 Map of the Rijckholt-St. Geertruid area.

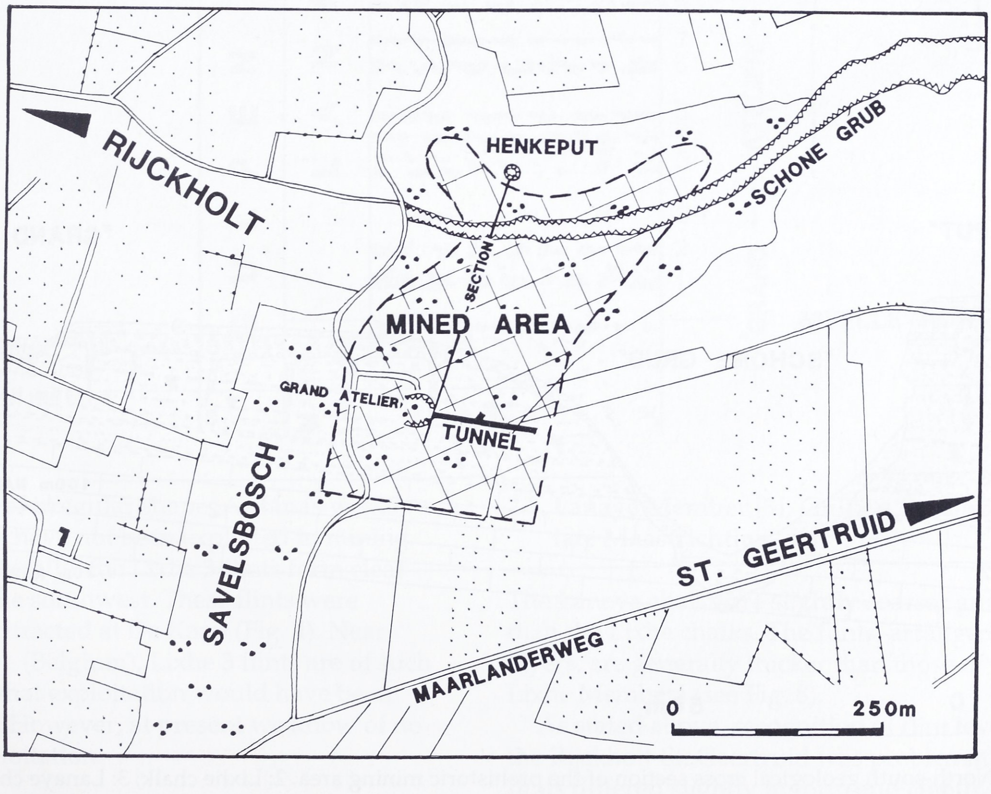


Fig. 5 Extent of the prehistoric mining area.

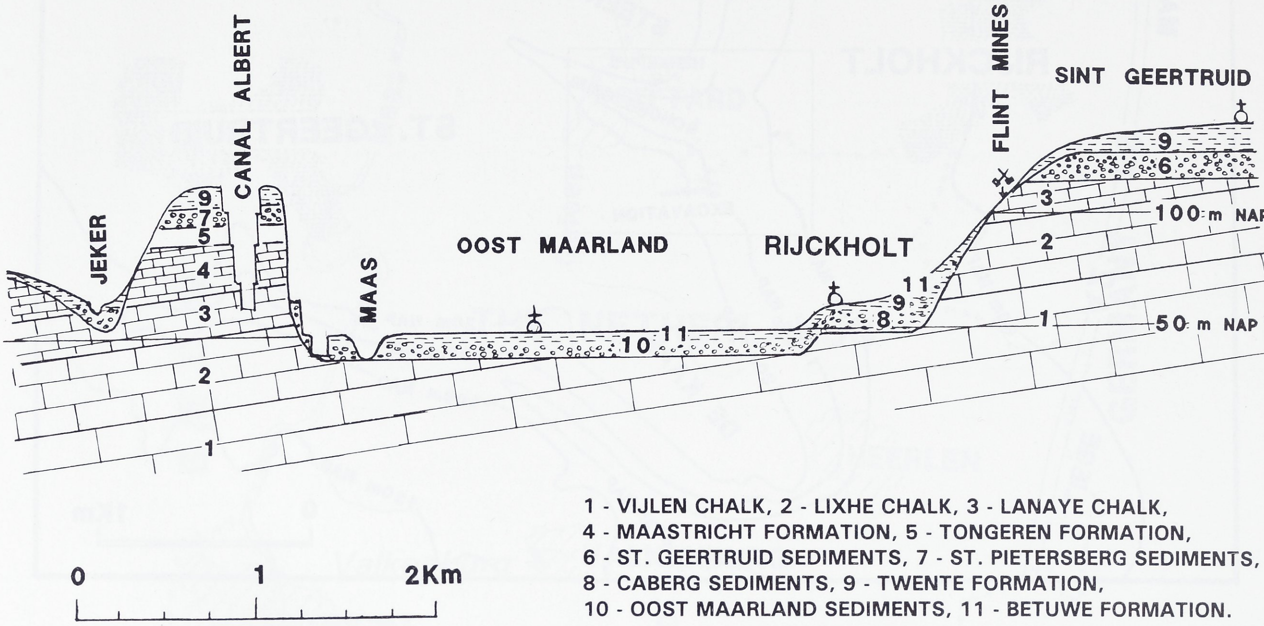


Fig. 6 East-west geological cross section of the Meuse (Maas) River valley, south of Maastricht.

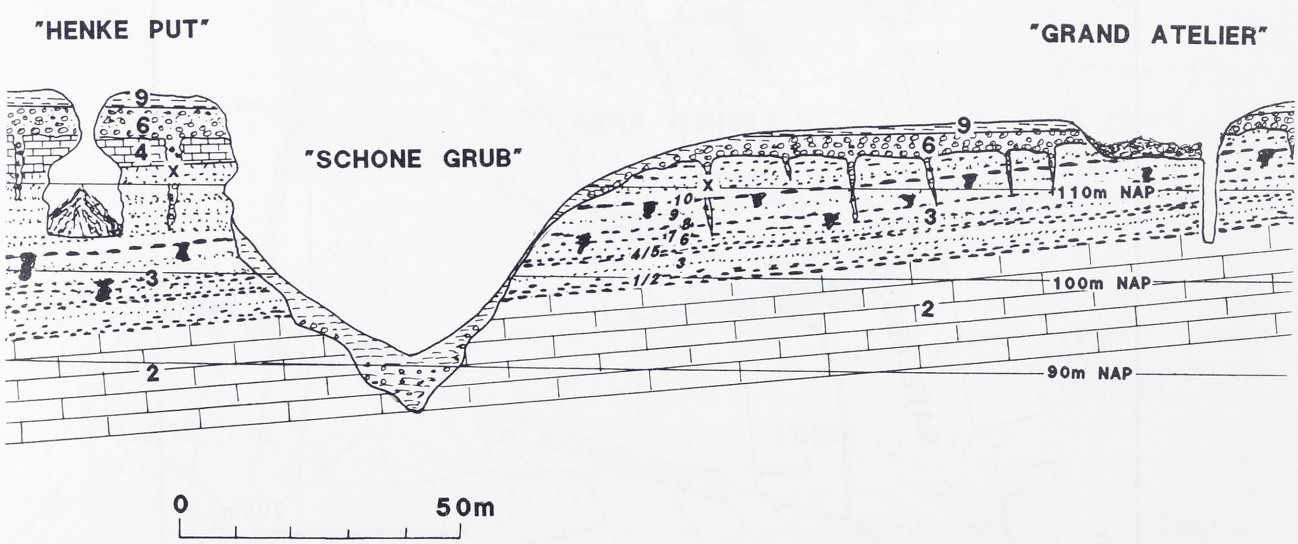


Fig. 7 North-south geological cross section of the prehistoric mining area. 2: Lixhe chalk; 3: Lanaye chalk, *1/10: flint beds*; 4: Maastricht Formation; 6: St. Geertruid sediments; 9: Twente Formation (loess); X: solution pipes.

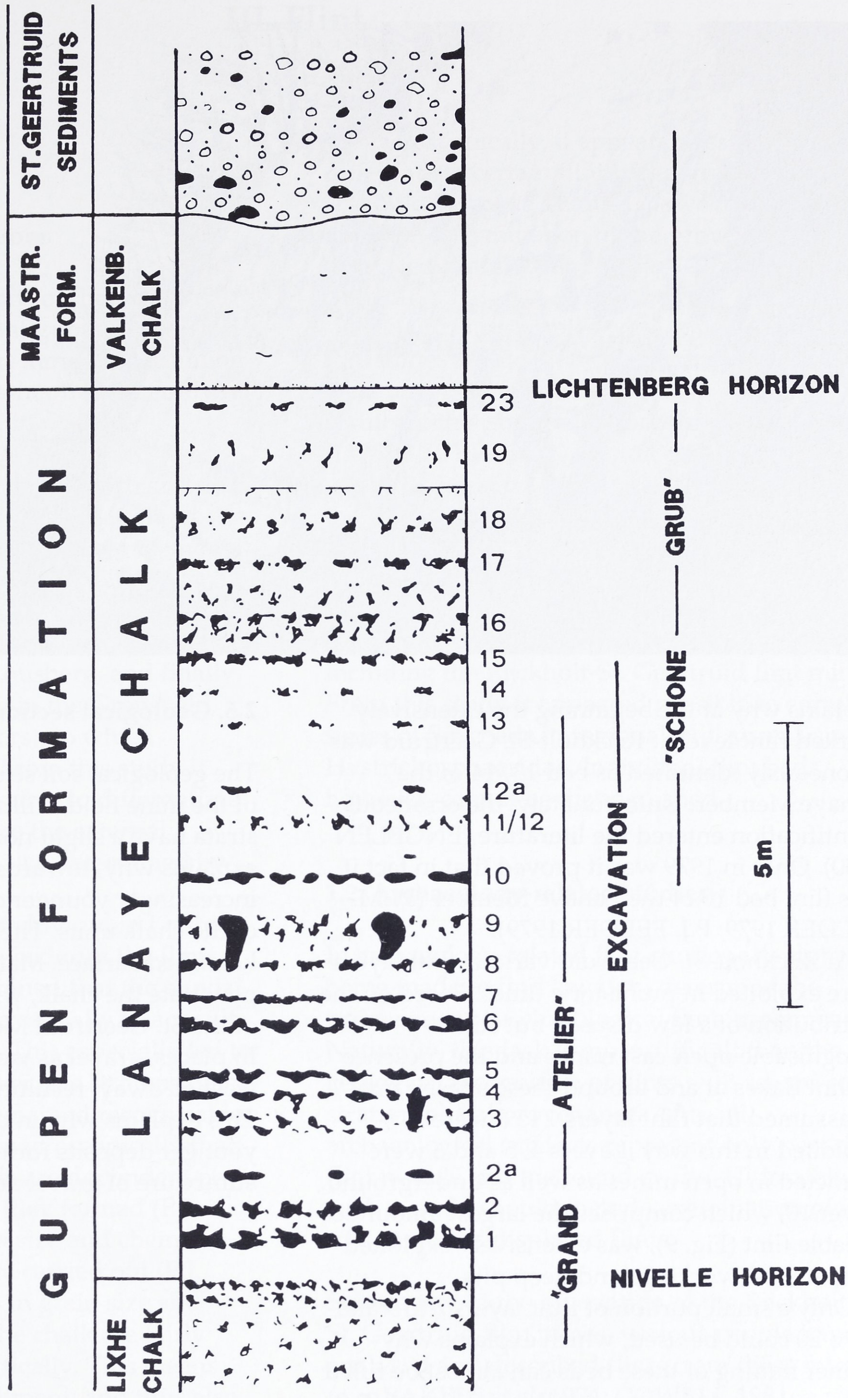


Fig. 8 Stratigraphy of the Lanaye Member (Zone IIIg) in the area excavated.

small and of irregular shape. As far as we know, these flints have not been exploited in mining. Stratigraphically, the Lixhe 3 flints form clear layers in the southwest. These flints were possibly extracted at De Kaap (Fig. 4). Near Halembaye (Belgium), Lixhe 3 flints are of such thickness that exploitation would have been profitable. However, at present we know of no site of exploitation.

2.3. Lanaye Member [3], Gulpen Formation, late Maastrichtian

The Lanaye chalks are slightly coarser grained than the Lixhe chalks. The flints, arranged in 20 layers, are generally thicker than those of the Lixhe Members (see Fig. 8).

As stated above, recognition of flint levels in the Rijckholt-St. Geertruid was problematic. The flints differed slightly in form and colour. This

Fig. 9 Flint layers in the Lanaye Member (Zone VIIw) at Lixhe.

explains why at the beginning the extensively worked flint level at Rijckholt-St. Geertruid was erroneously identified as bed 13/14 of the Lanaye Member. Unfortunately, the erroneous identification entered the literature (ENGELEN 1980). Only in 1979 was it proved that in fact it was flint bed 10 of the Lanaye Member (W.M. FELDER 1979; P.J. FELDER 1979).

At Rijckholt-St. Geertruid various flint layers were exploited in prehistoric times. Based on the distribution of a few disused but still recognisable open-cast mines and the presence of flint flakes at and around these sites, it may be assumed that flint layers 1 to 3 were exploited in this way. Layers 4, 5 and 6 were extracted in open mines as well as underground. Layer 10, which comprises the largest amount of useable flint (Fig. 9), was extensively exploited in open-cast workings and deep pits.

Only a small portion of flint layers 7 to 9 and 11 to 20 could be used, which explains why former mining of these beds can almost be ruled out. In places, however, small quantities of flint may have been mined, for instance in the 'Schoone Grub'.

2.4. Valkenburg Member [4], Maastricht Formation, Maastrichtian

In the Rijckholt-St. Geertruid area, the Valkenburg Member contains little or no flint. The chalk is coarse grained and has clay and glauconite particles.

2.5. Geological section

The geological soil structure in the direct vicinity of the mine field is illustrated in Fig. 7. The chalk strata have a slight northwesterly dip. This explains why, towards the northwest, increasingly younger deposits are at the surface of the chalk units. The top of the chalk is a karstified surface. Many solution structures penetrate the chalk, which is overlain by gravels of the St. Geertruid Member [6] and by loess [9]. In places, gravel as well as loess are strongly washed away, resulting in steep faces locally. This explains why in depressions and valleys younger deposits formed, comprising an admixture of gravel and loess.

III. Flint

1. Geological aspects

1.1. Geological investigations

Macroscopical investigations of flint in Limburg (P.J. FELDER 1960) and contiguous areas were carried out mainly with the aim of determining their stratigraphic value rather than of studying their archaeological recognition. This investigation of *in situ* flints recognised five types. Of these types only types 1a, 1b and 3 are important archaeologically. Type 1a (glassy, black, occurring in Lixhe and Lanaye members) includes the flints mined at Rijckholt-St. Geertruid. Type 1b (glassy, brownish, occurring in the Kunrade limestones) comprises flints from Kunrade and Lousberg, and finally type 3 (granular, occurring in the Gronsveld, Emael and Nekum members), to which Valkenburg flints belong. From this study it emerged that it was impossible to differentiate flints macroscopically, since the external appearance of the flints is also determined by local lithology.

In investigating the flint eluvium in Limburg (P.J. FELDER 1961), which includes the flints from Rullen, it was determined that the eluvial flints principally differed externally as a result of erosion and infiltration. This especially led to a change in colour. However, the stratigraphic provenance of the flints remained recognisable. After having determined macroscopically that, in external aspect, the flints are dependent on the chalk matrix in which they formed (P.J. FELDER 1960; 1961), grain size and chemical analyses of the chalks were carried out (P.J. FELDER 1975). Variations in grain size and chemical composition in the chalk are fairly wide horizontally and vertically. This means that recognition of the sediment, and thus also of flints, on the basis of grain size and chemical composition are possible only to a small degree.

In describing the lithology of the late Cretaceous strata (W.M. FELDER 1975), flints were primarily mentioned on account of the variation in their shape (pipelike, nodules and beds) and in the structureof successive layers. Thus, individual flint layers nowadays can be identified, but only when they may be studied within the context of a broader stratigraphic succession.

Macroscopically, it appears possible to differentiate certain flint types stratigraphically. It should be borne in mind, however, that detailed determination of the provenance of a displaced flint nodule remains extremely difficult.

In 1965, flint samples were collected from the flint mines at Rijckholt-St. Geertruid, and these were analysed for microfossils. In 1972 the results of this study were published (LOBENSTEIN 1972). In that paper the author concluded that it was impossible to distinguish the individual flints on the basis of microfossils.

In 1995, RADEMAKERS presented a comparative inventory of Hystrichosphaeridae in the flint layers of the Lanaye Member. He studied 48 flint beds occurring at four localities, including the Rijckholt-St. Geertruid flint mines. From this study it appeared possible to correlate series of flint beds in regional exposures using Hystrichosphaeridae. Individual flint beds, however, cannot be distinguished.

1.2. Archaeology-related studies

In archaeology-related flint studies attempts are being made to find a way to determine the provenance of archaeological flint implements. Naturally, this task is more difficult than the geological recognition of flints with regard to stratigraphical provenance. After all, archaeological artefacts represent only part of a flint nodule and are found *ex situ*. Ultimately, such a study should include examination of *in situ* as well as displaced flints.

Subsequent to the excavation of the Rijckholt-St. Geertruid flint mines, various people have analysed and described flints from these mines (e.g. BAKELS *et al.* 1974; COWELL 1981; THOMPSON *et al.* 1986; KARS *et al.* 1987 and de WARRIMONT & GROENENDIJK 1993).

In 1974 BAKELS *et al.* published a neutron activation analysis of flint from the prehistoric mines in comparison with flint from various other sources. Their preliminary conclusion was that neutron activation analysis alone was not enough to solve archaeological problems. Although differences between flints from the various deposits (amongst others Gulpen Formation (type 1a, P.J. FELDER 1960), Kunrade limestones (type 1b, P.J. FELDER 1960) and Maastricht Formation (type 3, P.J. FELDER 1960) were expressed in this analysis, it was impossible to distinguish flints from Rijckholt-St. Geertruid from other prehistoric exploitation sites such as Rullen, Mheer and Banholt.

In 1981 COWELL published a thorough study of trace elements in flints. A total of 197 samples from the Maastricht area were examined. Of these 18 were from the Rijckholt-St. Geertruid flint mines (layer 10). As the other flint samples came from other layers (13/14) the results were difficult to interpret.

In 1986 THOMPSON *et al.* reported on a study in which flints from Rijckholt-St. Geertruid were examined, analysing 16 different trace elements using the ICPAES method (= Inductively Plasma Atomic Emission Spectrometry). The authors considered this method to present good opportunities for distinguishing flint types. The study, however, would have to be extended.

In 1990 KARS *et al.* described flints from Rijckholt-St. Geertruid on the basis of their petrographical and geochemical composition. The authors considered their investigation to be the start of a promising project. They stressed the need for further studies, which were carried out subsequently. In 1991 McDONNELL *et al.* reported on the results of a petrographical and geochemical study of Rijckholt-St. Geertruid flints and from a number of other exploitation sites, e.g. Rullen and Mheer-Banholt. The authors pointed out that a combination of petrography and geochemisty made it possible to subdivide the flints into three categories. The results of their analysis of the Rijckholt-St. Geertruid flints show a good correspondance with the results for Lanaye Member flints (McDONNELL *et al.* 1997).

In 1993 de WARRIMONT & GROENENDIJK described the results of a macroscopical study combined with a spectrometric examination. They reached the conclusion that the six known archaeological sites between Maastricht and Aubel are subdivisible into two groups; the Rijckholt group and the Rullen group. The Rijckholt flints could still not be distinguished from the other source areas, with the exception of the Rullen group. Further studies are needed.

Until now, in archaeological descriptions the external appearance of flints (subjective method) was the most widely applied method to characterise flint artefacts. In addition to terms such as 'Rijckholt flint', also 'Valkenburg flint', 'Lousberg flint' and 'Rullen flint' were used. Such names demonstrate that indeed differences are seen to occur between the various flint types. These names, however, should never be actually linked to the mining of flint at these localities. It should be borne in mind that other localities (other than the ones mentioned) could be considered as well. For instance, 'Rijckholt flint' has not only been found at Rijckholt-St. Geertruid but also in the entire Lixhe and Lanaye members, as well as in the Zeven Wegen Member, the flint eluvium and the Meuse gravels.

The results of all studies referred to above have not yet enabled the flints from the Rijckholt-St. Geertruid mines to be unambiguously differentiated from those of other localities. The similarities with other flints of the Lixhe and Lanaye members are too close and differences too small. The usual term 'Rijckholt flint' in archaeology should therefore be replaced by 'Lixhe-Lanaye flint' to avoid erroneous interpretations and conclusions.

2. Archaeological descriptions

Parallel to the above-mentioned analyses, a good many attempts were made by archaeologists to describe the macroscopical characteristics of 'Rijckholt' flint, to distinguish it from flint varieties from other sources that at first sight closely resemble each other, both on a local/regional (southern Limburg) and on a supra-regional (western European) scale (e.g. LÖHR *et al.* 1977; ZIMMERMANN 1988; de WARRIMONT & GROENENDIJK 1993; ZIMMERMANN 1995).

These attempts found their starting point mostly in the wish to establish reliable connections between raw material varieties found at settlement sites and at extraction points. Such connections are a *conditio sine qua non* for all studies of e.g. procurement strategies, distribution patterns and exchange mechanisms. The *Working Group on western flint*, in which regional lithic specialists, geologists, and petrologists co-operate, was initiated in 1989 to study the flint raw materials exploited and used during the Neolithic in the southern parts of The Netherlands and adjacent areas in Belgium and the Rhineland. The project has three aims (de GROOTH 1994):

1 - to establish identical reference collections ('lithotheques') at different research centres working in the study area;
2 - to develop a set of variables with which the different flint types can be reliably described on a macroscopic level;
3 - to perform petrographical and geochemical analyses of the samples, as an independent method of characterising raw materials and studying within- and between-source variation.

Preliminary results of these analyses were published by McDONNELL *et al.* (1997). The following macroscopic description of the flints exploited at the Rijckholt mines is based on the variables used in this project.

The flints in layer 10 of the Lanaye Member are nodular in shape and in general have a length, width, and thickness of at least 20 cm. They show a broad range of variation in texture, colour and in the size, shape and colour of macroscopically visible inclusions, often within single nodules. Moreover, quite often a notable variation, with gradual changes, is visible in individual nodules.

The colour varies from very dark to very light grey, both sometimes with a suspicion of blue.[2] The lighter grey parts often contain areas with dark and light zoning. The surface of artificial fractures is smooth, but not glossy, the texture mainly fine grained. Occasionally the darkest parts may be described as 'glasslike', i.e. they show a slight translucency, best visible along the edges of blades and flake.[3] Most of the material, however, is completely opaque.
The main types of inclusions are:
- groups of black and white round specks (< 1 mm);
- small and medium-sized (> 1 mm, < 10 mm) round or ovoid spots, light grey or white, smooth, with the same texture as the matrix;
- small and medium-sized (> 1 mm, < 10 mm) round or ovoid spots, black or very dark grey;
- (> 10 mm) spots, round or irregular, abrupt border, light grey or whitish, with a rougher texture than the matrix;
- medium-sized and large ringed spots (5-50 mm), round or irregular in shape, with a smooth and whitish outer ring and a smooth or rough, light grey centre;
- vague, large lighter grey flecks.

Natural fracture planes often are covered with iron incrustations. Fresh pieces possess a thin and rough ('sandpapery') cortex, off-white or yellowish/light brownish in colour.

In the wasters recovered during excavation no preference for dark or light material was visible. Both dark and light grey artefacts circulated over long distances, e.g. three conjoinable blades and flakes of the light grey/opaque extreme found at the Michelsberg site at Linden-Kraaienberg (LOUWE KOOIJMANS & VERHART 1990); very dark grey blades reached the Schussenried settlements in Baden-Württemberg (KEEFER 1988).

Several of the existing archaeological descriptions of so-called 'Rijckholt flint' lump together flints from different layers within the Lanaye and Lixhe members, worked at different extraction points in the region (e.g. Banholt or Mheer, Rode Bosch). Thus, the 'clear dark brown zones' directly under the cortex mentioned by ZIMMERMANN (1988) as one of the characteristics of Rijckholt flint, were neither encountered on a sample of 1,000 stone picks from the underground mines, nor on cortical flakes recovered from the fills of shafts 19 and 24. This trait seems to be connected with material exploited at Banholt and Mheer, as recently suggested by de WARRIMONT & GROENENDIJK (1993).

In this respect it is also important to keep in mind that those combinations of traits often described as characteristic for 'Rijckholt' flint are in fact extremes of the continuum defined in the present study.

On the basis of these macroscopically visible characteristics 'Rijckholt', or rather 'Lixhe-Lanaye' flint may be distinguished from 'Baltic'

[2] No Munsell color values are presented here, because 'Rijckholt' flint is extremely susceptible to weathering/patination.

[3] FELDER's (1960) two-fold division of 'texture' referred only to regional material. In recent macroscopic descriptions, used for a broader range of raw material types, the variable texture is divided into three categories: glass-like, fine-grained, coarse-grained. Glass-like applies e.g. to the so-called 'light-grey Belgian flint' of the Liège region (LÖHR et al. 1977, 154), to flints of the Obourg-type (MARIËN 1952), and to most of the Baltic flints (ZIMMERMANN 1995, 48); the material from the Lanaye and Lixhe Chalks, as well as the Kunrade Chalks would be described as 'fine-grained', and 'Valkenburg' flint as coarse-grained.

flint types, and from several types exploited in the vicinity of Rijckholt: 'Lousberg', 'Simpelveld', 'Vetschau', 'Valkenburg', 'light-grey Belgian'; as well as (most of the) material from 'Rullen' and, with some hesitation, 'Banholt/Mheer'. It is still impossible, however, to make a reliable distinction between material from Rijckholt, Jandrain-Jandrenouilles, or Spiennes, all deposited in the same geological period (de GROOTH 1994).[4]

[4] In this respect a new method, based on the non-destrcutive study of meso-fossils in flints, seems very promising, but awaits full publication (AFFOLTER 1991a; 1991b; 1996).

IV. Investigations at Rijckholt prior to 1964

Between Rijckholt and St. Geertruid, in the slopes of the eastern Meuse valley, occur a series of woods known as the Savelsbos Nature Reserve. Thanks to protective maintenance this splendid wooded slope with its deeply scored dry valleys accommodates a flora and fauna of national value. Previously the area obtained international renown on account of the discovery of prehistoric flint extraction activities.

After its discovery in 1881, Belgian archaeologists studied the area for a number of decades. It appeared then that the flint for the production of tools had been extracted at the site and, to be precise, largely in underground mining.

The discoverer of the prehistoric flint exploitation on the Savelsbos plateau, the Belgian scientist Marcel de Puydt of Liège University, was active with colleagues in the Savelsbos until 1914. His student, Jean Servais, curator at the Archaeological Museum Curtius in Liège, continued the investigations until 1923.

In 1903, the later famous Belgian trio became established when Prof. Hamal-Nandrin included the Savelsbos flint industry in his working field. For fifty years until 1953 Hamal-Nandrin had excavations carried out especially targeting the 'Schoone Grubbe' as well as the knapping areas.

Dutch scientists strongly doubted the prehistoric age of the Rijckholt flint industry, until investigations of the Groningen archaeologists Prof. van Giffen en Dr. van der Sleen, in 1923-1925, supplied irrefutable evidence. At the outer limit of the 'Grand Atelier' an extensive mining gallery system was discovered.

After van Giffen's research, no further investigations were carried out by Dutch scientists at Rijckholt and the Savelsbos was left to Hamal-Nandrin again.

In 1928, a group of French Dominican friars of the Rijckholt monastery started an intensive research along the 'Schoone Grubbe' at the instigation of Hamal-Nandrin, which was to last for more than three years.

An extensive description of the discovery of the flint exploitation at Rijckholt-St. Geertruid, and subsequent investigations, has been published in RADEMAKERS (1998).

More than forty years after van Giffen, in the spring of 1964, Prof. Waterbolk commenced his extensive investigations on the plateau at the forest margin and at the Grand Atelier (WATERBOLK 1994).

V. The Working Group's Excavations

1. Aims and objectives

During Waterbolk's 1964 investigations it became apparent that the Rijckholt mine field must be of an extent hitherto unknown. In the plateau trench a good many filled-in shafts were discovered. In the trial trench adjacent to the Grand Atelier a few shallow niches were visible which could possibly represent mining galleries. If this was the case, then it could be assumed that more shafts must exist between these galleries and the mine field on the plateau, 150 metres distant (WATERBOLK 1994).

Opportunities for underground research were out of Prof. Waterbolk's reach. Such an investigation could only be carried out by asking professional miners to join. Then the specially formed 'Prehistoric Flint Mines Working Group' of the Dutch Geological Society, Limburg Section, offered its services. For a large part, this group comprised well-trained miners and technicians of the Limburg collieries, who were familiar with local geology and who were interested in the archaeological aspect of the investigations. This team offered its free time and energy for which they received no compensation over a number of years. When permission was granted to the working group it was duly noted that there were no funds available for this research, which meant that the team itself had to work out where to acquire the necessary means.

The main goal of the excavation was to demonstrate the feasibility of driving an underground reconnaissance tunnel across the mining area and examine the thus exposed mining galleries from there. The choice of a horizontal reconnaissance gallery was based on the fact that the flint layer crops out in the 'Grand Atelier'.

2. Working methods during the excavation

On May 21, 1964, W.M. Felder contacted Staatsbosbeheer in order to obtain permission to continue the excavation carried out by Waterbolk at Rijckholt-St. Geertruid. The next day, during an excursion of the Dutch Geological Society, members of that society were asked to join in the excavation of the prehistoric flint mines at Rijckholt-St. Geertruid. After the first preliminary permits had been granted, on June 6, 1964 the excavation was started. None of the members had ever participated in an excavation, but they did have mining experience and were trained in geology. It was for the first time that miners were about to excavate prehistoric mines.

By mutual agreement it was decided to dig a tunnel between the two excavation sites on the plateau and on the wooded slope, respectively, where Waterbolk had encountered flint mining activities (Fig. 5). The tunnel was to follow the level of the prehistoric flint mines as closely as possible. We started clearing the dumped material at the lowest of Waterbolk's excavation sites, from where the tunnel had to be driven. Since only wooden props were available, a wooden structure was built at the entrance of the tunnel. On June 13, 1964 the first three timber props were placed in the tunnel; it was thought desirable to dig a trench as a ramp for the wheelbarrows that were used for the transport of excavated material.

At first, two wheelbarrows were available. When one of these was filled up it was pushed outside, making way for the other. To make sure that this ran smoothly a platform was made in front of the ramp, the so-called wheelbarrow loop.

The work method was adapted to the available financial means, especially during the trial excavation. During this excavation virtually no money was available. Unavoidable costs such as lighting and tools were borne by the members themselves. This explains why we had only manual tools such as hammers, saws, pickaxes, shovels and a very large saw for cutting limestone. Later, a grant-in-aid from the Dutch Organization for Pure Scientific Research allowed us to pay 50% of the mining costs. All other costs were covered by sponsorship, in kind or otherwise.

The first props placed were made of wood as at that time no other material was available. Being miners, we knew that timber in fact was an inferior material, as it goes mouldy in a short period of time and rots in underground workings. Timber supplied by the State Forestry

Fig. 10 Prehistoric gallery with the original fill of chalk rubble.

Service was felled at the site as required. It was also clear to us that at a later stage the timber props must be replaced by steel ones. The size of the wooden roof props placed in the tunnel during the trial excavation corresponded to that of the steel replacements, viz. width and length of 2 m.

On July 4, 1964 the first prehistoric gallery became visible. The fill of galleries consisted of loose chalk rubble and thus differed clearly from the solid limestone, which greatly facilitated their recognition (Fig. 10). That the galleries, which were generally not higher than 60 centimetres, were largely filled was a surprise to some of the participants. They had expected to find empty galleries.This showed that different views were held on working methods in the prehistoric flint mines. A lot had yet to be learnt and discovered. After unearthing the first gallery a fence was placed at the entrance of the tunnel, in order to prevent unwanted visitors from disturbing the prehistoric workings. Despite all our efforts to obtain more information in the literature on prehistoric flint mining and methods of excavation employed, we did not come across any report of an excavation executed from a tunnel. Excavations described in the literature did not give any or only few answers to the many questions we had at that time. We had to find out for ourselves how to proceed with this excavation and to rely on mining experience gained in the Limburg collieries.

After discovery of the prehistoric galleries we started to excavate the loose rubble from them (Fig. 11), and then the first remains of prehistoric tools (stone picks) were found (July 7, 1964). These artefacts were called *hakken* (picks) because in our opinion, they had been used in this way. From the very start we thought it necessary to measure these finds three-dimensionally, using the exploited flint layer as a base. The method of measuring, however, changed over the years, which will be described elsewhere.

The chalk rubble was cleared from the gallery by means of a modified shovel with short handle and a flat, curved blade. At times it proved easier to use our hands and feet instead. The loose rubble was shoved backwards and pushed further away using our feet. Eventually it was loaded into a wheelbarrow and taken outside. Outside the tunnel it was dumped to be taken away by the State Forestry Service.

From the outset it was obvious that first the prehistoric galleries had to be surveyed and

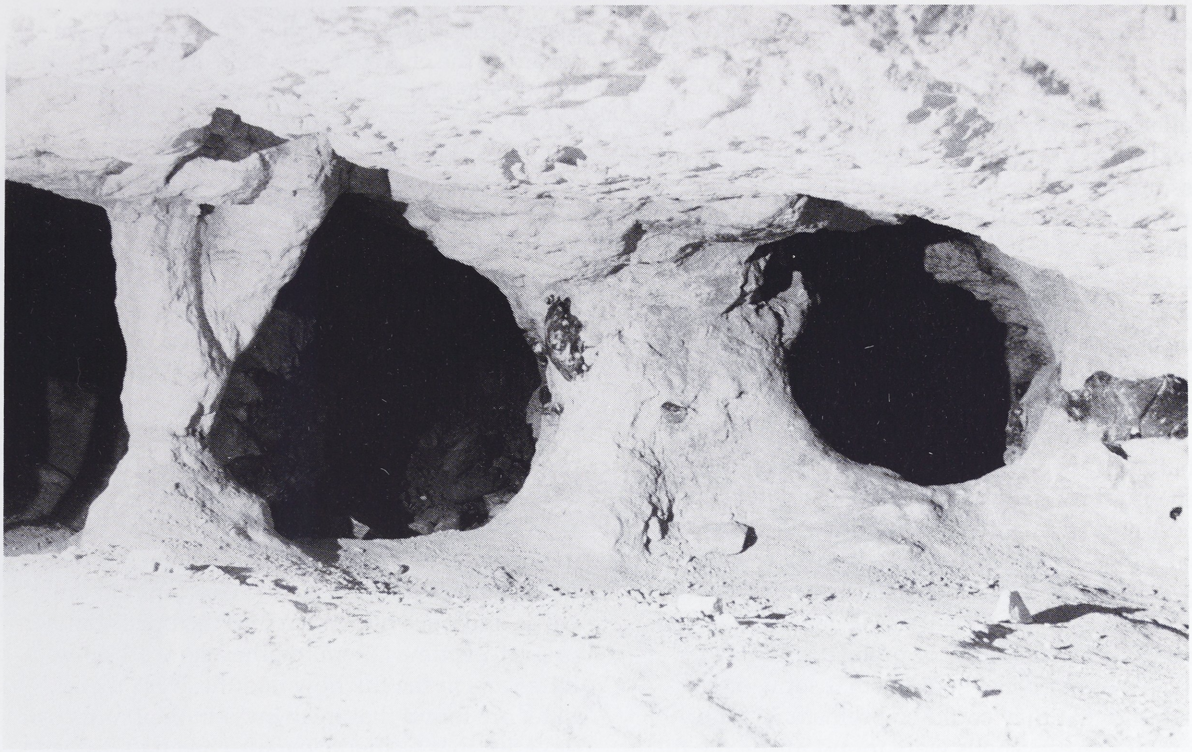


Fig. 11 Cleared prehistoric gallery with pillars left standing for safety reasons.

measured, before work on the tunnel could proceed. After all, by digging a tunnel, portions of the prehistoric galleries would be destroyed. Thus we were soon forced to measure not only the finds but also the galleries.

While clearing the galleries it was discovered that between the various galleries there were points of connection too small to crawl through. These we called 'breaches' (Dutch: *vensters* = windows) since they offered an insight into an adjoining gallery (Fig. 11).

In addition it proved increasingly more difficult to remove material from the gallery as this was emptied further and further. After some two metres had been cleared a second man was needed to transport the excavated rubble to the exit. Later we came up with a solution, in loading the material onto a long narrow sledge-like chest on towing runners and by pulling this outside using thick ropes. By also attaching a rope to the rear end the empty chest could be drawn back in again. Such a chest was called a *hond* (= dog) in the mining trade. Later these 'dogs' were made of steel and had wheels. From November 2, 1964 to April 23, 1965 the excavation was largely halted awaiting formal permits of government and *Staatstoezicht op de Mijnen* (State Mines and Quarries Inspectorate) to come through. In this period a small group of people reflected on how to proceed with the investigations of the prehistoric galleries and shafts. To attract less attention to our activities which took place mainly on free Saturdays, we from then on worked on Friday night.

Not until November 2, 1964 did we start work on a shaft (Shaft 1). Until that time, we had no good idea of what a shaft looked like. Thus it happened that a shaft was not recognised instantly but much later: Shaft 73 was the first to be discovered, but only much later recognised as such. Further difficulties in recognising shafts were encountered. Occasionally, solution structures were mistaken for a shaft.

Each working day again the newly discovered phenomena were discussed by the group, making sure that each participant was familiar with our changing views. Methods of working were continually adapted to these new ideas. Thus not only the recording procedure changed, but also the excavation itself. For descriptions of methods, not yet influenced by experience gained later, reference is made to publications which appeared during the time of excavation (RADEMAKERS 1964).

It soon became clear to us that the prehistoric galleries had been filled with chalk spoil from other galleries. The prehistoric miners thus saved themselves the trouble of transporting the chalk to the surface. For this reason, we were later even more surprised to find empty galleries rather than backfilled ones. Despite the fact that in the beginning some participants assumed the loose material to have been brought to the surface, it appeared more difficult now to come up with explanations for an empty rather than a filled gallery. Naturally all kinds of theories were proposed, which subsequently were compared with excavation results. Only then could such a theory be more or less accepted by the whole group.

Since an empty gallery often lay between two shafts we eventually assumed that this had been left empty as a safety measure. From then on, these empty galleries were called 'safety exit' or 'safety gallery'. At other sites the last working spot in the mine was not filled either.

On October 30, 1964 the first snail shells were found on top of the fill of prehistoric galleries. The shells appeared so fresh that some of us doubted that they could be prehistoric. Later similarly 'fresh' shells were found inside the fill so that there could be no doubt as to their prehistoric age.

At shaft 10 many shells were found. Here it appeared impractical to collect all shells separately as had been done before with all earlier finds. It was decided to take a large sample and study this at home. The excavation was halted temporarily at that site until the results of the study became available. At home, the sample was placed in a large tub with water, in order to float all shells and bones. Thus all finds could be scooped up easily with a sieve. Later it turned out that all material containing snail shells had been included in this large sample; no further finds were made in Shaft 10.

On October 14, 1966 near Shaft 15 a large number of snail shells and animal bones were encountered. A sample was taken for analysis at home. It appeared to contain twenty-one remains of rodents and 160 shells. During subsequent excavation of Shaft 15 samples were taken at all levels and studied (Report 7). The same was done of course in all subsequent shafts (Report 32).

On November 15, 1964 for the first time charcoal was found in the fill of Shaft 4. It was obvious that this had been thrown in from above. On December 19, 1964 Prof. Waterbolk himself came to view the find circumstances of the charcoal. Nowhere did we find any traces of underground fires (hearths), which is why we assumed the charcoal to have been dumped.

On November 26, 1964 we reached van Giffen's 1923 excavation. This was readily apparent from the way the gallery had been filled at that site. In the fill there were pieces of wood and paper.

During excavation of the first galleries we regularly encountered bones of small animals (possibly mice). At first, we assumed that the mice had crept in from the sides and could thus not be considered prehistoric finds. At Shaft 10, however, we discovered that relatively many bones occurred in a sandy fill which had probably been washed in. The bones were thus of the same age as this 'washed in' layer. We then also noted that the snail shells were found in positions that they could only have reached by crawling there. We had to conclude that live snails and mice had fallen into the open shafts in prehistoric times. Remarkable also were a few hazelnuts in the fill: how had these got there? Later we found that mice lived in the prehistoric galleries that we had cleared. They had dragged about spent flash bulbs. We even found these in galleries that we could not have entered previously. In this way we learnt to be extremely careful in drawing conclusions and in not littering the site.

Upon completion of the trial excavation (April 23, 1965) it was decided that each member from then on would himself measure all finds and enter details on so-called 'finds forms'. Later it appeared, however, that these forms had been filled in in different ways according to experience and knowledge of the person involved.

It will be clear by now that the views held by the various participants on prehistoric flint mining were and remained different, even after lengthy discussions held during breaks. One of the points, for example, from the very start was whether the prehistoric miners' picks had handles or not. Not until after the discovery of voids (October 14, 1966), with calcified wood on the floor of the void, did the discussions about this become less frequent. We assumed these voids to represent decayed handles.

On April 23, 1965 the official permit to excavate was obtained; now we could try to obtain funding and contact firms for supply of material. On May 14, 1965 we were able to start anew by replacing the timber props by steel

Fig. 12 The modern tunnel dug right across the prehistoric mining area after having been secured with steel supporting props.

ones (Fig. 12) and on May 22, 1965 rails and tip carts could be transported to the excavation site. On June 11, 1965 we experienced a large-scale roof collapse in the tunnel as a result of replacing the props. The clearance of this collapsed material, the supply of all kinds of material and the construction of rails took until September 18, 1965. Subsequently, an iron fence was placed at the entrance and a hand-operated winch at the end of the rails to be able to pull the filled tip carts out of the tunnel. The wheelbarrows had become superfluous. On August 20, 1966 an old motor scooter engine was built in to replace a winch at the end of the rails.

During deepening and widening of the tunnel entrance (November 26, 1965) a number of prehistoric stone picks were found on the floor which showed that while erecting the wooden entrance structure we had not recognised the underlying prehistoric gallery. This was explained as follows: loose rubble from a collapse lay on top of the fill of the gallery. Further it was determined that the prehistoric miners had dug into the fill of the workshop, since one of the galleries had been deepened at the end to the level of the fill of the 'Grand Atelier' and had then been filled with chalk rubble. We concluded that the Atelier had been filled before this gallery was started.

On November 5, 1965 we excavated the tunnel further, at which, at 12.30 pm, a human skull was found (see Section 7.5.1 and Report 5).

In digging the tunnel and placing steel props we proceeded as follows. First the prehistoric galleries exposed in front were studied and measured, after which we continued in the usual way in mining. At the front, a space was cleared for a new prop. After that the so-called leader rails were advanced and on the leader rails the so-called hood was placed, and eventually two props were placed below the hood. To finish packing irons were positioned between the former and the new construction, which prevented material from collapsing from the roof and walls. Finally the leader hooks (three on each side), to which the leader rails were attached, were all pushed ahead one prop. The distance between individual supporting props was a metre. After completion of the above, the tunnel had thus progressed a metre. After every three metres, rails, and later conveyor belt, were extended.

Work in the tunnel was initially done using manual tools only. We used steel pickaxes and special saws formerly employed in the extraction of chalk blocks for building. Later (January 21, 1966) we obtained from the Atlas-Copco firm a compressor enabling the use of a pneumatic hammer for breaking up the chalk.

Late in 1965 prop 18 was placed at the end of the tunnel. Late 1966 the tunnel was 39 metres long and a year later 97 m, late 1968 113 m, late 1970 123 m, and at the end of 1971 the greatest length of 137 m had been reached.

On January 19, 1968 part of the excavated area collapsed. In part, this was a result of increased mechanisation causing the tunnel to progress rapidly in length. We noted that, in future, we would have to support better the excavated galleries, especially near the tunnel.

Illumination underground consisted at the beginning of paraffin lamps. Later we had a car battery at our disposal to feed tunnel lights, while for working in the galleries electric miners' lamps were used. In the end we obtained an electric generator (December 2, 1965) to ensure the total electricity supply. This also enabled us to regularly recharge the batteries of the miners' lamps.

While clearing the prehistoric galleries it proved necessary to have supporting props in some places. Initially timber was used. Later we had a blacksmith saw iron tubes into pieces and weld iron plates to the ends. These were our iron props, which put a halt to the rotting of timber in the prehistoric mines. Only in the more unstable places did we use steel props similar to the ones used in coal mining.

By digging a tunnel (twice over at the beginning, first in timber, then in steel), the soil's equilibrium had been heavily disturbed. The cleared galleries there became so unstable that we were forced to line them entirely. Therefore we used (half)cylinder segments which in collieries were used to transport coal vertically downwards.

More than once we experienced difficulties with solution pipes. These gravel/sand pipes are dissolution funnels occurring in the chalk, filled with collapsed material from the top soil. Very often this material kept on falling behind us during tunnel construction. To avoid further collapse we had to drive iron plates in over the last hood so that a roof of iron plates arose, underneath which a new hood could be placed. In spite of all precautionary measures we experienced more collapses near these solution pipes and had to work long and hard to secure everything anew.

Between props 22 and 23 (February 19, 1966) the first fault was encountered in the chalk and immediately behind it a very large gravel pipe. Only at prop 27, i.e. 5 metres further on, did we find chalk again as well as a prehistoric gallery. The fault meant that we could not continue horizontally in digging the tunnel. We had to go higher to follow the galleries. Near prop 31 (July 27, 1966) another fault was located and at prop 34 it appeared that galleries were present above the tunnel. This caused serious problems with the railed transport of tip carts, since we had to redirect the tunnel. We decided to find out if we could obtain a conveyor belt.

On November 23, 1966 the first portion of the conveyor belt was delivered and on January 27, 1967 we started taking out the rails and placing the conveyor belt (Fig. 13). Now it had become possible to clear away rubble from all places in the tunnel by throwing it onto the conveyor belt. No people were needed anymore to transport the material outside, which meant an increase in the number of people actively involved in digging.

From January 1, 1967 the number of participants grew to 13, to 15 on July 1, 1967, 19 on December 31, 1967, and in 1968 to a maximum of 23. Digging could thus proceed in increasingly more places.

Initially it was customary that, when something special was found, everyone went there to have a look. As the number of excavation sites increased, this and the discussion of special features declined. The special finds were then examined by only one of the experienced diggers. Naturally, this work method meant that not all workers were and became similarly experienced. Some of us had participated since the very start while others had not. To prevent data from getting lost in this way, a report book was put in the shed (February 19, 1967) in which special features could be entered.

In addition to digging there were of course diverse other activities, such as the measuring of excavated galleries, maintenance of technical equipment and extension of the tunnel. As the excavated area increased so did these activities, with the result that the more experienced diggers had to perform other tasks more often,

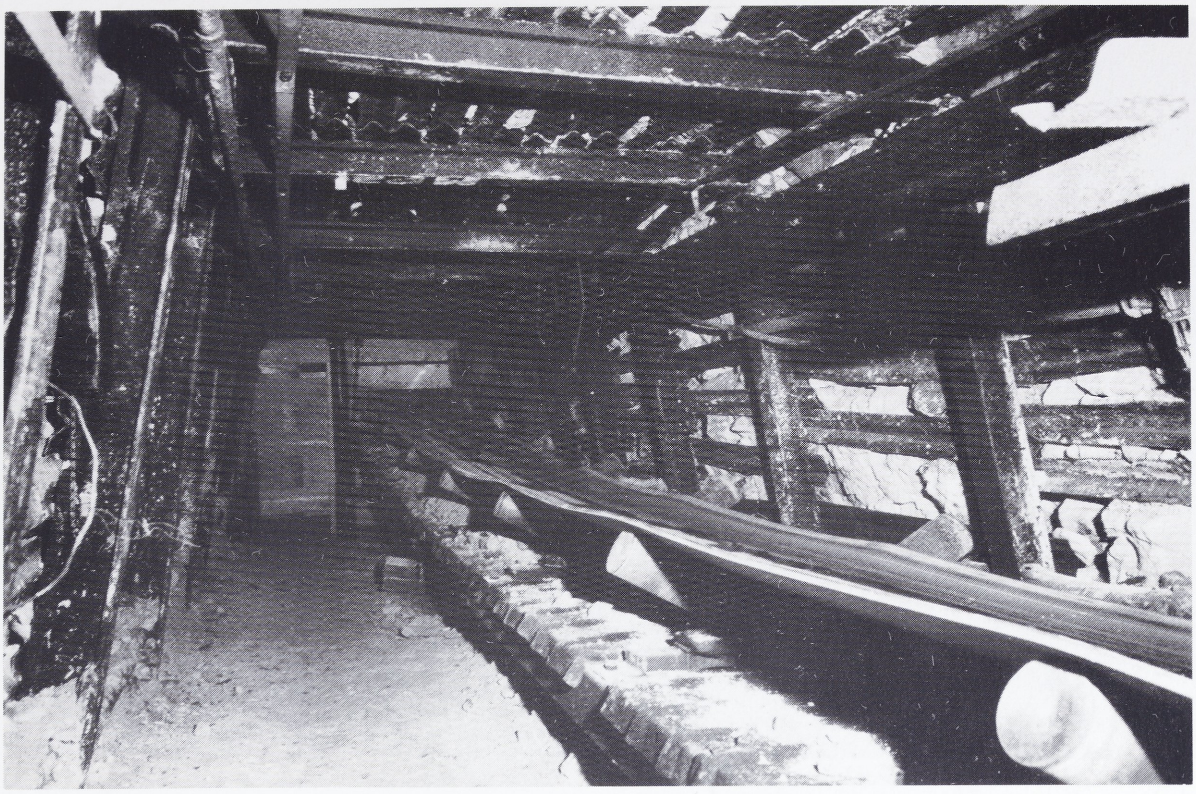


Fig. 13 The conveyor belt in the tunnel.

while more and more inexperienced people did the actual digging. Naturally, a kind of supervision by the more experienced diggers was adhered to.

Finds made during the excavation at first comprised almost exclusively stone picks. Fragments of such were soon recognised (at least the larger amongst them). After the first void in the fill of a gallery had been found (October 14, 1966), more voids were encountered (see Report 6). The same holds true for hammerstones. W.M. Felder had found a hammerstone on the tip outside the mine (June 18, 1966); on July 7, 1967 a hammerstone was collected from the mine. After this discovery many more followed (see Report 36).

On December 4, 1964 a concentration of stone picks, 15 pieces in all, was found in a small area (50 by 50 centimetres). Later we referred to such concentrations of stone picks as 'hoards' (Fig. 14). As soon as we had recognised hammerstones we found these more often in such hoards.

On discovering the hammerstones we soon assumed that some of these had been used to resharpen blunt picks. Unfortunately we did not look for the small flakes that were produced in the process. We did look for larger flakes, which in general were plotted. In the galleries only very few flakes were found. The majority were collected from the fill of shafts.

From the very beginning we distinguished three main types of stone picks. According to shape, these were referred to as triangular, quadrangular and axe-shaped picks. In spite of the fact that we later recognised all kinds of shapes (Report 24) we stuck to these names during the excavation.

The first deer antler was found on April 28, 1967. The number of deer antlers found during the excavation remained very low (Report 11). At Shaft 11 three niches were discovered from which flint had been extracted at two metres above the regular flint bed exploited (October 28, 1966).

Rope marks at the shaft's mouth were not recognised until very late (February 5, 1971). At Shaft 49 very clear and and deep rope marks were found (Fig. 21). Subsequently, vague marks were also seen in shafts that had been excavated earlier.

In Shaft 24 for the first time a strong concentration of flint waste was encountered

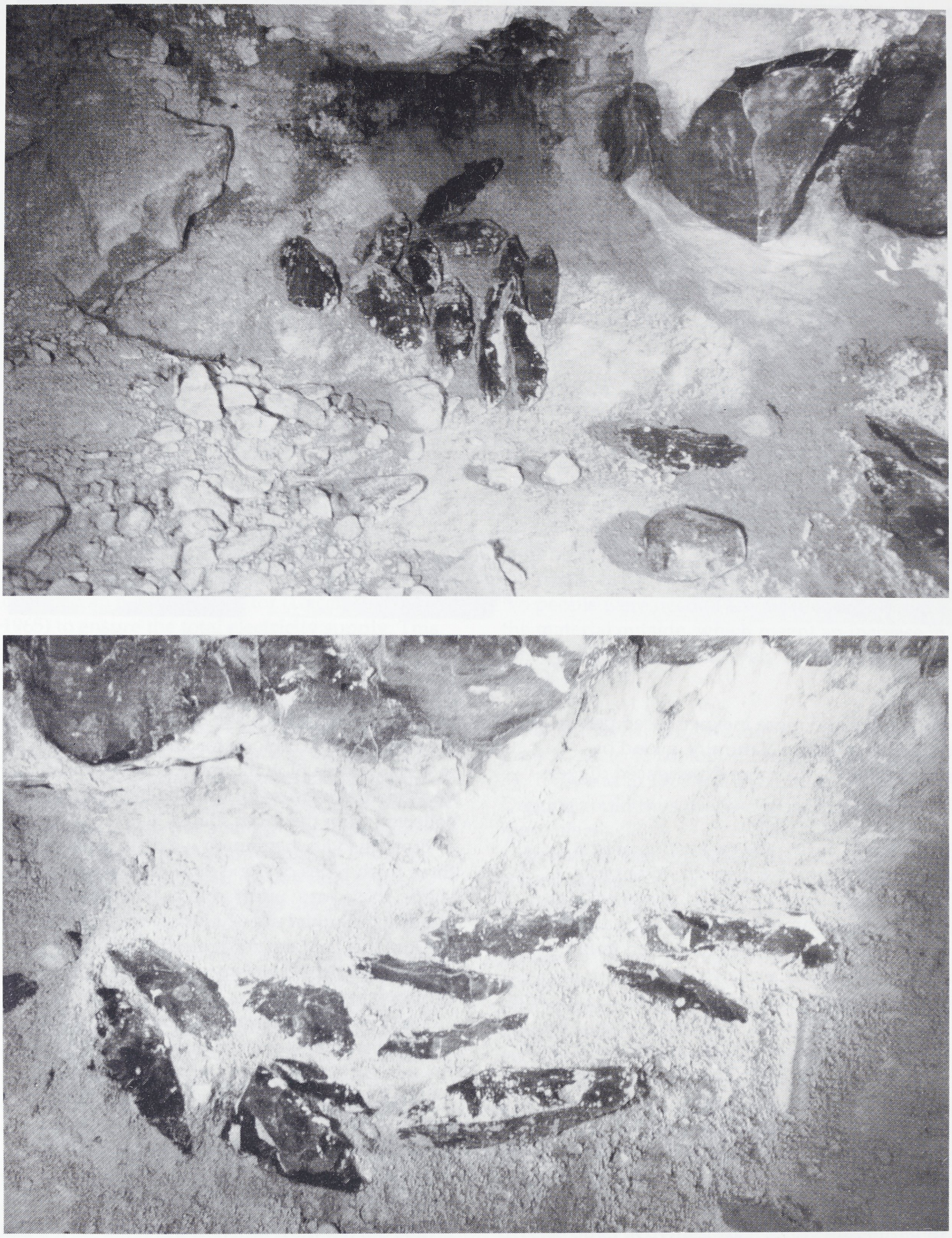


Fig. 14 Two of the stone pick 'hoards' encountered in the galleries.

(called the 'china cabinet'). Subsequently, flint waste was found in more shafts, and included cores.

The fill of a shaft generally consisted of a layer of chalk rubble, on top of which rested material thrown in from the surface. At times,

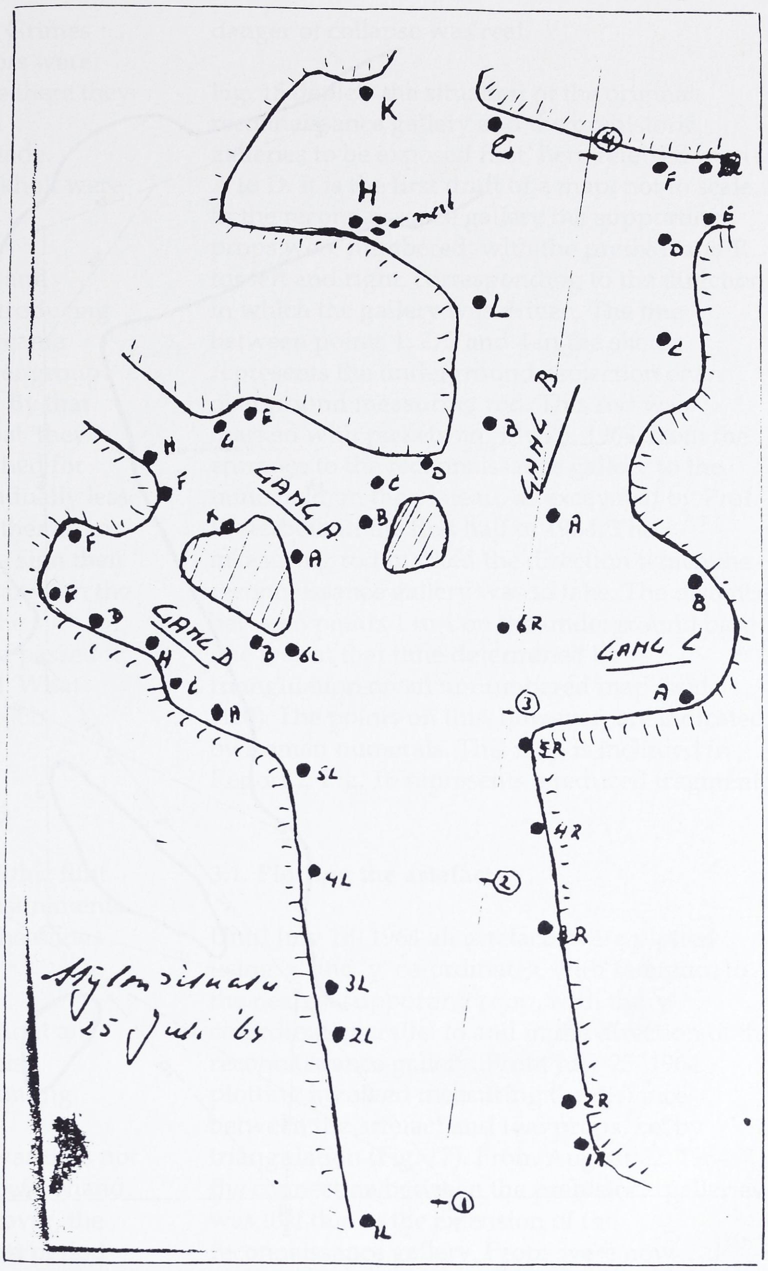


Fig. 15 First field sketch of the map drawn during the trial excavation.

traces of rain and/or mud wash were clearly visible. Higher in a shaft there was invariably a consolidated layer, which, during the excavation, prevented more material from collapsing behind us. A gravel/sand pipe, on the other hand, did not stop collapsing since there was no consolidated layer there. In general, the presence of chalk in the fill appeared to be a good indication of the presence of a shaft. The fill of solution pipes lacked chalk rubble.

The fill of prehistoric galleries generally consisted of chalk rubble that originated from digging the galleries. Into an empty gallery also other refuse was thrown, such as worn-out tools and unusable flint. There were clear differences in the degree of filling. Some galleries were entirely, others only partially filled and some were hardly filled at all. We characterised these latter as empty. When assembling data during the excavation care was taken to document the percentage of fill. Occasionally a level was discovered in the fill of a gallery which clearly showed that prehistoric miners had crawled about over the fill (crawling floor). These crawling floors were given but little attention during the Rijckholt-St. Geertruid excavation. Here crawling floors are poorly developed only

Fig. 16 Fragment of map illustrating measurements by triangulation.

on account of the crumbly chalk. At Grimes Graves (United Kingdom) these floors were recorded in transverse sections since there they were better developed, and allowed reconstructions of the filling to be made. Transverse sections of the fill at Rijckholt were drawn only in some instances.

As the number of participants grew and mechanisation advanced further, introducing improvements during excavation became increasingly more difficult. The larger group could no longer be reached directly. By that time, participants tended to think that 'they knew it all'. The report book in the shed for jotting down all tribulations was gradually less often used, and was looked upon rather as an attendance register. All they did was sign their names. Fewer and fewer notes appeared on the findsregistration forms over time. The excavation had reached its peak, and passed it, as far as discoveries were concerned. What followed now was more of a routine job.

3. Recording methods employed

During the investigation of the Neolithic flint mines at Rijckholt-St. Geertruid measurements were taken to record the outline of the mines surveyed and to plot artefacts.

The trial excavation was started without any insight into scope and duration of this excavation; eight years in all, not counting conservation.

Documentation of the first finds was thus not based on a procedure agreed upon beforehand, but ad hoc and so provisional. Moreover, the method of measuring during that first period was changed several times and adapted to the way the excavation developed. Annotated original measurements from this period can be found in Report 4.

When working out the measurements for the final plan at the end of the excavation campaign, the first data were indispensable as they could not be repeated. After all, in driving a tunnel (also called reconnaissance gallery, and, later, main gallery), portions of the exposed galleries were inevitably destroyed. Moreover, at that time a few of the small mining units situated at the outer end of the reconnaissance gallery had to be closed off. In this area, tree roots destabilised the already thin cover and the danger of collapse was real.

Fig. 15 depicts the situation of the original reconnaissance gallery and the prehistoric galleries to be exposed first, here referred to as A to D. It is the first draft of a map, not to scale. In the reconnaissance gallery the supporting props were numbered, with the prefix L and R, for left and right, corresponding to the direction in which the gallery was driven. The line between points 1, 2, 3 and 4 in the sketch represents the underground projection of an overground measuring rod. This rod was marked with pickets on July 25, 1964, from the entrance to the reconnaissance gallery to the mine field on the plateau, as excavated by Prof. Waterbolk in the first half of 1964. The measuring rod marked the direction which the reconnaissance gallery was to take. The distance between points 1 to 4 on the underground base line was at that time determined by triangulation on an unnumbered map (scale 1:20). The points on this, however, are indicated by Roman numerals. This map is included in Report 2. Fig. 16 represents a reduced fragment.

3.1. Plotting the artefacts

Until July 18, 1964 all artefacts were plotted using 'x' and 'y' co-ordinates, with reference to the nearest supporting prop, with the 'y' co-ordinate parallel to and in the direction of the reconnaissance gallery. From July 25, 1964 plotting involved measuring the distance between the artefact and two props, i.e. by triangulation (Fig. 17). From August 22, 1964, the connection between the prehistoric galleries was lost due to the extension of the reconnaissance gallery. Props were now identified by using coloured paint. Galleries A to D were renamed Blue, Red, Black and Green, respectively.

As soon as we had a base line in the reconnaissance gallery, this formed the basis for triangulation. Now the position of the supporting props, which up to that moment had been used as measuring points, could be recorded.

During the remainder of the excavation period the positions of artefacts were plotted using numbered measuring points, as based on trigonometry. The measuring points consisted of metal tokens with serial numbers. New

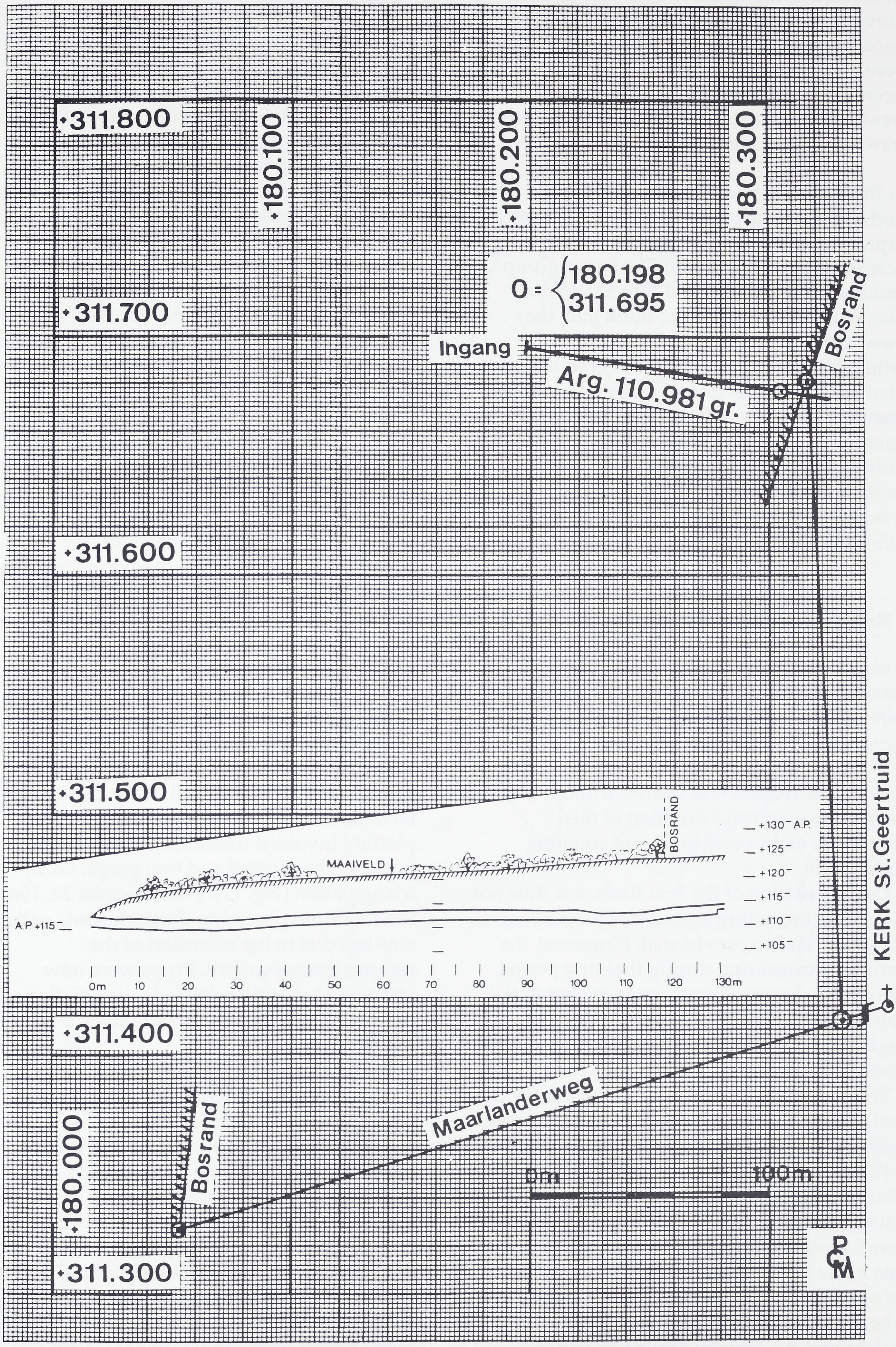


Fig. 17 Location of the tunnel in the Savelsbos as determined by surveying.

measuring points were positioned in such a way that they could be plotted from two previous points. Measurements and a sketch of the situation recording the direction of measurement were entered on a 'registration form for artefacts collected' at the site.

3.2. Plotting the map

All galleries, shafts and solution pipes encountered during the excavation were plotted by triangulation, with reference to the base line in the main gallery. This measuring network consisted of taut strings. Measurements were taken at the average height of the flint layer exploited. The outlines of the shafts were projected on this plane.

On the basis of a field survey during the excavation and a subsequent supplementary survey by the Dutch Geological Survey, a map of the studied portion of the Neolithic mine field was drawn.

The map consists of three sheets, numbered GB-A -8810a to 8810c, at scale 1:50. A filmed copy of these drawings was transferred to the Provincial Depot for Archaeological Finds at Maastricht (Fig. 18). A reduced version in colour, scale 1:400, is included in RADEMAKERS (1998).

3.3. Plotting the main gallery

Upon completion of the excavation and conservation of the main gallery, its position was plotted anew. At the Working Group's request this was done by the Surveying Department of the former state colliery Emma, in collaboration with the group.

These measurements are recorded on the Working Group's drawing no. 199-57-67. Fig. 17 is based on portions of this drawing.

The original has also been transferred to the Provincial Depot for Archaeological Finds, and a copy is included in Report 30.

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

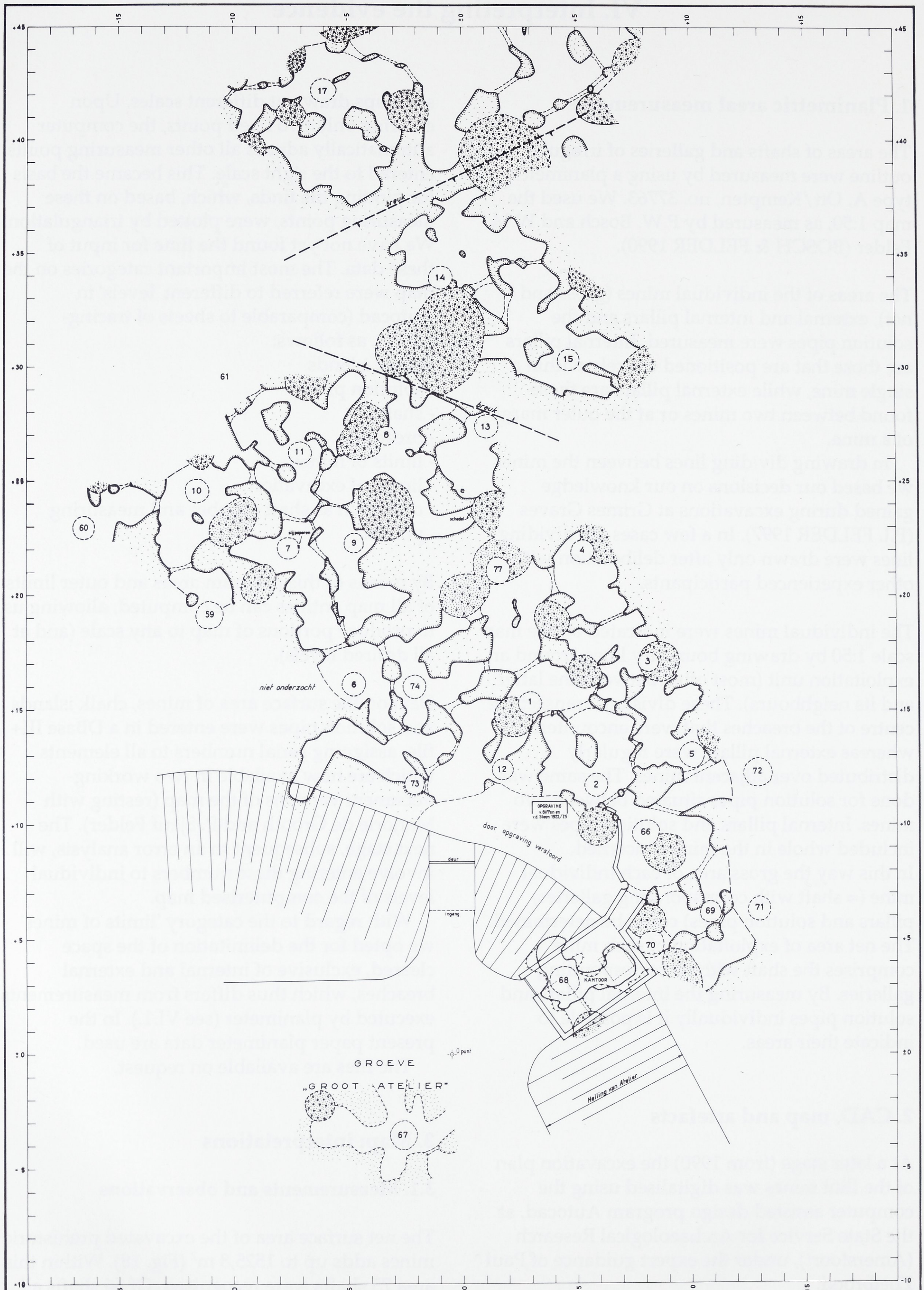


Fig. 18.1 Map of the excavated mines - Western part.

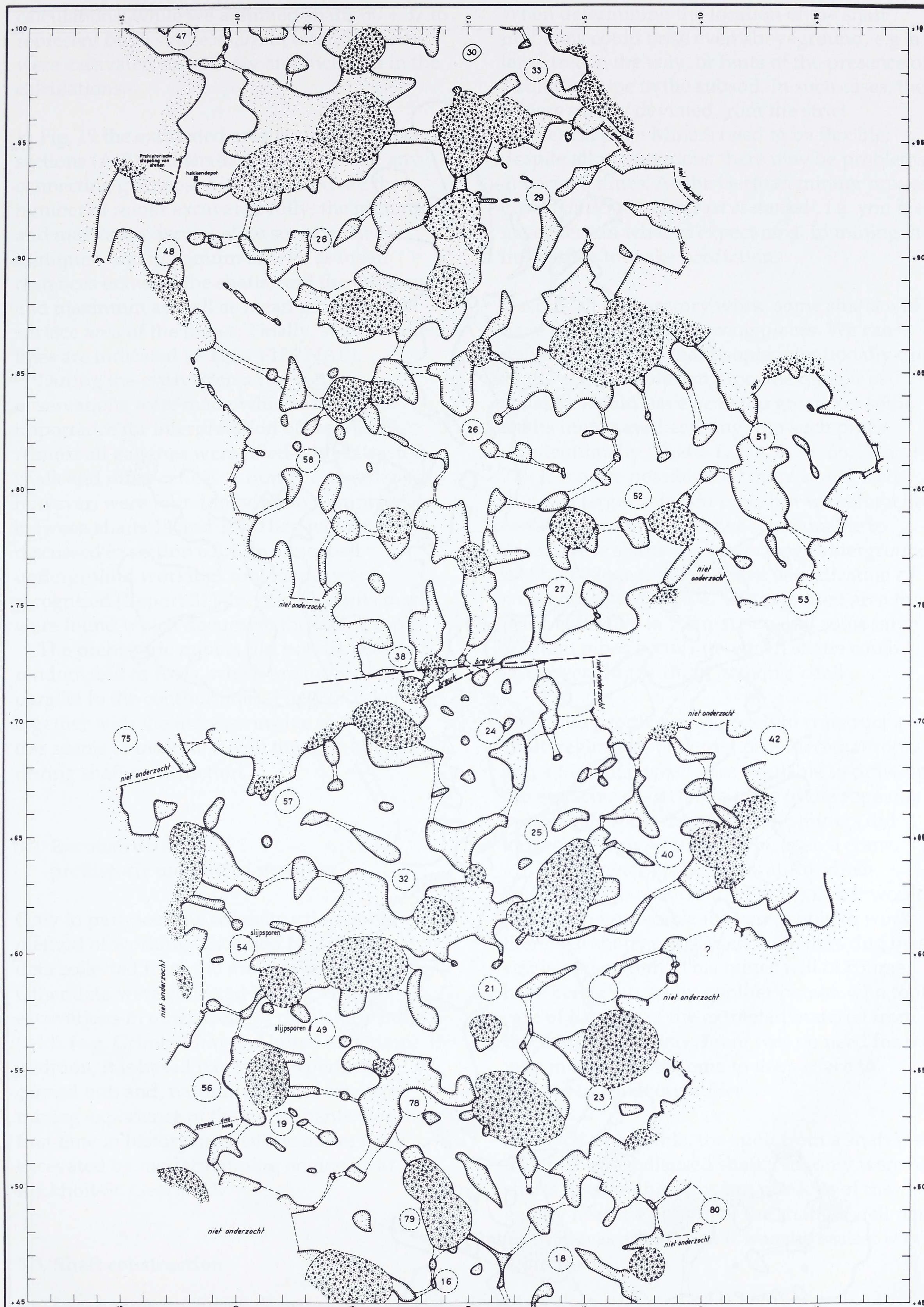


Fig. 18.2 Map of the excavated mines - Middle part.

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

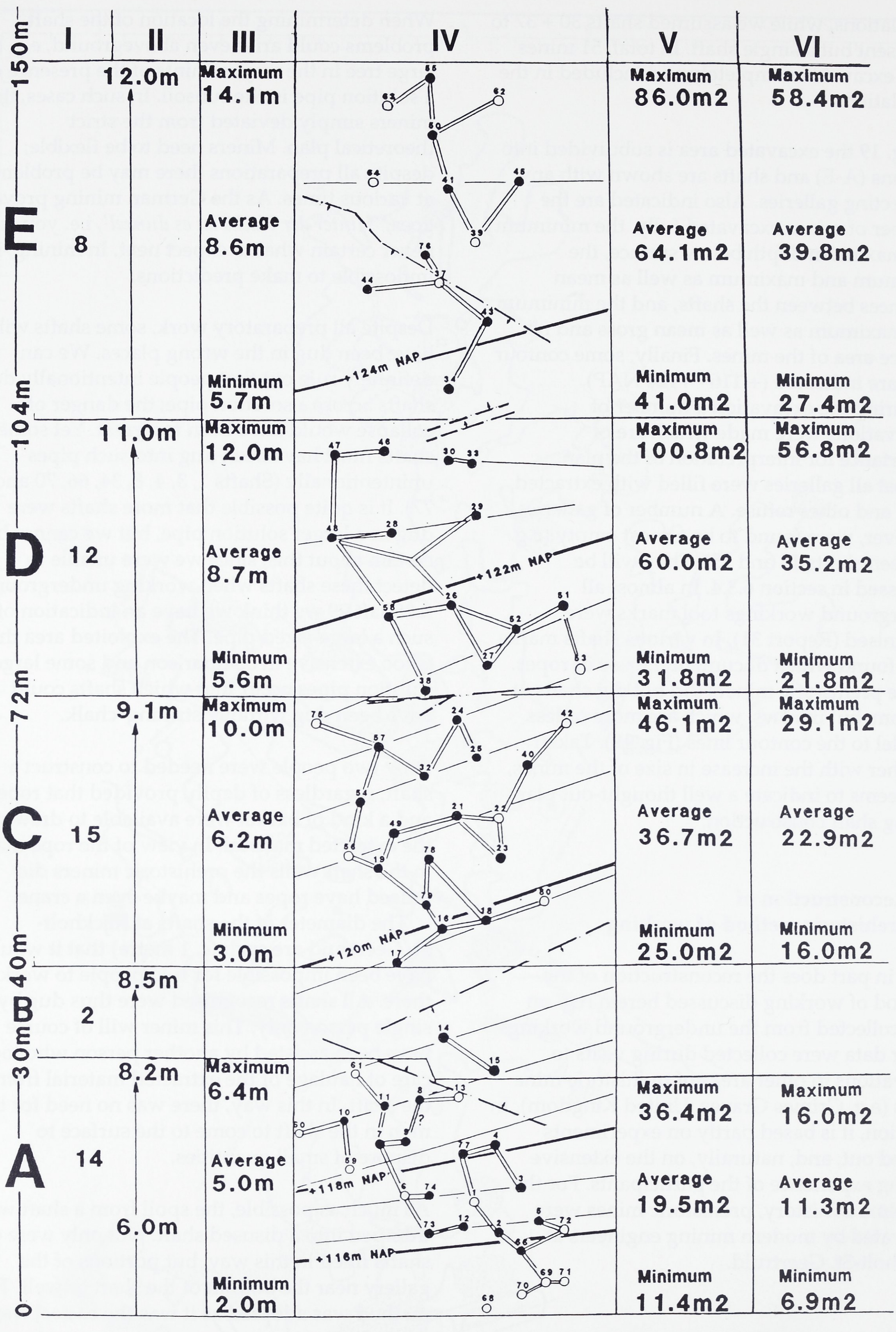


Fig. 19 Schematic overview of connections between mines.
I: number of mines; II: maximum depth of shafts; III: distance between shafts; IV: shafts in excavated area, closed symbol: completely excavated mine, open symbol: partly excavated mine; V: gross area; VI: net area.

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

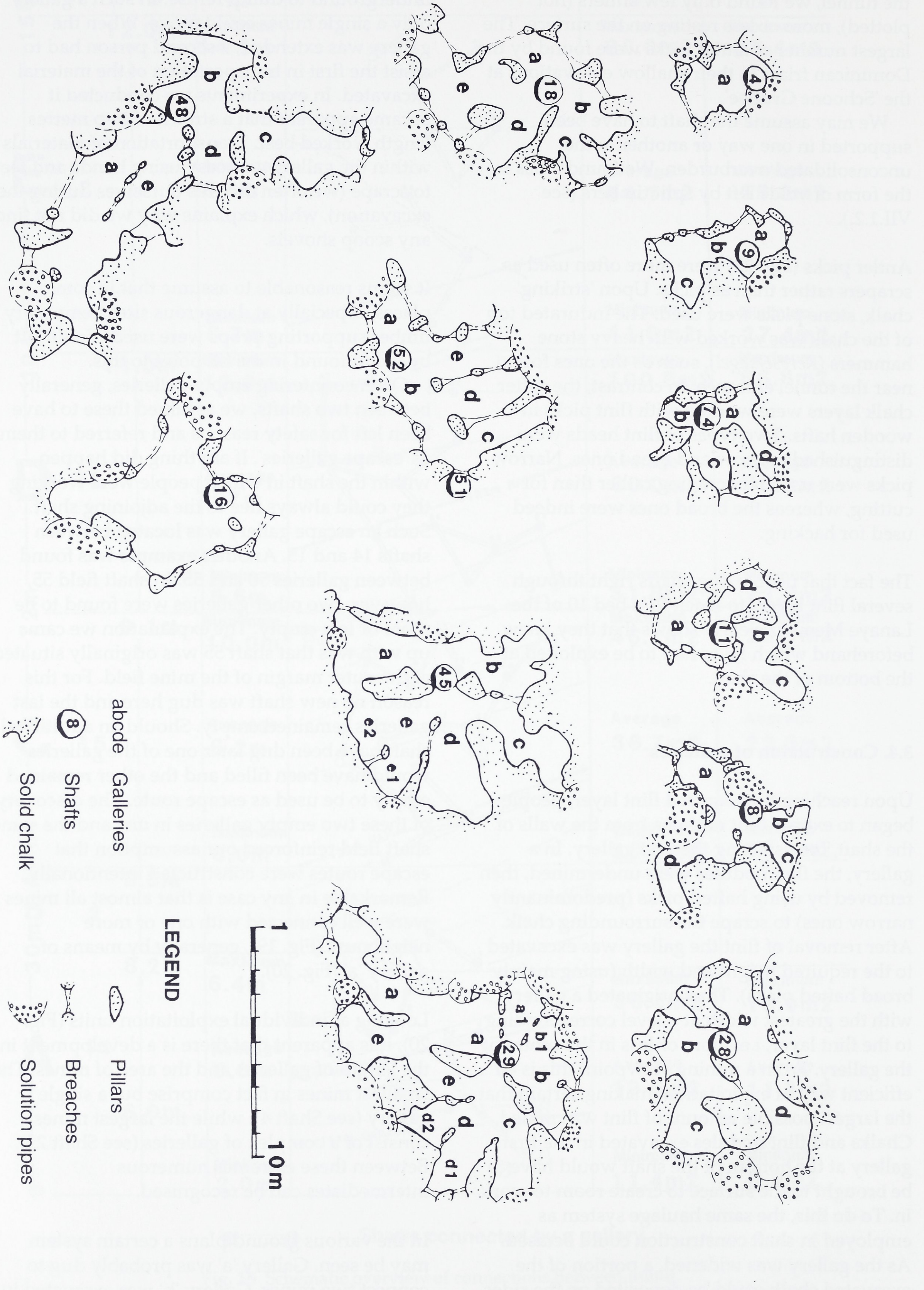


Fig. 20 Ground plans of characteristic mines.

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.

VII. Finds

1. Mining implements

1.1. Rope marks

In various shafts rope marks were encountered (Fig. 21). We assumed that these ropes had been used to lift material from the mine. At the surface there were no signs at all of any kind of crane. However, we think it likely that large excavated flint nodules were too heavy to lift from the mine without the use of a crane. The rope marks show that great power was exercised during lifting.

1.2. Wooden implements (voids)

Tools made of wood have not been preserved as such, having entirely decayed. Occasionally a void remained in the fill of shafts and galleries (Fig. 22). On the bottom of such voids we often found calcified remains of wood, allowing us to conclude that the void represented the original wood.

A total of 43 voids were found, which can be grouped as follows:
- 3 straight, semicircular voids 50, 130 and 140 cm long and 8, 8 and 12 cm in diameter, from the fill of a shaft. Therefore we assume this to have originally been split timber used for lining the shaft.
- 2 straight, circular voids 90 and 98 cm long with a diameter of 5 cm, which possibly were used forlining the shaft or as supporting props.
- 6 straight, circular voids (one slightly curved) 40-65 cm long (mean length 54 cm) and 8-10 cm in diameter (mean 9 cm), possibly representing timber supporting props.
- 9 straight, circular voids 42-55 cm long (mean length 52 cm) and diameters of 3-6 cm. Possibly used as handle. Indeed, one of the voids was found to contain a stone pick there where this would originally have been fixed to the handle.
- 1 trapezoid, flat void with a 15 cm base and a 5 cm top and a height of 20 cm. The diameter varies between 1½ and 2 cm. The assumption is that this was a wooden scraper or part of a shovel.
- 2 club-shaped voids, one 55 cm long and with diameter ranging between 7.5-13 cm and the other 60 cm long and with diameter up to 4-7 cm. It is thought that these voids are the remains of hammers or of special handles for picks.
- 20 circular voids 20-39 cm long and 3-5 cm in diameter, which possibly represent waste products or broken handles of hafted flint picks.

1.3. Bone tools

During the excavation few bone fragments were collected. Naturally the small number of finds allow only assumptions to be made as to their original use. It is possible that a few bone fragments were derived from activities at the surface and thus do not represent tool fragments used underground. A deer antler found was used as a pick (Fig. 23), while another specimen possibly served as a scraper (part of a hoe-shaped elk antler). Other remains of deer antlers are of such small size that it may be assumed that the fragments were discarded. A single ulna fragment, possibly *Bos*, appears to have been used as a pick, may be as a robust point on a softer handle (wood or deer antler).

As far as could be determined, a scapula (14 cm long) was not used as an implement. It may be that this bone, like other small bones (sheep ?), represent discarded remnants of meals.

1.4. Stone tools

Hammerstones

In total, 216 hammerstones were found (Fig. 24), which were described in detail by WILLEMS (1975), who distinguished two weight classes, namely specimens of 100-500 gr. and those of more than 1,000 gr.

He assumed that the small hammerstones were held in one hand to prepare stone picks and resharpen blunt instruments. We consider it likely that the picks were produced at the surface. In our opinion, no picks were made in the mines, as the amount of flint waste found there was very limited. We think that the

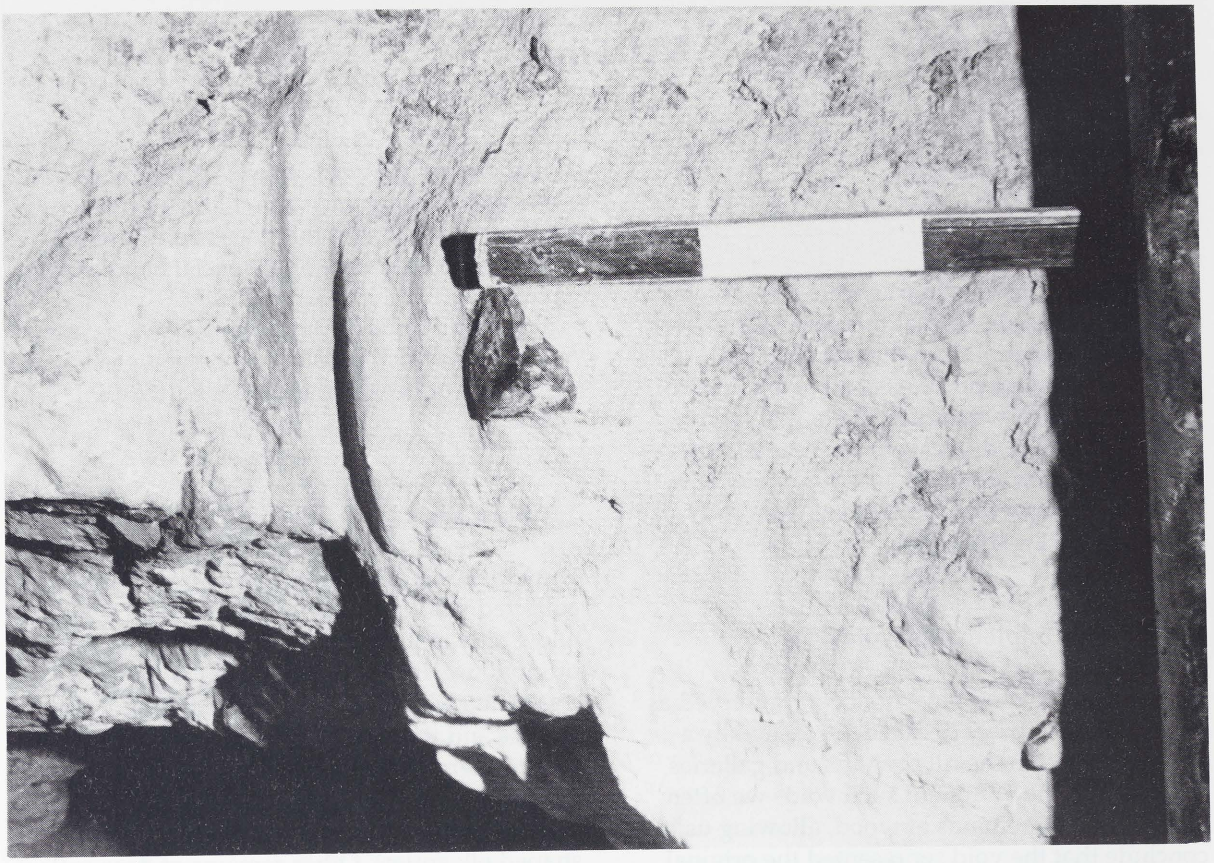


Fig. 21 Rope marks at the foot of a prehistoric mine shaft.

Fig. 22 A void in the fill of an gallery as an indication of a wooden object now decayed.

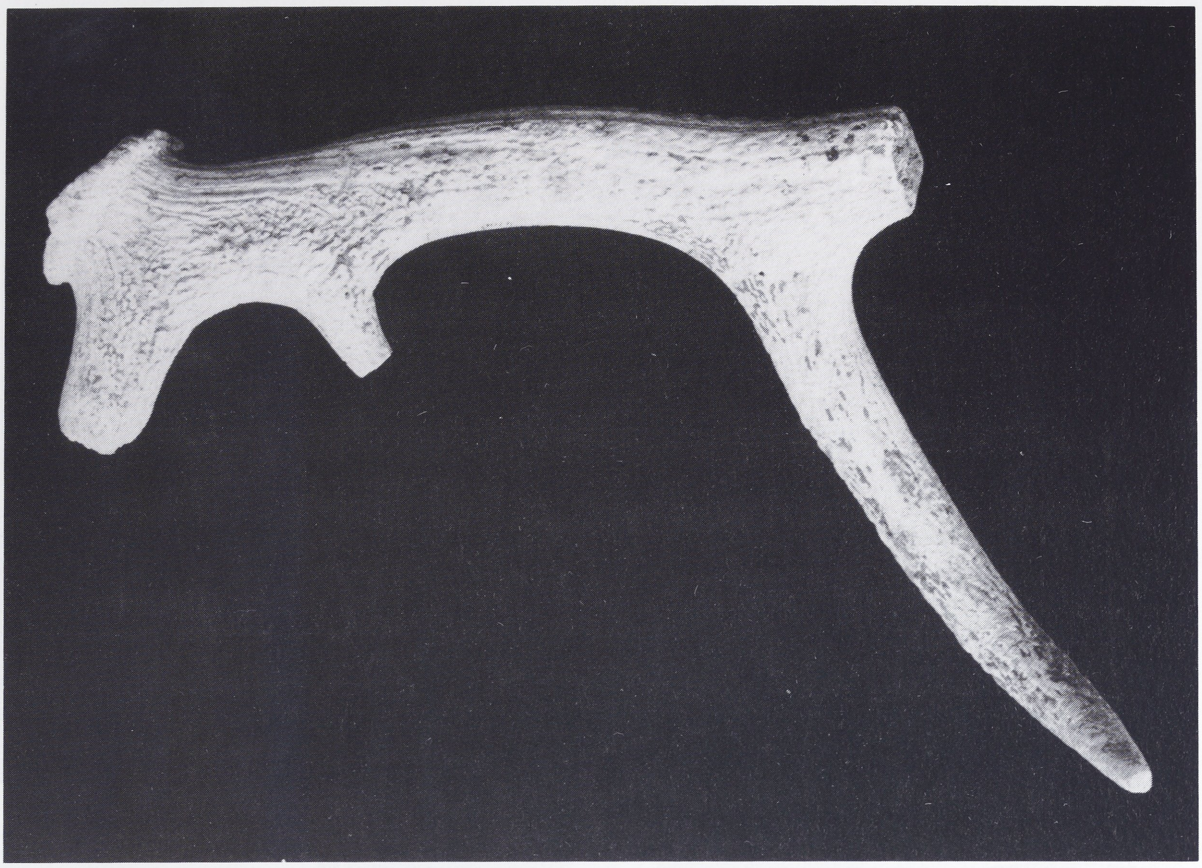


Fig. 23 Portion of a deer antler used as a mining tool.

	weight (gr)	%
primary & secondary decortication flakes	30,050	51.5
flakes without cortex	13,350	22.9
cores	5,150	8.8
artificial blocks	4,550	7.8
crested blades & rejuvenation pieces	3,650	6.2
burnt pieces	1,000	1.7
blade fragments	300	0.5
1 failed preform of bifacial implement	300	0.5
	58,350	99.9

Table 2 Contents of Shaft 19.

smaller hammerstones were exclusively used to resharpen blunt picks in the underground workings.

Remarkable also is that the majority of the small hammerstones (68%) consist of indurated chalk originating from within thicker flint nodules (paramoudras). These indurated chalk hammerstones are in fact 'soft' hammerstones, which enabled precision shaping of flint, such as sharpening stone picks. WILLEMS (1975) assumed the heavier hammerstones to have been held in both hands for cleaving thick and

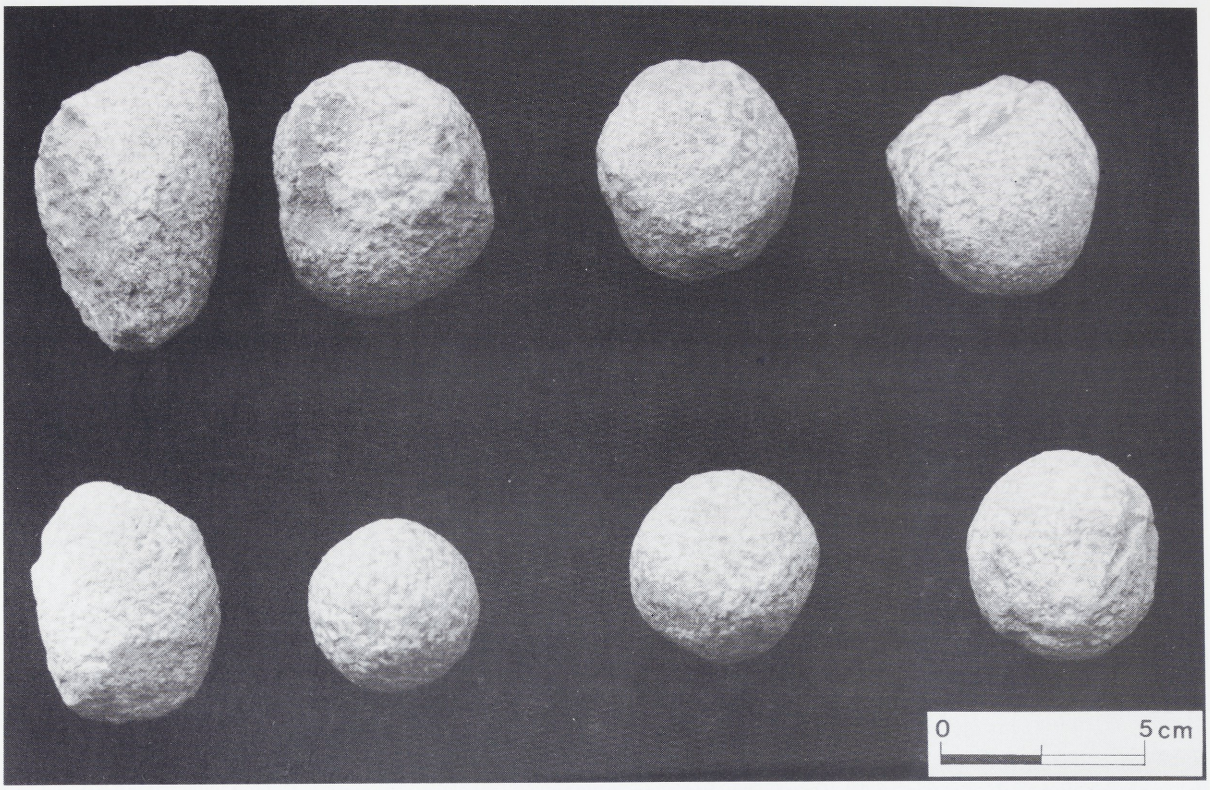
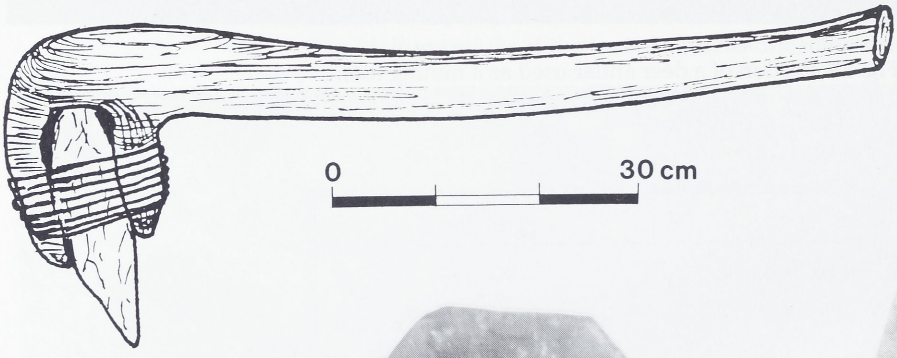


Fig. 24 Hammerstones.



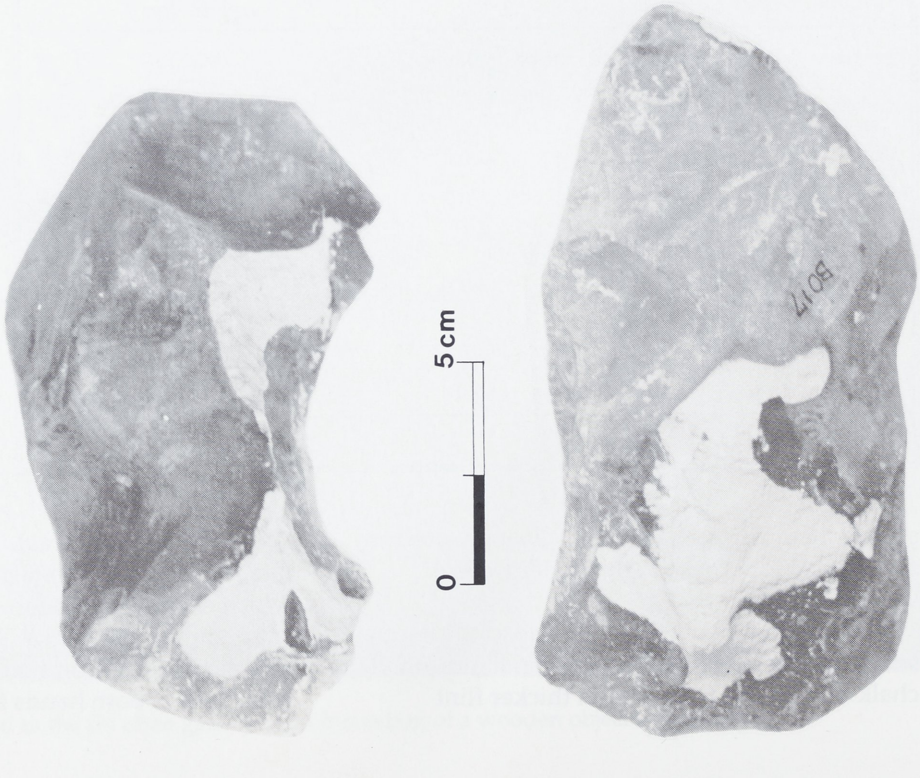


Fig. 25 Stone hammers (*Kerbschlägel*).

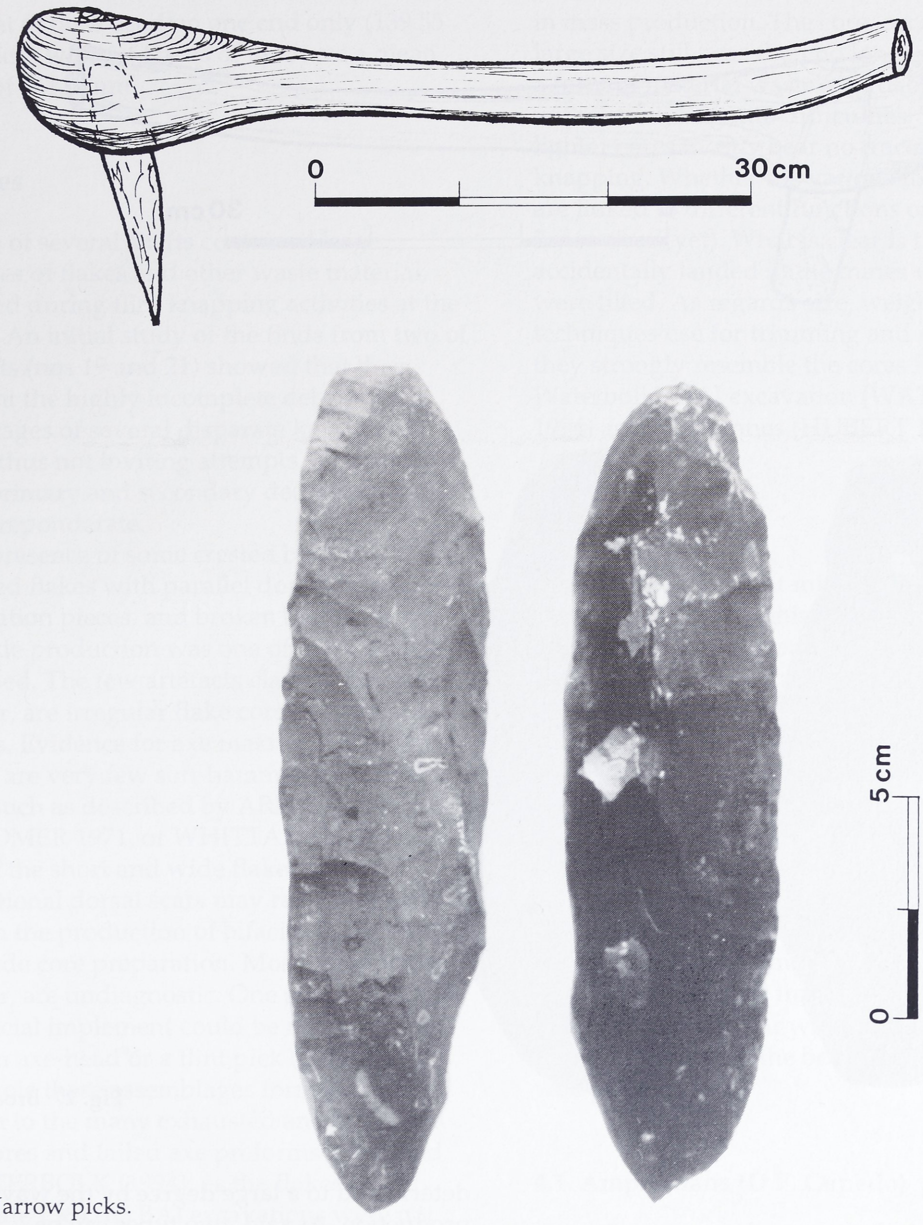


Fig. 26 Narrow picks.

heavy flint nodules. Traces of such use were in various places seen on heavy flint nodules. The majority of the heavier hammerstones are quartzites and thus 'hard', enabling a rough knapping to be performed.

Stone picks and pick fragments

Of the 14,549 artefacts found 14,217 represent stone picks or pick fragments, amounting to 97,71 %. Form the very beginning, these common finds received ample attention, but so far no generally accepted description is available.

Different forms of picks were soon distinguished, viz. 'triangular', 'quadrangular' and 'axe-shaped'. However, it proved impossible to assign each flint pick to one of these forms. All archaeologists who have so far distinguished these types have been forced to add all kinds of intermediate types (see Reports 24, 25, 27 and 29).

Ultimately, the stone mining tools were divided into three types, viz. stone hammers (*Kerbschlägel*) (Fig. 25), narrow hafted flint picks (Fig. 26) and broad or axe-shaped hafted flint picks (Fig. 27).

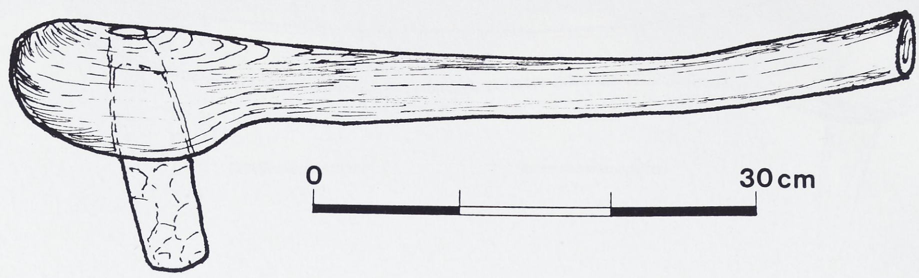


Fig. 27 Broad picks.

Stone hammers

The stone hammers found represent but a small portion of the total; they were probably used for removing hard chalk at the top of the chalk layer (in the shafts). As far as we know, they were not used in the underground galleries.

Narrow and broad flint picks

The width of these picks varies between 35 and 74 mm, their thickness between 18 and 58 mm. Depending on the width/thickness ratio triangular, quadrangular and oval forms in cross section could be produced. Naturally, many intermediate types may be distinguished. We think it likely that the cross section was determined to a large degree by the way of production. As said, two types can be distinguished, viz. narrow picks in which width more or less equals thickness and which have a sharp pointed end, and broad ones in which width exceeds thickness and which have a wide axe-shaped edge. However, intermediates between these types occur.

The length of the picks varies between 109 and 221 mm. It was easily determined which end of the picks was actually used; either a single one or both. Based on the find of hammerstones (and on calculations) it was determined that the stone picks, upon becoming blunt, were resharpened. A stone pick could thus be used more than once. Because of wear its length decreased. The mean length of picks that were used on both ends (137.3 mm)is less than that of ones used on one end only (139.55 mm). Picks without traces of use have a mean length of 161.0 mm.

2. Flakes

The fills of several shafts contained large quantities of flakes and other waste material, produced during flint knapping activities at the surface. An initial study of the finds from two of the shafts (nos 19 and 21) showed that they represent the highly incomplete debris of the initial stages of several disparate knapping events (thus not inviting attempts at refitting) in which primary and secondary decortication flakes preponderate.

The presence of some crested blades, elongated flakes with parallel dorsal ridges, core rejuvenation pieces, and broken blades shows that blade production was one of the activities performed. The few artefacts classified as cores, however, are irregular flake cores, or discarded precores. Evidence for axe making is less clear, as there are very few soft-hammer trimming flakes (such as described by ARNOLD 1981, NEWCOMER 1971, or WHITTAKER 1994). Some of the short and wide flakes with bi-directional dorsal scars may represent early stages in the production of bifacial tools rather than blade core preparation. Most of the flakes, however, are undiagnostic. One single preform of a bifacial implement could be intended for either an axe-head or a flint pick (Table 2). As a whole these assemblages form a useful addition to the many exhausted and reworked blade cores and failed axe preforms published by WATERBOLK (1994), as the flakes found during the 1964/65 BAI excavations were not recovered and studied.

3. Cores

During the excavation of the Rijckholt flint mines in the fill of the shafts and galleries a number (58) of cores were collected. These strongly vary in weight, between 300 and 2,500 gr, and were used to produce large blades, up to 20 cm long and 4 cm wide. The majority of cores clearly show that the striking of the last blade did not produce the desired result and failed on account of e.g. a coarse-grained rock structure halfway down the blade under production. The quality of the blade is the most important factor in mass production. The core, occasionally of large size still, was then no longer used, which is a form of material waste affordable at the site without running into difficulties. The smaller, lighter cores mostly bear no traces of such failed knapping. Whether the various forms of cores are linked to different functions or specialisation is not clear (yet). What is clear is that cores accidentally landed in the mines when the shafts were filled. As regards size, weight, and the techniques use for trimming and reducing them, they strongly resemble the cores found both in Waterbolk's BAI excavation (WATERBOLK 1994) and at Spiennes (HUBERT 1980).

4. Faunal remains

In the prehistoric flint mines at Rijckholt-St. Geertruid many animal remains were encountered. A very small number of these were used by prehistoric miners as tools and later discarded. The majority, however, landed in the mines without human interference. The open shafts acted as traps for small animals such as snails, amphibians and small mammals. Occasionally these small animals landed in the shafts by rain wash, either dead or alive. In some places it could be determined that rain water, mixed with mud, bones and snail shells had flowed into the mines. Live animals also landed in the mines; numerous scratch marks on the gallery walls bear witness to this. In the chalk environment the bones and shells were well preserved.

4.1. Amphibians (D.F. Cupedo)

Skeletal remains of frogs and/or toads were recovered from shafts 8, 10, 15, 16, 18, 19, 21, 32, 54, 56 and on post D.

4.2. Birds (D.F. Cupedo)

Remains of six birds were encountered. From Shaft 15, a pelvis fragment of a small bird and from Shaft 56 the remains of three birds were recovered (find no. 14600): a bird of prey and two smaller species. Skull remains show these latter two to have been insectivorous species of the size of a robin.

A left femur of a larger-sized bird (length 59 mm) was recovered from Shaft 25. Shaft 54 yielded a fragment of a right tibia.

Order Chiroptera (bats) sp. ind.			1
Order Insectivora (insectivores)			
	Family Talpidae	*Talpa europaea* (mole)	1
	Family Soricidae	*Crocidura russula* (house shrew)	1
		Sorex araneus (common shrew)	2
		Sorex minutus (pygmy shrew)	2
Order Rodentia (rodents)			
	Family Sciuridae (squirrels)		1
	Family Muridae	*Apodemus sylvaticus* (wood mouse)	5
		Apodemus flavicollis (large wood mouse)	20
		Apodemus sp.	31
	Family Microtidae	*Microtus arvalis* (common vole)	6
		Microtus agrestis (field vole)	3
		M. arvalis or *M. agrestis*	7
		Pitymus subterraneus (vole)	3
		Clethrionomys glareosus (bank vole)	11

Table 3 Small Mammals, minimum number of individuals.

4.3. Mammals (D.F. Cupedo)

The following larger mammals were encountered. Find no. 4286 consists of a number of badly crushed fragments of a deer antler. No. 4160 is a large fragment of the left antler of a red deer (used as hacking tool) (Fig. 23).

Nos 7994, 2476, 11769 and 3520 are fragments of palmate antlers. In Shaft 32 a few vertebrae, proximal rib fragments and a mandible fragment with three molars possibly of a sheep were found.

Find no. 12552 is a left scapula 14 cm in length.

In addition, a few bone fragments of bovines, used as tools, were recovered.

Of small mammals very many skeletal parts were collected, of these only the skull remains were identified. Table 3 shows the minimum number of individuals of each species.

The identification of species of the genera *Microtus* and *Apodemus* occasionally presented problems. Fragments of upper and lower jaws of *M. arvalis* and *M. agrestis* cannot be distinguished with confidence when all teeth are missing. In such cases they are here listed as *M. arvalis* or *M. agrestis*.

There are but quantitative differences between skulls and mandibles of *Apodemus sylvaticus* and *A. flavicollis*. For these species HUSSON's (1962) criteria were used in identification, viz. length of the tooth row and of the mandible. Specimens in which the length of the tooth row was less than 3.9 mm (and in lower jaw length less than 14.0 mm) were identified as *A. sylvaticus*. Specimens in which the length of the tooth row exceeded 4.1 mm (and lower jaw length exceeded 15.0 mm) were assigned to *A. flavicollis*. The number of individuals of both species should thus be looked upon as indicative only.

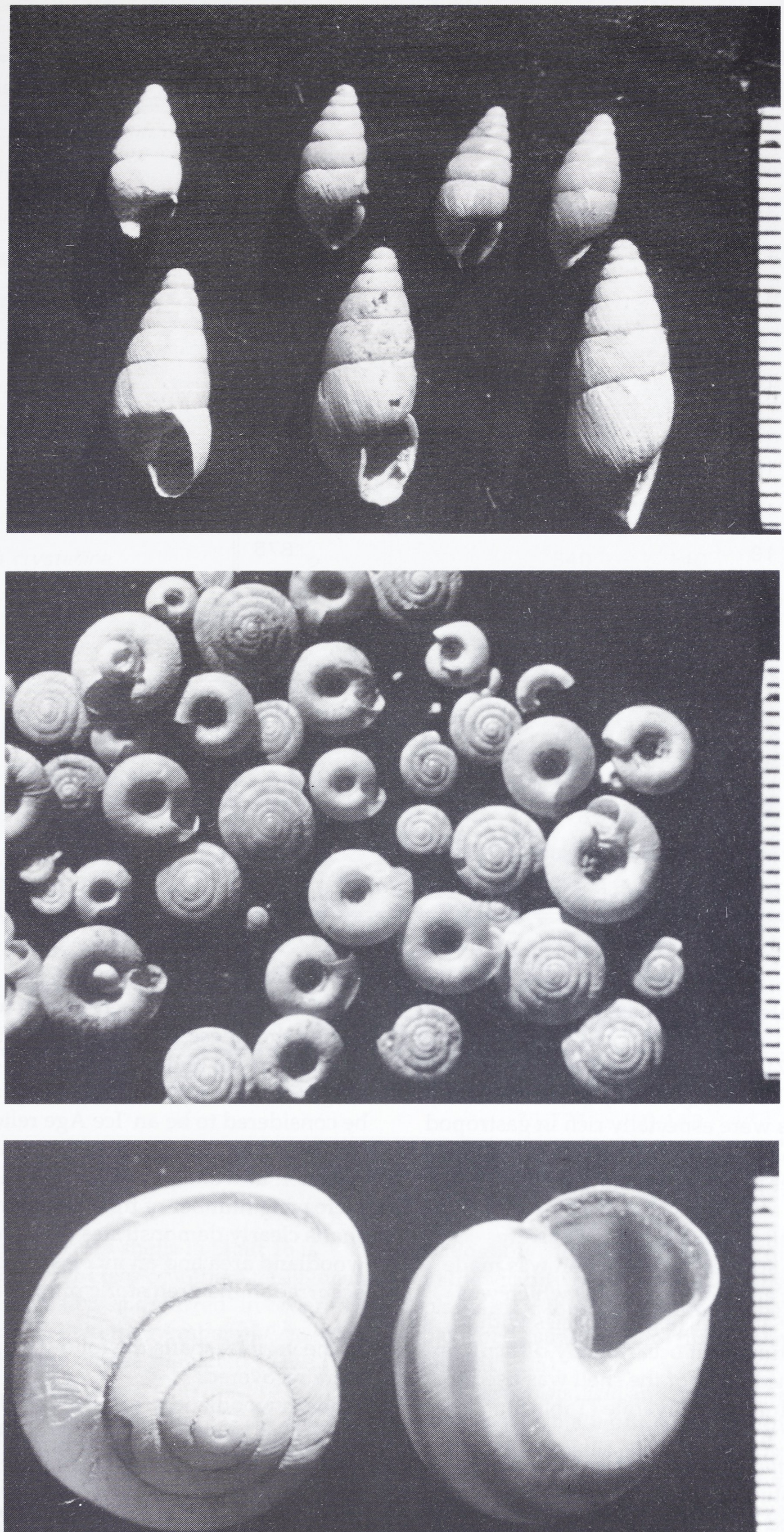


Fig. 28 A selection of gastropods collected from the shafts.

Site	Position	Number
1	shaft 2	4
2	in gallery between shafts 3 and 4	3
3	shaft 3	3
4	shaft 4	2
5	shaft 8	11
6	shaft 10	1,209
7	shaft 11	3
8	shaft 15	5,652
9	shaft 16	598
10	shaft 18	159
11	shaft 19	875
12	shaft 21	6,969
13	shaft 25	1
14	shaft 32	99
15	shaft 40	2
16	shaft 42	4
17	shaft 54	167
18	shaft at structure 53 (= vicinity of shaft 21)	4
19	post D (= vicinity shaft 21)	8

Table 4 Sites yielding gastropods.

4.4. Invertebrates (gastropods, P.J. Felder)

A total of 15,771 specimens were recovered, collected from 19 sites (Table 4). Remarkable is that a few sites were especially rich in gastropod shells; these may have been shafts that remained open for longer periods of time.

Gastropod shells recovered (Fig. 28) were assigned to 24 species. A distinction was made between adult and juvenile shells, which was relatively easy at times (e.g. in species with a reflected aperture), but occasionally difficult, in which cases the height of the shell was used to distinguish adult from juvenile (Table 5).

Carychium minimum and *C. tridentatum* are difficult to distinguish. In Shaft 15, these small species showed a curious distribution pattern, occurring in large numbers on one side of the shaft only. From this pattern we may conclude that the small shells where blown to one side during their descent by natural ventilation.

As far as we know, *Ena montana* does no longer occur in southern Limburg, and may thus be considered to be an 'Ice Age relic'.

Discus rotundatus prefers farms and is less common in woodland areas (*c.* 10%). The increasing number of this species in the various shafts clearly demonstrates that a reduction of woodland area and an increase in open fields occurred in the prehistoric mining area.

In the various shafts the following percentages were recovered:

modern woodland area	10.0%
shaft 8, at 26 m in tunnel	20.0%
shaft 10, at 25 m in tunnel	23.2%
shaft 15, at 30 m in tunnel	35.9%
shaft 16, at 46 m in tunnel	39.8% *
shaft 19, at 53 m in tunnel	33.5%
shaft 21, at 49 m in tunnel	44.3%

Genus/species	Number	Adult	Juvenile
Carychium minimum or *C.tridentatum*	2,679	2,441	438
Succinea putris	10	10	
Succinea oblonga	80	53	27
Cochlicopa lubrica	101	31	70
Acanthinula aculeata	123	63	60
Ena montana	52	37	15
Ena obscura	152	38	114
Punctum pygmaeum	157	157	
Discus rotundatus	5,861	1,496	4,365
Vitrina sp.	8		8
Vitrea crystallina	340	140	200
Aegopinella nitidula	1,620	155	1,465
Oxychilus sp.	118	77	41
Cochlodina laminata	105	70	35
Clausilia bidentata or *Iphigena lineolata*	197	106	91
Bradybaena fruticum	343	128	215
Perforatella incarnata	5	3	2
Trichia hispida	2,331	410	1,921
Helicodonta obvoluta	159	67	92
Helicigona lapicida	66	42	24
Cepaea nemoralis or *C. hortensis*	951	649	302
Unidentified	313		313
Total	15,771	6,173	9,598

Table 5 Species of gastropods recovered.

* = the number of *Cepaea* shells in Shaft 16 is very high (54.3%), whereas on other sites a mean percentage of 4.2% *Cepaea* occurred. In order to obtain comparable data the number of *Cepaea* in Shaft 16 in this table was recalculated to the average number.

Succinea, *Vitrina* and *Vitrea*: these are genera that prefer moist environments and indicate that conditions during the prehistoric mining activities were more humid than they are today. These genera no longer occur at the site.

Possibly large-leaved herbs (Butterbur) grew in the vicinity of the mines, as these are pioneer plants after forest clearance, or the climate could have been slightly more humid than it is today (Atlanticum).

Clausilia laminata and *Iphigena lineolata* are species which are difficult to distinguish.

Cepaea nemoralis and *C. hortensis*: fully-grown shells of these species can be distinguished by the coloured apertural margin. Juvenile shells lacking this margin, but also the occasionally strongly eroded and damaged adult shells,

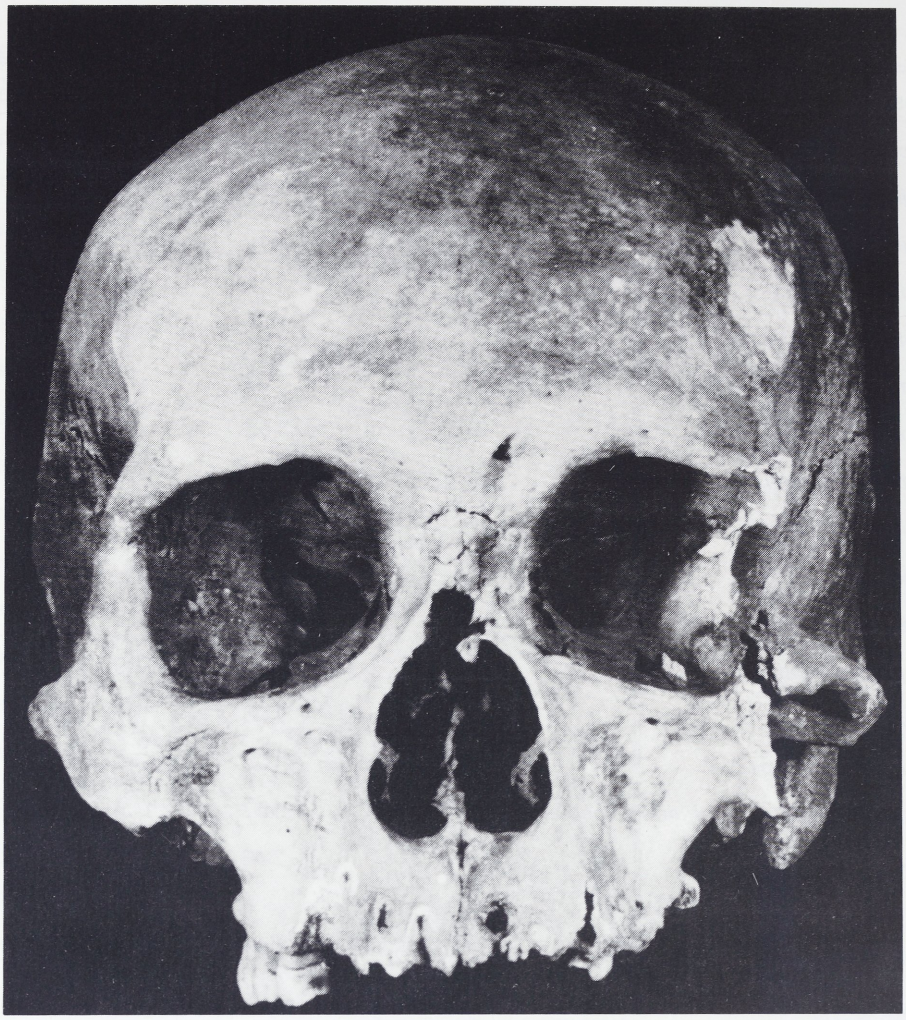


Fig. 29 The Rijckholt I skull.
(Photograph courtesy of Laboratorium voor Anatomie en Embryologie, Rijksuniversiteit Groningen).

could not be identified to species. *Cepaea* nowadays lives along the fringes of woods and in the vicinity of farms, preferably on stinging nettle. These plants prefer places where dung or rotting organic material occurs. In Shaft 16 remarkably many *Cepaea* were found, namely 325 out of a total of 598 shells. We may thus assume this shaft to have been near the edge of woodland where many stinging nettles grew (possibly as a result of the occurrence of a latrine nearby).

5. The Rijckholt skulls

5.1. 'Rijckholt I skull'

One of the most spectacular finds during the 1964-1972 excavation campaign at the Neolithic flint mines of Rijckholt, is the well-preserved human skull (Figs 29, 30), which was found on November 5, 1965.

The skull was encountered at the end of a Neolithic mine gallery (Fig. 31), at a distance to the associated shaft of *c.* 6 m. Halfway, the gallery made a right angle and came to a dead end in a solution pipe. The site was situated *c.* 8 m[5] below ground level. The dead end of the gallery was filled with chalk rubble over a

[5] In the daily find protocol, summarized in Report N° 5, a distance of 12 m was recorded. The present number derives from data obtained during the more accurate survey documented in Report N° 30.

Fig. 30 The Rijckholt I skull.
(Photograph courtesy of Laboratorium voor Anatomie en Embryologie, Rijksuniversiteit Groningen).

distance of *c.* 3 m, and to up to 60% of its height. From the roof larger chalk blocks collapsed subsequently. The first 3 m of the gallery were almost completely filled, with the fill reaching the roof. The shaft was filled as well and could not be recognised at the surface.

Important with respect to this find are the dates from a number of charcoal samples from nearby galleries (cf. Chapter VIII).

Upon discovery, the site of the skull was left undisturbed until, with Prof. Dr. Waterbolk, Prof. Dr. de Wilde and Dr. van Vark (all Rijksuniversiteit Groningen) present, a further investigation was initiated. During inspection of the site we asked Prof. de Wilde to take the skull for study to the Laboratory of Anatomy and Embryology of the Rijksuniversiteit Groningen.

In December 1971 we received the report of a preliminary study carried out by order of Prof. de Wilde by Dr. van Vark. This report is included in Report 5. The conclusion reached in this report is that the skull could be identified to period and even to population group within the Neolithic (see section VII.5.5.). The fact that only the skull was present, and the way this was placed in the gallery indicate a ritual burial. The burial in a working underground flint mine is evidence of a relationship between the dead person and the miners. Probably he was one of them at some time.

The skull was transferred to the Provincial Depot for Archaeological Finds at the Bonnefantenmuseum (Maastricht), where it is registered under collection no. 3313A.

5.2. Hamal-Nandrin's skull

Already some 40 years earlier, on April 17, 1923, human remains were found in the Rijckholterbos by Prof. Hamal-Nandrin of Liège. The site was in the central part of the northern slope of the 'Schoone Grubbe'. The finds comprised a skull and half a mandible with associated fragments of right femur, collected at a distance of *c.* 2 m. All remains were found at 2,20 m depth in the slope scree which, at that site, contained many worked flints.

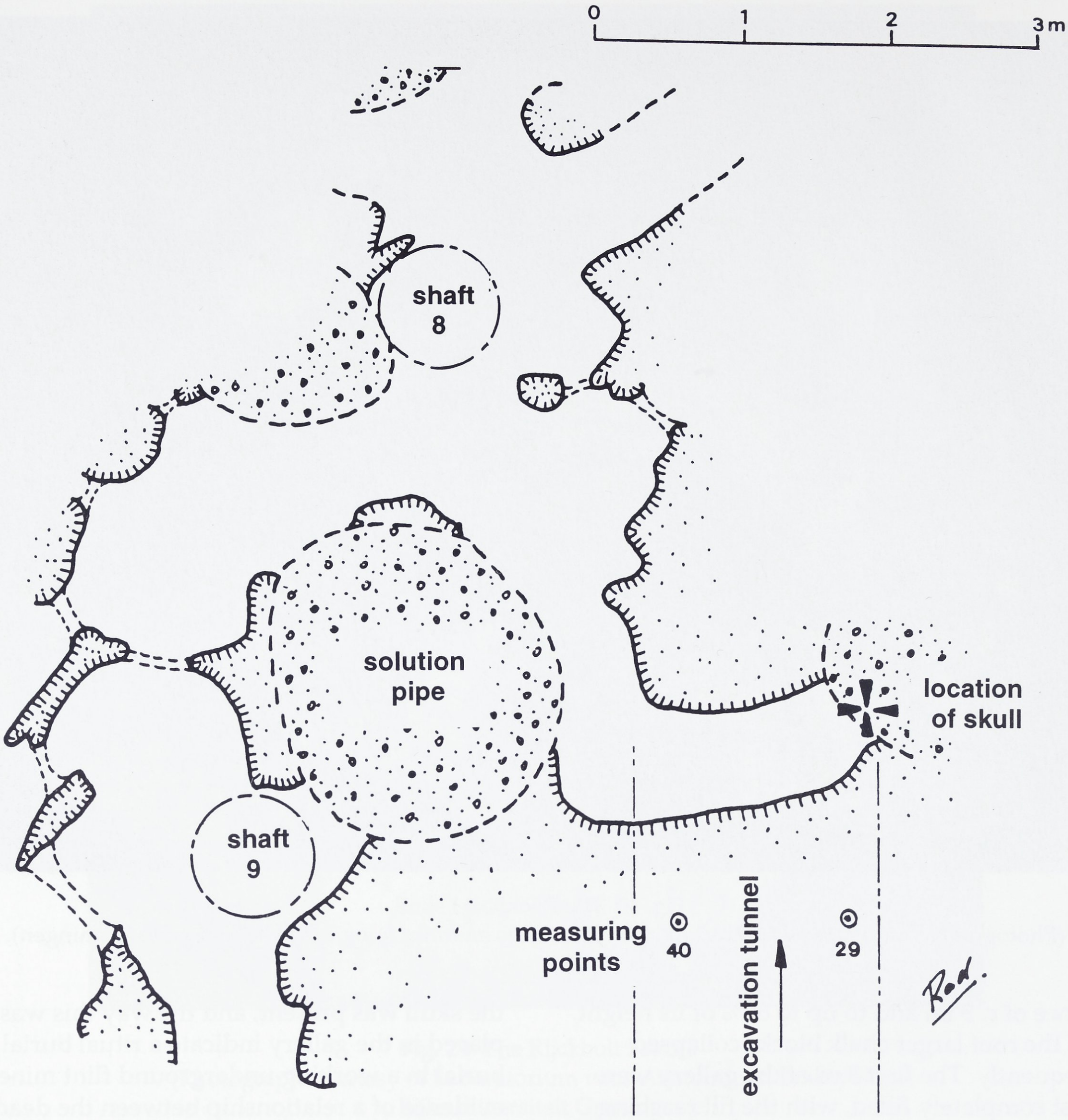


Fig. 31 Provenance of the Rijckholt I skull.

A paper on his work at Neolithic Rijckholt (HAMAL-NANDRIN & SERVAIS 1923) includes a stratigraphical description of the site (LOHEST & FOURMARIER 1923, pp. 137-140) and a detailed anthropological report (FRAIPONT *et al.* 1923, pp. 140-148). The stratigraphy of the site did not allow the age to be determined, but a Neolithic age could not be ruled out.

Shortly before his death, Prof. Hamal-Nadrin donated this skull to the Bonnefantenmuseum, where it is registered under number 2969A.

5.3. The skull of the Dominican friars

Between 1929 and 1932, French Dominican friars of the Rijckholt monastery also carried out excavations. At the 'Schoone Grubbe', they recovered '*... a very well-developed crown of a skull...*' (PÈRES MOOS *et al.* 1937, 11). No additional skeletal remains were found, at *c.* 1,40 m depth in a layer of chalk rubble with many worked flints. The horizontal distance to the edge of the 'Grubbe' was only 0,50 m.
In their paper, the friars provided but a brief description of the find and its circumstances; there are no photographs. The skull was probably taken to their mother house in France. However, we have not been able to substantiate this.

5.4. An Enigma

In *Hannonia Praehistorica* (LEFRANCQ & MOISON 1962) we came across an allusion to the find of the crown of a human skull originating from a shaft in the prehistoric mine field at Rijckholt. The specimen was donated in 1958 by Louis Tomballe (Bois de Breux) to the Museum Curtius (Liège), where it is registered under number LT/209.

During a visit to this museum the specimen appeared to consist of a fragment of a human skull. As far as we know, this find was not described at that time. The possibility of acquiring reliable data on this find must be considered out of the question.

5.5. Summing up

The Neolithic flint mines at Rijckholt-St. Geertruid have since their first discovery yielded four human skulls. Two of these are available for study and are easily classified, viz. the 'Rijckholt I skull' and that of Hamal-Nandrin.

A detailed description of the Rijckholt skulls and their find circumstances was published separately (RADEMAKERS 1972).

A comparison of the results of a preliminary study of the 'Rijckholt I skull' with data on the Hamal-Nandrin skull published in 1923, shows remarkable differences. The 'Rijckholt I man' was dolichocephalic in contrast to the 'woman' of Hamal-Nandrin, who was brachycephalic. Whereas for Hamal-Nandrin's skull obvious similarities to modern Scandinavian Lapp were claimed, 'Rijckholt I man' was determined to be definitely not assignable to a recent Lapp population. Of 'Rijckholt I' it is further assumed that he possibly belonged to an Early Neolithic population from the period prior to the invasion of population groups having completely different skull morphologies at the start of the Late Neolithic in northwest Europe. These considerations raise the question whether these are indications of differences in origin between the Neolithic miners and the other Neolithic people they lived with.

Since the publication of van VARK's report (1971) new data have become available (e.g. GERHARDT 1976; WAHL & KÖNIG 1987; WAHL & HÖHN 1988), which triggered a reappraisal of a few observations in that report. Two of his conclusions need a special reconsideration:

- 'The skull can probably be classified to period and perhaps even to population group within the Neolithic'.
- 'Rijckholt I possibly belonged to an early Neolithic population from the period predating the invasion of population groups with completely different skull morphologies in the late Neolithic in northwest Europe'.

With reference to these observations, it can now be stated, that:

- The Rijckholt I skull can still be assigned to the Neolithic, in particular to the Early and Middle Neolithic, and even falls within the range of the Michelsberg population, who are considered to be the first people to have exploited the Rijckholt flint mines (compare e.g. the chignon formation).
- With regard to the age of Hamal-Nandrin's skull less conclusive evidence is available, since modern studies are lacking. The find circumstances do not yield conclusive evidence either. With a certain amount of caution - see brachycephalic Michelsberg people from Alsace (WAHL & HÖHN 1988) - it might be concluded that this specimen is indeed of a more recent date (Bell Beaker age) than the Rijckholt I skull. 'Bell Beaker people', however, are no longer considered to have been just invaders.

From the above, it may be concluded that there is no reason to suppose that there were two different populations: the Rijckholt I skull entirely corresponds to the morphological range of potential 'users' of mined Rijckholt flint (i.e. representatives of the Michelsberg culture in general). The existence in the Late Neolithic (Bell Beaker period) of 'brachycephalic' newcomers, whether or not these represent local evolution, has no bearing upon the Rijckholt situation: the underground mining took place much earlier, in the Middle Neolithic.

6. Marks made by hafted picks

During the excavation campaign at Rijckholt thousands of miners' picks were recovered. Typical of these finds is that these were expendable tools and that their raw material is almost indestructible, which explains the large numbers found.

Fig. 32 Pick marks on chalk slab originating from the ceiling of a gallery in mine Nr. 8.

More subtle in this respect are the marks made by hafted stone picks which testify to the activities of the prehistoric miners, left behind in the soft chalk of the galleries. They are restricted to particular areas and very fragile.

Such marks occur in many places in the investigated mines (Fig. 32). In general, they consist of a limited number of marks. Larger concentrations of marks occur only in some places. The reason for this is the often impaired cohesion of the rock under the influence of pressure. Because of this, even during the early construction of the galleries or over longer periods of time, plate-like stripping or collapse occurred. Also unintentional wear by prehistoric miners during the exploitation can be demonstrated. In the limited number of occurrences of relatively large concentrations of pick marks these appear to be random as far as direction, length and form are concerned. With regard to strike direction a cerain preferential direction could be expected, in view of the limited space within the galleries. A compass rose diagram could perhaps reveal this (Fig. 33). The distribution of the lengths of marks at the various localities could possibly be clarified by means of comparative graphs. In order to achieve this it was necessary to document the strike angle of all pick marks, and, where these could be demonstrated, their direction and length.

Care was taken not to damage or soil the marks. We used sheets of transparent plastic which were attached to the gallery walls or to the ceiling by small nails. Using ballpoints, pick marks could be traced on these sheets (Fig. 34). In the early 1970s this called for a lot of experimenting in order to find ballpoints which could be used upside down/point down and this also in a humid environment on a non-hygroscopic material. These data are listed in tables, incorporated in compass rose diagrams and included in Report 31.

7. Charcoal

In a few places underground charcoal was found, at the bottom of shaft fills as well as in the fill of galleries. The locations of these sites

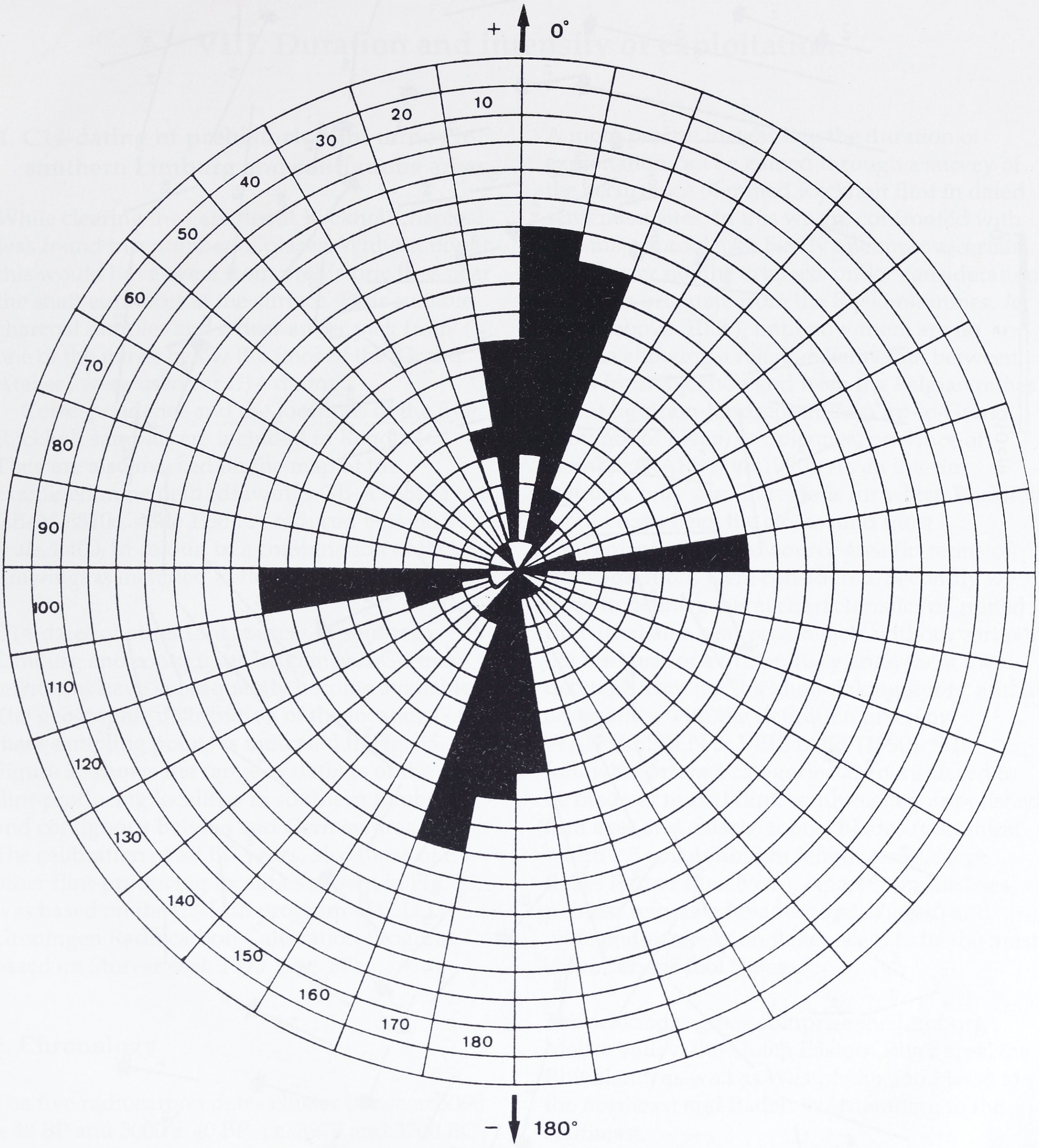


Fig. 33 Compass rose diagramm of tool marks in measuring area 4.
Open symbol: direction of strike known; closed symbol: direction of strike uncertain.

are marked on the map of the mines examined (Report 2). The charcoal samples of four locations proved suitable for C14-dating (see Section VIII.1.).

On the basis of our investigation over a number of years and in an extensive mining complex, we may definitely conclude that the charcoal did not originate from underground hearths. Open fires, whether or not representing the seat of fire of a hearth, torch or other illumination sources, would undoubtedly have left traces. Such traces could be soot traces as well as red burnt chalk surfaces. Such traces have not been encountered anywhere by us.

The use of open fire was, at least in view of the circumstances and working methods applied in the Rijckholt mines, not to be expected. During our own underground activities we noted that extra illumination was not necessary. Daylight coming in through the open shafts in a mine was sufficient for the Neolithic miner, who worked the lightly coloured rock in the galleries. There was no need for hearths, as these would have been bothersome and dangerous because

Fig. 34 Orientation of tool marks in the roof of a gallery. Arrows indicate known directions of strike.

of smoke forming below narrow shafts and in the low, narrow galleries. Fire used for ventilation was not needed either in view of the limited size of the still open, not yet infilled portions of galleries during exploitation.

The underground use of open fire by Neolithic miners at Rijckholt was not needed. No indications of such use were found. All charcoal found underground must therefore have come from fires at the surface and was dumped together with the other waste and matrix in the mines at that time.

VIII. Duration and intensity of exploitation

1. C14-dating of prehistoric flint mines in southern Limburg and contiguous areas

While clearing the galleries at Rijckholt charcoal was found in a number of places. Without doubt this would have come from prehistoric fires near the shaft entrances at the surface. Four suitable charcoal samples and a deer antler pick from one of the mines below the floor of the 'Grand Atelier', were used for C14-dating.

Correspondence and the locations of the five Rijckholt samples are included in Report 16. They are also marked on the map of the examined mine field (drawings GB-A^0-8810a to GB-A^0-8810c, scale 1:50). A reduced version at scale 1:400, in colour, of a combination of these drawings is included in Report 2.

C14-dates of other flint sources in southern Limburg and contiguous Belgian and German territories have subsequently become available. The geographic distribution of the locations of these sampling points is indicated in Fig. 35. Figure 36 shows the range of datings of the flint-producing localities in southern Limburg and contiguous Belgian and German areas. The calibration of all BC years, also those of the other flint-producing localities shown in Fig. 36, was based on the CAL.15 program of C.I.O. Groningen Radiocarbon Calibration Program based on Stuiver *et al.* 1993 (Fig. 37).

2. Chronology

The five radiocarbon dates cluster between 5090 ± 40 BP and 5000 ± 40 BP, i.e. 3970 and 3700 BC (Table 6). This is not really surprising, as the samples were all situated rather close together, in the Grand Atelier area and in the adjacent western part of the underground excavation (BOSCH & FELDER 1990, fig. 3). The dates indicate that the 'Grand Atelier shaft system' is broadly coeval with the western part of the main mine field.

The radiocarbon dates show that at least some of the mines were contemporary with the Dutch Middle Neolithic A (according to the proposed new chronological system for Dutch Prehistory), or in cultural terms with the early stages of phase III of the Michelsberg Culture (MK, LOUWE KOOIJMANS 1980).

A more precise insight into the duration of exploitation can be gained through a survey of the occurrence of mined Rijckholt flint in dated settlement sites. In this we are confronted with two major problems: Firstly one must ascertain whether or not the artefacts under consideration really do originate from the Rijckholt mines. As stated above (III.2.), until now there are no criteria allowing a reliable distinction between flints from Rijckholt and from the Belgian mines e.g. at Jandrain-Jandrenouilles (Orp-le-Grand, province of Liège) or Spiennes, province of Hainaut (KARS *et al.* 1990). As an interim solution, only sites in regions for which Rijckholt would have been the closest and most conveniently situated source area (in terms of transportation) were considered. Secondly we have to define general characteristics of 'mined flint' (that also bear on artefacts without cortex). On the basis of a preliminary analysis of the debitage from the Rijckholt flaking floors, and in accordance with the definition given by WANSLEEBEN & VERHART (1990), the following artefact categories are considered to be made of mined flint: semifinished or polished flint axes and chisels, robust blades (minimum width 2.5 cm, minimum length 8 cm), large flakes (larger than 5 cm). Apart from the axes, pointed retouched blades (*Spitzklingen*) and wide end-scrapers on flakes seem to be the most characteristic tool types.

The selected regions comprise the Limburg Meuse valley, the Dutch Eastern River area, the Rhineland, as well as Westphalia and Hesse to the northeast and Baden-Württemberg to the southeast.

Maastricht, Watermolen-Vogelzang (BROUNEN 1995) may provide a *terminus post quem* for the systematic mining activities at Rijckholt. The site, discovered 1991 by Mr. B. Knippels and investigated in 1994 and 1995 by the Gemeentelijk Oudheidkundig Onderzoek Maastricht, is located in the Meuse valley, some 4 km to the north of the mines. Until now (spring 1996), however, no typical artefacts made of mined Rijckholt material were recovered from a stratigraphic position. The pottery may be assigned to the Early Michelsberg Culture (MK I) (according to Prof. Jens Lüning, oral comm., June 1995; this early dating is corroborated by the single radiocarbon

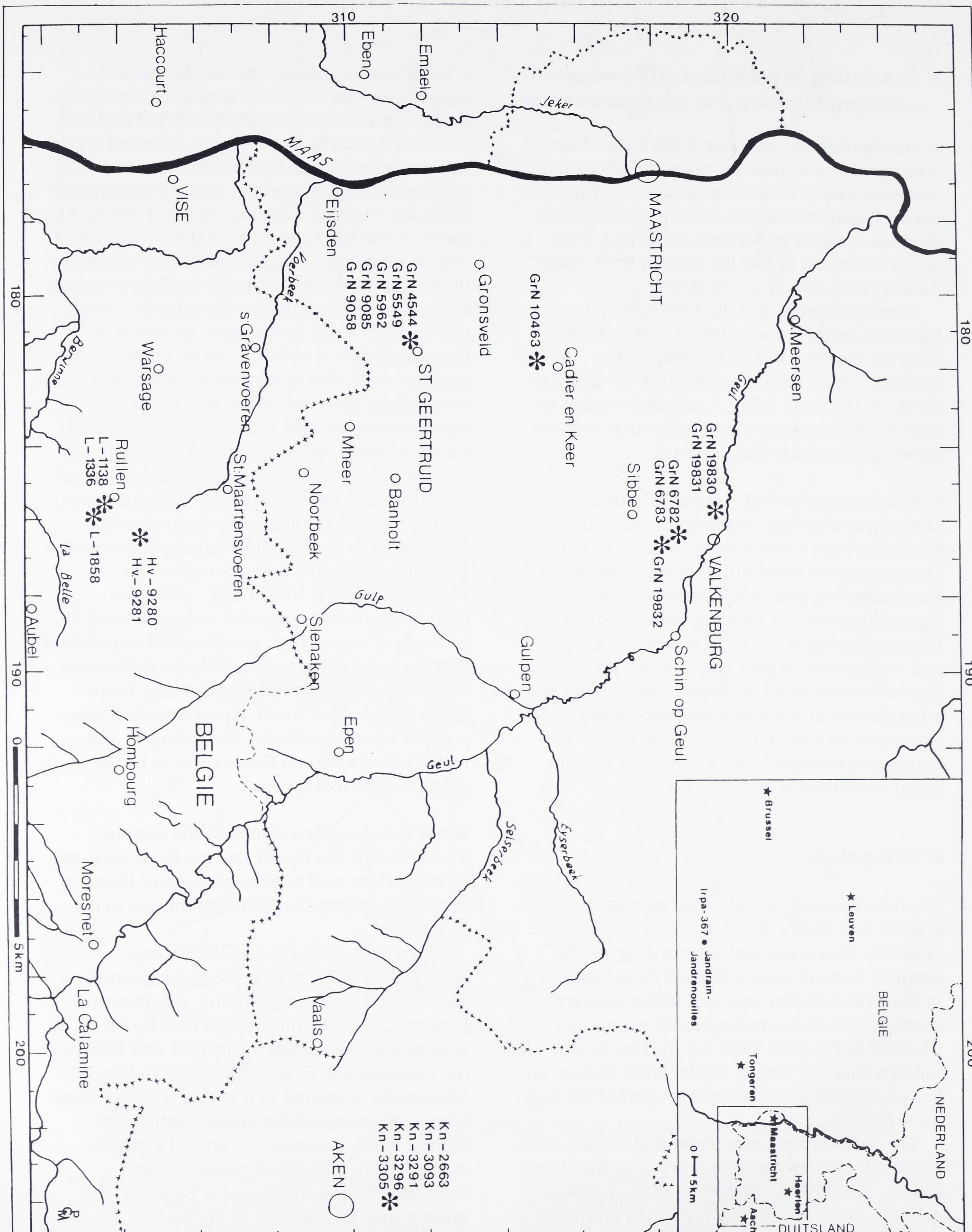


Fig. 35 Locations of flint extraction sites in southern Limburg and contiguous Belgian and German areas for which radiocarbon dates are available.

Sample	Date BP	Cal BC range at 2 sigma	Cal BC range at 1 sigma
GrN 4544 Charcoal from a gallery between shafts 3 and 4	5070 ± 60	3978-3760 3742-3714	3948-3898 3884-3798
GrN 5549 Charcoal from the fill at the bottom of shaft 23	5000 ± 40	3942-3858 3818-3698	3902-3882 3802-3754 3750-3712
GrN 5962 Charcoal from the fill at the bottom of shaft 19	5090 ± 40	3966-3892 3890-3796	3954-3926 3918-3914 3876-3808
GrN 9085 Charcoal from a mine below the floor of the «Grand Atelier»	5080 ± 45	3968-3786	3948-3908 3878-3806
GrN 9058 Deer antler from a mine below the floor of the «Grand Atelier»	5065 ± 45	3966-3774	3946-3898 3886-3844 3842-3798

Table 6 The Rijckholt Radiocarbon dates.

date: 5310 ± 80 BP (GrN 21043), i.e. between 4328 and 3978 BC). Artefacts apparently made of mined Rijckholt flint, however, are reported from the MK I site Inden 9 in the Rhineland (ALDENHOVENER PLATTE 1975; SCHWELLNUS 1983).

In the areas under consideration artefacts made from mined Rijckholt flint are known from a number of sites belonging to the Early and Middle Michelsberg Culture (MK II-III, as defined by LÜNING 1968), its Dutch facies Hazendonk 2, or the local derivative Hazendonk 3 (LOUWE KOOIJMANS 1981; 1983), all dated between 5600 and 4700 BP (LOUWE KOOIJMANS 1976; 1980), i.e. between *c.* 4420 and 3520 BC. Rijckholt artefacts also reached settlements belonging to the Funnel Beaker Culture in the north (STAPEL 1989) and the Schussenried Culture in the south (KEEFER 1988).

In recent years, moreover, an increasing number of finds attributed to the Vlaardingen/Stein/Wartberg group, dated between 4700 and 4100 BP (LOUWE KOOIJMANS 1983), i.e. between 3520 and 2630 BC, indicates that the exploitation may have gone on for a considerable time. This is corroborated by the single pottery shard found during excavations, a base fragment, recovered by van Giffen in the backfill of a mine shaft on the plateau (van GIFFEN 1925, pl. 4: VII, 35), that can be assigned to the Stein group (LOUWE KOOIJMANS 1974; LOUWE KOOIJMANS & VERHART 1990). The settlement data show no evidence for any decrease in the intensity of exploitation in the Stein/Vlaardingen period.

The exploitation of the Rijckholt mines probably did not end after the Stein/Vlaardingen/Wartberg period. Some Rijckholt artefacts were found associated with Bell Beaker pottery at Meerlo, Meerloërheide (VERLINDE 1971, especially fig. 8, 9). It is difficult to assess the duration of the exploitation, because well-dated, single-period sites from later periods are virtually absent, and the relevant artefacts cannot at the moment be distinguished from their Middle Neolithic counterparts (ARORA 1986; SIMONS 1989). The post-Neolithic occurrence of mined flint from Rullen, Valkenburg, the Lousberg, and to a lesser extent Rijckholt on the Aldenhoven Plateau, however, has been extensively documented by ARORA (1985) and SIMONS (1989), and at Spiennes settlement traces from the Bronze and Iron Ages are seen as evidence for the continuing exploitation of that mine site (HUBERT 1980). Thus, at Rijckholt shaft-and-gallery mines were probably used for at least thirteen hundred years, between *c.* 3950 BC and *c.* 2650 BC.

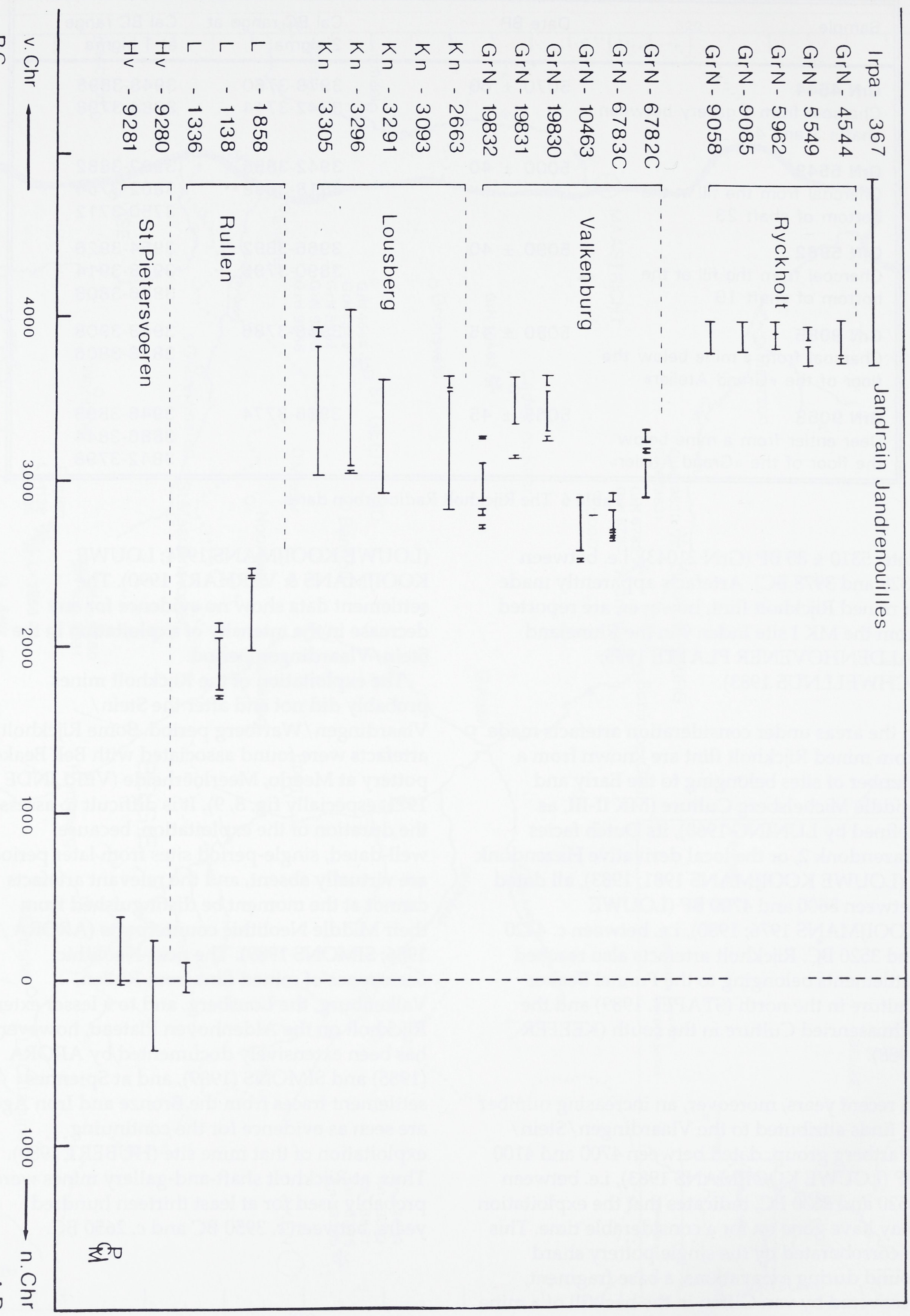


Fig. 36 Distribution of radiocarbon dates from flint mines in southern Limburg and contiguous areas.

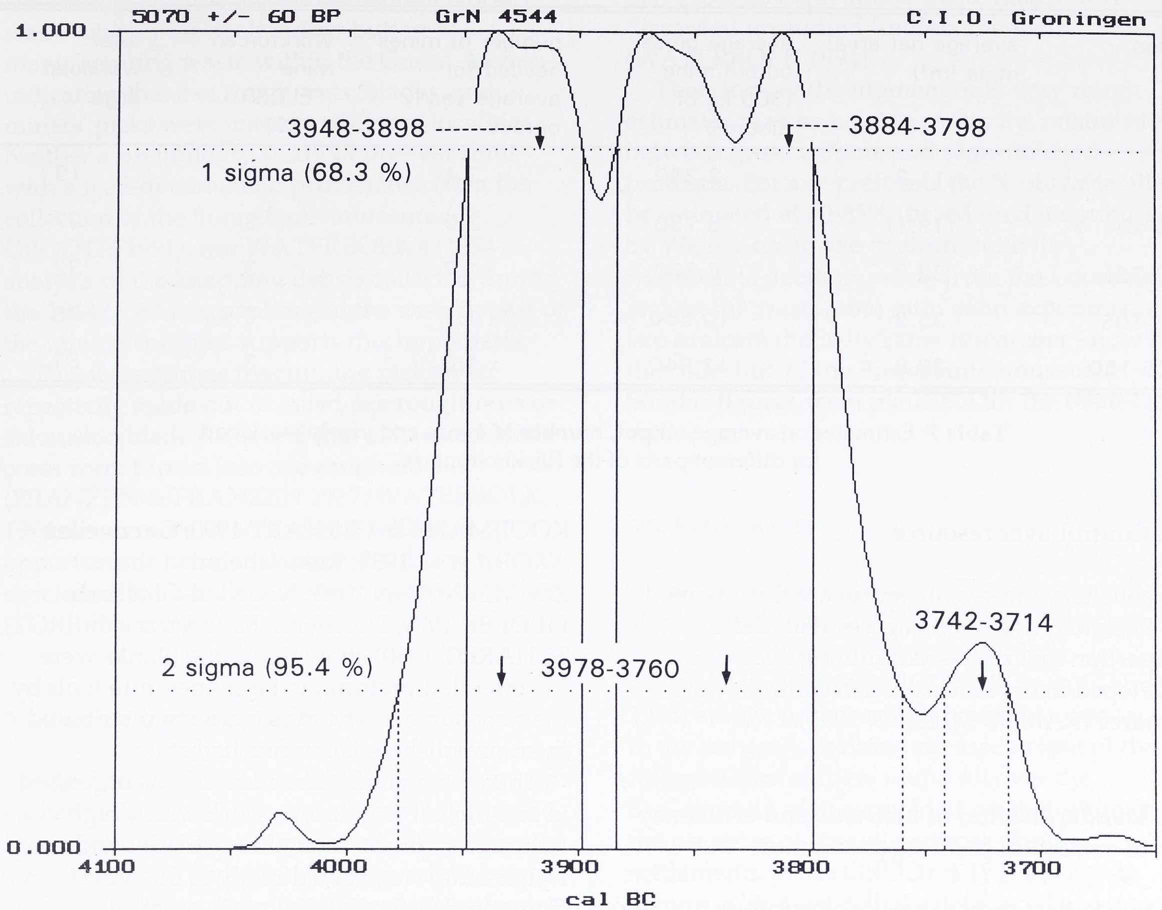


Fig. 37 Calibration diagram of a charcoal sample from the Rijckholt flint mines.

3. Socio-economic aspects

This chapter will try to interpret the organisational aspects of mining at Rijckholt, i.e. the ways it was embedded in the socio-economic life of the communities involved (SAHLINS 1972). In this context it is extremely important to bear in mind that deep-shaft mining was not undertaken for its own sake, but to obtain suitable raw material in a structured way. The ultimate purpose of the process, of course, was to manufacture preforms and (parts of) tools that could be used in a variety of ways, economic as well as social or ritual (McBRYDE 1986; McBRYDE & HARRISON 1981; TORRENCE 1989; de GROOTH 1994; 1997). For a better understanding of the procurement strategies applied, one must study, in an integrated approach, the assemblages both of the extraction and workshop sites and of the settlements consuming their output (ERICSON 1984; TORRENCE 1986).

This procedure involves the careful consideration of aspects such as the duration and intensity of exploitation; the presence or absence of some sort of control over the resource, and, in case access is seen as restricted, of the type of social formation (family, moiety, clan, tribe, etc.) vested with the ownership rights; the relative and absolute volume of production, and the amount of standardisation in production methods, resulting in an efficient use of the resource; the spatial correlates of the reduction sequence, especially the existence of repeatedly used special activity-areas within the site, indicating standardised practices in the division of labour; the location and character (permanent or temporary) of the miners' settlements; the way the distribution of the product was organised (TORRENCE 1986; de GROOTH 1991).

position	average net area/ mine (m²)	average gross output/mine (300 kg of flint/m²)	number of mines needed for average yearly output	workforce/ mine (FELDER 1980)	total workload days
A: 0-30	11.3	3,390	3.4	2	19
B: 30-40	(19.1)	5,730	2.0	3	27
C: 40-72	22.9	6,870	1.7	3	32
D: 72-105	35.2	10,560	1.1	3	45
E: 105-150	39.8	11,940	1.0	3	51

Table 7 Estimates on average output, number of mines and yearly workload for different parts of the Rijckholt mines.

3.1. Control over resource

No conclusive traces of control are documented for Rijckholt, unless one agrees with the suggestion that deep-shaft mining itself was developed in order to establish control over the resource (RAMOS-MILLÁN 1991).

3.2. Standardisation of methods and efficiency of extraction and tool production

On the basis of their expertise as mining engineers, the excavators describe the prehistoric miners as very skilled and efficient, obtaining an optimal result without taking unnecessary risks. Moreover, the systematic procedures followed in the lay-out of both individual mines and the (excavated part of) the complex as a whole, as well as the optimal way the miners adapted these procedures to changing geological circumstances, clearly point to a high level of professional competence, maintained for many generations (see chapter VI.3.).

Dense concentrations of knapping debris are found on the surface above the mining complex (de GROOTH 1991; WATERBOLK 1994). They show that robust blades (with an average width of 20-30 mm), massive flake scrapers, and rough-outs for axes with an oval cross-section were the main types produced on the site. Hoards of, partly conjoinable, blades found both at the mines (OPHOVEN & HAMAL NANDRIN 1955; WOUTERS 1989) and at settlement sites all over the distribution area (e.g. Linden, Kraaienberg 1: LOUWE KOOIJMANS & VERHART 1990; Garzweiler: ARORA *et al.* 1988; Rüsselsheim: ZIMMERMANN 1995; Neuwied-Gladbach: FIEDLER 1979; Dorsheim, Kr. Kreuznach: SCHARDT 1980) show that these blanks were the intended preform, to be shaped into tools by their consumers. The axes too were distributed in an unpolished, i.e. unfinished state.

Thus the manufacture of tools was organised in an efficient way too, as work with a high failure rate (production of long blades and axe rough-outs) was done directly at the mines. Compared to the Bandkeramik practice of transporting unworked nodules to settlement sites (de GROOTH 1987; 1994), this method led to a substantial decrease in the mass of potentially worthless material that had to be transported.

The majority of Rijckholt flint axes are smallish in size (with a length not exceeding 15-20 cm). According to J. Pélégrin (oral communication 19th October 1991 at the *Table-Ronde Internationale: les mines de silex au Néolithique en Europe occidentale* at Vesoul) axes with oval cross sections of this size could have been made by normal, 'competent' knappers. Only the exceptionally large, so-called 'ceremonial' axes (over 25 cm in length) would have been manufactured by skilled, experienced workers.

3.3. Special activity areas

Waste by-products of blade and axe manufacture are found in dense concentrations all over the mining area. According to van der SLEEN (1925) a marked differentiation of activities (reflecting a clear division of labour) was visible in the spatial distribution of manufacturing waste within the Grand Atelier, indicating that axe rough-outs, blades, and miners' picks were made at different localities. Neither a preliminary study of pre-war finds with a well-documented provenance from the collection of the Bonnefantenmuseum (de GROOTH 1991), nor WATERBOLK's (1994) analysis of the knapping debris collected during the 1964/5 BAI excavations at the eastern part of the mining complex supports this hypothesis.

The observations that mining picks were repeatedly made out of failed axe rough-outs or exhausted blade cores and that exhausted blade cores were turned into axe rough-outs (FRANZEN & FRANZEN 1987; WATERBOLK 1994) seem more in accordance with the opportunistic behaviour often displayed by craft specialists, than with full-blown professionalism (TORRENCE 1986).

3.4. Intensity of production

On the basis of the chronological data presented earlier in this study, we can attempt to appraise the volume and intensity of work. The degree of standardisation and specialisation might be assessed through a combination of the estimates of the gross volume of flint extracted (see chapter I.5.10.) with a detailed analysis of debitage waste, exhausted cores, blades, and discarded rough-outs from different parts of the site, thereby determining the actual flint working techniques employed and their efficiency in terms of tool/waste ratios as well as the relative importance of axe *vs* blade production through time. Then one might hope to be able to estimate the workload represented by the waste by-products. With the present data set such a comparison is, unfortunately, impossible, despite the huge masses of workshop debris stored in numerous museums and university collections. During most of the pre-war investigations knapping debris was not collected systematically (e.g. Hamal-Nandrin, cf. WOUTERS 1989), sometimes the material became dispersed in many different collections (van Giffen's 1923 excavations, stored at the RMO [Leiden], the Bonnenfantenmuseum, Maastricht and the Groningen BAI, or its present whereabouts are unknown altogether [most of the material excavated by the French Dominicans, WOUTERS 1989]. Even during the BAI 1964/65 excavations waste flakes were discarded unstudied/undocumented (WATERBOLK 1994).

Therefore, at the moment only very rough estimates may be used to assess the relationship between gross volume and semi-finished products. For axe-preforms the % of waste may be estimated at 70-85% (based on data published by Weiner on an axe-preform with its conjoinable debitage waste from the Lousberg, and on the waste/tool ratio of an experimental axe-preform made by same researcher - now in the collection of the Bonnefantenmuseum). Similar figures seem plausible for the blades as well.

3.5. Settlements

Some animal bones, charcoal fragments and a single shard found in the back-fill of shafts on the plateau during 1923 and 1964 BAI excavations (CLASON 1971; 1981; van GIFFEN 1925) are the only traces of habitation connected to the mines. A preliminary assessment of the different flint scatters found all over the St. Geertruid plateau yielded no indication for the presence of special-purpose mining settlements (cf. de GROOTH 1991). They do comprise 'domestic' flint artefacts, like worn-out or broken polished axes (several of them made from non-local raw materials!), scrapers, borers, arrowheads, and retouched flakes and blades, as well as fragments of stone querns (FRANZEN *et al.* 1991; HAMAL-NANDRIN & SERVAIS 1923; ROEBROEKS 1980; WATERBOLK 1994; and Archives Bonnefantenmuseum). The broad range of activities they represent would argue for them to stem from agrarian settlements. In fact, the fertile loess soil of the plateau would have justified occupation by farming communities in its own right (BAKELS 1978). There is, however, given the lack of extensive excavations or at least a systematic analysis of the relevant surface collections, no way to decide whether the plateau sites should be seen as the result of permanent or periodic occupation. In a qualitative sense these traces are indistinguishable from similar scatters found at several sites on the lower and middle terraces both to the south and to the north of Rijckholt (BROUNEN *et al.* 1990; internal reports by Mr Bert Knippels to the GOBM; and archives Rijksdienst voor het Oudheidkundig Bodemonderzoek and Bonnefantenmuseum).

3.6. Evaluation[6]

In the following discussion it will be assumed that mining at Rijckholt was a male activity, as was the case in all ethnographic examples known to us, where women could at most participate in the tranportation of mined material to the settlements (de GROOTH 1994c). According to generally accepted criteria for the recognition of specialist acquisition of raw material and manufacture of stone tools at mining and quarry sites (ARNOLD 1985; ERICSON 1984; MILLER 1987; TORRENCE 1984; 1986), mining and manufacture at Rijckholt undoubtedly were specialist activities. There is no need, however, to see the excavation of deep shafts *per se* as a task so technically complicated and time-consuming that the miners would have needed daily practice to maintain their skills, and thus necessarily would have been full-time professionals. Basically, the term 'specialist' refers to those people who perform complicated tasks more successfully than others and, because of their special skills, tend to perform them more often as well (ARNOLD 1985) or to co-ordinate the work of less-experienced team-mates (BURTON 1984), without implying anything about the amount of time involved. The criteria apply to both part-time craft specialists working in acephalous societies and full-time commercial professionals (MILLER 1987), and they should cover cases of horizontal or between-group specialisation (LECH 1980) as well.

Given the estimated maximum of *c.* 2,000 shafts (chapter I.5.8.), and 1,300 years of shaft-and-gallery mining (chapter VIII.3.), on the average only one and a half shafts a year would have been exploited. On the basis of FELDER's (1980) calculations it has been shown that 35 days were needed to exploit the average mine, so the average yearly workload for mining would have amounted to 52 days.

With an estimated 15,000,000 kg of flint extracted through deep-shaft mining (chapter I.5.10.), an average gross output of *c.* 11,539 kg would be produced every year. The number of mine-shafts to be sunk in order to achieve this output depends on their size, and thus varies considerably in different parts of the complex. The same holds true for the workload and workforce needed (Table 7).

Thus, in the beginning the sinking of 3-4 shafts would be needed to acquire the necessary amount of raw material, whilst later on a single big mine would suffice.

These figures, of course, reveal nothing about the size of the labour force or the actual time spent on mining. For the smaller mines we can either imagine a two- or three-person team working for 60-70 days, whereas others would be employed in the production of blades, axe rough-outs, and, last but not least, hafted flint picks. Enlarging the number of people involved would automatically lead to a corresponding decrease in the amount of time needed: if four teams worked simultaneously, the job could be done within 19-25 days, on a part-time basis (either by members of a single large community or by four different groups). The largest mine exploited (shaft 44) nearly at the end of the sequence, would employ 4 people, working for 70 days. From an organisational point of view - and taking into account the observed safety procedures such as the presence of connecting galleries between shafts etc. (see chapter VI.3.4.) - one might even argue that, especially in the deeper/later parts of the complex, extraction was not undertaken every year, but was a special activity, performed intermittently, whenever the needs (be they economic, ritual or social, see infra) arose.

Such interruptions would not interfere with maintaining the observed high level of professional skills. On the one hand, in non-industrialised societies technological traditions are passed on from generation to generation, even when the tasks are complicated and actually are rarely performed. On the other hand, the lay-out of former mines would remain recognisable for a long time, through changes in vegetation, the traces of back-filled shafts and workshop sites, rubbish tips, accumulations of debris etc.

From the way the shafts were connected by means of 'safety' galleries an interesting pattern emerges, at least when we assume that mining started at the shallow shafts in the western part of the excavated transect and moved towards the east, where deeper shafts were necessary, over time. First, the excavated part of the mining complex comprises several distinct groups of interconnected mines. On the west-east axis, i.e.

[6] This interpretation partly differs from earlier accounts, which were based on a shorter exploitation period, a higher estimate of the total size of the mining complex, and lower estimates of the amount of waste material created during tool production (e.g. FELDER 1980; FELDER & OFFENBERG 1990).

moving upwards towards the plateau, the interruptions are clearly connected to the presence of geological faults. Such technical restraints cannot account for the segregations visible on the north-south axis (i.e. following the contour lines), and therefore suggest the existence of several independent, coeval organisational units. Secondly, it seems plausible that within these units subsequent (neighbouring) shafts were initially placed on roughly the same contour line (at roughly the same altitude), before the exploitation moved higher up the slope.

We are as yet unable to interpret these units in terms of the social formations (family, moiety, clan, tribe, etc.) involved and the timespan needed in working them. The integration of the evidence from the mines with the (scanty) data on the general character of settlement structure and subsistence strategies of MK/Hazendonk and Stein/Vlaardingen people may, however, provide part of the answer.

The available evidence shows that during both the MK/Hazendonk and the Stein/ Vlaardingen periods different subsistence strategies co-existed. In the Dutch coastal and river regions many sites are thought to represent periodic visits of people familiar with agriculture, but depending partly on the exploitation of wild resources as well (LOUWE KOOIJMANS 1985; LOUWE KOOIJMANS & VERHART 1990; van GIJN 1990). The Michelsberg culture on the sandy soils in the Meuse valley is regarded by Wansleeben and Verhart as a more or less mobile society. Any permanent habitation is thought to have been in the shape not of real villages, but of small isolated and dispersed settlements (WANSLEEBEN & VERHART 1990, 399). The same should hold true for the Stein/ Vlaardingen sites in this area. The settlement and environmental data for MK and Stein/Vlaardingen habitation in the loess zones of Belgium, Dutch Limburg and the Rhineland conform to this picture, notwithstanding the large (up to 100 hectares: WHITTLE 1977, 228) causewayed enclosures known from this area. One of them lies close to the Spiennes mines, another one was possibly situated eight kilometres to the northwest of Rijckholt, on the other bank of the River Meuse (DISCH 1969; 1971-72). There is, however, little evidence for substantial houses, and very few traces of local crop cultivation or large-scale grazing are visible in pollen diagrams (BAKELS in press). The Stein group seems to have had a much stronger impact on its environment, as documented by recent pollen evidence from the Maastricht-Randwijck site showing heavy deforestation (BAKELS *et al.* 1993), but actual traces of habitation are as insubstantial as are the Michelsberg ones, and an assessment of the relative importance of cereal cultivation versus cattle breeding is impossible at the moment. Whatever their purpose, the enclosures seem to reflect a rather strong sense of territoriality (FLEMING 1982), a notion supported by the presence of distinct regional pottery styles and subsistence strategies within both the MK and the Vlaardingen/Stein groups. On the basis of the available evidence the societies involved may be described as tribal, with only a low level of social ranking, living in dispersed groups that meet for special activities on a regular basis. In such a situation it would be extremely unlikely that groups not belonging to the regional socio-economic polity would have had unrestricted access to high-quality resources. Mining rights rather would belong to the members of several small communities living nearby. These miners did not live permanently at the mines, but settled there periodically in temporary extraction camps. The groups may be conceptualised as having lived within a radius of thirty kilometres, i.e. within a six-hour walking distance of Rijckholt; in other words, as groups in whose common home range (BAKELS 1978, 5) the source of raw material was situated. The environment in the loess zones was rather less diversified than that in the river valley and coastal areas further to the north and northwest. Thus one can easily envisage a number of perishable goods that may have moved to Rijckholt: salt, caviar, smoked herrings and eels, sealskins and other furs. One may even ask, whether it would not have been primarily the miners that were eager to maintain the exchange networks (instead of the other way round) as a means to obtain highly valued and desirable goods.

In that case it would seem that deep-shaft flint mining at Rijckholt was an intermittent activity, not undertaken for purely economic or practical reasons, and that artefacts of mined flint were exchanged not only for economic, but for ceremonial/social purposes in a pluriform, multi-directional network. One should bear in mind, too, that the exploitation period of other flint mines in the region - such as Valkenburg, Lousberg, Rullen, Jandrain-Jandrenouilles - at least partly overlapped with that of Rijckholt (according to the radiocarbon dates in chapter VIII.1.), whilst the 'consumers' outside the region obtained artefacts from these other sources as well. On the other hand, settlement debris from the Rijckholt/St. Geertruid plateau contains quite a number of *Spitzklingen*, arrowheads and axe-heads from non-local raw material, stemming from e.g. northern France.

Perhaps enclosures, systematic mining and structured long-distance exchange all may be regarded as efforts to redefine/re-emphasise middle Neolithic group identity both internally and externally.

Internally, in the construction of mines and enclosures alike, the cooperation of large numbers of people whose day-to-day relationships as close neighbours may well have been rather stressed, could have served primarily to lessen tensions and to re-establish and strengthen traditional kinship ties and reciprocal obligations.

Externally, characteristic flint types may well have served as a means to mark the producers' group identity in their increasingly important communications with the outside world (de GROOTH 1997). Flint mining, then, would have fulfilled a similar function in middle Neolithic communities as did the rituals performed at the ceremonial enclosures. Thus, it would serve as a means of maintaining communication, regulating social relations between social groups which had to reconcile a partly mobile subsistence strategy with the need for establishing a permanent presence in distinct territories (MIDGLEY 1992).

The benefits of the spatial and temporal concentration and intensification of mining activities may then be regarded not only in terms of minimising expenditure of time and energy, but also of stimulating inter-group activities, controlled sharing of scarce resources and intensification of both regional and long-distance communication.

Finally, we must bear in mind that the act of digging deep holes into the earth itself must have had strong symbolic and ritual connotations. At the moment, these can mainly be guessed at. The skull deposited so carefully at the end of a gallery belonging to shaft 8 (VII.5.1.), as well as the other cranium finds connected to the mining fields, offer a tantalizing glimpse.

IX. Concluding remarks and future investigations

At the start, the excavators of the Rijckholt-St. Geertruid flint mines had to face the problem of not having an established method of excavating prehistoric mines. Practical experience enabled us to develop a sound method as we went on. The disadvantage of such a procedure is that in the course of time the style of reporting changed. Such changes make the reports difficult to read.

During the excavation observations were made which at that time were probably not duly noted, e.g. the occurrence of chalk hammerstones. Amongst the chalk blocks these hammerstones went unrecognised. Subsequent to the discovery of one of these hammers, other examples were recognised during the excavation. Thus, during the first part of the excavation the apparent lack of hammerstones does not mean that none were found, but rather shows that they had not been recognised as such.

One of the goals of the excavation was to construct a tunnel connecting the two previous excavations and examine as many galleries as possible from that tunnel. As the excavation was carried out in the spare time of the participants, limited time was available. Keeping this in mind, we never attempted to examine a gallery in minute detail because of the time needed to do so. This work was deferred to a later occasion. Firstly, as many data as possible had to be acquired and the mine field made accessible. The more detailed investigations, however, have not been carried out to this day.

Throughout the excavation we attempted to record all phenomena in detail. Naturally, this resulted in a lot of documentation. In addition to the original journals and registration forms, a total of 39 reports were written, assembling all data. These are all deposited at the Provincial Depot for Archaeological Finds (Maastricht).

The total data set of the excavation is so extensive that it is impossible to include it in the present publication. During the excavation extentive records were made of the percentage of fill of the galleries. Combined with the sections of the galleries these data may possibly be used for a detailed reconstruction of methods employed in these mines. During a future, more detailed excavation campaign one should make sure to record more cross sections. It may thus prove possible to recognise crawling floors, such as the ones we subsequently noted at Grimes Graves.

Much time was devoted to discussing and categorising the stone picks found. At the start views differed as to whether or not these picks had handles. The discovery of voids corresponding to decayed wooden handles ended this discussion. Soon the picks were assigned to three types (of triangular, quadrangular and oval cross section). Later these forms were further subdivided, although the original threefold subdivision was adhered to. In a number of reports this aspect of the excavation was written up. At this time, we think that an impartial outsider should have another look at the picks.

Flakes did not receive much attention, especially the smaller ones which resulted from the resharpening of picks. These were not collected, or noted. In future excavations, these should be considered in more detail.

X. Basic statistics

1. Surface area

According to data supplied by the Dutch Geological Survey:
Prehistoric area within which flint was either picked up, excavated or worked: 25 hectares.
Prehistoric mining area, inclusive of exploitation by means of open-cast workings, bell-shaped pits and shafts: 12 hectares.
Prehistoric mining area with shafts and underground galleries: 8 hectares.

Each mine consists of a shaft (pit), the floor of which, on the flint layer, was extended through several galleries.

3. The excavation

Start of the excavation on June 6, 1964, completion on May 31, 1972.

Excavations were carried out by volunteers with an increasing number of participants (a

	people	time	man days	people/ day
1964	12	26	170	6.5
1965	13	53	313	5.9
1966	14	48	397	8.3
1967	19	47	489	10.4
1968	21	57	612	10.7
1969	23	51	561	11.0
1970	23	46	537	11.7
1971	23	50	506	10.1
1972	14	19	172	9.1
		378	3766	10.0

Table 8 Working capacity during the years of excavation.

minimum of 12 people and a maximum of 23). In total, from 1964 to 1972, 378 days were spent working by 10 members on average. The work done by one or two people at any time other than the normal working day (Friday night) has not been considered a working day, but been included in the normal day instead.

2. Classification of exploitation

It was agreed to adhere to the following classification:

1 - picked up at the surface = 0.00 - 0.50 m depth
2 - exploited in open-cast workings = 0.50 - 2.00 m depth
3 - exploited in bell-shaped pits = 2.00 - 4.00 m depth
4 - dug from mines = 4.00 - 12.00 m depth

Bell-shaped pits are pits the floors of which, on the flint layer, were extended by means of niches. Shaft 1 may be an example of such a pit (with 5.6 square metres worked), whereas from a mine of the same depth 7.5 square metres or more was extracted.

4. Excavated area

Numbers referring to areal extent shown here are based on measurements obtained by P.J. Felder by using a planimeter (Report 13). The gross size of the excavated area amounts to 2,436.6 square metres, inclusive of pillars and solution pipes in the area. The net size of the excavated area is 1,525.8 square metres, being the areal extent of shafts and galleries, excluding pillars and solution pipes.

During measuring the shafts were consecutively numbered 1 to 80. Numbers 20, 31, 35, 36 and 65 were not used. Of 75 shafts, 56 mines were excavated completely, and portions of the remaining 19. Of those excavated completely 4 (shafts 1, 37, 67 and 68) have been excluded from measurements, and numbers 30 and 33 were considered to represent a single mine. In four places galleries were excavated, the shafts of which remained unknown.

5. Individual mines

Smallest mines:
shaft 12 = net 6.9 m^2 and gross 11.4 m^2
shaft 3 = net 7.5 m^2 and gross 14.2 m^2

Largest mines:
shaft 29 = net 56.8 m^2 and gross 100.8 m^2
shaft 44 = net 58.4 m^2 and gross 88.0 m^2

6. Increase in shaft depth and exploited area

For depths of mines reference is made to Report 30.

7. Percentages

Geological supply:
gross area - solution pipes (2,436.6 m^2 - 272.5 m^2) = 2,164.1 m^2.
Exploited area:
1,525.8 m^2 = 70.51 % of geological supply.

8. Average size of mines

Based on the fact that the average gross area of the mines is 40.57 m^2 and that the excavated area amounts to 8 hectares, it may be assumed that there were a total of 1,972 shafts (round off to 2,000).

Average size of the 51 mines that were completely excavated:
25.1 m^2 = 70.3 %, 40.6 m^2 = 62.2 %

9. Flint layer

The amount of flint from the flint layer exploited (layer 10 of the Lanaye Chalk Member) could not be measured in the mines; instead measurements were taken in adjoining chalk quarries.

position	shaft depth	net area (m^2)	gross area (m^2)
0-30	5.0-8.0	6.9-16.0	11.4-36.0
30-40	8.0-8.4	17.4-20.7	30.3-35.2
40-72	8.4-9.1	16.0-29.1	25.0-46.1
72-104	9.1-11.0	21.8-56.8	31.8-100.8
104-150	11.0-12.0	27.4-58.4	41.0-86.0

Table 9 Position, depth and size of excavated shafts.

gross area	2,436.6 m^2	100.0 %
solution pipes	272.5 m^2	11.2 %
external pillars	576.5 m^2	23.7 %
internal pillars	61.8 m^2	2.5 %
exploited area	1,525.8 m^2	62.6 %

Table 10 Extension of excavated areas.

position	gross area (m^2)	net (exploited) area (m^2)	net area as % of gross area	net area as % of geological supply
0 - 30	19.5	11.3	57.9	66.4
30 - 40	32.8	19.1	58.2	78.9
40 - 72	35.7	22.9	64.3	73.9
72 -105	57.0	35.2	61.8	70.8
105-150	64.1	39.8	62.2	67.1

Table 11 Size of excavated mines.

W.M. Felder's measurement: average flint thickness is 20 cm. Average flint area is 50 %. Thickness per square metre equals 10.0 cm and weight per square metre is 275 kilos.
P.J. Felder's measurement: average flint thickness is 16.6 cm. Average flint area is 71.2 %. Thickness per square metre equals 11.8 cm and weight per square metre is 325 kilos.

10. Amount of flint

Based on a minimum amount of 275 kg and a maximum of 325 kg per square metre, and an average 70.5 % of the geological supply exploited, the following can be deduced (of the areal extent 11 % must be subtracted, this being the area occupied by solution pipes in which no exploitable flint occurs):

Area 25 hectares = 250,000 m^2 - 11 % = 222,500 m^2
flint weight:

gross minimum	61,187,500 kg
gross maximum	72,312,500 kg
extracted minimum	43,143,306 kg
extracted maximum	50,987,543 kg

Area 12 hectares = 120,000 m^2 - 11 % = 106,800 m^2
flint weight:

gross minimum	29,370,000 kg
gross maximum	34,710,000 kg
extracted minimum	20,708,787 kg
extracted maximum	24,474,021 kg

Area 8 hectares = 80,000 m^2 - 11 % = 71,200 m^2
flint weight:

gross minimum	19,580,000 kg
gross maximum	23,140,000 kg
extracted minimum	13,805,858 kg
extracted maximum	16,316,014 kg

11. Flint knapping

Extracted flint nodules were primarily worked for blanks, semi-finished axes, stone picks and blades. This process resulted in 70-85 % of waste.

12. Number of artefacts found

Registration numbers 1 to 15,371 refer to artefacts. A total of 14,549 objects were collected and subsequently numbered, which means that 822 registration numbers were not used.
The numbered objects comprise:

	N	%
picks or fragments of picks	14,217	97.7
hammerstones	216	1.5
cores	58	0.4
other artefacts	37	0.3
miscellaneous	21	0.1

Table 12 Numbers of excavated artefacts.

13. Pick, stone pick, and fragmentary pick

It was agreed to use the term pick to refer to the tool proper, viz. the handle and the pick itself. The term stone pick refers to the worked flint, which together with the handle forms a pick. A fragmentary stone pick may consist of a pointed end, a top end or a middle portion.

In order to determine the number of stone picks found, three samples were counted:

Sample 1, numbers 1-250:
247 objects (161 stone picks, 77 fragmentary picks and 7 miscellaneous).
Sample 2, numbers 14,101-14,601:
406 objects (250 stone picks, 137 fragmentary picks and 19 miscellaneous).
Sample 3, numbers 15,000-15,371:
406[7] objects (227 stone picks, 23 dubious stone picks, 146 fragmentary picks and 10 miscellaneous).

This listing shows that out of the 1,059 finds in these samples there were 360 fragmentary picks, i.e. 34 % of the total. Assuming this percentage to be valid for the total number of artefacts found, 4,946 fragmentary picks have been encountered during the excavation (34% of 14,549). The total number of 14,217 of stone picks and fragmentary picks would thus comprise 9,271 stone picks and 4,946 fragmentary picks.

To arrive at the total number of stone picks the number of fragmentary picks need to subdivided by 2 (4,946:2 = 2,473) and these should be added to the number of stone picks: 9,271 + 2,473 = 11,744.

The number of stone picks calculated in this way (11,744) may be subdivided by the exploited area of 1,525.8 m^2, so as to obtain the average number of stone picks per square metre, viz. 11,744:1,525.8= 7.7.

14. Average size of stone picks

Sample	N	length (mm)	width (mm)	thickness (mm)	weight (gr)
1 (Nrs. 1-250)	161	154.86	53.03	35.58	292.74
2 (Nrs. 14,101-14,601)	250	148.78	55.83	36.88	301.14
3 (Nrs. 15,000-15,371)	227	141.67	48.98	34.88	281.11
4 (Stone picks without traces of wear; measured by W.M. Felder)	96	169.38	54.30	35.38	296.67
5 (Stone picks without traces of wear; measured by P.J. Felder)	25	161.04	50.04	37.08	308.08

Table 13 Average size of stone picks.

[7] This series of finds was only numbered after fragments had been assembled. Of the 146 fragmentary picks, 48 pieces could be reassembled to 24 broken stone picks.

15. Minimum and maximum size of stone pics

Sample	length (mm)	width (mm)	thickness (mm)	weight (gr)
1 (Nrs. 1-250)	min. 115 max. 221	min. 35 max. 74	min. 18 max. 50	min. 140 max. 498
2 (Nrs. 14,101-14,601)	min. 116 max. 195	min. 37 max. 70	min. 20 max. 58	min. 125 max. 455
3 (Nrs. 15,000-15,371)	min. 109 max. 182	min. 35 max. 69	min. 17 max. 49	min. 170 max. 480

Table 14 Minimum and maximum size of stone picks.

16. Hammerstones

Silicified chalk:	147
Ditto with flint fragments:	11
Flint:	2
Quartzite:	42
Quartz:	11
Conglomerate:	3
Total:	216

17. Miscellaneous

Cores: 58
Voids: 42
Antlers: 6

Other bone objects:
Scapula (14 cm) and a single pick or a joint of bone.
Bones of 6 birds
Bones of amphibians (not counted, 12 sites).
Bones of small mammals (12 species), e.g. bat, mole, shrew, squirrel and diverse species of mice (not counted).
Snail shells, 15,771 specimens representing 24 species.
One human skull lacking mandible.

18. Start and finish

Start of excavation: June 6, 1964.

Completion of excavation: May 31, 1972.

Earliest dated find at Rijckholt-St. Geertruid: Middle Palaeolithic (ROEBROEKS 1980).

Latest dated find of flint implements from Rijckholt-St. Geertruid:
Iron Age (de GROOTH 1991).

Start of prehistoric flint mining activities at Rijckholt-St. Geertruid:
5,200 BP (= 4,000 BC).

End of prehistoric flint mining at Rijckholt-St. Geertruid:
4,100 BP (= 2,650 BC, end of Stein Group) or possibly 4,700 BP (= 3,400 BC, end of Michelsberg Culture).

XI. Abstract - Zusammenfassung

From 1964 to 1972, the Prehistoric Flint Mines Working Group of the Dutch Geological Society, Limburg Section carried out excavations of flint mines at Rijckholt-St. Geertruid. The volunteer members of this group spent 3,767 man-days of free time exploring these mines. The writing of interim reports and of the present publication possibly took as many days off.

The excavation proceeded from a tunnel, almost 150 metres long, which was driven right across the mining area. On either side the prehistoric galleries were examined over a width of 10 metres. A total of 75 shafts and 1,526 square metres of galleries were encountered and examined, the entire area measuring 2,436 square metres. A mining area of such an extent had not been investigated previously. The total area, however, is even more extensive.

Underground mining extends over *c.* 8 hectares; flint was extracted from an area measuring *c.* 12 hectares, while the region with prehistoric knapping debris is larger still and measures almost 25 hectares.

All shafts, galleries and objects found were plotted in great detail. The excavation yielded 14,549 artefacts, amongst which 14,217 stone picks, 216 hammerstones, 43 voids (of wooden objects) as well as a few bones of deer and cattle. In addition, a human skull, numerous bones of smaller mammals, thousands of snail shells and charcoal were collected. Radiocarbon (C14) dating of the charcoal finds yielded an age range of 3,970-3,700 BC, but mining activities probably continued till 3,400 BC or even 2,650 BC.

Methods employed during the excavation are described, and an attempt is made to reconstruct methods applied in prehistoric times.

Calculations of the total amount of flint extracted (14-16 million kilogrammes from an area of 8 hectares) and the number of shafts in the area (*c.* 2,000) suggest that more than 400,000 artefacts may still be present in the subsoil at Rijckholt-St. Geertruid.

Key words: Archaeology, Neolithic, Michelsberg Culture, Vlaardingen-Stein-Wartberg Group, flint, mining, Rijckholt-St. Geertruid, Limburg, the Netherlands.

Von 1964 bis 1972 hat die "Arbeitsgruppe Prähistorischer Feuersteinbergbau" der Niederländischen Geologischen Gesellschaft, Sektion Limburg, im Feuersteinbergwerk von Rijckholt-St. Geertruid Ausgrabungen durchgeführt. Die Mitglieder der Gruppe haben zusammengenommen 3.767 Tage ihrer Freizeit mit der Untersuchung des Feuersteinbergwerks zugebracht. Die Abfassung von Zwischenberichten und die vorliegende Publikation haben etwa noch einmal soviel Zeit gekostet.

Die Ausgrabungen gingen von einem nahezu 150 m langen Tunnel aus, der quer durch das neolithische Abbaugebiet getrieben wurde. Auf beiden Seiten des Tunnels wurden die prähistorischen Stollen auf einer Länge von 10 m untersucht. Bisher ist kein weiteres Feuersteinbergwerk in diesem Umfang erforscht worden. Auf einer Gesamtfläche von 2.436 m^2 wurden 75 Schächte und 1.526 m^2 Stollen untersucht. Das eigentliche Abbaugebiet ist allerdings noch sehr viel größer.

Der Untertagebau erstreckt sich über ca. 8 Hektar. Insgesamt wurde Feuerstein in einem etwa 12 Hektar großen Bereich abgebaut, Schlagabfälle finden sich aber in einem ca. 25 Hektar großen Areal.

Alle entdeckten Schächte und Stollen wurden detailliert dokumentiert. Die Ausgrabungen erbrachten 14.549 Artefakte, davon 14.217 Steinpickel, 216 Hammersteine und 43 Hohlräume von hölzernen Objekten, sowie einige Knochen von Reh und Rind. Außerdem kamen ein menschlicher Schädel, zahlreiche Knochen von kleineren Säugetieren, tausende Schneckengehäuse und Holzkohle zutage. ^{14}C-Messungen an Holzkohlen ergaben Datierungen zwischen 3.970 und 3.700 BC, allerdings werden die Abbauaktivitäten bis etwa 3.400 BC oder sogar 2.650 BC angedauert haben.

Die angewendeten Ausgrabungsmethoden werden beschrieben und es wird der Versuch unternommen, die prähistorischen Abbaumethoden zu rekonstruieren.

Die Kalkulation der absoluten Menge des abgebauten Feuersteins (14-16 Mio. Kilogramm von einem 8 Hektar großen Abbaugebiet) und

die Anzahl der Schächte (ca. 2.000) läßt vermuten, daß sich im Untergrund noch mehr als 400.000 Steinartefakte befinden.

Schlüsselwörter: Archäologie, Neolithikum, Michelsberger Kultur, Vlaardingen-Stein-Wartberg Gruppe, Feuerstein, Feuersteinbergbau, Rijckholt-St.Gertruid, Limburg, Niederlande

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Excavations of Prehistoric Flint Mines at Rijckholt-St. Geertruid (Limburg, The Netherlands)

by the 'Prehistoric Flint Mines Working Group' of the Dutch Geological Society, Limburg Section

edited by P.J. (Sjeuf) Felder, P. Cor M. Rademakers & Marjorie E.Th. de Grooth

From 1964 to 1972, the 'Prehistoric Flint Mines Working Group' of the Dutch Geological Society, Limburg Section carried out excavations of flint mines at Rijckholt-St. Geertruid. The excavation proceeded from a tunnel, almost 150 metres long, which was driven right across the mining area. On either side the prehistoric galleries were examined over a width of 10 metres. A total of 75 shafts and 1,526 square metres of galleries were encountered and examined, the entire area measuring 2,436 square metres. A mining area of such an extent had not been investigated previously. The total area, however, is even more extensive. Underground mining extends over *c.* 8 hectares; flint was extracted from an area measuring *c.* 12 hectares, while the region with prehistoric knapping debris is larger still and measures almost 25 hectares. All shafts, galleries and objects found were plotted in great detail. The excavation yielded 14,549 artefacts as well as a few bones of deer and cattle. In addition, a human skull, numerous bones of smaller mammals, thousands of snail shells and charcoal were collected. Radiocarbon (C14) dating of the charcoal finds yielded an age range of 3,970-3,700 BC, but mining activities probably continued till 3,400 BC or even 2,650 BC. Methods employed during the excavation are described, and an attempt is made to reconstruct methods applied in prehistoric times. Calculations of the total amount of flint extracted (14-16 million kilogrammes from an area of 8 hectares) and the number of shafts in the area (*c.* 2,000) suggest that more than 400,000 artefacts may still be present in the subsoil at Rijckholt-St. Geertruid.

Von 1964 bis 1972 hat die "Arbeitsgruppe Prähistorischer Feuersteinbergbau" der Niederländischen Geologischen Gesellschaft, Sektion Limburg, im neolithischen Feuersteinbergwerk von Rijckholt-St. Geertruid Ausgrabungen durchgeführt.
Bisher ist kein weiteres Feuersteinbergwerk in diesem Umfang erforscht worden. Die Ausgrabungen gingen von einem nahezu 150 m langen Tunnel aus, der quer durch das neolithische Abbaugebiet getrieben wurde. Auf beiden Seiten des Tunnels wurden die prähistorischen Stollen auf einer Länge von 10 m verfolgt. 75 Schächte und 1.526 m^2 Stollen wurden auf einer Gesamtfläche von 2.436 m^2 untersucht. Das eigentliche Abbaugebiet ist allerdings noch sehr viel größer. Der Untertagebau erstreckt sich über ca. 8 Hektar. Feuerstein ist in einem etwa 12 Hektar großen Bereich abgebaut worden, Schlagabfälle finden sich aber in einem ca. 25 Hektar großen Areal. Alle entdeckten Schächte und Stollen wurden von den Ausgräbern detailliert dokumentiert. Die Ausgrabungen erbrachten mehr als 14.000 Artefakte. Außerdem kamen Tierknochen und Schneckengehäuse sowie ein menschlicher Schädel zutage. ^{14}C-Messungen an Holzkohlen ergaben Datierungen zwischen 3.970 und 3.700 BC, allerdings werden die Abbauaktivitäten bis etwa 3.400 BC oder sogar 2.650 BC angedauert haben. Im vorliegenden Buch werden die angewendeten Ausgrabungsmethoden beschrieben und es wird der Versuch unternommen, die prähistorischen Abbaumethoden zu rekonstruieren. Die Kalkulation der absoluten Menge des abgebauten Feuersteins (14-16 Mio. Kilogramm von einem 8 Hektar großen Abbaugebiet) und die Anzahl der Schächte (etwa 2.000) läßt vermuten, daß sich im Boden noch mehr als 400.000 Steinartefakte befinden.

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