VII

THE ORIGIN OF LITHIC RAW MATERIALS

by

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The Grubgraben toolmakers made use of a variety of flints and radiolarites which do not exist in the immediate vicinity of the site. Among the materials of local origin were large pieces of sandstone (arkose), gneiss, biotitic gneiss, and quartz which can be found on the edge of the plateau and along the bluff slopes. In addition, cobbles of quartz, quartzite and granulite are relatively abundant among the Kamp River gravels. But there is neither flint, hornstone, chert, nor radiolarite to be found in either primary or secondary deposits within and around the graben. Good knapping materials are scarce in the Wachau as well. The Willendorf assemblages, for example, contain a large proportion of specimens made from imported flints while radiolarite assumed to come from the Danube River gravels and quartzites of local origin completed the inventory (Kozlowski, 1986). The regional survey undertaken in 1987 had for objective a re-evaluation of potential lithic sources within a 50 mile radius of the site. A second and equally important goal was to determine the origin(s) of lithic materials used by Paleolithic toolmakers at Grubgraben. A series of field surveys and laboratory analyses were conducted with these views in mind.

The field survey covered a territory comprised within a 55 mile radius of the site which included a variety of secondary deposits. The cobble beaches of the Danube River were possible sources of good flint-knapping materials within 15 km to 30 km of the site. The Plio-Pleistocene alluvial fans north and south of the Danube River constituted other potential sources of flint and radiolarite cobbles. The nearest occurrence of radiolarites was 70 km to 80 km to the east, in the Wiennerwald where the Mauern radiolarite quarry exploited during the Neolithic is located. The locality was included in the survey.

A variety of lithic sources are known at distances of 80 to 300 km of the site (Fig. VII-1). The nearest among these are outcrops of white flint in the area of Stranska Skala near Brno in Central Moravia which were exploited by late Gravettian groups. Further north are the Saale glacial moraines of the Upper Oder Basin which contain cobbles of northern Baltic flint. The source is known to have been exploited by Gravettian groups: Northern flints were an important component of assemblages not only at Petrjovice which is located near the edge of the glacial moraines, but also at Dolni Vestonice and at Willendorf (Kozlowski, 1988). Radiolarites are abundant to the northeast in the Vah Valley in Slovakia and to the east in Hungary, especially in the areas between Lake Balaton and the bend of the Danube (Biro, 1988).

Samples included in this study were (a) flint and radiolarite specimens collected during the 1987 survey of exposed, chert bearing sediments located in lower Austria as well as (b) archaeological samples from the Epigravettian site of Grubgraben. In addition, previously analyzed samples from more distant outcrops namely Stranska Skala (Czechoslovakia) and Makow in the Upper Oder Basin (Poland) were introduced to complement the study and to test hypotheses concerning the origin and distribution of lithic raw materials during the Epigravettian.

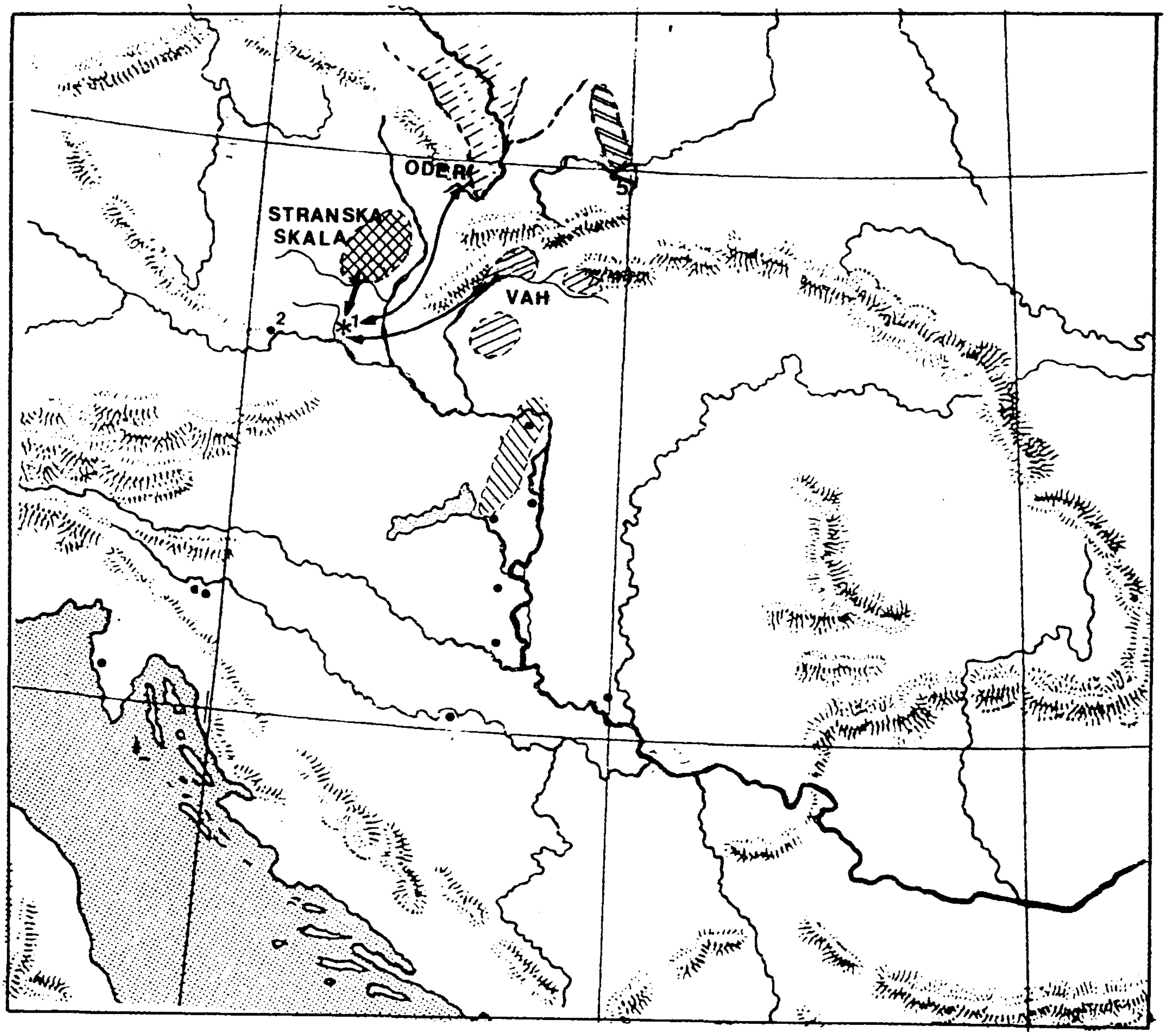


Fig. VII-1 Map of flint and radiolarite outcrops in the northwest region of Central Europe (after Koslowski, 1986).

LITHIC RAW MATERIAL SOURCES IN LOWER AUSTRIA

The 1987 survey covered areas situated within 50 miles of the site including first the Wachau, a section of the Danube Valley west of Grubgraben, second, the alluvial fans in the area of Hollabrun to the northeast, and last, the limestone hills of the Wienerwald to the southeast (Fig. V-2). The list of localities from which samples of flint and/or radiolarite were obtained, together with the abbreviations used in this section is as follows:

Late Pleistocene and Holocene Danube gravels:
1 - Willendorf, Wi,
2 - Grimsing, Gr,
3 - Barcharnsdorf, Ba,

Pleistocene Traisen River gravels:
4 - Traisen, Tr, Pre-Glacial alluvial fan gravels (Plio-Pleistocene):
5 - Hart-Kleinsdorf, Ha,
6 & 7 - Hollabrun, Ho,
8 - Oberthem,Ob,
9 - Gneixendorf, Gn,
10 - Stratzing, St, Miocene-Burdigalien Diatomites ?
11 - Parisdorf, Pa

Cretaceous limestones:
12 - Weidlingbach, We,
13 - Steinriegel,Ste,
14 - Mauer, Ma.

(a) Holocene Danube River gravels:

Since the course of the Danube River has been regulated, gravel beds are no longer accessible. However, it was possible to examine at several points along the Wachau piles of gravels that were being dredged out of the river by machinery.

The petrographic composition of the Danube gravels is relatively varied. Quartz and various types of magmatic and metamorphic rocks form the predominant elements. However, flint and radiolarite pebbles constitute a small percentage, estimated at less than 1% of the remaining rock types, which is to say that they are few and hard to find. Flint and radiolarite pebbles are usually cracked and covered with a weathered outer layer (water worn cortex). The petrographic composition of the Danube gravels along the Melk to Krems road, on the east bank of the river is largely similar to that of gravels found on the west bank between Spitz and Willendorf.

(b) The Traisen gravels :

The Traisen gravels contain predominantly fragments of metamorphic rocks and quartz. Limestone, radiolarite and flint pebbles are also present but they represent only a very small proportion of the gravels. The degree of roundness of the pebbles indicates long distance transport of the rock fragments.

(c) The cone deposits:

1. Alluvial cones in the area of Hart-Kliensdorf contain sandy sediments consisting primarily of quartz fragments and occasional radiolarite pebbles. The thickness of the deposits is not known but is estimated to exceed 30m. Radiolarite pebbles that occur in the Harlt-Kilensdorf sands are very rare and heavily weathered.

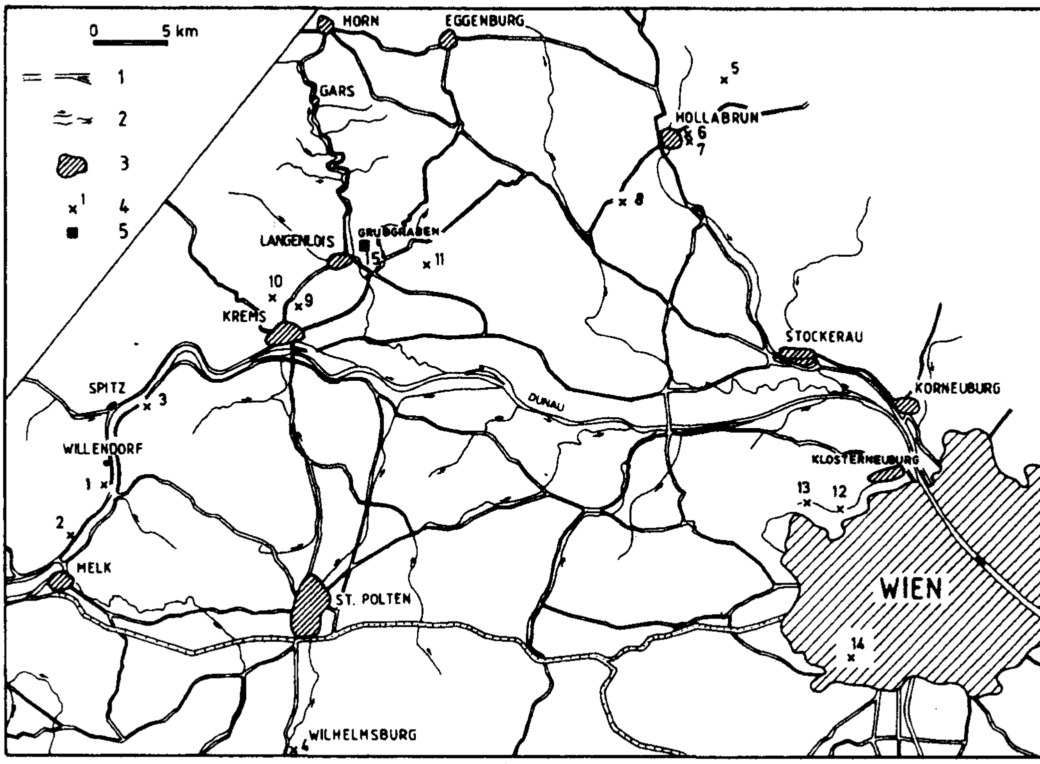


Fig. VII-2 Map of the survey area : 1, roads; 2, rivers; 3, towns and cities; 4, surveyed localities; 5, Grubgraben.

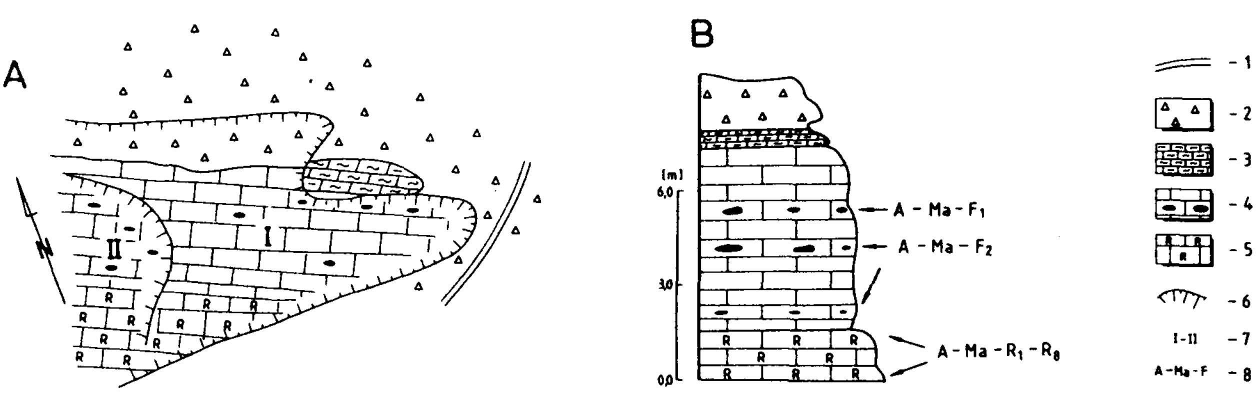


Fig. VII-3 Profile of the Mauern Quarry; A, geological map; B, profile. 1, road; 2 Holocene sediments containing Neolithic artifacts; 3, red clays; 4, limestones; 5, radiolarites; 6, slopes; 7, quarry levels; 8, samples locations.

2. Two sandpits identified in the area east and southeast of Hollabrun contain lenses of fine-grained gravels. At these localities, pebble diameter ranges between 2 and 3cm. Among the pebbles are occasional pieces of green radiolarite and greyish flint. The exposures within the sandpits were over 200 m long. Yet when the site was examined only one flint and four radiolarite pebbles were recovered. Both types were found to be very poor flaking material.

3. A large gravel pit with a 50m long exposure is located in a wooded area, about 5 km southeast of Hollabrun, near the village of Oberthen. The Oberthen gravels are characterized by variable grain size and uniform petrographic composition. The main component is quartz. Pieces of magmatic rock, and gneiss occur sporadically. The gravels have a typical fluvio-glacial structure. They are covered by a mantle of loess of varying thickness.

4. About 500 m east of the village of Gneixendorf is a large abandoned gravel pit. Gravels at the Gneixendorf pit include some large pebbles, measuring as much as 20cm in diameter, among which are rare pieces of red radiolarite. Some of the radiolarite pebbles show numerous veins of second generation calcite or quartz. The pebble surface is rough or glossy.

5. Another quarry is located outside of Stratzing, a short distance from Grubgraben. Here, gravels include fine and medium sized particles. The dominant material is quartz. A single flint pebble and a small quantity of red radiolarite pieces were recovered at the site.

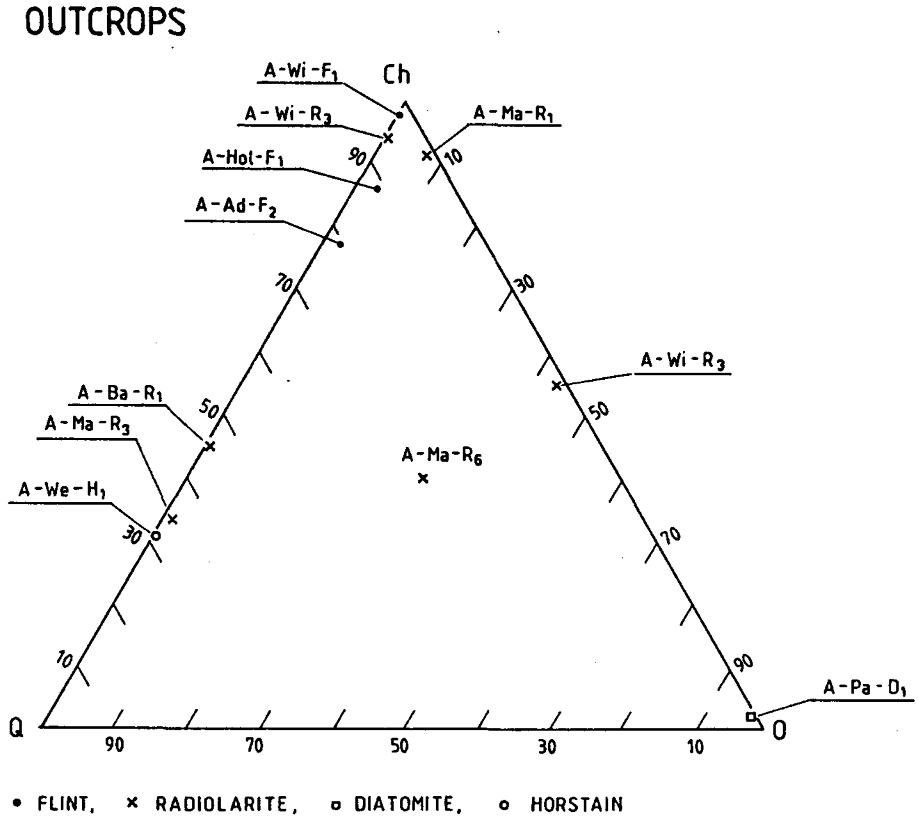
In summary, the 1987 field party was able to examine and sample several outcrops of alluvial fan gravels. Differences between the various exposures appear to be minor. Flints are scarce or absent, radiolarites are rare, small to medium in size and, in the Danube gravels especially, cracked and weathered. Still, the quantity of radiolarite pebbles decreases notably from south to north. The exposures located farther north of the Danube contain smaller number of radiolarite pieces than the one located to the south. This observation confirms the view that radiolarite and flints occurring in the Danube alluvia as well as those occurring in the Plio-Pleistocene alluvial deposits were transported from the south (Alpine piedmont) rather than from the north (Carpathians). Further research to identify the origins of these materials should focus on areas located south of the river.

(d) Burdigalian (Miocene) diatomites

Outcrops of diatomites were found to occur in the township of Parisdorf. In a small quarry we were able to identify several petrographical types including a dark olive variety characterized by a compact structure and fairly good cleavage. Although this particular variety of raw material was not recovered at Grubgraben it could have been used for toolmaking.

(e) Cretaceous limestone

Deposits of mixed (sandstone-shale-limestone) petrographic composition were recorded at two places along the bed of the Weidling River which originates from the limestone hills of the Wienerwald and flows in a southwest to northeast direction 2km east of the Vienna city limits. The first locality was near Weidlingbach and the other near Steinrigel. In addition to materials typical of flysch, the Weilding river gravels contained only two fragments of red cretaceous radiolarite. Pieces of hornstone were noted among the sandstone and mudstone pebbles. The hornstone were greyish in color and had differing technological properties. Cracked specimens, intersected by numerous epigenic calcite veins, were predominant.



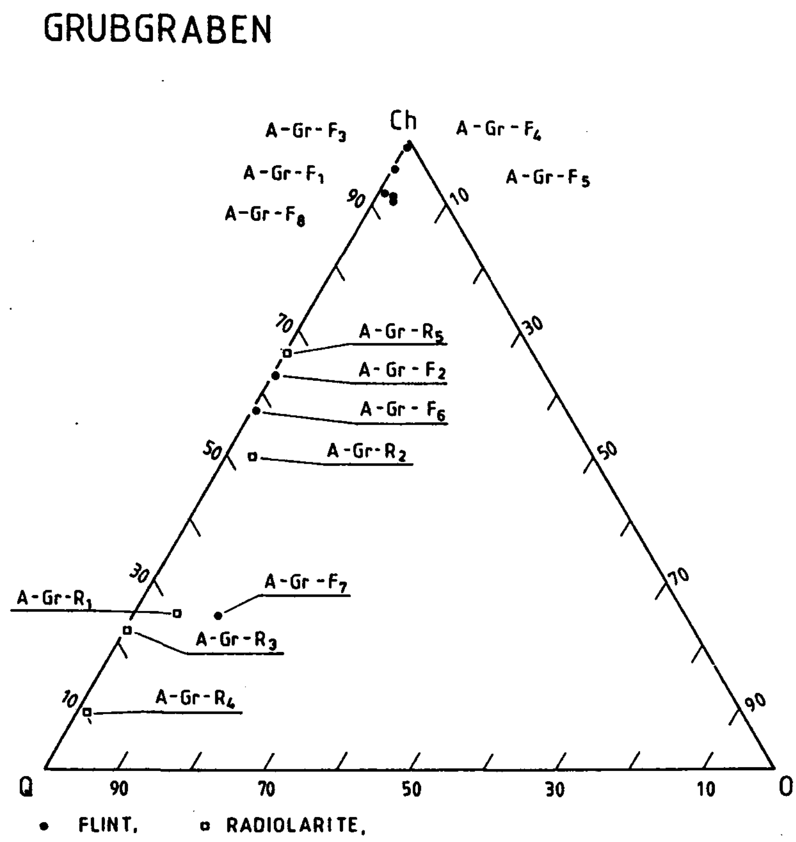


Fig. VII-4 Diagrams of mineral composition, top, survey samples, bottom, Grubgraben samples. Ch, chalcedony, O, opal, Q, quartz. Dots designate flint samples, x radiolarites, square diatomites, and circles hornstones.

The Mauern Hill is a park situated in a western district of Vienna. A small abandoned quarry is preserved inside the park. Radiolarites and limestones with flint and shales are visible on the exposed face of the quarry (Fig. VII-3). The deposits were strongly disturbed by tectonic activities. Neolithic workshops were found in sediments which lay unconformably at the top of the chert bearing deposits. The lithic artifacts they contained were all of local radiolarite. The site is generally regarded as a quarry.

SAMPLES FROM NATURAL OUTCROPS

The macroscopic characteristics of samples collected from natural outcrops in the course of the field survey are summarized in Tables VII-1 and VII-2. Variables entering in the sample descriptions include: color, presence or absence of inclusions, luster, transparency, cleavage, fracture and estimated frequency of occurrence in the deposits. Samples which exhibited good technological properties (identified by an x in the tables) were selected for subsequent detailed minerological and petrographical observations,

Samples were labelled as follows: A-W1-F1 where the first letter indicates the country of origin, A stands for Austria; the second set of letters indicates the locality of origin, Wi stands for Willendorf; the third letter indicates the type of raw material, F stands for flint, R for radiolarite, H for hornstone, D for diatomite, A for Agate. The number following the material type identifier is arbitrarily assigned to designate a variety of raw materials found at that site.

Altogether 11 samples were selected for mineralogical and petrographical analyses , i.e.: one radiolarite and two flint samples from Willendorf, A-Wi-F1, A-Wi-F2, A-Wi-R3; one radiolarite sample from Sarcharnsdorf, A-Ba-R1, one flint sample from Hollabrun A -Ho-F1, one radiolarite from Parisdorf, A-Pa-R; one hornstone from A-We-H1; and three radiolarite samples from the Mauern Quarry, A-Ma-R1 , A-Ma-R3, A-Ma-R6. Results of the mineral composition analysis are shown in Table VII-3. During the analysis, particular attention was paid to the proportion of opal, quartz and chalcedony, the latter in the form of very fine, crystalline quartz with grains smaller than 0.005 mm. Variations in the relative proportion of the three mineral components are displayed in figure VII-4. The samples form 2 clusters. One characterized by very high percentage of quartz includes 3 flint samples from Willendorf, Hollabrun and a radiolarite from Willendorf (Wi-R3). The second cluster characterized by higher percentages of chalcedony includes a hornstone sample from Weidlingbach and radiolarites from Mauer (Ma-R3) and Barcharnsdolrf. The diatomite and 2 radiolarite samples (Ma-R2 and Wi-R3) which contain higher percentage of opal fall outside of the two clusters. The distribution of flint and radiolarite samples overlaps, however radiolarite samples exhibit a much greater degree of variability in the proportion of mineral components than the flint samples.

In addition to quartz, chalcedony, and opal some of the samples contained carbonate minerals which are in relatively high percentage in the hornstone sample from Weidlingbach and one of the radiolarite from Mauern (Ma-R1); traces of opaque minerals (pyrite and iron oxides) were recovered in all samples; traces of mica, almost exclusively muscovite, were noted in two samples of radiolarite (Ba-R1 and Ma-R3). Anhydrite was identified in one sample of radiolarite (Ba-R1) and one sample of hornstone (We-H1).

Microscopic analyses were used to verify macroscopic observations. A series of polaroid photographs provide an illustration of the particular structure of each sample. The radiolariae filled with fine crystalline quartz of samples Ma-R3 and the pseudomorphs of sample MA-RG are clearly visible (Fig. VII-13).

Flint samples are fine-grained, with 75 to 95% of grains under 5 microns. With one exception (Ma-R1), the radiolarite samples contain much greater percentage of grains between 5 and 10 microns.

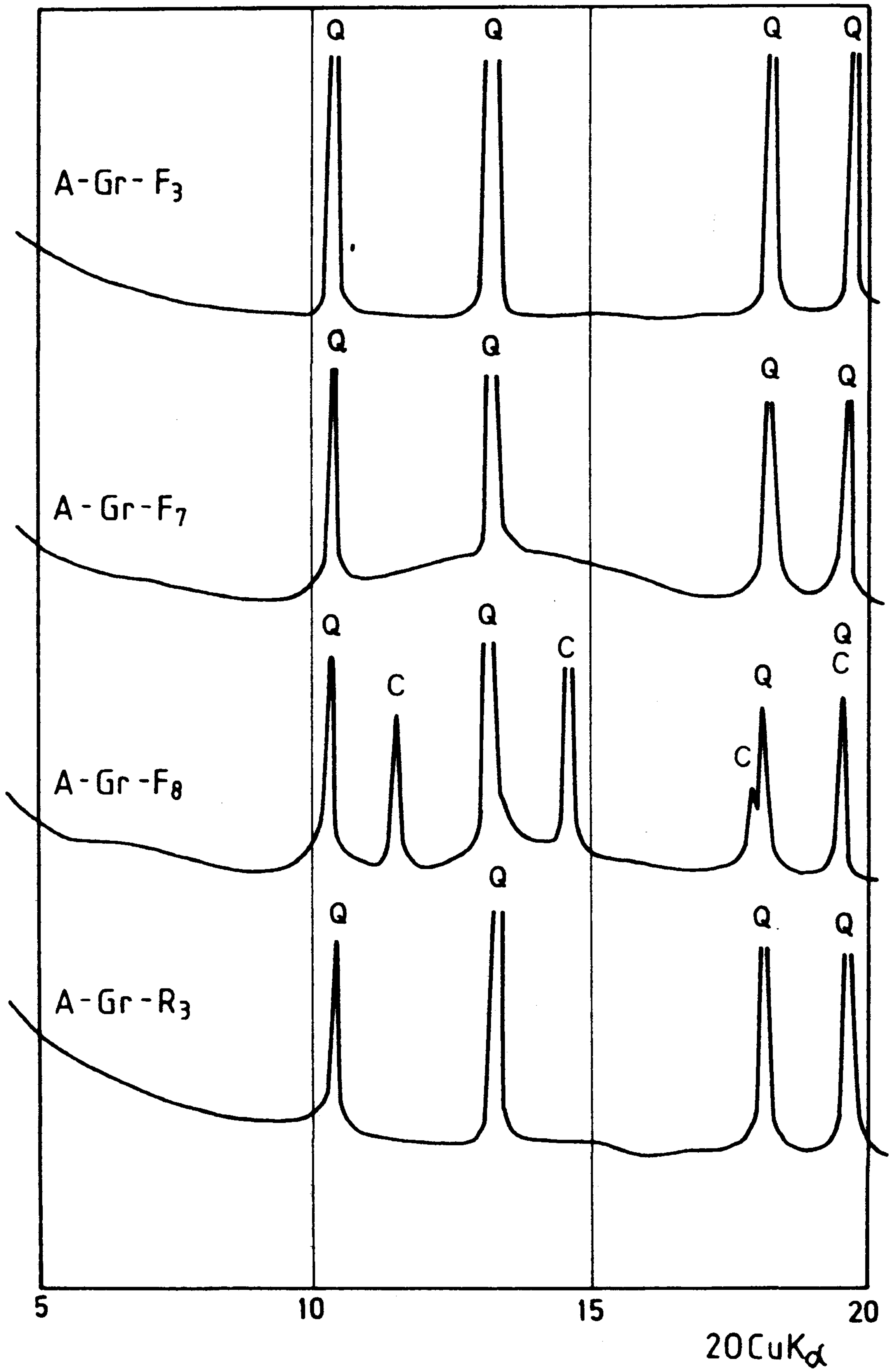


Fig. VII-5 Xray diffraction patterns of selected samples.

FLINT AND RADIOLARITE SAMPLES FROM GRUBGRABEN

Raw materials introduced by Epigravettian tool makers at the site of Grubgraben are marked by their variability. Eight varieties of flint, 5 varieties of radiolarites, and one example of agate were identified in 1987. All samples appear to have good cleavage. And there are very few pieces of cracked material.

Flints range in color from whitish (F4), to light grey (FS, F7) or grey (F6), and yellowish brown (F3) to greyish brown (F2, F1).

F2 and F8 are transparent while other varieties tend to be opaque. A heavy white patina affects F1 and F2 and spots of grey-white patina occur on F4 specimens. The presence of patina is viewed as an important descriptor of raw materials (Pawlikowski, 1989). It is formed as a result of complex chemical and mechanical processes taking place in the outer zone of fine crystal flints. Fully crystallized flint and radiolarite do not become patined.

Radiolarites are a dark reddish brown (R1), light reddish brown with occasional spots (R2), light green (R4), dark grey (R5) or marked by green and red bands (R3).

Table VII-6 summarizes data obtained from microscopic analyses; the relative frequencies of minerals are given in Table VII-7; and information concerning grain size distribution is in Table VII-8 and Figure VII-6. Series of Xray analyses were performed in the range of 0 to 20 - CuK in order to supplement microscopic studies (Fig. VII-5). Four samples were selected for Xray analysis: A-Gr-F3, A-Gr-F4, A-Gr-F8, and A-Gr-R3.

Sample A-Gr-F3

The Xray analysis established that the single component of the flint sample is quartz of the order of dhkl =4.26, 3.34, 2.46 and 2.29 A.

Sample A-Gr-F7

The diffractogram of this sample showed quartz reflections exclusively with the same dhkl values as sample A-Gr-F3. The diffractogram base was increased in the range of 10 to 17 -CuK. This confirms the presence of inclusions of a substance with weakly ordered atomic structure, in this case opal.

Sample A-Gr-F8

Xray diffraction has established that quartz is accompanied by calcite with values of dhkl = 3.85, 3.03, 2.49 A.

Sample A-Gr-R3

The diffractogram of this sample shows that the single component of the radiolarite sample is quartz.

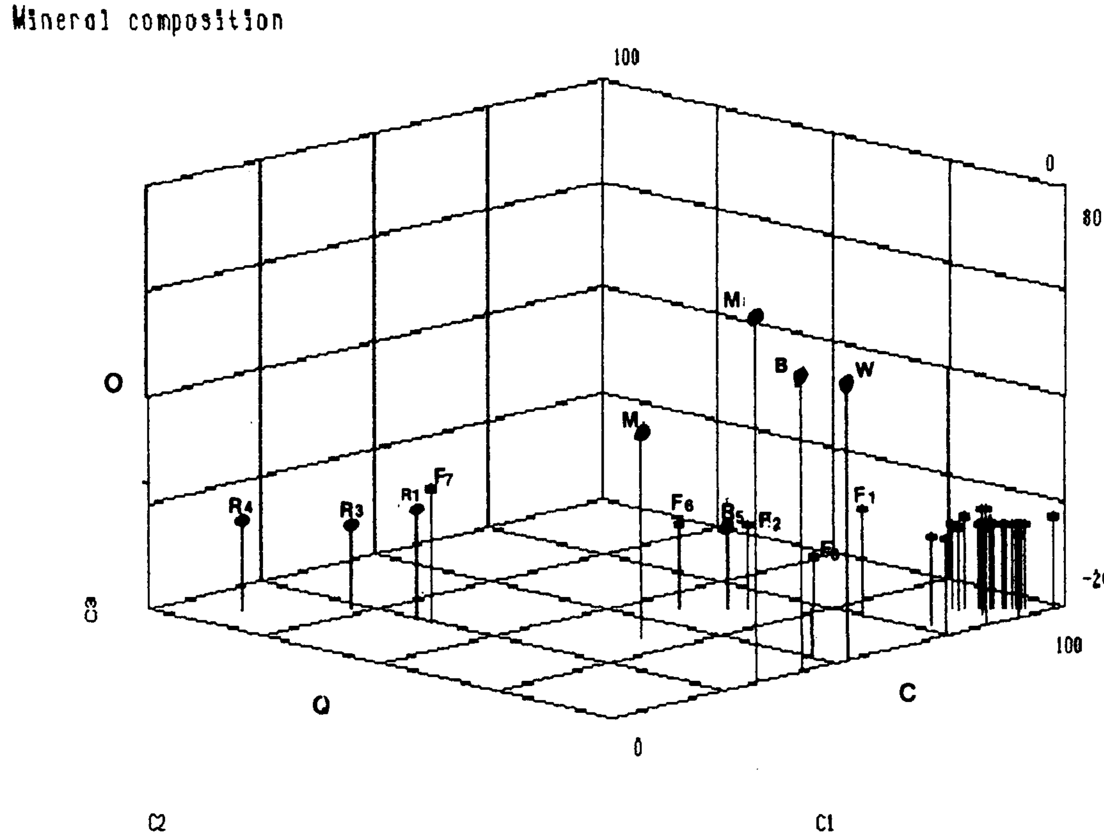


Fig. VII-6 Three dimensional diagram of mineral composition illustrating sample clusters.

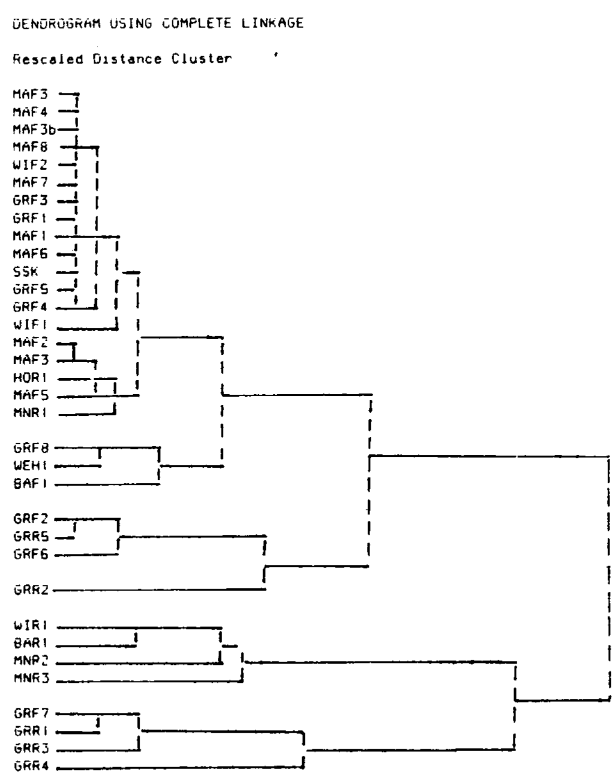


Fig. VII-7 Dendrogram derived from cluster analysis of distance matrix.

DISCUSSION

1- Flint samples:

The complex nature of the data set which includes discrete attributes and quantitative attributes presented in the form of percentages precluded the use of parametric statistics. The first step was to evaluate global similarities by counting the number of shared traits between sample pairs. All quantitative data were collapsed into discrete variable categories. The highest degree of similarities was noted between (a) samples of Northern flint from the Makow site in Upper Silesia and the Grubgraben flint categories F1 (43 % shared traits) and F2 (37%) and (b) sample of Stranska Skala flint with F5 (37% shared traits). The low proportion of shared traits between Grubgraben flints and radiolarite samples and samples from lower Austria made it very unlikely that Grubgraben materials were procured from surveyed sources in Lower Austria.

A second set of comparative analyses was done at the University of Kansas:

(a) When macroscopic attributes alone are considered, the grey, transparent, patined flint F2 shows a great deal of similarity to samples of Northern flint from Makow. The whitish-grey, opaque varieties F3, F4, F5 appear closely related to a sample from Stranska Skala. The green radiolarite has no direct equivalent but varieties of brown radiolarites are difficult to separate on the basis of macroscopic characteristics alone.

(b) A plot of the three major mineral components, chalcedony, quartz and opal (Fig. VII-6) shows a homogeneous cluster characterized by a high percentage of chalcedony which includes all of the northern flint samples, the Stranska Skala sample and the white and grey flints from Grubgraben. Grubgraben flint samples F2, F6, F7 and F8 fall outside the cluster. Furthermore, radiolarite samples from Mauern and from the Danube gravels fall well outside of the range of the Grubgraben radiolarite samples.

(c) A distance matrix was calculated from all quantitative attributes (mineral content, grain size and elements) using Euclidian distance and a dendrogram was obtained using SPSS complete linkage clustering method. The results are comparable to the ones obtained from the plot of mineral content (Fig. VII-7). Samples F1, F3, F4 and F5 fall within the range of the Makow/ Stranska Skala cluster. F8 is rejected although it shows similarity to the hornstone sample WeH1. F2 and F6 appear relatively close in terms of their mineral content even though they differ markedly in their macroscopic characteristics. On the basis of mineral content and grain size composition, F2 is separated from the main cluster in spite of its macroscopic similarities with northern flint samples.

In summary, flint categories F3, F4, F5 are close to the Stranska Skala sample both in terms of macroscopic characters and in their mineral composition. Therefore it can be said that the hypothesis of a Moravian origin of these materials is largely verified. At the present time a Upper Silesian origin for F2 remains probable because of similarities in color, transparency and patina. Furthermore flints of that type are not known anywhere else in Central Europe. The source of some of the flint varieties (F6, F7 and F8) remains unknown.

Radiolarites exhibit a great deal of variability in color texture and mineral composition. Their mineral composition overlaps that of flints although a greater degree of variability can be observed among samples studied here. The Grubgraben samples exhibit a very low degree of similarity with Mauern samples. Their origin must be sought elsewhere. The Danube gravels may have been the source of some of the reddish-brown specimens found at Grubgraben. Grubgraben samples show some macroscopic similarities to radiolarites from the Vah Basin, in texture, color and in the presence of fine linear intercalations. Although it remains to be examined and substantiated by mineralogical analysis, the hypothesis that some of the Grubgraben radiolarites originated from the Vah Basin may be considered probable.

TABLE VII -1
Characteristics of raw material samples
from naturals outcrops

Sample	color inclusions	luster transparency	cleavage fracture	frequency of occurence
1 A-Wi-F_1	black	mat	very good	0.1%
	-	-	conchoidal	
1 A-Wi-F_2	beige	mat	very good	0.1%
	-	-	conchoidal	
1 A-Wi-F_3	light brown	mat	medium	0.1%
	white spots	-	rough	
1 A-Wi-F_4	light brown	satin	bad	0.1%
	-	-	rough	
1 A-Wi-R_1	reddish-brown	mat	bad	0.1%
	white veins	medium	rough	
1 A-Wi-R_2	olive	satin	very good	0.1%
	-	-	conchoidal	
2 A-Gr-R_1	red	mat	medium	0.1%
	veins	-	smooth	
2 A-Gr-R_2	green-grey	mat	bad	0.1%
	light veins	-	rough	
3 A-Ba-F_1	grey	mat	very good	0.1%
	-	-	conchoidal	
3 A-Ba-F_2	grey	mat	bad	0.1%
	white dots	-	rough	
3 A-Ba-F_3	black	mat	bad	0.1%
	white dots	-	rough	
3 A-Ba-F_4	black	glossy	bad	0.1%
	white spots	poor	rough	
3 A-Ba-R_1	cherry	satin	very good	0.1%
	-	-	conchoidal	
4 A-Tr-R_1	brown	mat	bad	0.1%
	white veins	-	rough	
4 A-Tr-F_1	light brown	mat	medium	0.1%
	-	-	rough	
5 A-Ha-F_1	grey	mat	poor	0.1%
	weathered	-	smooth	
5 A-Ha-R_1	greenish	mat	bad	0.1%
	cracked	-	rough	

Sample number	color	transparency	fracture	frequency of occurence
6 A-Ho-R_1	geyish-green	mat	very good	0.1%
	-	transluscent	smooth	
6 A-Ho-F_2	grey	satin	medium	0.1%
	-	-	rough	
6 A-Ho-R_1	red-brown	mat	medium	0.1%
	white veins	-	rough	
8 A-Ob-R_1	brown-red	mat	bad	0.1%
	weathered	-	rough	
9 A-Gn-R_1	brown	mat	medium	0.1%
	veins	-	smooth	
	weathered			
10 A-St-R_1	red-brown	mat	bad	0.1%
	white veins	-	rough	
10 A-St-R_2	brown-green	mat	medium	0.1%
	-	-	smooth	
10 A-St-R_3	green	mat	medium	0.1%
	light veins	-	smooth	
11 A-PaD_1	olive	satin	good	deposit
	-	-	conchoidal	
12 A-We-H_1	light grey	mat	poor	2-3%
	light veins	-	rough	
13 A-Ste-H_1	grey	mat	bad	3-5%
	light veins	-	rough	
14 A-Ma-F_1	black	mat	bad	2-3%
	limestone	-	smooth	
	interlayers			
14 A-Ma-F_2	black	mat	poor	1.2%
	bluish spots	-	smooth	
14 A-Ma-R_1	red-cherry	satin	very good	deposit
	white veins	-	conchoidal	
14 A-Ma-R_2	grey-red	mat	medium	deposit
	white veins	-	smooth	
14 A-Ma-R_3	red-green	mat	very good	deposit
	spotted	-	smooth	
14 A-Ma-R_4	cherry-grey	mat	good	deposit
	spotted	-	smooth	
14 A-Ma-R_5	white-pink	mat	medium	deposit
	spotted	-	smooth	
14 A-Ma-R_1	green-grey	mat	very good	deposit
	banded	-	conchoidal	
14 A-Ma-R_7	dark green	mat	good	deposit
	-	-	conchoidal	

TABLE VII-2
Microscopic characters of raw material samples from natural outcrops

Sample	structure texture	micro-photography	mineral components primary		secondary
A-Wi-F_1	fine and equal size crystals random	1	chalcedony	opal	opaque min.
A-Wi-F_2	fine and different size crystals random	2	chalcedony	quartz	opal carbonite opaque
A-Wi-R_3	fine and different size crystals random	3	chalcedony opal	quartz	carbonate opaque min.
A-Ba-F_1	fine and different size crystals random	4	chalcedony	quartz	opal opaque min.
A-Ba-R_1	fine and different size crystals random	5	chalcedony opal	quartz	quartz anhydrite carbonate opaque min. mica
A-Ho-F_1	fine crystals random	6	chalcedony	quartz	opal carbonate opaque min.
A-Pa-D_1	non-crystalline biogenetic random	7	opal		chalcedony quartz opaque min.
A-We-H_1	fine and different size crystals random	8	chalcedony	carbonates	anhydrite quartz opal opaque min.
A-Ma-R_1	different size crystals	9	chalcedony	opal	quartz carbonate
A-Ma-R_3	different size crystals random	10	opal	chalcedony	quartz mica opaque
A-Ma-R_6	different size crystals random	11	quartz opal chalcedony	-	carbonate opaque

TABLE VII-3
Mineral composition of raw materials
from natural outcrops (% of volume)

Component	Samples					
	25	26	27	28	29	30
	A-Wi-F_1	A-Wi-F_2	A-Wi-R_3	A-Ba-R_1	A-Ba-F_1	A-Ho-F_1
chalcedony	97.4	94.8	53.3	42.1	75.4	86.9
quartz	-	4.8	1.5	0.5	19.6	10.8
opal	2.4	0.2	44.3	50.0	4.9	1.9
carbonates	-	0.1	0.6	1.7	-	0.3
mica	-	-	-	0.1	-	-
opaque minerals	0.2	0.1	0.3	0.3	0.1	0.1
anhydrite	-	-	-	5.3	-	-

Component	Samples				
		31	32	33	34
	A-Pa-D_1	A-We-H_1	A-Ma-R_1	A-MaR_3	A-Ma-R_6
chalcedony	1.5	73.7	83.4	32.9	39.5
quartz	0.6	0.3	1.1	1.1	32.2
opal	97.6	2.9	7.4	65.8	28.0
carbonates	-	13.9	8.0	-	0.2
mica	-	-	-	0.1	-
opaque minerals	0.3	0.6	0.1	0.1	0.1
anhydrite	-	9.1	-	-	-

TABLE VII-4
Grain-size analysis of
raw materials from natural outcrops (% of volume)

Fractions um	A-Wi-F_1	A-Wi-F_2	Samples A-Wi-R_3	A-Ba-F_1	A-Ba-R_1
0-5	97.4	94.8	53.3	75.4	42.1
5-10	2.1	4.3	35.6	24.3	36.0
10-20	0.5	0.9	11.1	0.3	13.3
20-40	-	-	-	-	8.6

Fraction			Samples			
um	A-Ho-F_1	A-Pa-D_1	A-We-H_1	A-Ma-R_1	A-Ma-R_3	A-Ma-R_6
0-5	86.9	-	73.7	83.4	32.9	39.5
5-10	8.6	-	22.3	10.3	64.0	58.0
10-20	4.5	-	-	6.3	4.1	2.5

TABLE VII-5
Characteristics of lithic raw materials
from Grubgraben.

Sample	color inclusions	luster transparency	cleavage fracture	frequency of occurence
A-Gr-F_1	brown-grey white patina	satin -	very good smooth	high
A-Gr-F_2	grey-brown white patina	satin transparent	very good smooth conchoidal	medium
A-Gr-F_3	yellow-cream	satin poor	good smooth	high
A-Gr-F_4	white grey spots	satin -	very good conchoidal	medium
A-Gr-F_5	light-grey grey-white patina	mat -	good smooth	rare
A-Gr-F_6	grey rare white spots	mat -	very good smooth	rare
A-Gr-F_7	light grey of various shades	satin -	very good smooth or conchoidal	rare
A-Gr-F_8	grey-spotted -	glossy transparent	very good smooth	rare
A-Gr-R_1	cherry-brown	satin -	very good smooth	medium
A-Gr-R_2	red-brown rare light spots	satin -	very good smooth or conchoidal	medium
A-Gr-R_3	green-cherry spotted	satin -	very good conchoidal	rare
A-Gr-R_4	light-green	satin transparent	very good conchoidal	medium
A-Gr-R_5	dark-green -	mat -	very good conchoidal	rare
A-Gr-A_1	grey, with thin white-blue rings	satin transparent	very good conchoidal	rare

TABLE VII-6
Microscopic characterization
of raw materials from the site of Grubgraben

Sample	structure texture	micro-photography	mineral components: primary	secondary	accessing
A-Gr-F_1	micro-crystalline random	12	chalcedony	quartz	opal carbonate opaque
A-Gr-F_2	fine and different size crystals random	13	chalcedony	quartz	carbonate opaque
A-Gr-F_3	fine and different size crystals random	14	chalcedony	quartz	opaque
A-Gr-F_4	fine and non crystalline random	15	chalcedony	carbonates	opal quartz opaque
A-Gr-F_5	micro-crystalline random	16	chalcedony	quartz	opal opaque min.
A-Gr-F_6	fine and different size crystals	17	chalcedony	quartz	opaque min.
A-Gr-F_7	fine and different size crystals random	18	quartz	chalcedony opal	opaque min.
A-Gr-F_8	fine and different size crystals random	19	chalcedony	calcite	quartz opal opaque min.
A-Gr-R_1	fine and different size crystals random, veined	20	quartz	chalcedony	opal carbonate opaque min.
A-Gr-R_2	fine and different size crystals random	21	chalcedony	carbonates	quartz opal opaque min.

TABLE VII-6
Microscopic characterization
of raw materials from the site of Grubgraben

Sample	structure texture	micro-photography	mineral components primary	secondary	accessing
A-Gr-R_3	fine and different size crystals random	22	quartz	chalcedony	iron oxide
A-Gr-R_4	fine and crypto-crystalline random	23	quartz	chalcedony	opal

TABLE VII-7
Mineral composition of raw materials from
the site of Grubgraben (% of volume)

Component	Samples					
	A-Gr-F_1	A-Gr-F_2	A-Gr-F_3	A-Gr-F_4	A-Gr-F_5	A-Gr-F_6
chalcedony	90.5	62.9	94.5	90.1	89.9	57.6
quartz	8.0	36.7	4.4	0.4	7.5	42.1
opal	0.7	-	-	0.3	2.5	-
carbonates	0.7	0.3	-	8.9	-	-
mica	-	-	-	-	-	-
opaque minerals	0.1	0.1	1.1	0.3	0.1	0.3

Component	Samples					
	A-Gr-F_7	A-Gr-F_8	A-Gr-R_1	A-Gr-R_2	A-Gr-R_3	A-Gr-R_4
chalcedony	24.4	76.8	25.3	49.9	22.2	9.6
quartz	63.2	6.5	67.2	5.7	77.8	89.1
opal	12.1	1.0	5.9	3.9	-	1.3
carbonates	-	15.5	1.0	39.8	-	-
mica	-	-	-	0.5	-	-
opaque minerals	0.3	0.2	0.6	0.2	-	-

Component	Samples
	A-Gr-R_5
chalcedony	65.2
quartz	34.5
opal	-
carbonates	-
mica	0.1
opaque minerals	0.2

TABLE VII-8
Grain size distribution.
Samples from Grubgraben

Grain size	Sample					
um	A-Gr-F_1	A-Gr-F_2	A-Gr-F_3	A-Gr-F_4	A-Gr-F_5	A-Gr-F_6
0-5	3	31.0	3.1	8.2	9.1	36.3
10-20	3.6	5.1	1.0	1.7	2.0	6.1
20-40	1.6	1.8	2.4	-	-	-
40-100	-	0.2	-	-	-	-

Grain size	Sample					
um	A-Gr-F_7	A-Gr-F_8	A-Gr-R_1	A-Gr-R_2	A-Gr-R_3	A-Gr-R_4
0-5	24.4	76.8	25.3	49.9	22.2	9.6
5-10	72.3	20.1	73.1	38.6	69.6	87.6
10-20	4.3	2.2	2.6	1.5	9.2	2.8
20-40	-	1.9	-	-	-	-

Grain size	Sample
um	A-Gr-R_5
0-5	65.2
5-10	31.3
10-20	4.5

TABLE VII-9
Content of elements in raw materials from the site of Grubgraben (% of volume)

Sample	Ca	Mg	Na	K	Fe
A-Gr-F_1	0.0598	0.0107	0.0483	0.0232	0.0357
A-Gr-F_2	0.0430	0.0182	0.0215	0.0119	0.0902
A-Gr-F_3	0.0316	0.0083	0.0298	0.0197	0.0344
A-Gr-F_4	0.0451	0.0074	0.0230	0.0174	0.0300
A-Gr-F_5	0.1024	0.0078	0.0187	0.0120	0.0297
A-Gr-F_6	0.0221	0.0083	0.0186	0.0208	0.0491
A-Gr-F_7	0.0390	0.0697	0.0562	0.1400	0.1496
A-Gr-F_8	0.5387	0.0137	0.0722	0.0664	0.0394
A-Gr-R_1	0.0799	0.1142	0.1455	0.1803	0.8029
A-Gr-R_2	0.5758	0.0706	0.1235	0.1621	0.4886
A-Gr-R_3	0.0330	0.0395	0.1104	0.1259	0.1364
A-Gr-R_4	0.0687	0.1628	0.0909	0.3027	0.3819
A-Gr-R_5	0.0624	0.1906	0.1332	0.3363	0.3315

Sample	Mn	Zn	Ni	Cu	Pb	Cr
A-Gr-F_1	0.0003	0.0023	0.0046	0.0001	0.0009	0.0003
A-Gr-F_2	0.0005	0.0001	-	-	0.0008	0.0003
A-Gr-F_3	0.0002	0.0005	-	-	0.0009	0.0005
A-Gr-F_4	0.0002	0.0001	0.0008	-	0.0007	0.0003
A-Gr-F_5	0.0003	0.0007	0.0008	0.0001	0.0006	0.0004
A-Gr-F_6	0.0003	0.0013	-	-	0.0006	0.0006
A-Gr-F_7	0.0007	0.0004	0.0008	0.0001	0.0020	0.0008
A-Gr-F_8	0.0027	0.0009	0.0010	0.0003	0.0011	0.0005
A-Gr-R_1	0.0038	0.0016	0.0016	0.0001	0.0019	0.0013
A-Gr-R_2	0.0480	0.0009	0.0010	-	0.0014	0.0007
A-Gr-R_3	0.0011	0.0002	0.0005	-	0.0007	0.0006
A-Gr-R_4	0.0016	0.0008	0.0016	0.0001	0.0009	0.0012
A-Gr-R_5	0.0017	0.0008	0.0014	0.0001	0.0028	0.0013

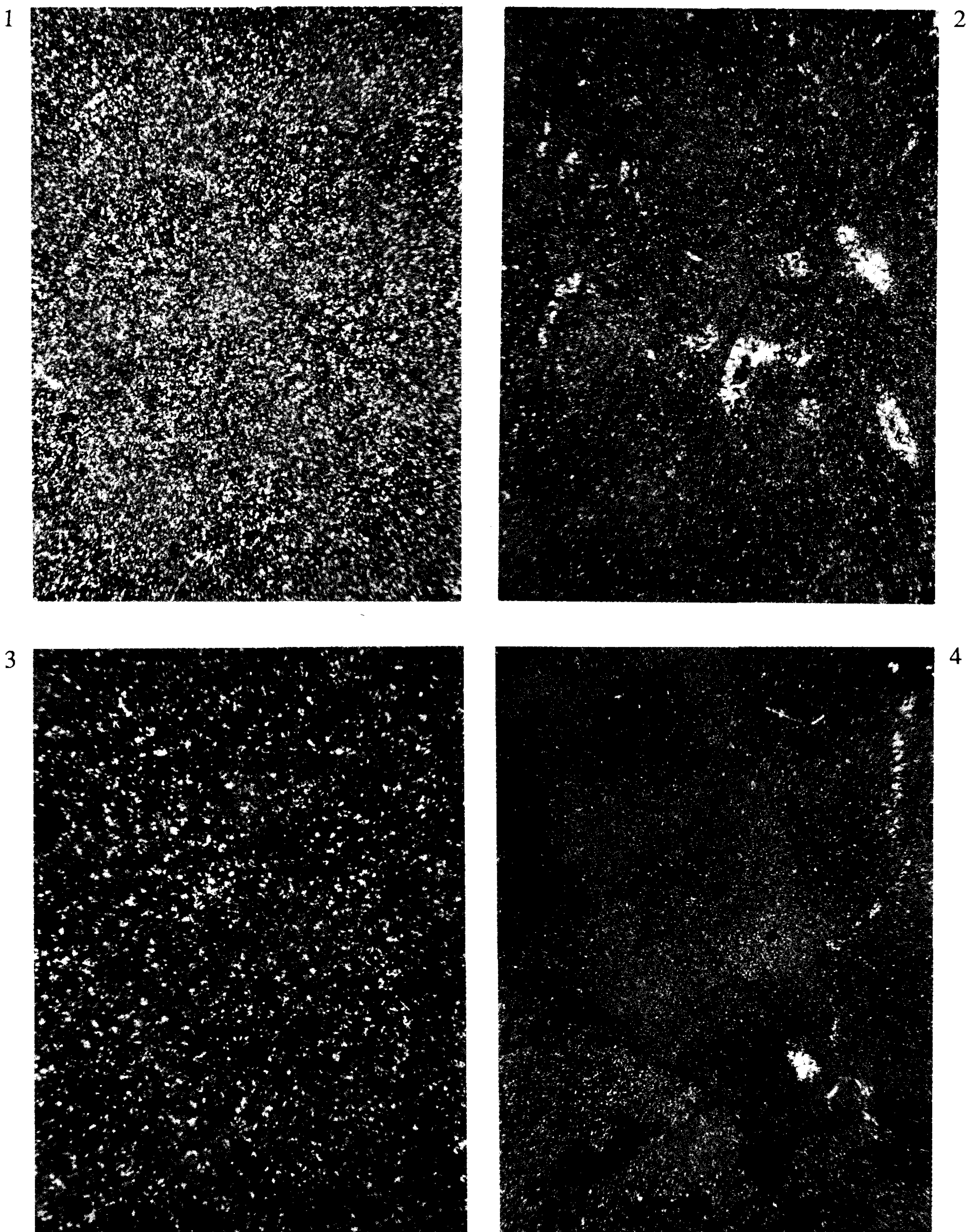


Fig. VII-8 Phot.1. Sample A-Wi-F1. Chalcedony. Polaroids x, 32x
Phot.2. Sample A-Wi-F2. Fine crystalline quartz at chalcedony background. Polaroids x. 32x
Phot.3. Sample A-Wi-R3. Opal-chalcedony background. Polaroids x. 32x.
Phot.4. Sample A-Ba-F1. Fine quartz at chalcedony back ground. Polaroids X. 32x.

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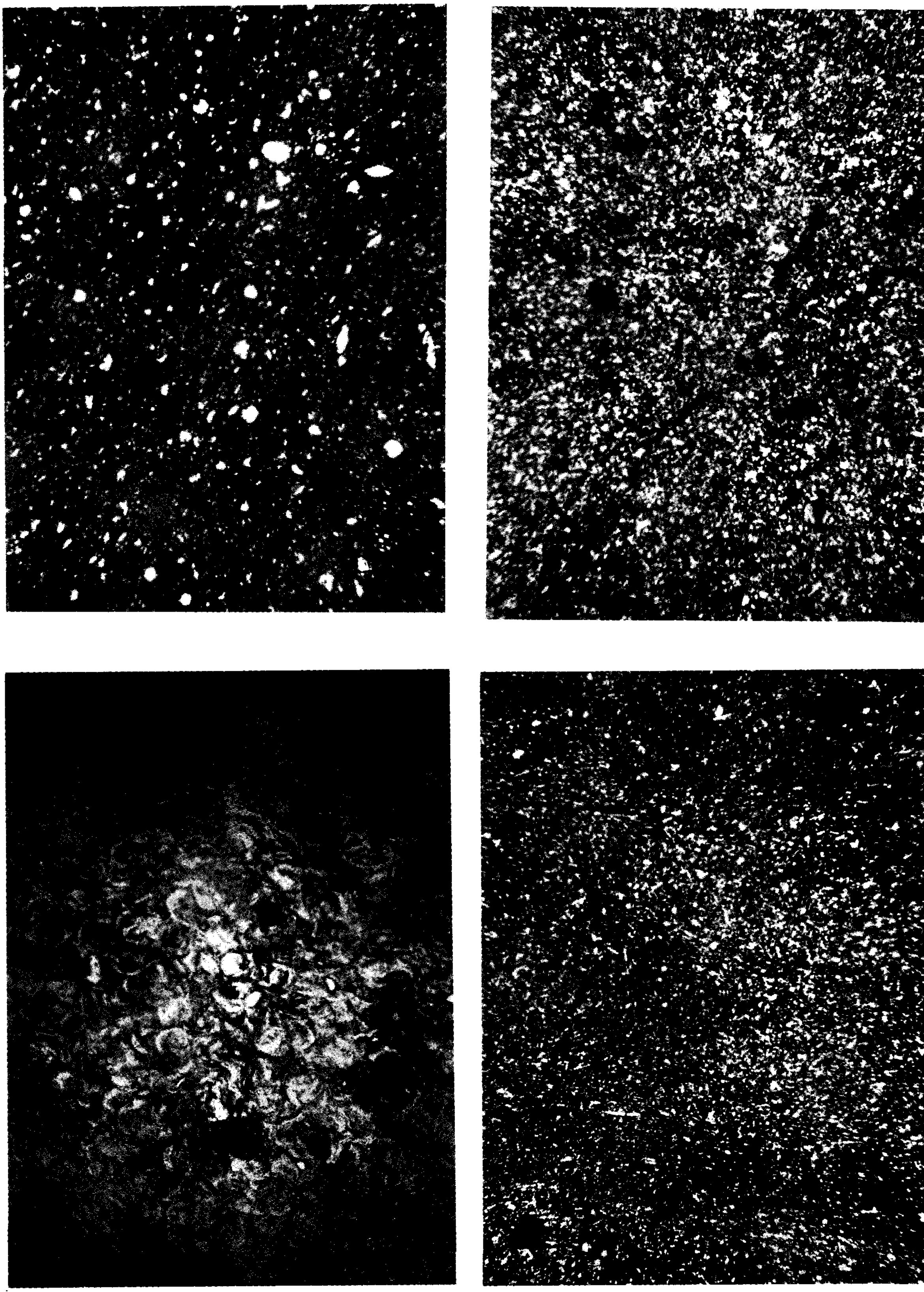

Fig. VII-9 Phot.5. Sample A-Ba-R1. Opal-chalcedony background with disseminated fine quartz. Polaroids X. 32x.

Phot.6. Sample A-Ho-F1. Chalcedony and fine crystalline quartz. Polaroids x. 32x.

Phot.7. Sample A-Ra-D1. Diatomea-opal skeletons. 1 polaroid. 32x.

Phot.8. Sample A-We-H1. Chalcedony background of hornstone. Polaroids x. 32.

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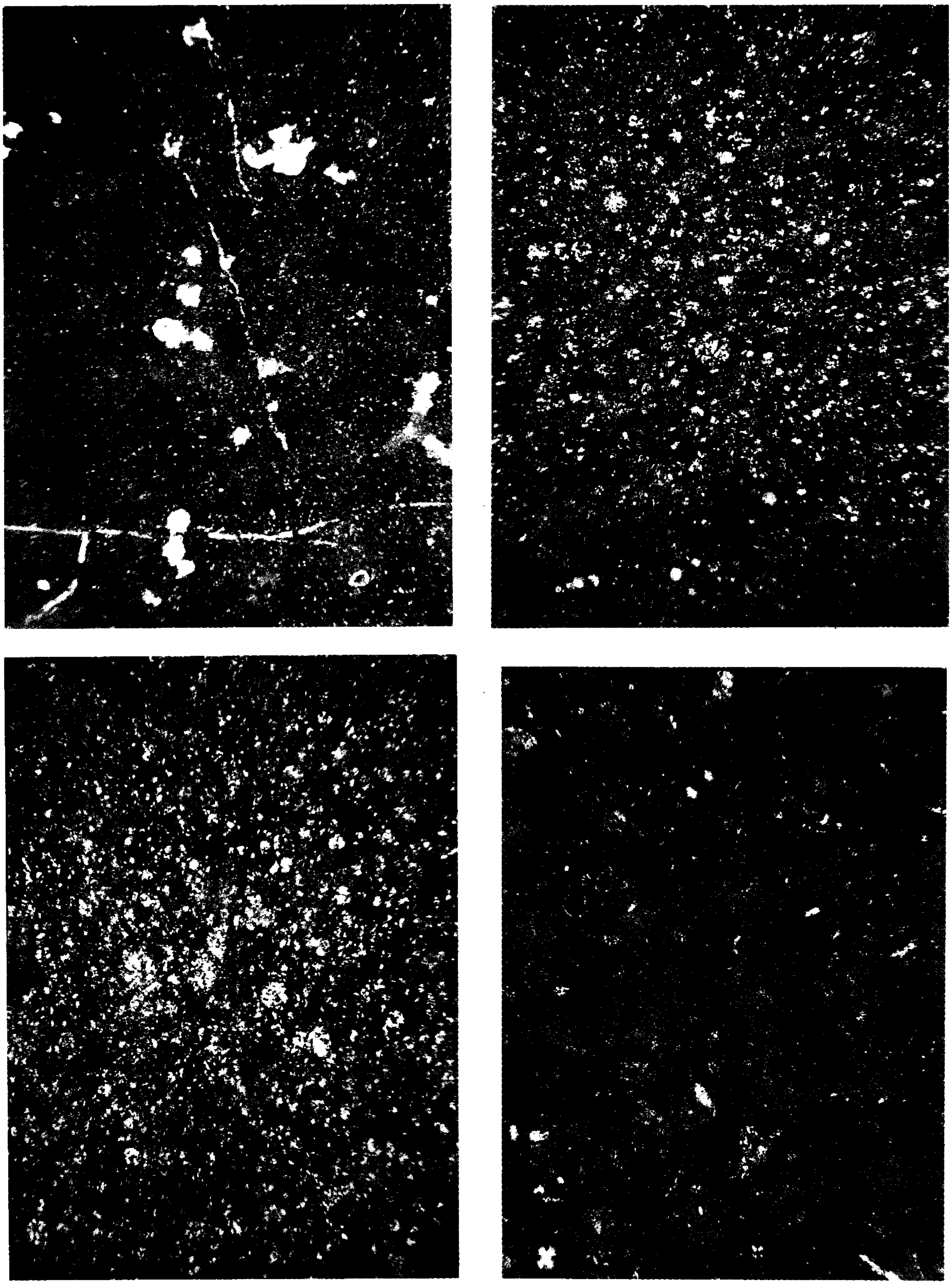

Fig. VII-10 Phot.9. Sample A-Ma-R1. Chalcedony containing concentrations of quartz and calcite veins. Polaroids x. 32x.

Phot.10. Sample A-Ma-R3. Radiolaries filled with fine crystalline quartz. Polaroids x. 32x.

Phot.11. Sample A-Ma-R6. Chalcedonic pseudomorphes after radiolaria at chalcedony-opal background. Polaroids x. 32x.

Phot.12. Sample A-Gr-F1. Fine crystalline quartz, chalcedony background. Polaroids x. 32x.

13 14 15 16

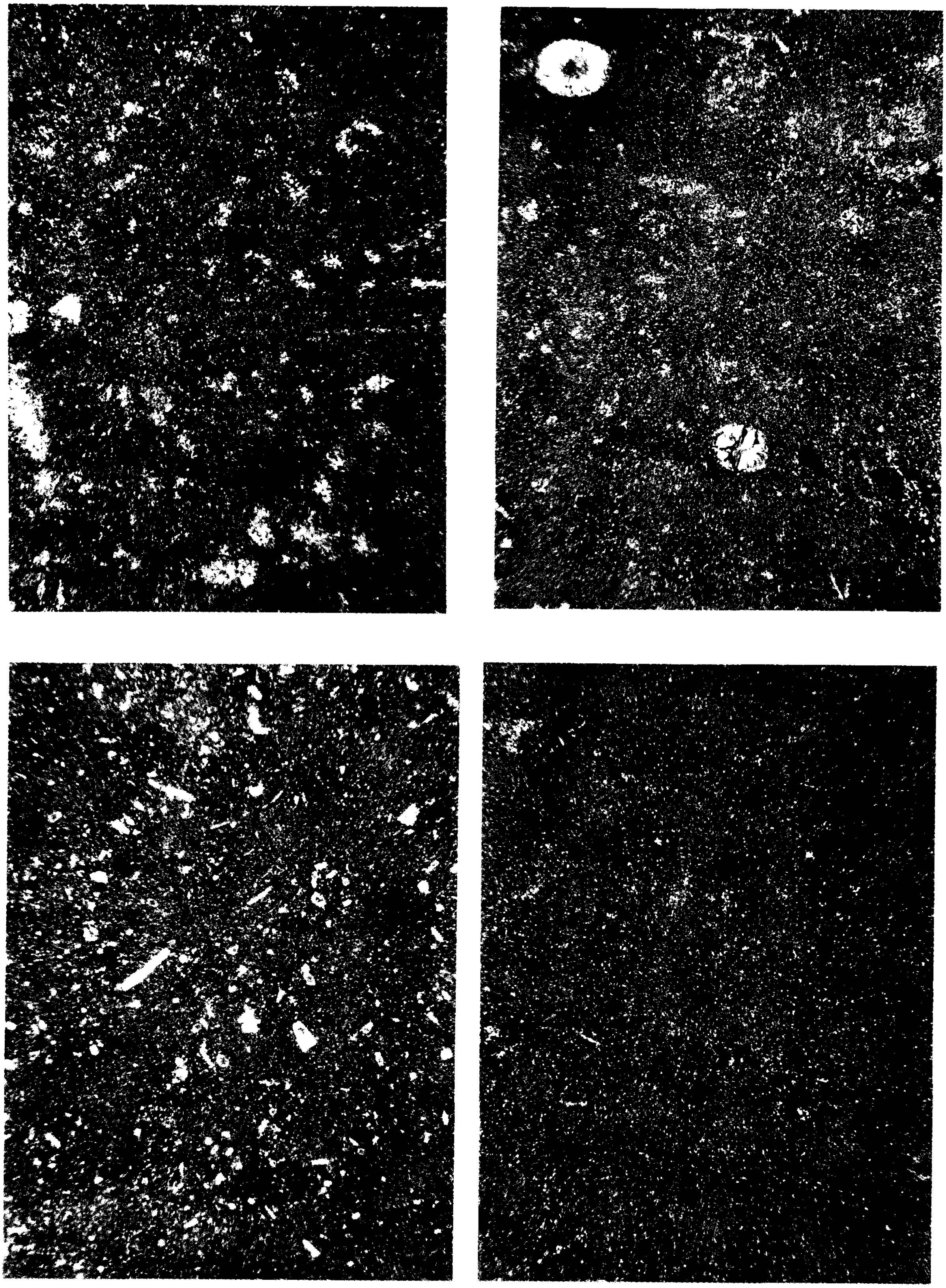

Fig. VII-11 Phot.13. Sample A-Gr-F2. Fine crystalline quartz and chalcedony . Polaroids x. 32x.

Phot.14. Sample A-Gr-F3. Pseudomorphes of quartz after foraminifera disseminated within the calcedony mass. Polaroids x. 32x.

Phot.15. Sample A-Gr-F4. Crystals of calcite and opaque minerals, chalcedony background. Polaroids x. 32x.

Phot.16. Sample A-Gr-F5. Chalcedony . Polaroids x. 32x.

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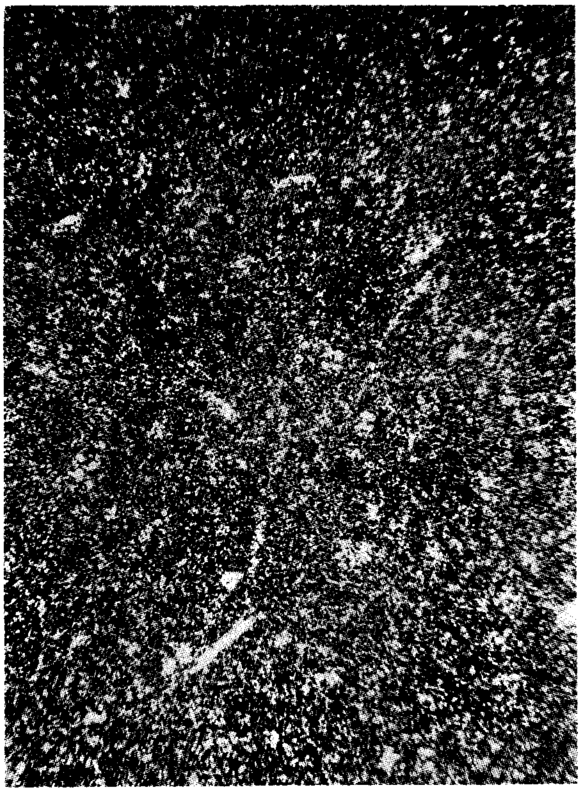

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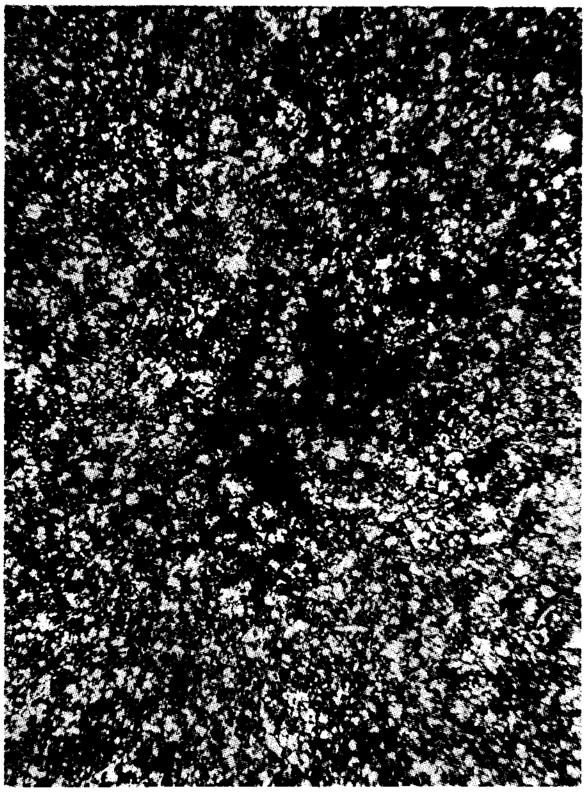

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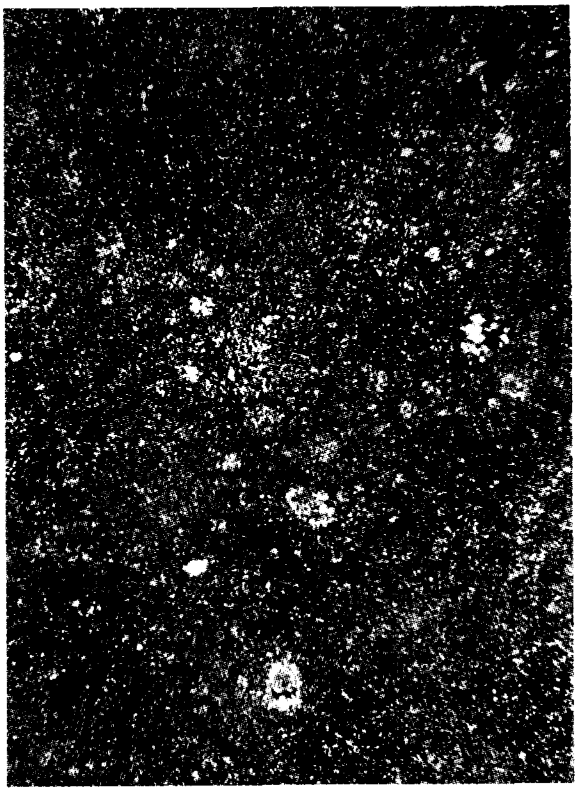

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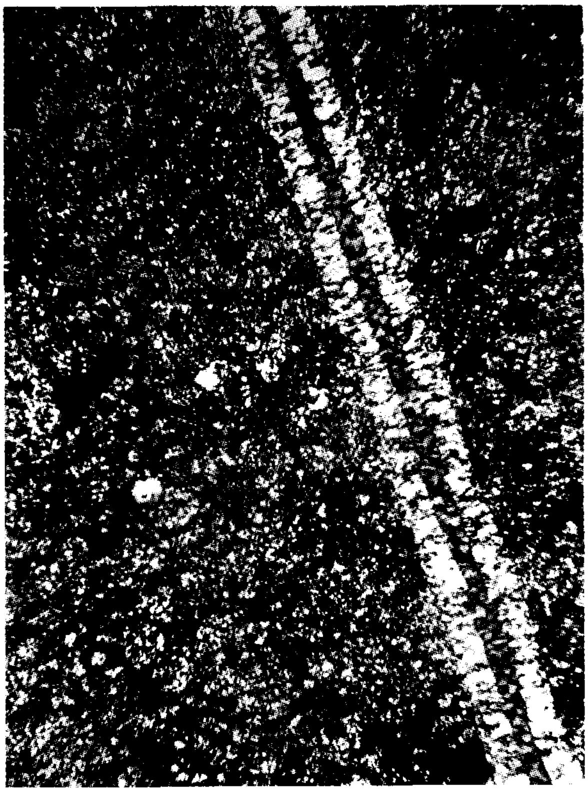

Fig. VII-12 Phot.17. Sample A-Gr-F6. Concentrations of quartz, chalcedony background. Polaroids x. 32x.

Phot.18. Sample A-Gr-F7. Quartz, chalcedony, opal (black). Polaroids x. 32x.

Phot.19. Sample A-Gr-F8. Crystals of carbonates at chalcedony background. Polaroids x. 32x.

Phot.20. Sample A-Gr-R1. Vein of fine quartz cutting the radiolarite. Polaroids x. 32x.

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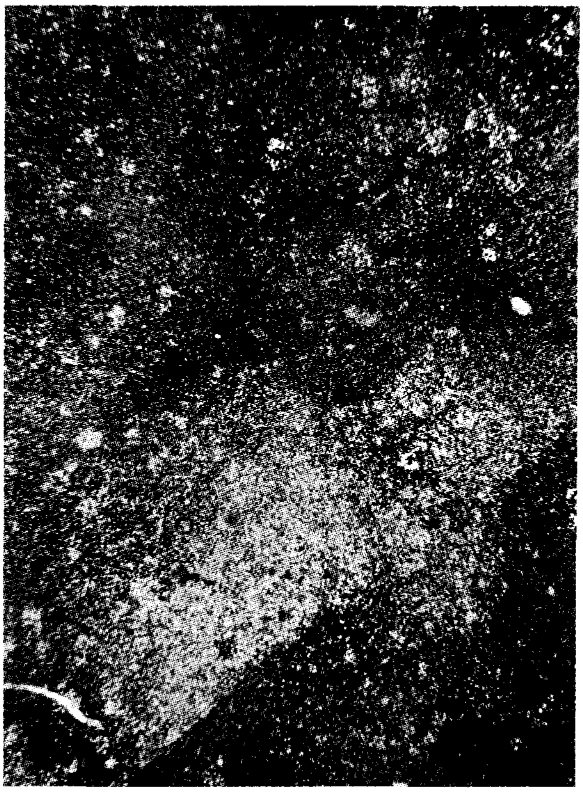

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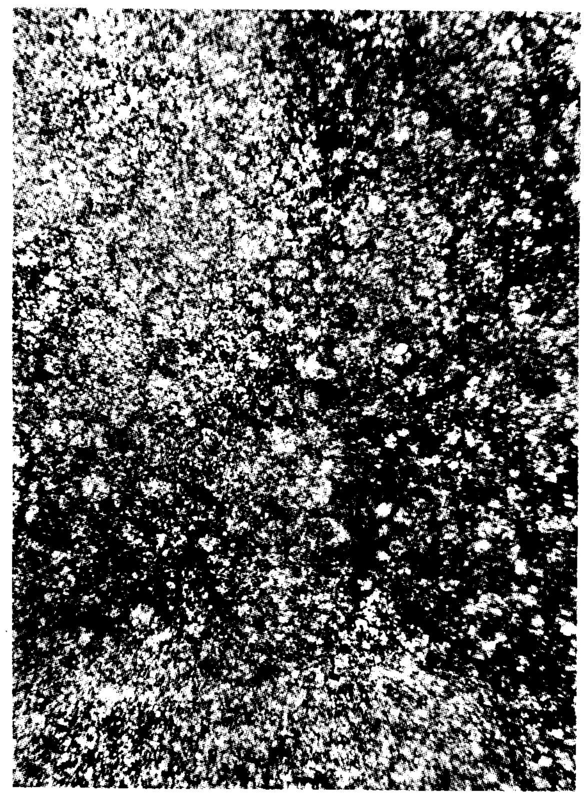

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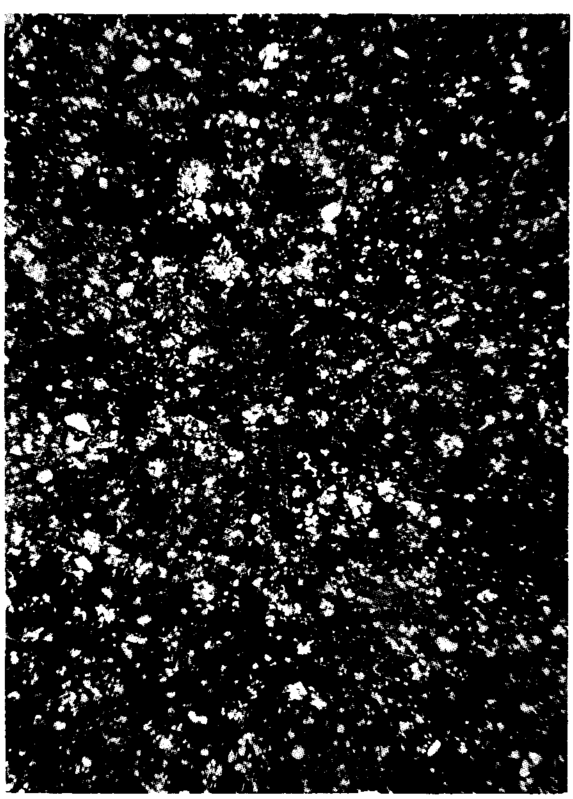

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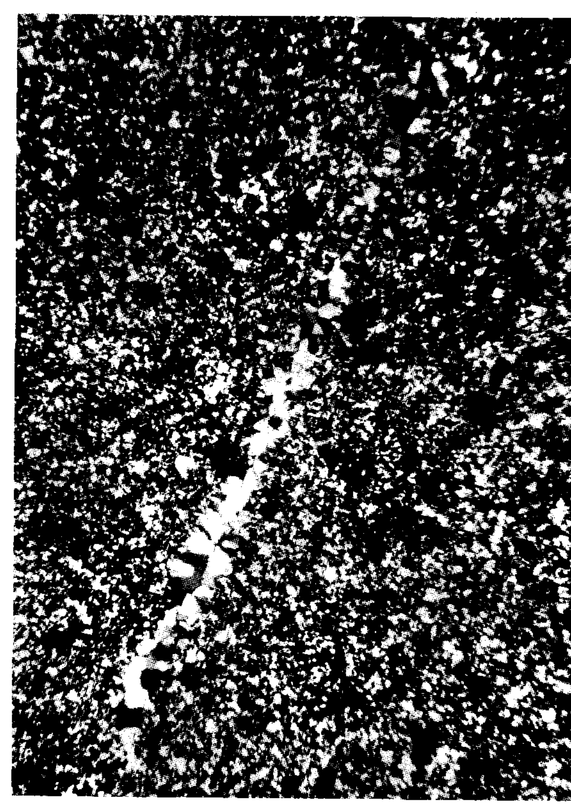

Fig. VII-13 Phot.21. Sample A-Gr-R2. Spots of carbonates in chalcedony mass. Polaroids x. 32x.

Phot.22. Sample A-Gr-R3. Dark spots of iron oxides mixed with chalcedony. Polaroids x. 32x.

Phot.23. Sample A-Gr-R4. Quartz pseudomorphes derived from radiolaria. Polaroids x. 32x.

Phot.24. Sample A-Gr-R5. Quartz pseudomorphes after radiolaria. Polaroids x. 32x.

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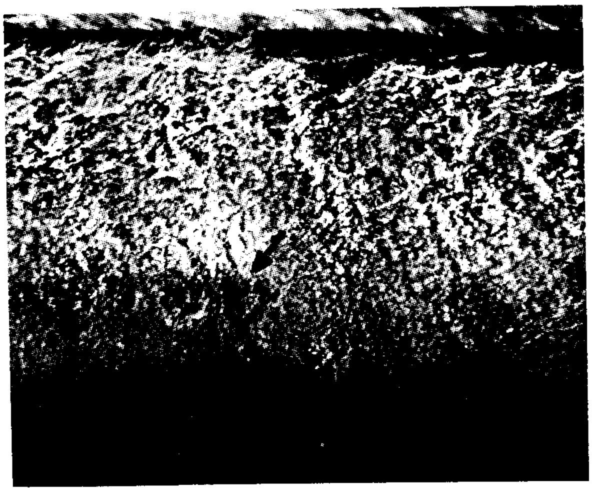

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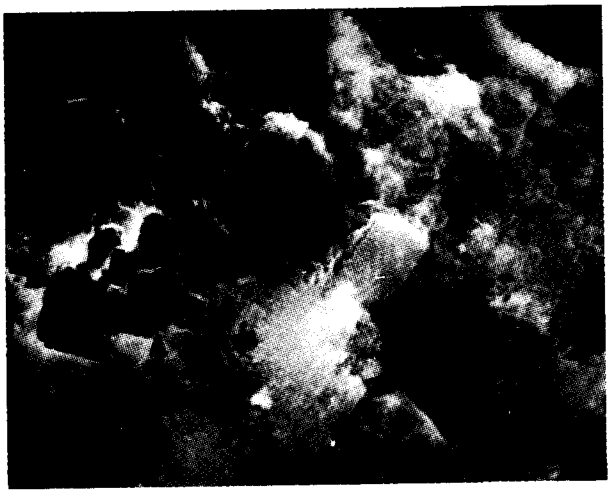

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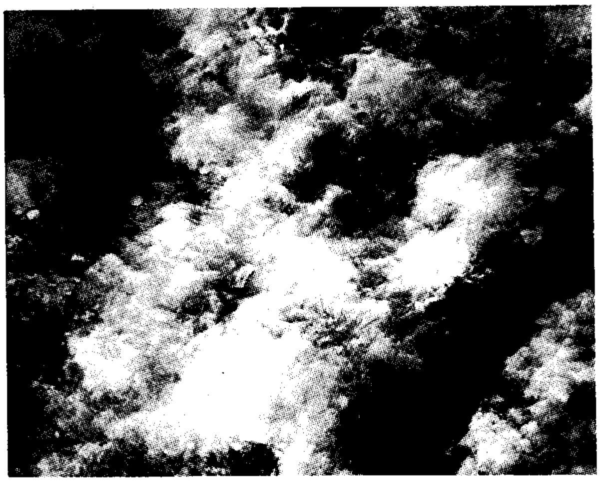

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Fig. VII-14 Phot.25. Sample A-Gr-F2. Structural changes of the flint at zone of patination. Black internal part flint. Light patina. Between patina and internal part (arrow) one can see the zone of structural changes. SEM. 100x.

Phot.26. Sample A-Gr-F2. The structure of patina. SEM. 2400x.

Phot.27. Sample A-Gr-F2. Crystals of calcite (arrows) filling up the secondary empty space at the zone of patination. Big light crystals (central part of picture) are recrystallised quartz. SEM. 2400x.

Phot.28. Sample A-Gr-R2. The structure of Internal part of radiolarite. One can see bigger crystals of quartz disseminated in the chalcedony mass . SEM. 1200x.