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NORTH PERUVIAN CERAMICS IN THE ASPECT OF PETROGRAPHIC ANALYSIS

The ceramics studied originates from the North Peruvian Andes or, more precisely, from the area covering the uppermost parts of the basins of the mountain rivers Alto Chicama, Moche, Chuquicara and Condebamba. A. Krzanowski carried out archaeological investigations in that area in 1973, when the ceramics in question was collected. It comes from 19 sites, most of which (15) are situated in the Alto Chicama basin (designated as AC). The others, i. e. AC-97 and AC-98 lie in the basin of the Chuquicara, C° Caupar in the Moche basin and Marca Huamachuco in the Condebamaba basin (fig. 1).

Of the abundant ceramic material available, 50 fragments were selected for petrographic investigations. Moreover, analysis was carried out on a Chimu culture vessel. Though its provenance has not been established, it is known that it has been found in the Alto Chicama region. In view of the difficulties encountered when interpreting the archaeological material from the Alto Chicama, the undisputed origin of the vessel is of great importance since any possible similarities or differences in the technique of manufacture can serve as chronological and culture indicators. The vessel also deserves note for another reason, viz. as a specimen that was damaged and repaired. A hole in the body was pasted up with clay and the vessel was fired again. Microscopic analysis has revealed certain technical details of that reparation.

Investigations were also carried out on the ceramics manufactured today in the village Caulimalca, the only pottery centre in the area studied. Ethnographic studies [1] yielded precise data on the technique of manufacture. Microscopic analysis permitted a comparison of this pottery with the archaeological ceramics, using the same criteria and having ascertained the errors and limitations inherent in this method.

The archaeology ceramics was collected, with a few exceptions, from the surface of sites and is, therefore, represented only by fragments of vessels. The specimens were selected so as to obtain the fullest possible answer to the questions that arose during typological analysis of the archaeological material. The selected fragments

[1] R. Krzanowska A. Krzanowski, *Garncarstwo ludowe w dolinie Alto Chicama w północnym Peru* [*Popular Pottery in Alto Chicama Valley in North Peru*],,,Etnografia Polska" 1976, vol. XX, no 1.

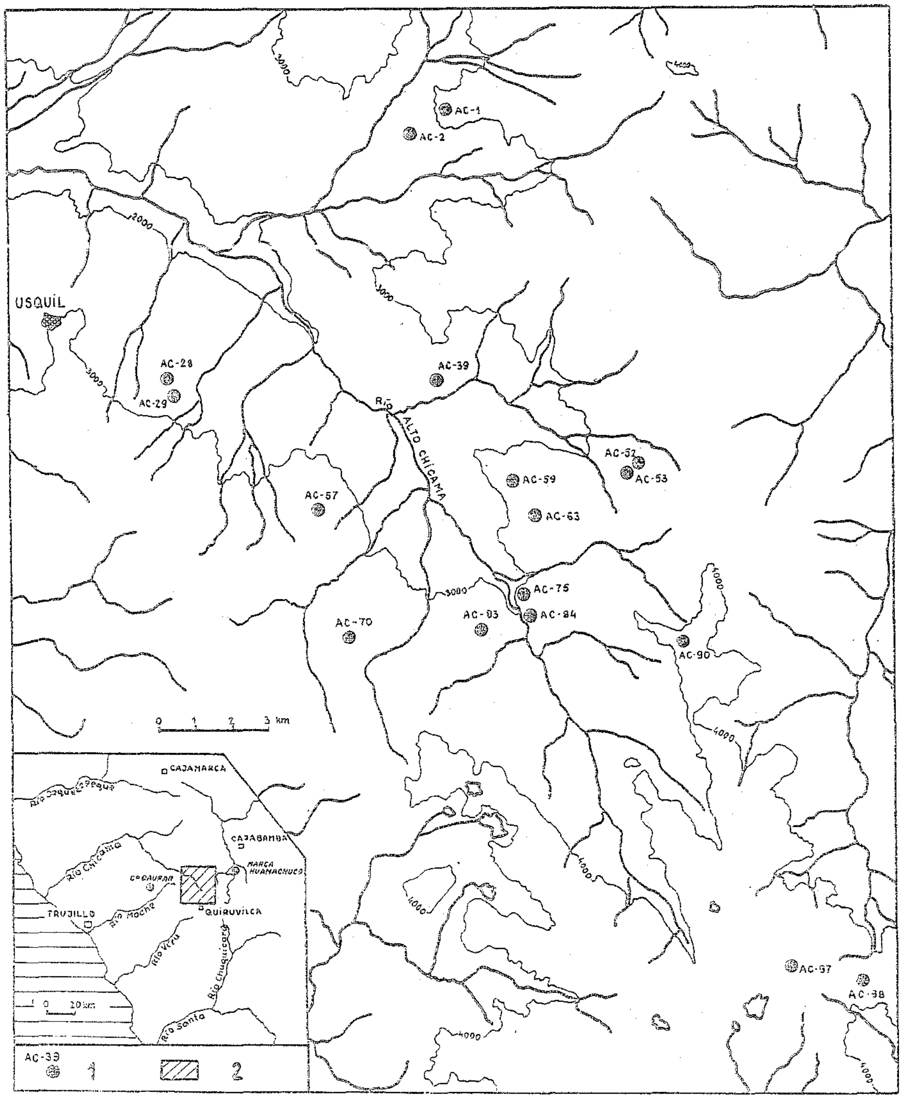

Fig. 1. Archaeological map of the Alto Chicama region
1 — archaeological site, *2* — area shown on a large-scale map

represent all types of ceramics known in the area studied, including both the most typical and doubtful varieties. Analysis was made on five main types of ornamented ceramics, i.e. Huamachuco Impressed, Huamachuco-on-White, Alto Chicama, Sausacocha and Cajamarca III [2]. Moreover, a few ornamented fragments belonging

[2] Further on the names of these types will be abbreviated: Huamachuco Impressed — HI, Huamachuco-on-White — HW, Alto Chicama — AC, Sausacocha — SA.

Table 1

Origin and classification of investigated ceramics

Petrographic group	Sample number	Ceramics type	Archaeological sites																		
			AC-1	AC-2	AC-28	AC-29	AC-39	AC-52	AC-53	AC-57	AC-59	AC-63	AC-70	AC-75	AC-83	AC-84	AC-90	AC-97	AC-99	Cerro Caupar	Marca Huamachuco
I-A	1	HI																		x	
	2	HI (?)	x																		
	3	HI									x										
	4	HI	x																		
	5	?									x										
	6	HI	x																		
	7	HI (?)									x										
	8	HI		x																	
	9	HI	x																		
I-B	10	HI																			x
	11	?																			x
	12	HI (?)									x										
	13	HI (?)													x						
	14	?															x				
	15	HI (?)														x					
I-C	16	HI					x														
	17	HI (?)								x											
II	18	HW																			x
	19	HW																			x
	20	HW																			x
	21	HW																	x		
	22	HW																	x		
	23	HW			x																
III-A	24	AC												x							
	25	black-on-ground											x								
	26	AC												x							
	27	AC										x									
III-B	28	SA																x			
	29	SA																x			
	30	Chimu					x														
	31	?															x				
	32	red wares					x														
	33	Chimu	x																		
	34	Chimu													x						
	35	SA						x													
	36	?							x												
	37	?									x										
	38	SA						x													
	39	?															x				
III-C	40	Caulimalca																			
	41	HI																			x
	42	red wares				x															
	43	red wares													x						
	44	?																			x
	45	AC												x							
IV	46	Cajamarca III																			x
	47	Cajamarca III																			x
	48	Cajamarca III																			x
	49	Cajamarca III				x															
	50	Cajamarca III	x																		
	51	Cajamarca III															x				
III-A	52	Chimu																			

Explanation: for the ceramics types the following abbreviations are used: HI — Huamachuco impressed, HW — Huamachuco-on-white, AC — Alto Chicama, SA — Sausacocha.

in other, less common types, as well as unornamented fragments representing some characteristic elements of the vessel morphology (rims, handles) were subjected to analysis. The primary aims of the studies were:

1) to define the petrographic types of the ceramics and correlate them with the archaeological types;

2) to determine the essential characteristics of the manufacturing process of the ceramics, such as the composition of the paste, the presence and kind of tempering material, firing conditions, the technique of shaping vessels, etc.;

3) to determine the kind and provenance of raw materials used for manufacturing the ceramics.

The archaeological knowledge about the North Peruvian Andes, particularly about the area from which the ceramics to be studied was derived, is very meagre. Everything we know about the archaeology of this area we owe to the investigations of H. and P. Reichlen and T. McCown carried out in the forties. It was not till the seventies that the finds of A. Krzanowski in the Alto Chicama region and those of A. Żaki [3] in the Upper Moche basin revealed the presence of several ceramic types and styles which had not been noticed or distinguished before. This was the case with the HI, HW, AC and SA ceramics. Although known for thirty years, these have only recently been defined, described and named by A. Krzanowski [4].

Ceramics of the Humachuco Impressed (HI) type was first discovered in 1900 by Max Uhle in Marca Huamachuco, but it was only in 1945 that it was published by T. McCown together with his own materials [5]. McCown, however, failed to distinguish this type from the whole assemblage of modelled or ornamented ceramics, treating it as one group. In this paper, the name HI refers only to a strictly defined kind of characteristically ornamented earthenware vessels.

The HI ceramics is commonly found at the archaeological sites in the Alto Chicama region, its clear and homogeneous features making this type readily distinguishable from all the others (fig. 2). It is represented by one kind of vessels: jars of various size, with an ovoidal or biconical body. They have a characteristic short neck and arch-like, strongly flared rims. The curve between neck and body is rounded or weakly marked. Occasionally small handles are placed symmetrically on the upper part of jar bodies. Sometimes the handles are of the lug type. Vessels of this type were unpainted and ornamented only with rows of circles impressed in fresh clay. This circle ornament was impressed round the throat or on the body, frequently not directly on the vessel surface but on a clay strip glued on for that purpose.

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[3] The rsults of those studies have not been published yet. Some general information is given in *Sprawozdania z posiedzeń Komisji Naukowych, PAN Oddział w Krakowie*, t. XVIII/2, 1974, XIX, 1975.

[4] A. Krzanowski, *Yuraccama. The Settlement Complex in the Alto Chicama Region* [in] *Polish Contributions in New World Archaeology*, Kraków 1977. A. Krzanowski, *Nuevos tipos de cerámica en la sierra norte del Perú (region Usquil-Quiruvilca-Humachuco)* in: Seminario Internacional "Andes 77", Warszawa 1978.

[5] T. McCown *Pre-Incaic Huamachuco. Survey and Excavations in the Region of Huamachuco and Cajabamba*, University of California Publications in American Archaeology and Ethnology, vol. 39, no 4, 1945.

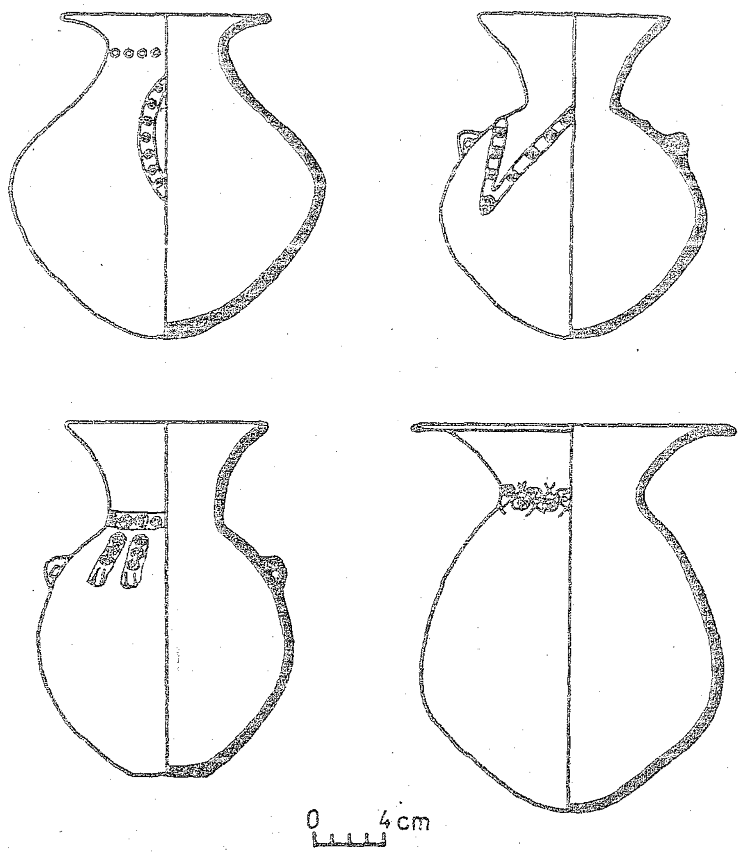

Fig. 2. Pottery of the Huamachuco-Impressed type

The ceramics in unevenly fired, its colour varying irregularly from nearly black to brick-red. The paste is of the same colours, but the outer surfaces of walls are frequently light whereas the interior is dark. This fact indicates that the pottery was fired in a not quite oxidizing atmosphere with non-uniform access of air, presumably in an open heap of fuel.

The HI ceramics is the dominant, and frequently the only type found at the majority of sites in the area studied. The determination of its age presents considerable difficulties as it can be dated only by correlation. Its co-occurrence with a few imports of the Chimu coastal ceramics seems to be indicative of the Late Period. McCown assings this ceramics to the Late Huamachuco phase [6], which, according to the recent chronological divisions, corresponds more or less to the Late Intermediate Period and Late Period (11th — 16th cent.). A more precise dating is not possible at the present state of knowledge.

[6] T. McCown, *op. cit.*, p. 337.

The Huamachuco-on-White (HW) ceramics has been found in Marca Huamachuco and some other sites in the Alto Chicama region. In all the known localities it co-occurs with the HI ceramics. McCown thought that the two types were contemporaneous and represented the Late Huamachuco phase [7]. Their relation, however, seems to be confined to the vicinity of Marca Huamachuco since in the regions of Alto Chicama and Upper Moche only the HI ceramics has been found at most sites. Moreover, if one could judge by certain stylistic similarities to the Huari ceramics, the HW type would be genetically related to the Middle Period, so it presumably dates from the close of that period or the beginning of the next (i.e. 10th — 12th cent.). This thesis does not discount the possibility that the two Huamachuco types were contemporaneous, but raises serious doubts as to their spatial and chronological relations.

A study of the fragments collected by A. Krzanowski, as well as the description given by McCown, has revealed that the HW ceramics is most characteristic in its ornamentation, having no equivalent in any other known type of ceramics. It is a newly named type in the Peruvian archaeology, comprising several types of ceramics distinguished by McCown, such as Black-and-Red-on-White, Red-on-White, etc. They are all characterized by patterns painted on white slip. It seems that McCown made arbitrary divisions basing on small pottery fragments and using the colour of the pattern as a criterion. Yet, it is feasible that black and red colours were used side by side, and the existence of one-coloured patterns can be accounted for by the fact that only fragments of vessels covered with a two-coloured pattern were available.

The characteristic feature of the HW ceramics is that it is covered with a uniform layer of white or cream slip on which a pattern in black (or dark-brow) and red (or brown-red) colours is not very carefully painted with thick lines. The most common pattern consitss of overlapping (sometimes double) circles with a dot in their centre (fig. 12). McCown found also fragments painted in spirals and strongly curled "S's". No whole vessel of this type or any characteristic fragment is available, allowing for at least partial reconstruction of the shape. The fragments of the body that have been found are usually thick (8—14 mm) and of inconsiderable curvature, which suggests that the vessels were fairly large. The ceramics is uniformly fired and has solid colour, the same on the surface and in croos-section, varying slightly from beige to orange.

The Alto Chicama (AC) ceramics is the third type of ornamented pottery, newly defined in the Peruvian archaeology. Its name originates from the Alto Chicama basin, where it was first collected from a few sites by A. Krzanowski. The AC ceramics has been reported so far only from that region. Since it co-occurs with the HI type, it presumably also dates from the late periods [8].

The AC vessels have a lip ornamented by pressing or incising (fig. 14: 24, 26, 27, 45). It is generally unpainted or exceptionally painted all over red. Two dominant

[7] T. McCown, *op. cit.* 337 p.

[8] A. Krzanowski (1978), *op. cit.*

forms of vessels have been found. One is represented by a pot with an orifice diameter of 22—28 cm, short neck and the curve between neck and body gently rounded or well marked. The rims are arch-like and turned out or straight. The other form is represented by wide bowls (20—28 cm in diameter) with arch-like rims, curved inwards (fig. 3). The vessels have walls ranging from 6 to 10 mm in thickness. The

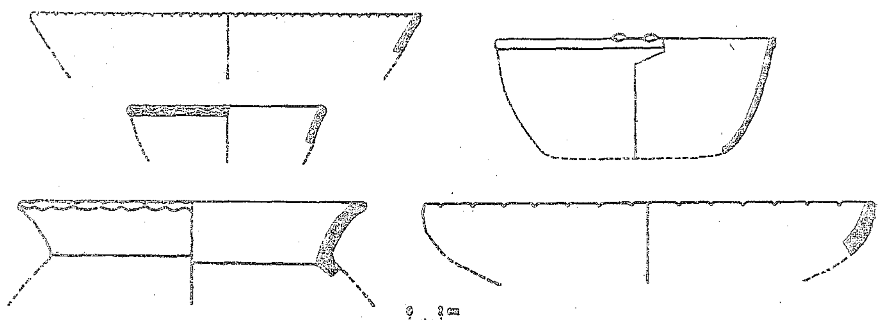

Fig. 3. Pottery of the Alto Chicama type (bottom) and Sausacocha type (top)

surface is roughly smoothed, usually light-beige, or occasionally brown-red or gray-brown in colour. The colour is the same or slightly darker in cross-section.

The Sausacocha (SA) ceramics was found for the first time by McCown at the sites near Huamachuco. The name, derived from Lake Sausacocha on the shores of which the sites with this ceramics were situated, was suggested by Lumbreras in his brief critical review of McCown's papers [9]. Lumbreras is of the opinion that the SA ceramics dates from the Early Period while McCown assings it to this Middle Huamachuco I phase, i. e. to the 7th—8th cent. [10] The dating of the SA ceramics is not certain because in all the sites investigated by McCown and Krzanowski it occurs as the only type, not accompanied by any diagnostic imports. Since not a single fragment of the Cajamarca ceramics from any phase has been found in the investigated sites, it can be presumed that the SA type represents the ceramics dating from the period preceeding the Cajamarca I. This means that the SA ceramics dates from the Early Period or the beginning of the Early Intermediate Period.

In the SA ceramics the lip was ornamented using various techniques. Generally, a zig-zag clay strip was added at the lip, or the lip was incised as in the Alto Chicama type. The lip may also have been jabbed with a blunt tool that left depressions on it. Moreover, some vessels have small knobs placed in pairs on the lip, opposite one another (fig. 16). The ceramics is unpainted, but occasionally traces of red paint are visible. The vessels are characteristically thin-walled (3—5 mm) with the surface carefully polished. They are brown or yellow-brown, sometimes dark-brown in colour, being of the same colour or darker in cross-section. The type in question

[9] G. Lumbreras, *Algunos problemas de arqueología peruana* [in:] *Antiguo Perú. Espacio y tiempo*, Lima 1960, p. 136.

[10] T. McCown, *op. cit.*, p. 340.

is represented presumbaly by no other pottery but shallow bowls with slightly flared rims of a diameter varying from 10 to 24 cm (fig. 3).

The last type studied is Cajamarca III. As this ceramics is well known in the Peruvian archaeology, no detailed description will be given here. It is widespread mainly in the North Andes, but has also been found in the Central Andes and on the coast. H. and P. Reichlen, who carried out archaeological research in the Cajamarca region, were the first to give a detailed description of this ceramics and to date it to the Middle Period (6th — 9th cent.)[11]. The ware of the Cajamarca culture exhibits very characteristic features, and phase III can be easily distinguished due to stylistic purity of forms and patterns, which have been markedly changed in a later period by introduction of some elements of the Huari culture. The Cajamarca III pots have most frequently the form of thin-walled tripod vessels or bolws on a ring base (fig. 4). Red or black patterns are painted on the light-oragne-or cream-

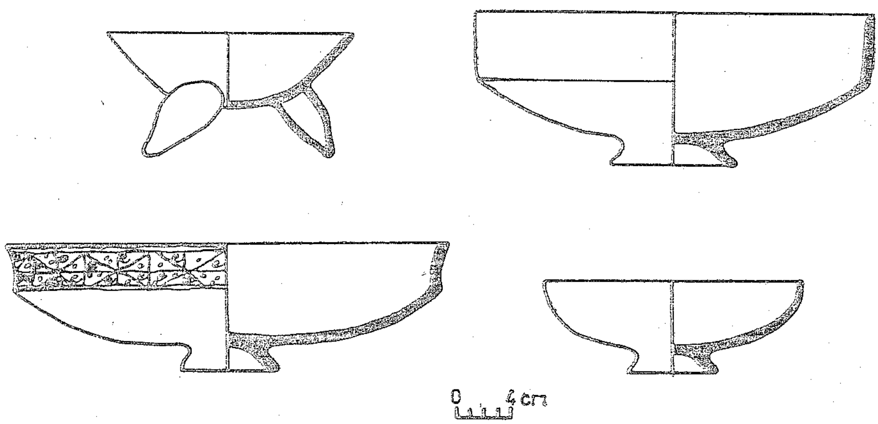

Fig. 4. Pottery of the Cajamarca III type

-slipped surface. The typical motifs are lines, zigzags, spiral curves, stylized figures of men and animals. The pattern is small, abounding in details. It is painted with a thin brush, rather carelessly, as if in a hurry. This very "busy" cluttered appearance gave rise to the term "cursive" style, commonly used in the Anglo-American literature. The paste is hard, fine-grained, whitish or cream-coloured. It is well and uniformly fired.

Although petrographic studies of the Peruvian ceramics have a tradition of nearly a hundred years standing, their results can be summarized in a few sentences. Their precursor was undoubtedly A. Bamps, who at the Congress of Americanists in 1883 demonstrated the utility of microscopic studies with particular reference to Peruvian ceramics[12]. Linné's monographic study, which is the only publication

[11] H. Reichlen P. Reichlen, *Recherches Archéologiques dans les Andes de Cajamarca*, "Journal de la Société des Américanistes, N. S." 1949, vol. XXXVIII, 1949.

[12] A. Bamps, *La céramique americaine au point de vue des éléments constitutifs de sa pâté...*, Internacional Congrés des Américanistes, Copenhagen 1884.

of that type for South America, gives very little information regarding the archaeological Peruvian ceramics. Linné publishes only two microscopic analyses (the Lambayeque and Nazca ceramics) yielding qualitative data [13].

Recently, a few attempts at petrographic analysis of the Peruvian ceramics have been made. The results of 11 analyses of the Huarpa ceramics from central Peru have been published by Benavides [14], who fails, however, to give the percentage of individual components, confining himself to dubious estimates (much, little, traces, etc.).

The ceramic material from Cuzco, collected by a Spanish archeological expedition, was also subjected to petrographic analysis. A relatively large number of pottery fragments (33) were investigated, but only qualitative data were given. Since the ceramics studied shows relatively little petrographic differentiation, the usefulness of such incomplete analysis in questionable. It seems that its authors were keen on using special laboratory equipment rather than on obtaining data really useful for the archaeologist [15]. Basing only on microscopic studies [16], A. Krzanowski made recently petrographic analysis for some types of ceramics (mainly San Blas and Quillahuaca) from the Upper Huaura region. The qualitative and quantitative analysis carried out on 17 samples was in some respects (e. g. grain size) more thorough than that performed in this paper.

Since technological investigations of ceramics usually appear as appendices or supplements to archeological reports, it is conceivable that some other petrographic analyses of the Peruvian ceramics failed to be noted. Nevertheless, of those available, the studies of Bamps and Linné are only of historical value whereas the others give a faint idea of the possibilities inherent in petrographic analysis.

We presume that the present paper is the most comprehensive study available dealing with the petrographic aspect of the Peruvian ceramics. To determine the composition of the paste and to define petrographic groups, the ceramics was subjected to microscopic, X-ray and thermal analyses. The investigations were focused on determining the nature of nonplastic admixture as detailed studies of clay minerals would require the use of complex methods which cannot guarantee that diagnostic data would be obtained for the ceramics [17].

Microscopic examinations were carried out on thin sections cut out perpendicular to the walls of vessel fragments, i.e. in their cross-sectional plane. Wherever possible, the cutting was situated in the plane normal to the plane of orifice and passing at the same time through the vertical axis of the vessel. The thin sections thus obtained were oriented identically to the form of vessels, due to which compa-

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[13] S. Linné, *The Technique of South American Ceramics*, Göteborg 1925, pp. 64 and 68.

[14] M. Benavides Calle, *Analisis de la ceramica Huarpa*, Revista del Museo Nacional, Lima 1971, vol. XXXVII.

[15] J. R. Galván García, E. Sánchez Montañés, *Aplicación de las técnicas de microscopia electrónica y difracción de rayos X al estudio de céramicas arqueológicas (peruanas)*, Atti del XL Congresso Internazionale degli Americanisti, Roma-Genova 1972, vol. II.

[16] A. Krzanowski, *Archaeological Investigations in the Upper Huaura Basin Peru (Part II)*, "Acta Archaeologica Carpathica", 1978, vol. XVIII.

[17] A. Shepard, *Ceramics for the Archaeologist*, Washington 1974, p. 147.

risons could be made, particularly those regarding the texture. Planimetric measurements were made, counting about a hundred grains at a time and expressing the results in round percentages by volume. Moreover, the diameter of individual grains making up the paste was measured. The investigations were made with a Polmi A polarizing microscope.

X-ray analysis was carried out in the TUR-61 diffractometer on samples ground in an agate mortar, using Fe-filtered CoK_α radiation. X-ray diffraction patterns were taken in the range 5—25°, having ascertained that reflections characteristic of the minerals of the montmorillonite, chlorite and vermiculite group were absent. Instrument setting used were: scanning speed 2°/min., chart speed 600 mm/hr, time constant 1, slits 0·6/1·2. The results were interpreted using Micheev's catalogue [18].

Thermal analysis was made with an E. Paulik, J. Paulik, L. Erday derivatograph (Hungary). The measurements parameters were: weighed portions 600 mg, heating rate 12°/min., sensitivity: DTG — 1/30, DTA — 1/3, TG — 100, temperature range: room temperature — 1000° C. Minerals were identified by comparing the results with the data of Ivanova [19].

The analyses allowed for assigning all the specimens to four distinctive petrographic groups, two of which were further divided into subgroups.

Petrographic group I. The ceramics belonging in this group can be divided into three subgroups differing in the mineralogical composition, specifically in the proportions between individual components (mainly talc shales and quartz). The group comprises 17 specimens in all, most of which (9) were assigned to subgroup I-A.

Subgroup I-A. Microscopic studies have revealed that the ceramics groundmass [20], making up 40—52 vol.% (Table 2), consists of thermally changed clay minerals. That the groundmass is changed to varying degrees is evidenced by different extinction of polarized light. The clay minerals are generally intensely sintered; consequently, the determination of the grain-size distribution presents considerable difficulties. Specimens 3 and 7 show slight vitrification of the groundmass, seen in polarized light.

In all the specimens the tempering admixture consists of fragments of rocks of talc shale type (35—50%). They represent mudstone of obscure origin indurated during diagenesis, exhibiting a distinct parallel structure. Besides talc, the shales contain varying amounts of opaque minerals which accentuate the linearity of the structure (fig. 5). The presence of talc has been confirmed by X-ray analysis (fig. 6, curve I-A/4), and the reflections d_{hkl} = 4·68, 3·47, 3·11, 2·46, 2·30 Å, characteristic of this mineral, can be observed in X-ray diffraction patterns. The size of rock fragments is variable, ranging from 0·8 to 1·8 mm. The fragments are angular,

[18] В. И. Михеев, *Рентгенометрический определитель минералов*, Москва 1957.

[19] В. П. Иванова, *Термограмы минералов*, Москва 1961.

[20] The "groundmass" is understood to mean thermally changed clay minerals which exhibit isotropy under the microscope but fail to yield d_{hkl} reflections in X-ray diffraction patterns, producing only a raised background in the region between 6—9.5 Co K_α.

Table 2

Mineral composition and granulation of the subgroup I-A ceramics

Components \ Sample number	1		2		3		4		5		6		7		8		9	
	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%
Groundmass	—	52	—	50	—	45	—	45	—	45	—	42	—	40	—	52	—	47
Fragments of shale rocks	1·80	38	1·80	40	0·90	50	1·06	45	1·05	42	1·20	43	1·25	45	0·80	35	1·35	35
Quartz	0·30	3	0·30	5	0·30	2	0·30	7	0·70	8	0·20	6	0·30	9	0·04	3	0·30	2
Plagioclases	0·10	1	—	—	—	—	—	—	—	—	—	—	—	—	0·07	2	0·10	2
Opaque minerals	0·35	5	0·30	4	0·45	3	0·15	2	0·30	3	0·20	8	0·15	5	0·09	8	0·30	5
Heavy minerals	0·09	1	0·09	1	—	—	0·07	1	0·15	2	0·15	1	0·15	1	—	—	0·08	1

Explanation: within all tables, the columns denoted φ include the maximum grain size in mm, and the columns denoted % include the component contets in volume percents.

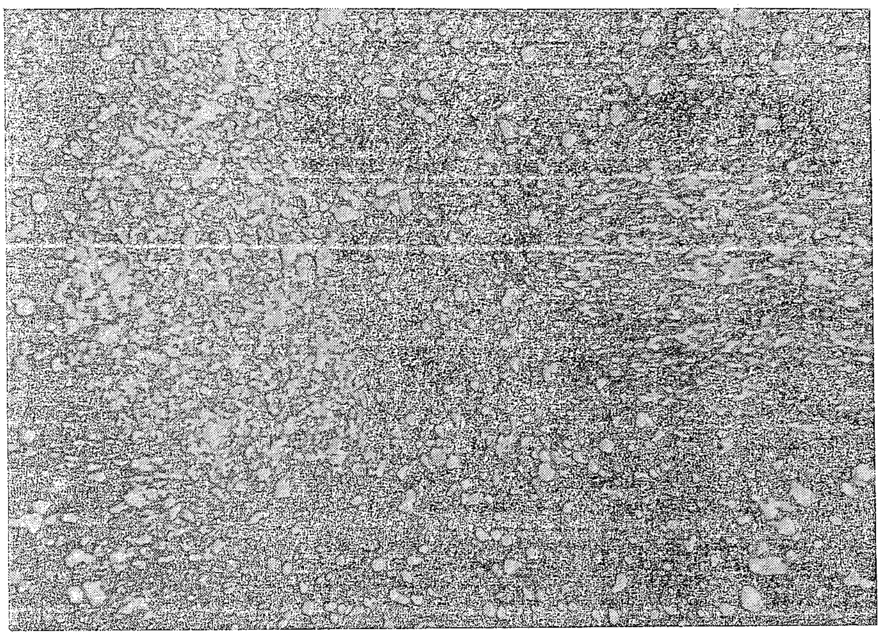

Fig. 5. Fragments of talc shales used as tempering admixture and fine quartz grains in the isotropic groundmass. Sample 3, petrographic subgroup I-A. Crossed nicols, 85 x

and their shape and mode of occurrence testify to pre-crushing of the tempering material. Quartz appears in an amount of 2—9 vol.%. Its grains are sub-rounded and pure, their maximum size rarely amounting to 0·7 mm (Table 2, sample 5). Plagioclases of the albite-oligoclase group occur sporadically and in small amounts (up to 2 vol.%), while the content of opaque minerals is fairly high (up to 8 vol.%) (Table 2, samples 6 and 8). They are represented mainly by hydrated iron minerals, among which goethite and haematite have been identified. In the group of opaque components, single fragments of coalified plants have also been detected. Heavy minerals, such as garnet, staurolite and, sporadically, zircon, are present in trace amounts. Moreover, single grains of amphiboles have been found.

From the archaeological point of view, this group shows typological homogeneity. Six specimens are undisputable fragments of characteristically decorated vessels of the HI type (fig. 7). Two lip fragments (2 and 7) exhibit morphological features that allow for assigning them with a good deal of probability to the same type. A shallow unornamented bowl (5) represents a group of vessels of undefined typological assignation, found at nearly all the archaeological sites.

Petrographic subgroup I-B. As in subgroup I-A, the dominant component of the ceramics is fragments of talc shales, making up 24—42 vol.% of the paste (Table 3). The rock fragments are usually angular or sub-rounded and contain, besides talc, a small amount of fine-flake clay minerals showing marked thermal

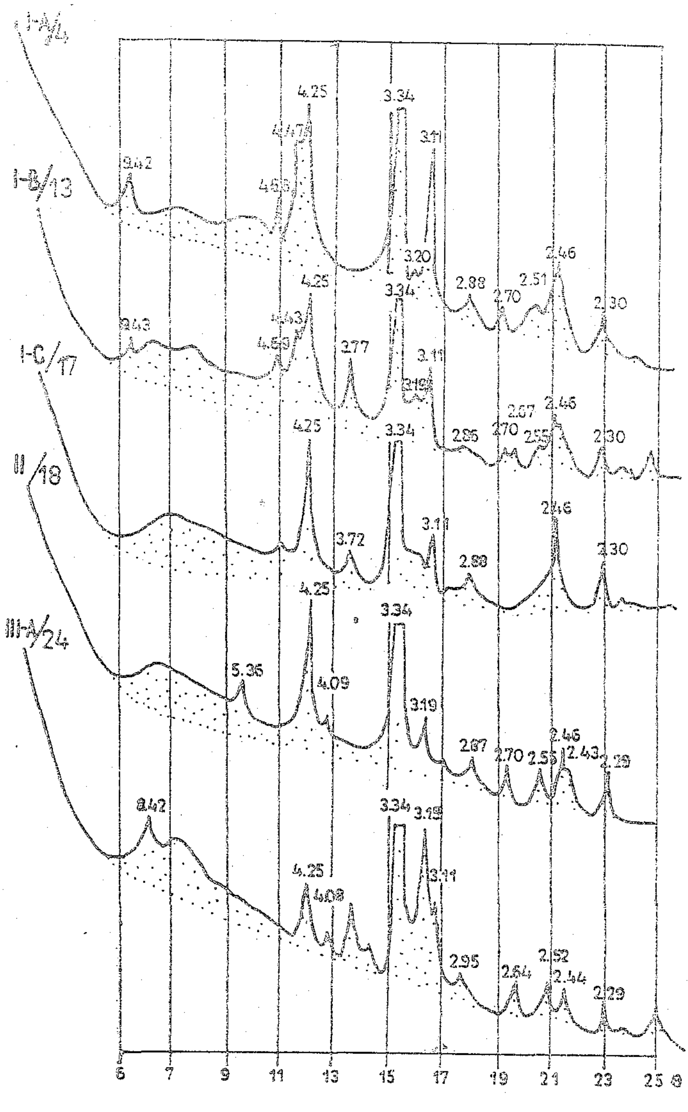

Fig. 6. X-ray diffraction patterns of the ceramics studied. Petrographic group and sample number are given beside the plots

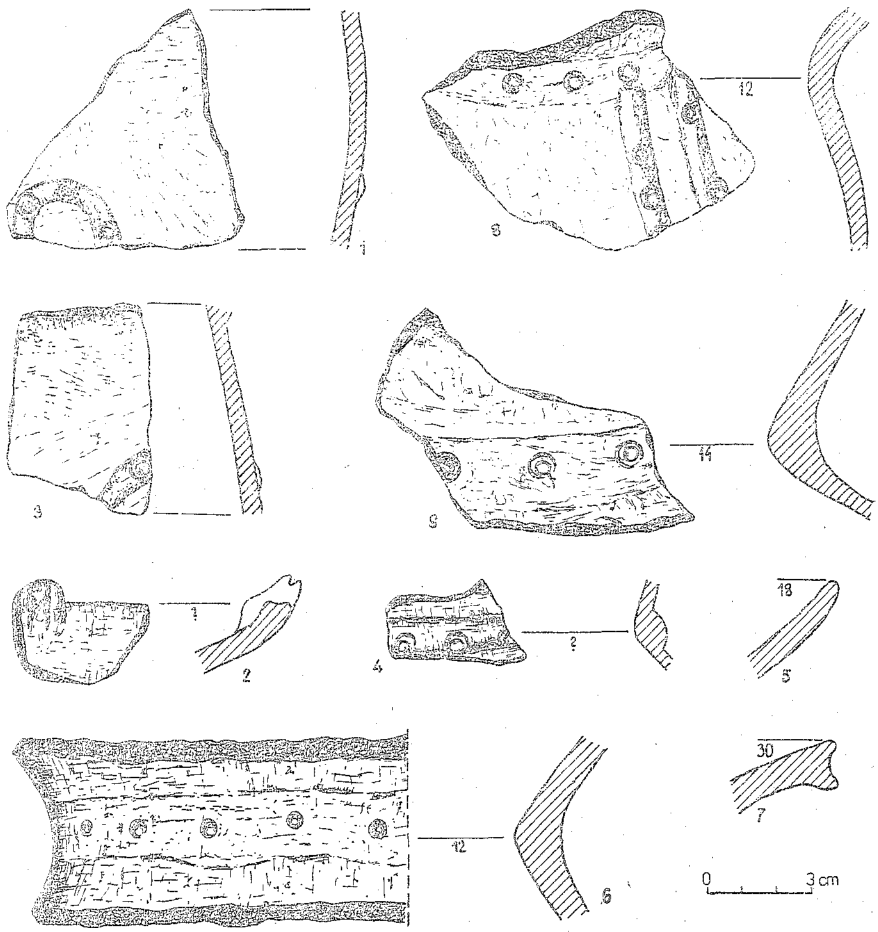

Fig. 7. Ceramics of petrographic subgroup I-A

Table 3

Mineral composition and granulation of the subgroup I-B ceramics

Sample number / Components	10		11		12		13		14		15	
	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%
Groundmass	—	45	—	40	—	45	—	43	—	48	—	57
Fragments of shale rocks	1·10	35	1·10	36	1·50	40	1·40	42	1·35	35	0·90	24
Quartz	0·15	14	0·10	10	0·15	11	0·30	10	0·45	13	0·35	14
Plagioclases	0·10	1	0·15	4	—	—	—	—	—	—	—	—
Opaque minerals	0·08	4	0·15	6	0·40	4	0·30	4	0·10	3	0·25	4
Biotite	—	—	0·07	4	—	—	—	—	—	—	—	—
Heavy minerals	—	—	—	—	—	—	0·06	1	0·08	1	0·07	1

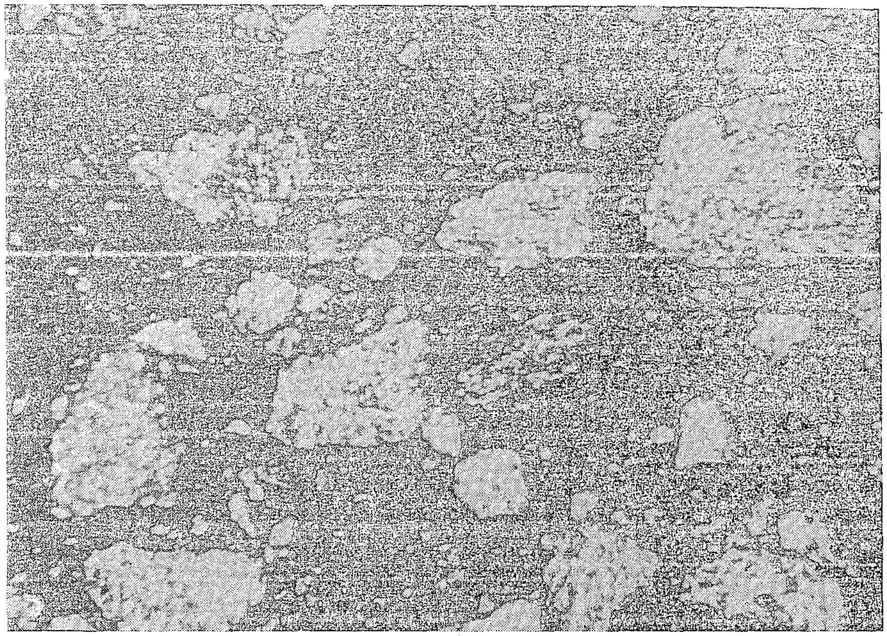

Fig. 8. Talc shale fragments and quartz and plagioclase grains uniformly distributed through the thermally changed clay groundmass. Sample 10, petrographic subgroup I-B. Crosseed nicols, 85 x

changes, as well as opaque minerals. Shale varieties with quartz grains have also been noted. Those rock fragments, up to 1·5 mm in size (Table 3, fig. 8), are, as a rule, uniformly distributed throughout the paste. The ceramics of this group contains a little more quartz — up to 14 vol.% of the material studied. Quartz grains are generally angular or sub-rounded, pure, without gas-liquid inclusions. Grains extinguishing normally are prevalent, and only single grains show wavy or mosaic extinction. This indicates that they have formed under the conditions of tectonic pressure. In specimens 14 and 15, fragments of medium-and fine-grained quartzose sandstones with basal cement have been found. Moreover, the ceramics contains variable amounts of opaque minerals which make up 3—6 vol.% of the material. Two specimens have also been found to contain a small amount of plagioclases (up to 4 vol.%).

From X-ray diffraction analysis (fig. 6, curve I-B/13) it appears that the mineralogical composition of the ceramics of this subgroup does not differ essentially from that of subgroup I-A. However, the content of talc is lower, which is evidenced by the reduced intensity of the basal talc reflection 3·11 Å. Moreover, quartz reflections of higher intensity appear in X-ray diffractograms. The presence of plagioclases has been confirmed by the reflection $d_{hkl} = 3{\cdot}19$ Å, characteristic of the acid plagioclase member. From the DTA curve (fig. 9, curve I-B/11) it is evident that the ceramics contains a small amount of pore water, as well as quartz yielding a weak endothermic peak at about 560° C. Further, small amounts of heavy minerals,

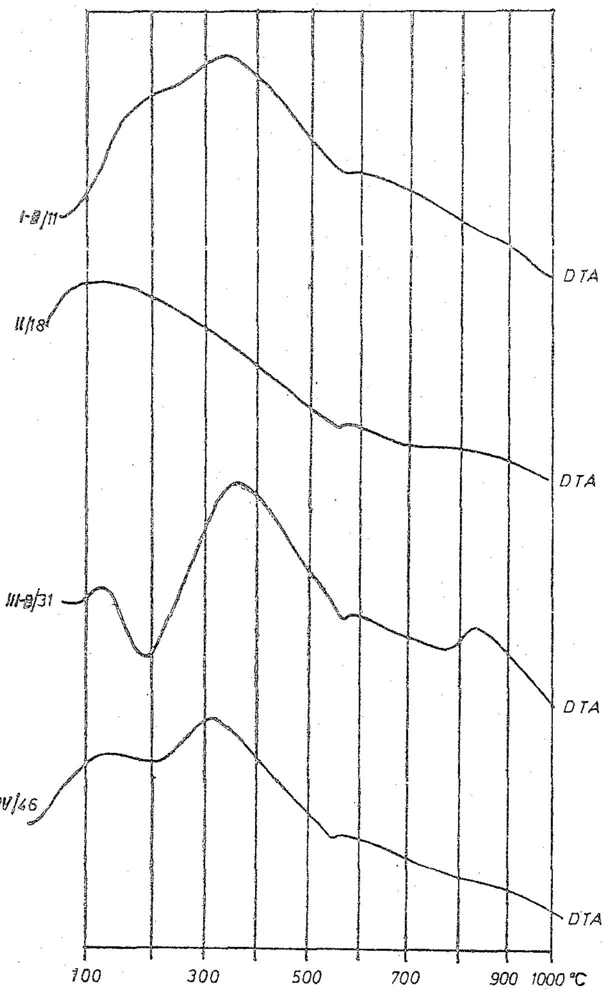

Fig. 9. DTA curves of the ceramics studied. Petrographic group and sample number are given beside the plots

such as garnet and staurolite, have been noted in this subgrup. Sample 11 has also been found to contain about 4 vol.% of well preserved biotite plates.

Archaeologically, four fragments (10, 12, 13 and 15) can be assigned to the HI type, although only one of them (10) is decorated with a typical pattern (fig. 10). Of two bowl fragments, one (11) shows close similarity to the type described by McCown as "bucchero".

Petrographic subgroup I-C. Specimens 16 and 17 were assigned to this subgroup. Their mineralogical composition differs slightly from that of the two subgroups discussed though here, too, fragments of talc shales are the most typical component (up to 20 vol.%). The ceramics also contains sharp-edged fragments

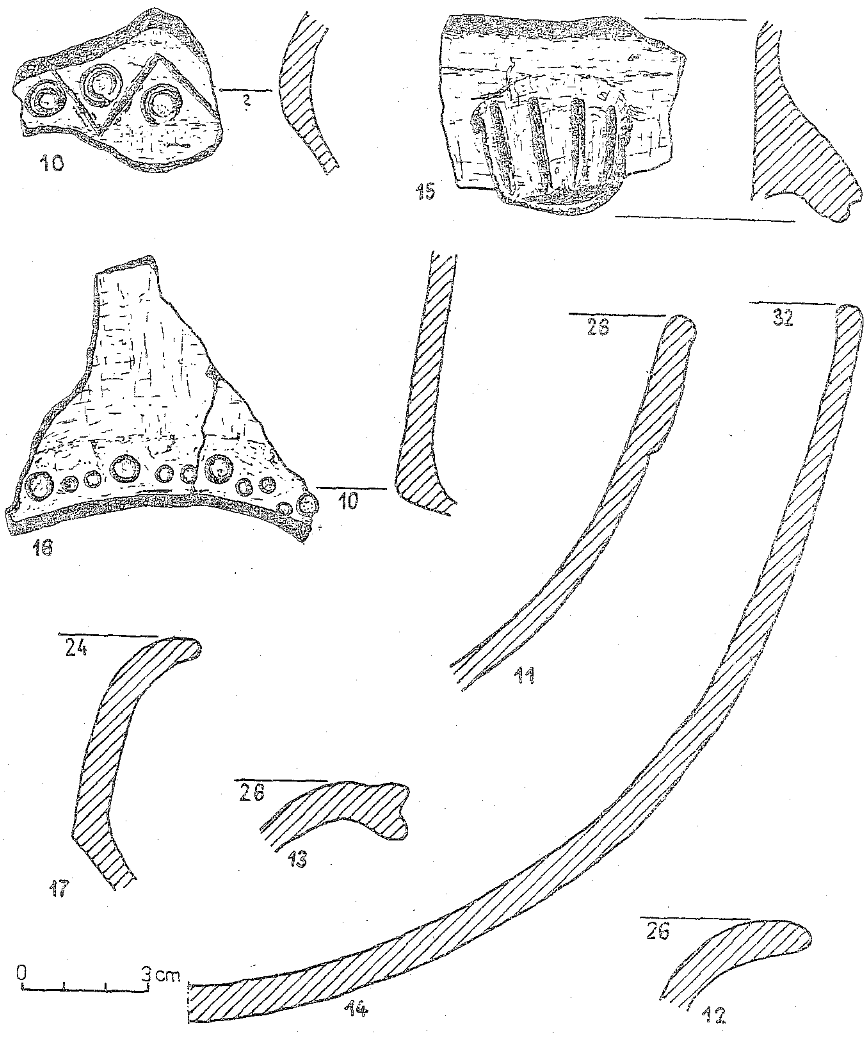

Fig. 10. Ceramics of petrographic subgroups I-B (10—15) and I-C (16—17)

of igneous rocks, rhyolites (Table 4), their amount not exceeding 3 vol.%. The rhyolites are fine-crystalline, with larger (up to 0·25 mm) single crystals of plagioclases of the albite group.

Both specimens have a quartz content of 32 vol.%. Quartz grains are pure, free of inclusions, showing a high degree of rounding. Both quartz and plagioclases are non-uniformly distributed through the groundmass made up of thermally changed clay minerals. Plagioclase and quartz grains are similar in size, attaining 0·3 mm. Opaque minerals, constituting about 5 vol.% of the paste (Table 4), appear as pigment and only occasionally grains up to 0·2 mm in size are present.

X-ray investigtions have confirmed the results of microscopic studies (fig. 6, curve I-C/17). As appears from the X-ray diffraction pattern, the principal components of the ceramics are quartz and a small amount of plagioclases. The presence of an insignificant amount of talc shales is borne out by the reflection 3·11 Å. It is worth noting, however, that its intensity is considerably lower than that of talc reflections recorded for the ceramics of subgroups I-A and I-B.

Table 4

Mineral composition and granulation of the subgroup I-C ceramics

Sample number / Components	16		17	
	φ	%	φ	%
Groundmass	—	42	—	40
Fragments of shale rocks	0·90	13	1·00	20
Fragments of igneous rocks	0·40	3	0·45	2
Quartz	0·30	32	0·20	32
Plagioclases	0·25	4	0·15	3
Opaque minerals	0·20	5	0·15	3
Heavy minerals	0·08	1	—	—

Both sherds assigned to this subgroup belong to the HI type (fig. 10). One (16) is a typically decorated fragment of the body, the other (17) is a rim fragment of a vessel shaped like the HI pottery.

The characteristics of the ceramics of petrographic group I. A characteristic feature of the ceramics in question is the presence of well preserved angular fragments of talc shales. The rock in the form of breakstone was added to the clay material as a tempering admixture, in an amount averaging 33 vol. %. The basic material generally contained a small, but widely varying, amount of quartz and plagioclases. The clay also contained a varying amount of iron of obscure primary form (Fe^{2+} or Fe^{3+}). Today only Fe^{3+} minerals are present in the ceramics, which is due both to the firing process and the subsequent lying of the pottery in the oxidation zone. The mode of occurrence of the components indicates that they were thoroughly mixed during the shaping of pottery. The absence of kaolinite, a mineral disintegrating at 560° C [21], suggests that a higher firing temperature was attained. It could have been as high as 980° C, but presumably did not exceed 700° C. This statement is borne out by a not very high degree of vitrification of clay minerals and by single mullite reflections recorded in X-ray diffraction patterns.

Petrographic group II. The ceramics belonging in this group shows a homogenous petrographic character. Its distinctive feature is the specific distribution of Fe^{3+} minerals (fig. 11) appearing in the form of streaks and aggregates, which indicates that they are presumably associated with the clay material. Alongside

[21] L. Stoch, Minerały ilaste, [*Clay Minerals*], Warszawa 1974.

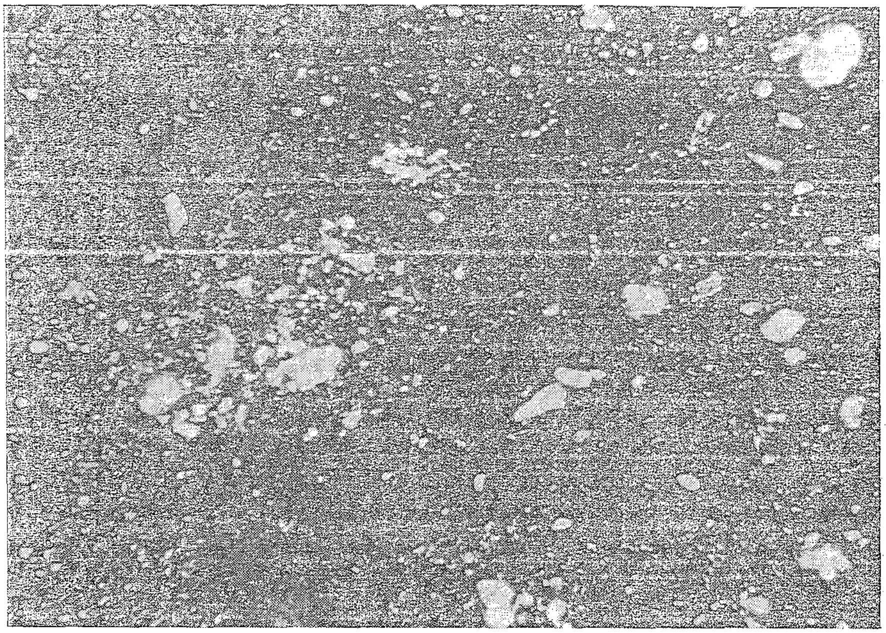

Fig. 11. Quartz, plagioclases and streaks or concentrations of opaque minerals, coexisting with fine rock fragments. Sample 20, petrographic group II. Crossed nicols, 85 x

of iron minerals, rock fragments, quartz, feldspars, biotite and heavy minerals are embedded in the thermally changed groundmass. The tempering admixture generally consists of sub-rounded or angular quartz grains and rock fragments. The latter are up to 1·85 mm in size (Table 5) and are represented by extrusive rocks and glass. They contain varying amounts of opaque minerals, as well as phenocrysts of acid plagioclases. Occasionally, fragments of igneous rocks can be found in the ceramics, yet they are unidentifiable due to a considerable degree of alteration [22]. Exceptionally, fragments of fine-grained sandstones showing a high degree of sorting are present in the ceramics. They contain mainly quartz and a small amount of altered clay minerals which assume in places the role of basal cement. Quartz is of variable grain size (from 1·05 to 0·07 mm). Its grains are pure, sharp-edged and uniformly distributed throughout the paste. Plagioclases occur in an amount up to 5 vol.%. Their grain size and the degree of rounding suggest that they were the original components of the clay and were not used as a tempering material. Potash feldspars, represented by orthoclase, are uncommon in the ceramics. They have been found only in sample 20 (Table 5). Biotite and heavy minerals are the accessory components of the ceramics. Among the latter, besides zircon, amphiboles have been identified, showing an angle of extinction $z/\gamma \approx 18°$, which is close to that of hornblende.

[22] In Table 5 the content of igneous rocks is given together with glass and volcanic rocks.

Table 5

Mineral composition and granulation of the group II ceramics

Sample number / Components	18		19		20		21		22		23	
	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%
Groundmass	—	65	—	59	—	50	—	53	—	57	—	65
Fragments of igneous rocks	1·00	11	1·85	10	0·95	15	0·90	22	0·95	32	0·95	20
Fragments of sandstones	1·20	12	0·95	10	0·70	10	—	—	0·75	2	1·10	7
Quartz	0·30	3	0·70	15	0·30	15	0·45	17	1·05	5	0·07	3
Plagioclases	0·35	5	0·04	1	0·30	4	—	—	—	—	—	—
Feldspars	—	—	—	—	0·15	1	—	—	—	—	—	—
Opaque minerals	0·15	3	0·20	4	0·35	4	0·30	8	0·30	4	0·25	5
Biotite	—	—	—	—	0·15	1	—	—	—	—	—	—
Heavy minerals	0·02	1	0·04	1	—	—	—	—	—	—	—	—

X-ray diffraction analysis (fig. 6, curve II/18) has revealed the presence of quartz, as well as mullite reflections 5·36, 3·71, 3·19, 2·89, 2·70, 2·55 Å. The values of interlayer spacings deviating slightly from those given in Micheev's catalogue [23] testify to the low degree of ordering of the structure of mullite, suggesting a firing temperature lower than 980° C. The grains of this mineral are submicroscopic. The reflection 3·19 Å confirms the presence of acid plagioclases whereas the raised background in the range 8·5—5·0 Å testifies to weak vitrification of the clay groundmass.

Thermal analysis has revealed poor thermal activity of the ceramics during its heating (fig. 9, curve II/18). The DTA curve shows only a faint endothermic peak at about 560° C, due to polymorphic transformation of quartz. Simultaneously, from the TG curve it appears that when heated to 1000° C, the ceramics shows a 1% weight loss.

Due to the characteristic mode of occurrence of opaque minerals (mainly haematite, accessory goethite), petrographic determination of the ceramics of group II presents no difficulties. Although its mineralogical composition is variable, it has a relatively low content of tempering material (28 vol.% on the average). The variability of the tempering admixture points to different sources, including both igneous and sedimentary rocks. The clay material required relatively little tempering because alongside of clay minerals, most likely of the kaolinite group, it contained quartz and plagioclase grains. It presumably also contained iron minerals. From the distribution of the compontents in the ceramics it may be inferred that the raw materials were not very thoroughly mixed. The firing temperature was certainly more than 560° C, which is evidenced by the absence of kaolinite. The formation of mullite, detected by X-ray method, suggests a temperature of the order of 800—900° C, this range being also indicated by the presence of vitrified groundmass.

From the archaeological point of view, the ceramics belonging in this group is homogeneous. The five fragments come from typically decorated bodies of the HW-type vessels.

[23] В. И. Михеев, *op. cit*

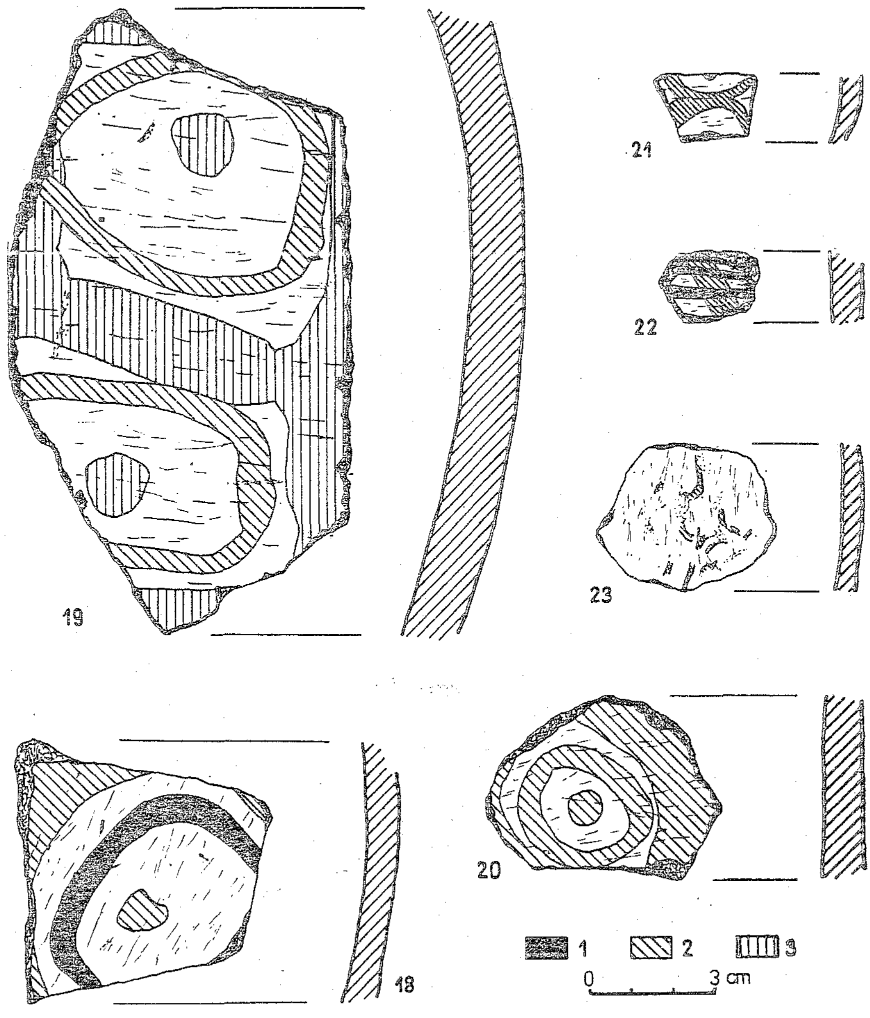

Fig. 12. Ceramics of petrographic group II
1 — black, *2* — red, *3* — brown

Petrographic group III. Three subgroups have been distinguished, differing slightly in mineralogical composition.

Petrographic subgroup III-A. Four fragments of vessels (Nos. 24—27) have been assigned to this subgroup. In this ceramics the dominant constituent (up to 75 vol. %) is the groundmass made up of isotropic slightly vitrified and thermally changed clay minerals (Table 6). Quartz appers in the form of large, pure and angular grains up to 1·3 mm in size. Both quartz and the other components are, as a rule, uniformly distributed throughout the paste. Some quartz grains have been found to contain gas-liquid and rutile inclusions. Plagioclase grains are equally large (up to 1·05 mm) and sharp-edged (fig. 13). Their identification from the angle of extinction indicates that they represent mainly oligoclase and exceptionally andesine. They exhibit mainly albite, occasionally periclinal or Baveno twinning. The plagioclases are well preserved, which testifies to the freshness of rock used for tempering the clay. Some grains show a thick-zonal structure. Opaque minerals making up the pigment of the ceramics are fine-grained, being not more than 0·35 mm in diameter. They are mainly goethite and haemetite. Heavy minerals are represented by single grains of amphiboles.

Table 6

Mineral composition and granulation of the subgroup III-A ceramics

Sample number / Components	24		25		26		27	
	φ	%	φ	%	φ	%	φ	%
Groundmass	—	64	—	52	—	75	—	75
Quartz	1·30	10	0·55	17	0·60	10	0·60	13
Plagioclases	1·05	20	0·60	17	0·55	11	0·55	8
Opaque minerals	0·20	4	0·35	13	0·25	3	0·25	3
Heavy minerals	0·40	2	0·10	1	0·08	1	0·08	1

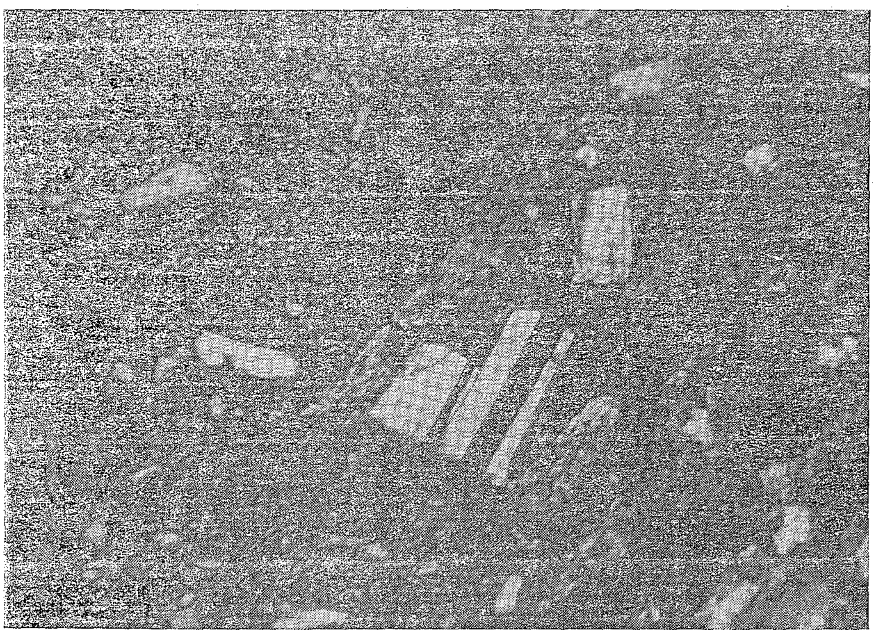

Fig. 13. Plagioclases of the oligoclase-andesine group and quartz grains embedded in the thermally changed clay groundmass. Sample 25, petrographic subgroup III-A. Crosed nicols, 80 x

From X-ray diffraction patterns (fig. 5, curve III-A/24) it is evident that the principal components of the ceramics are thermally changed clay minerals, quartz and plagioclases. The presence of slightly vitrified grounmass is evidenced by the background being raised in the region between 9 and 5 Å. The reflection 8·42 Å testifies to the presence of amphiboles.

Three of the fragments belonging in this petrographic subgroup are lips assigned to the archaeological type AC. The fourth is a body fragment painted in black strips (25) and represents the uncommon Black-on-Ground type (fig. 14).

Petrographic subgroup III-B. This subgropus is most amply represented since 12 specimens (Nos. 29—39) have been assigned to it. Besides the thermally

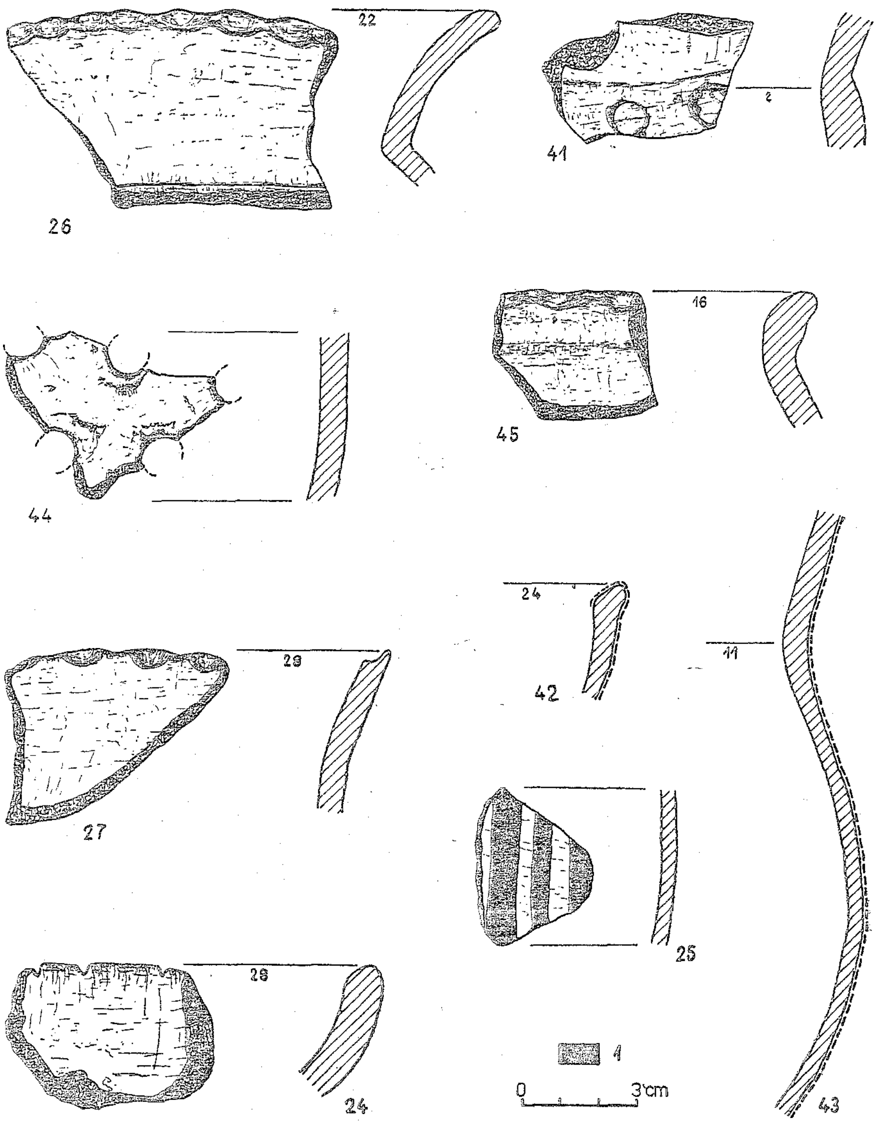

Fig. 14. Ceramics of petrographic subgroups III-A (24—27) and III-C(41—45)

1 — black; dashed line marks the axtent of painting in red

Mineral composition and granulation

Components \ Sample number	28		29		30		31	
	φ	%	φ	%	φ	%	φ	%
Groundmass	—	57	—	55	—	50	—	56
Fragments of the igneous rock	0·06	10	0·55	12	0·65	30	1·20	23
Fragments of the sedimentary rocks	—	—	—	—	—	—	0·10	2
Quartz	0·30	15	0·65	15	0·30	11	0·40	10
Plagioclases	0·65	15	0·20	14	0·30	2	0·30	4
Feldspars	—	—	—	—	—	—	0·15	2
Opaque minerals	0·10	2	0·10	3	0·60	5	0·15	2
Biotite	0·80	1	0·10	1	0·15	1	—	—
Heavy minerals	—	—	—	—	0·10	1	0·80	1

changed clay groundmass, the main and distinctive constituent of this ceramics are fragments of igneous rocks. Moreover, quartz, plagioclases, opaque and heavy minerals, potash feldspars and biotite have been identified (Table 7). The rock fragments are predominantly fine-crystalline and angular, making up 30 vol.% of the ceramics. They have been defined as rhyolite and dacite. They are not more than 1·2 mm in diameter, and their angular outlines imply they were added as a tempering material to the paste. Single larger (up to 0·2 mm) phenocrysts of plagioclases, frequently exhibiting a zonal structure, are embedded in the fine--crystalline matrix of these rocks. Plagioclases also occur independently as albite or, occasionally, as oligoclase in the changed groundmass of the ceramics, but in that case they are up to 0·65 mm in size. Considering the degree of roundness and their petrographic nature, plagioclases can be regarded as the tempering material in the majority of specimens. Potash felspars, making up 5 vol.% of the paste, are represented only by sharp-edged grains of orthoclase. In some cases, quartz is also to be treated as the tempering material which seems to have been added together with plagioclases, the proportions between these constituents varying over a wide range. In the pottery fragments numbered 28, 29, 30 and 36, a small amount of biotite has been detected. Its plates are somewhat rugged on edges. Heavy minerals are present in accessory amounts, and the few amphibole grains noted are well preserved, suggesting that they were not subject to transportation. The content of opaque minerals, represented mainly by goethite, varies from 1 to 5 vol.%. Due to their presence, the colour of the ceramics ranges from light-red to brown.

From X-ray diffraction patterns (fig. 15, curves III-B/31, III-B/32, III-B/36) it appears that all the specimens analyzed have a similar content of quartz yielding reflections 4·25, 3·34, 2·46, 2·30 Å. It is also possible that a small amount of magnetite is present, this being suggested by the reflection 2·55 Å. It is difficult to say, however, whether this magnetite is natural or formed during the firing of the pottery. As carbonate minerals are absent in the ceramics, the reflection 2·90 Å is presumably due to the presence of garnet.

Table 7

of the sub-group III-B ceramics

32		33		34		35		36		37		38		39	
φ	%	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%
—	57	—	60	—	69	—	62	—	58	—	59	—	62	—	76
0·95	22	0·90	15	1·10	13	0·65	10	1·20	17	1·05	10	0·55	15	0·60	11
—	—	0·20	2	0·10	2	—	—	—	—	—	—	—	—	—	—
0·50	8	0·10	5	0·60	7	0·45	14	0·60	10	0·40	25	0·40	17	0·40	9
0·50	7	0·50	10	0·50	4	0·45	8	0·35	3	0·40	2	0·30	2	0·25	2
0·10	3	0·30	5	0·25	2	0·15	3	0·10	5	0·30	2	0·30	2	0·10	1
0·04	3	0·35	2	0·35	2	0·10	3	0·35	5	0·40	2	0·30	2	0·90	1
—	—	—	—	—	—	—	—	0·15	1	—	—	—	—	—	—
—	—	0·08	1	0·09	1	—	—	0·09	1	—	—	—	—	—	—

DTA analysis has confirmed the presence of goethite. The DTA curve (fig. 9, curve III-B/31) reveals a pronounced endothermic peak at about 200° C, presumably due to dehydration of α-FeOOH, and an exothermic peak at 360° C attributed to the transformation of goethite into haematite. The endothermic peak at 560° C is characteristic of a new-formed variety of quartz. The weak exothermic peak at 820° C is most likely due to the change of the clay groundmass or to the transformation of iron minerals.

The ceramics assigned to the subgroup in question is archaeologically heterogeneous. Four fragments (28, 29, 35, 38) are of the SA type while the other specimens represent various types that have not been characterized yet. Three specimens belong to the Chimu culture (11th — 15th cent.). These are two rim fragments of bowls (30, 33) with thin walls and a black shiny, well polished surface, and the neck of a jar (34) decorated with a relief "brick-like" pattern (apparently moulded). A rim fragment of a bowl (32) represents the type of thin-walled ware, painted all over red. A beaker (39) painted in brown and white strips shows nothing but slight resemblance to the ceramics of the Middle Period. A body fragment, partly white slipped and showing traces of dark-brown paint, could be regarded as belonging to the HW type were it not for the fact that the ground is a red, well polished surface. The remaining fragments are two lips of simple bowls representing pots of daily use.

Petrographic subgroup III-C. As in subroup III-B, the principal components of the ceramics are rock fragments, plagioclases and quartz (fig. 17, Table 8). The basic tempering material consists of fragments of igneous rocks which, in contrast to subgroup III-B, are represented by coarse-crystalline rocks (up to 34 vol. %). The amount of this material varies significantly in individual pottery specimens. The size of fragments is variable as well, but they are, as a rule, not more than 1·1 mm in diameter. The igneous rocks are represented by various petrographic types, coarse-crystalline andesites and dacites being prevelent. In the finer-crystaline groundmass, made up of plagioclases and matrix, are embedded large crystals of oligoclase and andesine, as well as amphiboles and pyroxenes. The

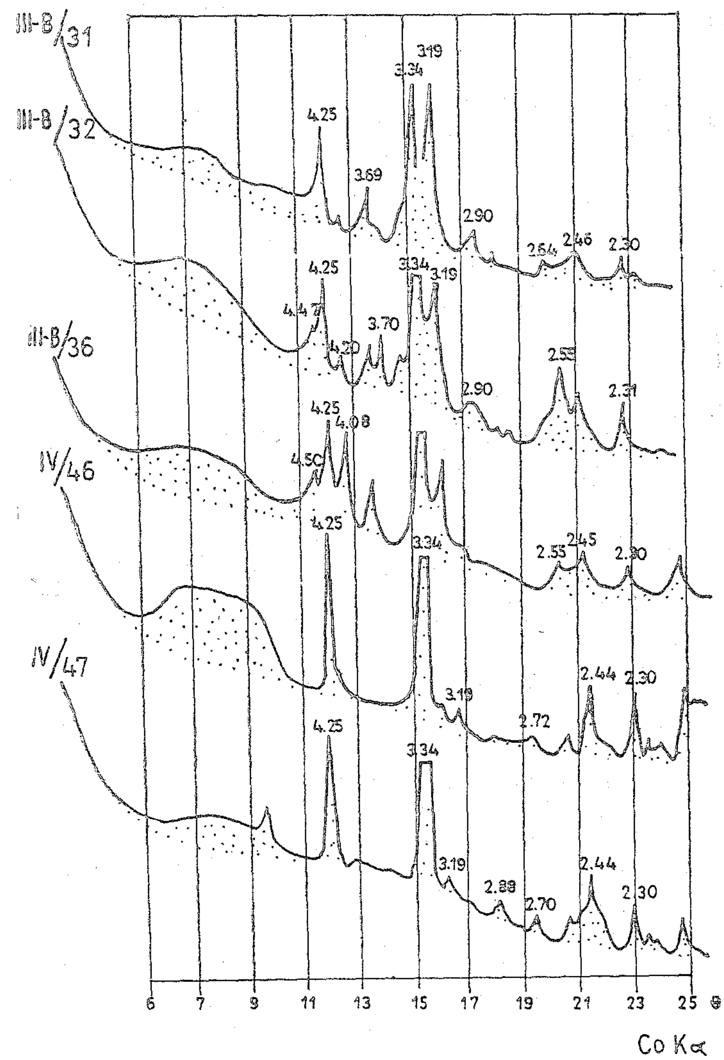

Fig. 15. X-ray diffraction patterns of the ceramics studied. Petrographic group and sample number are given beside the plots

state of preservation of the rocks is different — some fragments are strongly cataclastic while others are fresh. Besides coarse-crystalline fragments, fine-crystalline ones are present in lesser amounts, exhibiting a similar petrographic character. Plagioclases have also been noted, embedded in the paste groundmass. They sometimes show a zonal structure, being similar in nature to those found in rock fragments. Some grains are cataclastic and obviously involved in epigenetic processes leading to the formation of secondary minerals. The content of plagioclases amounts to 17 vol.%, and their diameter does not exceed 0·9 mm. In the ceramics of this sub-

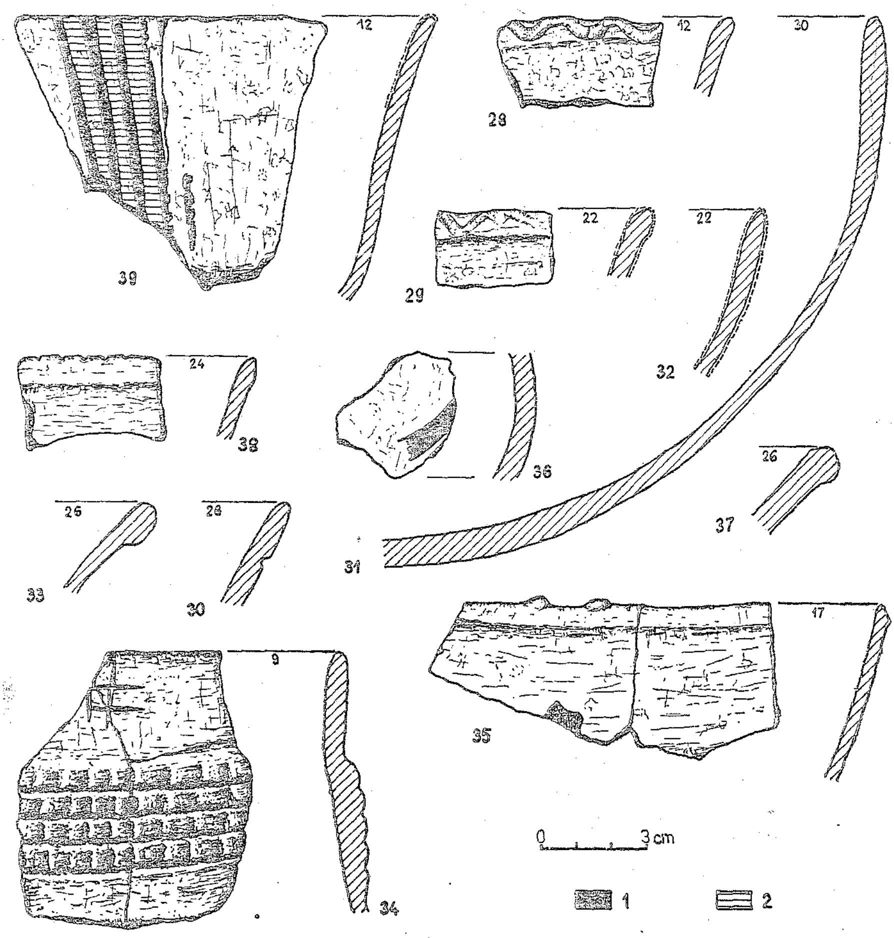

Fig. 16. Ceramics of petrographic subgroup III-B
1 — dark-brown, *2* — white; dashed line marks the extent of painting in red

group, the content of quartz is similar to that of plagioclases. It has been found, however, that these components occur interchangeably, i. e. if the content of quartz is high, that of plagioclases is low, and vice versa. Moreover, in sample 43 only, accessory potash feldspars have been found, appearing mainly in the form of well-rounded grains up to 0·45 mm in diameter. The content of opaque minerals is nearly constant (Table 8). They are represented by Fe^{3+} minerals, disseminated in the form of pigment. The content of heavy minerals is somewhat higher (up to 5 vol.%) than in the other two subgroups. They have been found both in the groundmass of thermally changed clay minerals and in the rock fragments.

The subgroup in question comprises heterogeneous ceramics, belonging to at least four types (fig. 14). One fragment (45) is a typically decorated lip of the AC type. The HI type is represented by fragment 41, ornamented with circles.

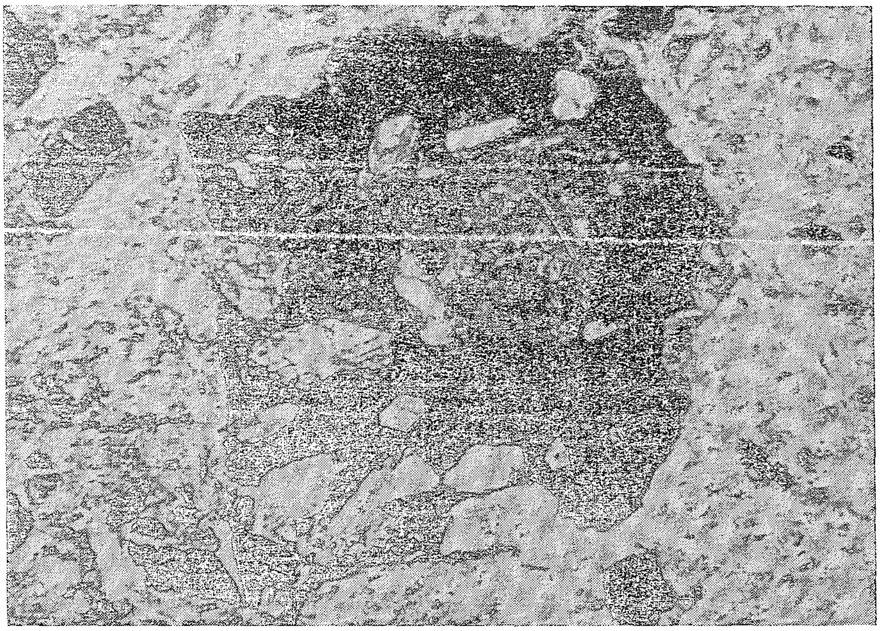

Fig. 17. Angular fragment of extrusive rock containing glass, amphiboles and epigenetically altered plagioclases. Sample 44, petrographic subgroup III-C. Crossed nicols, 80 x

Table 8

Mineral composition of the subgroup III-C ceramics

Sample number / Components	40		41		42		43		44		45	
	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%
Groundmass	—	51	—	50	—	61	—	64	—	63	—	63
Fragments of igneous rocks	0·90	34	1·00	25	1·10	10	1·05	15	1·10	10	0·90	4
Quartz	0·35	7	0·15	16	0·50	12	0·22	10	0·35	5	0·30	11
Plagioclases	0·20	3	0·10	3	0·50	12	0·35	3	0·80	15	0·90	17
Feldspars	—	—	—	—	—	—	0·45	2	—	—	—	—
Opaque minerals	0·25	4	0·15	4	0·10	3	0·15	4	0·30	2	0·45	3
Biotite	—	—	0·20	1	—	—	—	—	—	—	—	—
Heavy minerals	0·15	1	0·03	1	0·08	2	0·09	2	0·10	5	0·15	2

A rim fragment (42) and a fragment of a jar (43) belong to a group of vessels whose distinctive feature is their being painted all over red. A fragment of a colander with large holes (44) is to be assigned to the same group. The occurrence of these vessels points to the spatial and chronological relationship with the HI-type ceramics. Pottery manufactured today in the village of Caulimalca has also been assigned to this petrographic subgroup. Analysis was made on a fragment of a typical jar (fig. 20).

The characteristics of the ceramics of petrographic group III. The ceramics belonging in this group is petrographically distinctive owing to the characteristic mineralogical composition. The basis of classification is the presence of large amounts of plagioclases, usually more basic than albite, as well as the occurrence of angular fragments of rocks such as andesite and dacite. It is relevant to note, however, that the components of the ceramics occur in various quantitative proportions, and this fact may hinder the classification at the preliminary stage. It is therefore imperative that the classification be based on the precisely determined mineralogical composition and the mode of occurrence of both plagioclases and igneous rock fragments. A good indicator whereby this type of ceramics can be distinguished from the others is provided by amphiboles which, although occurring in varying amounts and not in all specimens, are typical of this type of ceramics only.

Both the raised background observed in X-ray diffraction patterns due to slight vitrification of clay minerals and the absence of kaolinite reflections suggest that the firing temperature was much higher than 560°C. Simultaneously, no mullite or magnetite formed artificially in the process of firing has been detected, which restricts the firing temperature range to 700—800°C.

Breakstone consisting of rock fragments, plagioclases and quartz was used as a tempering, material its content averaging 25—30 vol.%. It is worth noting, however, that in some cases the tempering material contained presumably also grains less than 0·5 mm in diameter. Consequently, the amount of the tempering admixture added to the clay cannot be estimated with confidence.

Petrographic group IV. The ceramics of this group has a characteristic mineralogical composition, differing significantly from the types described earlier in this paper. Clay groundmass changed to varying degrees makes up the body (60—78 vol.%) of the ceramics (Table 9). Its principal compontent (16—34 vol.%), uniformly distributed in the groundmass, is quartz. Quartz grains vary from 0·1 to 0·3 mm in size and are well-rounded (uncommonly sub-rounded or angular), pure, showing straight extinction in polarized light. The content of plagioclases,

Table 9

Mineral composition and granulation of the sub-group IV ceramics

Sample number / Components	46		47		48		49		50		51	
	φ	%	φ	%	φ	%	φ	%	φ	%	φ	%
Groundmass	—	78	—	75	—	70	—	66	—	60	—	60
Fragments of sedimentary rocks	0·35	1	0·10	3	0·30	4	—	—	—	—	—	—
Quartz	0·10	17	0·30	20	0·25	16	0·30	28	0·30	32	0·20	34
Plagioclases	—	—	—	—	0·20	6	0·15	4	0·35	7	0·15	5
Opaque minerals	0·06	2	0·10	2	0·20	3	0·30	1	0·06	1	0·08	1
Biotite	0·04	2	—	—	0·06	1	—	—	—	—	—	—
Heavy minerals	—	—	—	—	—	—	0·09	1	—	—	—	—

mainly albite, is considerably lower, but their diameter is close to that of quartz grains. Opaque minerals are present in small amounts as well, giving the ceramics a light cream-yellow colour in cross-section. Heavy minerals are very scarce, and so are fragments of sedimentary rocks represented by fine-grained sandstones.

X-ray diffraction analysis (fig. 15, curves IV/46 and IV/47) has confirmed the high degree of vitrification of the groundmass, evidenced by the markedly raised background in the region between 5 and 8·5 Å. The reflection 5·42 Å suggests the presence of mullite, which failed to be detected under the microscope because of the small grain size. Plagioclases from the albite group have been identified from the reflection 3·19 Å.

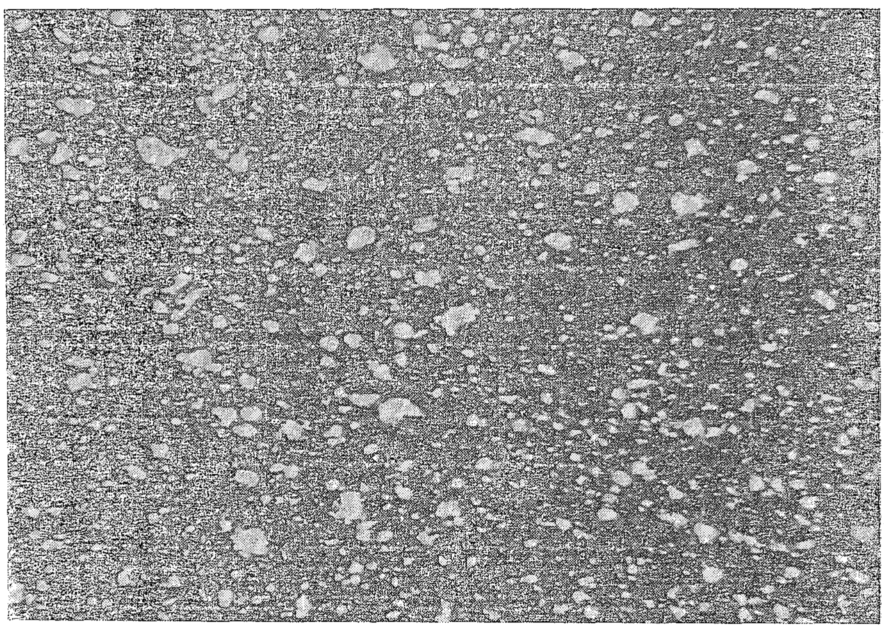

Fig. 18. Fine-grained quartz and single albite grains embedded in the vitrified clay groundmass. Sample 46. petrographic group IV. Crossed nicols. 85 ×.

As appears from thermal analysis (fig. 9, curve IV/46), only iron minerals and quartz are thermally active at temperatures up to 1000°C. On the DTA curve an endothermic peak appears at about 220°C, due to dehydration of hydrated iron minerals, presumably goethite. The weight loss of the sample observed on the TG curve is about 2%. The exothermic peak at 320°C is caused by the structural change of goethite into Fe_2O_3 [24]. It is feasible that also some Fe^{2+} is present, enhancing the exothermic peak while changing into Fe^{3+}. At 560°C an endothermic peak owing to the presence of quartz has been recorded.

[24] В. П. Иванова, *op. cit.*

Group IV, comprising six pot-sherds, is petrographically very characteristic. Thermally changed clay minerals make up on an average 70 % of the paste. They show a fairly high degree of vitrification, reflected in the isotropy of the groundmass. The degree of sorting of quartz grains, as well as their roundness and size, indicates that the initial raw material was not tempered. The ceramics was presumably produced from a clay material of mineralogical composition that did not require any corrections. Considering the quality of raw material and the degree of vitrification of the groundmass, this pottery can be regarded as more refined than the types described earlier in this paper. Moreover, it was fired at higher temperatures, amounting probably to 900° C.

The fragments assigned to petrographic group IV, i. e. pot-sherds and a spoon (fig. 19), are typical examples of the Cajamarca III style.

Chimu vessel (repaired). This ceramics is discussed separately because it deserves note as a vessel which has been damaged and then repaired (fig. 20). The thin section was made so as to obtain a cross-section through the damaged part.

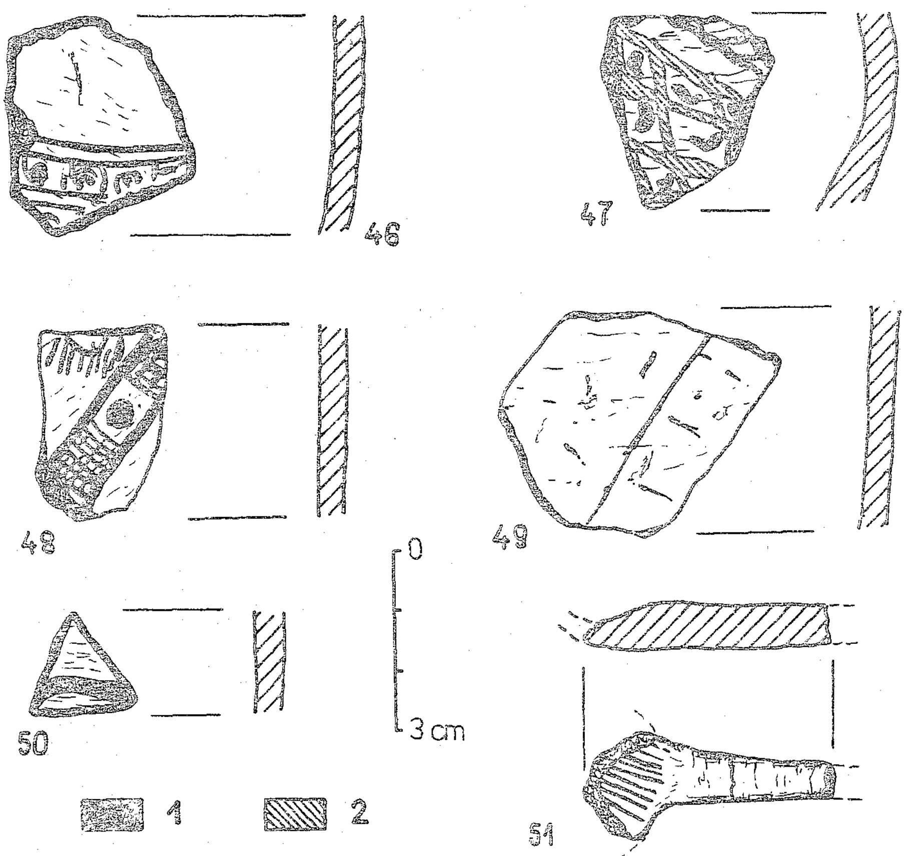

Fig. 19. Ceramics of petrographic group IV
1 — black or dark-brown, *2* — red

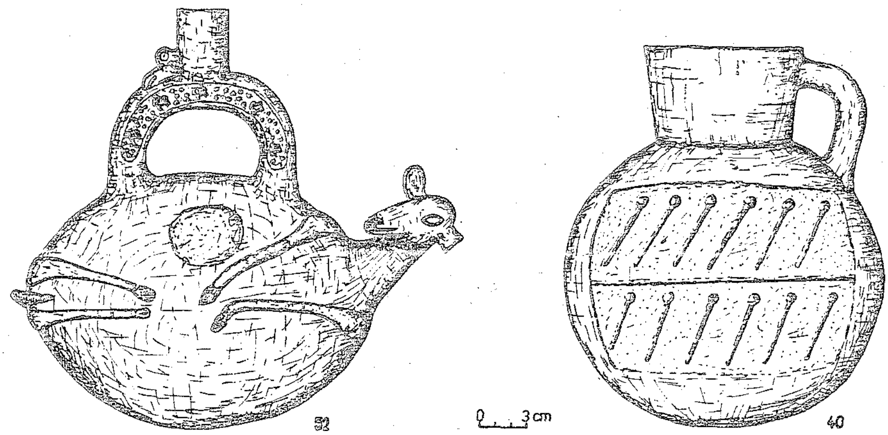

Fig. 20. Vessel of the Chimu culture (52) and a jar manufactured today in Caulimalca (40)

As appears from microscopic studies, the paste of the original and added parts exhibits slight yet significant differences in mineralogical composition. The dark part (original ceramics) is made up of the thermally changes and slightly vitrified groundmass which constitutes about 67 vol. % of the paste (Table 10). The groundmass contains plagioclase, quartz and amphibole grains as well as opaque minerals. Plagioclases are represented mainly by albite. Their angular grains are occasionally cataclastic, and so are quartz grains. Both plagioclase and quartz grains are up to 0·5 mm in size. Single muscovite flakes have also been found in the groundmass. Opaque minerals occur only as pigment, giving a brownish colour to the ceramics. In the lighter part (added) the content of thermally changed groundmass is somewhat lower (55 vol. %) whereas that of quartz and plagioclases a little higher. Quartz grains are angular and pure while plagioclases, occurring as andesine, were subject to intense epigenetic processes giving rise to small concentrations of calcite (albi-

Table 10

Mineral composition and granulation of the Chimu vessel (sample no 52)

Components	Original part		Glued part	
	φ	%	φ	%
Groundmass	—	67	—	55
Fragments of sedimentary rocks	0·90	4	0·30	5
Quartz	0·45	21	0·45	25
Plagioclases	0·30	5	0·50	7
Feldspars	—	—	0·45	3
Opaque minerals	0·25	1	0·35	4
Heavy minerals	0·80	2	0·20	2

tization) and, occasionally, epidote (saussuritization). Opaque minerals are present in substantial amounts. They appear as single grains that sometimes assume geometrical shapes. The above minerals are accompanied by fragments of pyroxenes with optical features close to augite. Both the original and added paste contains a small amount of epigenetic silica appearing in the form of fine-crystalline quartz [25]. Differences in the quantitative composition between the original and added ceramics are relatively insignificant. However, microscopic studies have revealed that diflerent raw materials were used in both cases. Although very similar in mineralogical composition, they were obviously derived from two different sources.

It has been found that the vessel was fired twice: once after it had been shaped and the second time when the damage was pasted up. The first firing temperature was higher than the other and, taking into account the presence of calcite, the latter could not have exceeded 900°C. To summarize, on the basis of mineralogical composition, the repaired vessel can be assigned to petrographic subgroup III-A.

Laboratory analyses have proved beyond a doubt that the ceramic asemblage under study shows marked differences in petrographic composition of the paste. The four petrographic groups distinguished differ so significantly from one another that the correct classification of the ceramics should present no difficulties.

Before the results of petrographic studies and their significance for archaeological interpretation are discussed at full length, mention must be made of certain limitations inherent in the method used and doubts arising therefrom. First of all, it must be emphasized that differences in petrographic composition of the paste are understood to mean the differences in the composition of nonplastic admixture, i. e. the tempering material. Little can be said about the clay itself or, strictly speaking, clay minerals.

The marked petrographic differences between the individual groups indicate that raw materials for the production of pottery were derived from various sources. Differences in the production technology (e. g. firing temperature) are of minor importance. The ceramics (except group IV) was tempered by adding various rocks. This statement is borne out by the presence of grains exhibiting shapes so angular that they could not have been the original component of the clay, but the natural weathering processes alone must be regarded as responsible for their formation. If the fragments of a rock or mineral were not only angular but also of a size close to or representing the coarsest fraction, they were considered to be the artificial tempering admixture. In general, it has been assumed that if fragments of the given component were less than 0.5 mm in size, they were not treated as a tempering admixture. Since the ceramics studied is essentially coarse-grained, it does not seem probable that rocks broken to diameters smaller than those of the natural clay components were added. The size 0.5 mm was, however, treated only as approximate [26]. The determination of the percentage of the tempering admixture

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[25] In Table 10 the content of silica is given together with sedimentary rock fragments although a possibility that it crystallized when the ceramics was buried cannot be discounted.

[26] Certain clues were provided by the studies of the Warsaw ceramics, based upon extensive analysis of raw materials. It has been found that the > 0.5 mm fractions is unmistakably characteristic of break-

presents considerable difficulties. Clays used for the production of pottery in the North Andes were presumably all of weathering origin and therefore contained originally a certain amount of angular fragments of various rocks. If those fragments fail to show the effects of weathering, it is difficult or quite impossible to distinguish them from the artificial tempering material (e. g. in the case when fragments of the same rock that was a source material for clay were added). Consequently, the content of tempering admixture determined on the basis of microscopic analysis is to be regarded as approximate. It would be possible to give an exact content of this admixture only if the provenance of clay were precisely known and comparative analyses were made [27].

A comparison of the archaeological types of the ceramics with the petrographic groups has revealed that there is a close relationship between them and that differences in petrographic composition can be correlated with the typological differences. All the analysed fragments of the HI type, except one, have been assigned to petrographic group I which, in fact, is the equivalent of this ceramics. The fact that the HI ceramics possesses distinctive petrographic features, distinguishing it unequivocally from any other types occurring in the area studied, is of vital importance. In the first place, evidence has been obtained to prove that it was right to distinguish this ceramics as a separate archaeological type. The same petrographic group comprises fragments of characteristic flared rims with rounded lips. On the basis of their spatial distribution and comparison with the whole vessels published by McCown, they were regarded as belonging to the HI type, and the present studies have provided further evidence lending support to such classification.

The petrographic group I also comprises rim fragments with the general characteristics close to those mentioned above. They are distinguished by a deep groove on the lip, which nearly cleaves it in two (figs. 7:7, 10:13). Such lips are fairly abundant at the archaeological sites studied, usually co-occurring with the HI ceramics. This suggests a possibility of assigning them to the HI type. Yet, among the vessels published by McCown there are no specimens with a "two-cleft" lip. Furthermore, the only fragments showing some similarity to those described have been found by that author as co-occuring with the SA and not HI ceramics. However, the results of petrographic analysis provide very strong evidence to suggest that the two types of rims and the HI vessels are related because they were manufactured by a population with the same, from the point of view of technology, pottery-making tradition.

Petrographic analysis also helped to dispel others doubts regarding the HI-type ceramics. It appeared that vessels shaped like the HI pottery but lacking ornamentation were made from the same raw materials, i. e. presumably by the same population (fig. 10:17). Furthermore, the same petrographic features have been

stone. L. Kociszewski, J. Kruppé, *Badania fizyko-chemiczne ceramiki warszawskiej XIV—XVII wieku* [*Physico-chemical Studies of the Warsaw Ceramics of the 14th—17th Centuries*], Studia i Materiały z Historii Kultury Materialnej 1973, vol. XLVII, p. 42.

[27] Such investigations were carried out successfully in Poland for the Warsaw ceramics (L. Kociszewski, J. Kruppé, *op. cit.*).

noted in grooved handles (figs. 7:2, 10:15) which, in so far as can be inferred from not very clear drawings of McCown[28], were also related to the HI-type vessels.

In group I there are also three decorated bowls (figs. 7:5, 10:11, 14), which evidences that the potters using shale as a tempering material produced not only jars but other pots of daily use as well.

From the above considerations it appears that the type regarded heretofore as HI comprises only a part of the ceramics manufactured by the groups of population employing very similar techniques of pottery production and using raw materials derived from characteristic sources.

Although very characteristic, the petrographic group I is not quite homogeneous and was therefore divided into three subgroups. The division criteria were the content of shales and the presence of other components. The highest shale content (up to 50%) has been noted in subgroup I-A, the lowest (up to 20%) in subgroup I-C. Quartz grains occur in inverse proportion, from 9% (I-A) to 32% (I-C) (Tables 2—4). Moreover, fragments of sedimentary rocks (sandstones) and igneous rocks (rhyolites) are present in the ceramics. This division does not seem to be reflected in the stylistic differentiation of the pottery. The existence of petrographic subgroups within virtually one and the same archaeological type implies that the technologies of manufacture of this ceramics were not quite the same. The clay was tempered to varying degrees and the raw materials were most likely derived from different sources. It follows, therefore, that the ceramics was made at several localities, possibly in every larger village. Worth noting, however, is the fact that the same tempering material was always added, and the differences in petrographic composition of the paste were presumably due to the use of different clays. That the production of ceramics was scattered and there was not a larger pottery centre in this area is confirmed by the fact that the ceramics found within one site is assigned, as a rule, to the same subgroup (Table 1). For example, all the HI fragments from site AC-1 are in subgroup I-A. It is interesting to note that the fragment from the neighbouring site AC-2 also belongs in this subgroup. Three out of four specimens of the HI ceramics from site AC-59 belong to subgroup I-A, and sites AC-83, AC-84 and AC-90, situated close to one another, also contain ceramics assigned to one subgroup (I-B). Petrographic differences noted within one and the same site were insignificant, being most likely caused by faulty preparation of the paste. If a sufficiently large number of specimens were subjected to petrographic analysis, it would be possible to say precisely how many of those "mini" pottery centres were active in the area studied and which regions they supplied with ceramics. Judging by the number of petrographic subgroups, at least three pottery centres existed, probably contemporaneously, in the area in question.

A fragment belonging to the HI type but with the paste of a composition corresponding to subgroup III-C deserves separate discussion (fig. 14:41). This unusual case can be accounted for either by the fact that the potters who manufactures the HI ceramics used exceptionally untypical raw materials or that ceramics of this

[28] T. McCown, *op. cit.*, fig. 14c.

pe was also made by other potters (e. g. producers of the AC ceramics), who ;ed their traditional sources of clay and breakstone. The latter explanation seems be more plausible because the manufacturers of the HI ceramics, deriving their w materials from different sources, always used broken shale as a tempering admix-re. Despite marked regionalization of the production, this feature seems to be significant in the pottery-making tradition as decoration with impressed circles. he existence of the HI ceramics showing a significantly different petrographic mposition suggests that this type became widespread among other groups of pulation, who produced a kind of "counterfeits".

Shales used for tempering could originate from the Santa-Carhuaz or Chicama ological formation. Both complexes consist of alternating beds of sandstones d shales, attaining a thickness of several hundred meters. Since those sediments e widespread throughout the area studied, it is out of the question that the raw aterial was unavailable and a substitute had to be used. It seems, therefore, certain at the use of a specific type of clay and tempering material was a matter of wilful oice, determined by the tradition rooted among the population of a given area.

The only analysed fragment of a colander (fig. 14:44) belongs in petrographic oup III-C. There is an apparent relationship between the occurrence of these landers and the HI ceramics. However, the fragment studied does not exhibit trographic features of group I. It seems that this case is to be treated as the frag-ent (41) discussed above. It is worth noting that both specimens come from the me site, Marca Huamachuco, where typical fragments of the HI ceramics have so been found.

From A. Krzanowski's investigations in the Alto Chicama region it appears at the HI ceramics was once the only type of decorated ware. A different opinion as held by McCown, who thought that it co-occurred with the HW ceramics d the differences between the two types resulted from different uses they were tended for. Petrographic differences between the HW and HI ceramics are pro-unced, indicating that the vessels were made from different clays and different mpering materials were used, although in both cases in was breakstone. It is nceivable, however, that the two types were contemporaneous, yet their producers rtainly had different pottery-making traditions.

Petrographic group II corresponds entirely to the HW ceramics. All the specimens me from three sites and, as was the case with the HI type, the petro-aphic composition of fragments found at the same site is very similar. e small number of analyses (6) does not allow making such inferences as for e HI type, but it seems feasible that the pottery production was scattered in this gion as well. The presence of iron compounds suggests that the HW ceramics is made from a special kind of clay derived from the local deposits.

Petrographic group III is most amply represented and most differentiated. has been divided into three subgroups but, in fact, it comprises at least six types ceramics. The group is not archaeologically homogeneous and there is no one pe of ceramics corresponding to the whole group. There is, on the other hand, distinct correlation between the petrographic subgroups and the specific archaeological types. Thus all the specimens of the SA type have been assigned to subgroup III-B, together with the Chimu ceramics. Considering the immense time interval that presumably separates the two types of ceramics, the similarity between the technologies of pottery production, and particularly the use of the same raw materials, must seem striking.

Substantial differentation in the petrographic (specifically quantitative) composition of subgroup III-B makes any detailed interpretation difficult [29]. It has only been found that the manufacturers of the SA ceramics used broken igneous rocks as a tempering admixture. Certain local differences have also been noted, e. g. pottery from site AC-52 contains potash feldspars, which are absent in the ceramics from site AC-97 but this one, in turn, contains a small amount of biotite (Table 7). These facts testify to the existence of local pottery centres and various provenance of raw materials.

The Chimu ceramics shows even more marked differences in composition, but they seem to be of no regional significance. A comparison of this ceramics (30, 33, 34) with a typical vessel of the Chimu culture (52) has yielded some interesting data. The differences are so great that although all fragments are in the same group, they have been assigned to different subgroups. Moreover, the Chimu vessel differs so significantly in its petrographic nature (bith in the kind of components and their grain size — Table 10) from the other fragments that it becomes obvious that the same raw materials could not have been used. A stirrup-spouted vessel (52) was tempered with sand, which suggests that it was made on the coast where, in contrast to the mountains, sand is abundant. The other fragments could be a local product made by the resident Chimu potters, who used materials that were available on the spot. This interpretation would account for the differences in the composition of the paste, but it is conceivable that they were caused by other factors, e. g. chronological differentiation and, consequently, certain technological evolution.

The AC type corresponds essentially to subgroup III-A (24, 26, 27) although one fragment (45) has been assigned to subgroup III-C. Subgroup III-A is distinguished from the others by the absence of igneous rock fragments and a high content of plagioclases. These petrographic features can be considered as characteristic of the AC ceramics since the only fragment (45) not belonging in III-A contains only 4% of igneous rock fragments but 17% of plagioclases. It is feasible that the AC ceramics was tempered with igneous rocks which were broken, however, into tiny fragments, hence rock fragments are absent and only their components can be found.

In subgroup III-C there are two pot-sherds representing the s. c. Red Ware (42, 43), covered with red paint or red slipped. The third fragment of this type (32) has a petrographic composition of subgroup III-B, which quantitatively hardly deviates from that of the two other fragments but differs in the use of broken fine-

[29] If petrographic studies of the North Peruvian ceramics are to be continued, a greater number of analyses should be made in this subgroup. With longer series of analyses it will be easier to define the actual standard (petrotype) and distinguish it from individual deviations.

crystalline rocks. The presence of fragments of various igneous rocks (andesite, dacite, rhyolite), both fine- and coarse-crystalline in the paste of the Red Ware implies that the manufactures of this ceramics had no preference for any kind of igneous rock. Raw matrials were presumably derived from deposits intersected by magmatic intrusions of various kinds, hence the noted petrographic heterogeneity of the breakstone.

Petrographic group III comprises two more vessels that deserve note for various reasons. Particularly interesting is the repaired vessel of the Chimu culture (fig. 20:52), discussed earlier in this paper. Petrographic analysis of both the original and added parts of the vessel yielded some information on the technique of reparation. The composition of the paste of these parts differs slightly yet so significantly that it can be stated with confidence that clays from different deposits were used. Therefore, it can be inferred that reparation was done at some other locality, and presumably much later, than the whole vessel. It is interesting to note that after reparation the vessel was fired again, but at a lower temperature than for the first time. Such technique of reparation of vessels has not been noted by Linné, who gives a detailed description of the methods used by South-American Indians [30], not has it been mentioned in any other publication.

Another vessel worthy of note is a present-day jar from Caulimalca. There are fairly precise data available on the technique of production of this ceramics, as well as on the sources of raw materials. The results of petrographic analysis, which was in this case a sort of test of its reliability, are in perfect agreement with the data yielded by ethnographic studies [31]. For example, the tempering material was correctly identified as fragments of andesitic rocks, and its content has been estimated at 34% while actually it was 30—40%. It follows therefore that petrographic analysis is capable of yielding reliable and sufficiently accurate data, but one must also be aware of the natural limitations inherent in this method. Caulimalca is an ancient pottery centre[32], and there is strong evidence to suggest that its traditions date from the pre-conquest period. Therefore, it is interesting to note that, as regards the raw materials used, the present-day pottery is completely different from the HI ceramics, which was the most popular and widespread type in the centuries preceding the conquest. On the other hand, it shows close similarity to the AC and Chimu ceramics, which types were considerably less common. The relations with the latter type seems to be significant since several technological similarities (e.g. the use of moulds, relief pattern) have been noted as well. It is feasible that the potters of Caulimalca are successors of the pottery-making tradition of the Chimu Indians, who settled down here presumably before the coming of the Spaniards.

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[30] S. Linné, *op. cit.*

[31] R. Krzanowska, A. Krzanowski, *op. cit.*

[32] W. Espinoza Soriano, *Geografía histórica de Huamachuco*; "Historia y Cultura" 1971, vol. V, p. 42.

[33] A. Shepard, *op. cit.*, p. 83.

The Cajamarca III ceramics raises no doubts in the matter of typological classification of the individual fragments (fig. 19) or the composition of the paste. Group IV comprises fragments of this type only, its petrographic features differing markedly from those of the other groups (Table 9). Its most characteristic features are the absence of tempering admixture and a generally low content of nonplastic minerals, which are fine-grained (up to 0·35 mm in diameter). Three of the analysed fragments come from Marca Huamachuco while the remaining three have been found at various sites in the Alto Chicama basin. Worth noting is the slight yet conspicuous differentiation in petrographic composition of these fragments. The ceramics from Marca Huamachuco contains sedimentary rock fragments and biotite, which have not been found in any fragment from the Alto Chicama region. The latter ceramics, on the other hand, contains plagioclases, which have been detected in only one fragment from Marca Huamachuco (Tables 1 and 9). This distinct division into two "subgroups" implies that Marca Huamachuco and the Alto Chicama region were supplied with ceramics of the Cajamarca III type by two different pottery centres using clay of the same kind but of different provenance.

Up to this point, our attention was focussed on the way of preparation of the paste and its composition, and nothing has been said about the subsequent stages of the pottery production. Microscopic studies have not extended our knowledge about the technique of shaping the vessels. Macroscopic observations suggest that they were moulded or formed by coiling. However, thin sections fail to show any orientation of grains, which would confirm the use of the latter method.

We know a little more about the next stage of production, i. e. about the firing. The investigations failed, however, to define precisely the firing temperature, giving a fairly wide temperature range varying from 560°C to 980°C for all the types of ceramics. In some cases only there are data allowing for narrowing this interval (the presence of mullite which forms at elevated temperatures, vitrification of the groundmass, etc.). In general, the ceramics of groups I and III was presumably fired at 700–800°C whereas that of group II at slightly higher temperatures (800–900°C). The ceramics of group IV was fired at the highest tempeatures, exceeding 900°C. It seems that vessels belonging in groups I and III, i. e. mainly of the HI, AC, SA and Chimu types, were fired in the open, and the maximum temperatures Atainable ranged between 900 and 1000°C. Temperatures close to the upper limit were difficult to attain under these conditions and, as shown by Shepard's studies [22], would be possible only if the firing were prepared and carried out with utmost care. This implies that the ceramics of group IV (Cajamarca III) and possibly also of group II (HW type) was fired not in the open but in pit kilns, in which higher temperatures were easier to attain.