

Sequential Slab Construction:
A Near Eastern Pottery Production Technology, 8000-3000 B.C.

by

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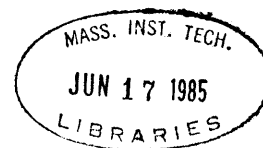
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Abstract

SEQUENTIAL SLAB CONSTRUCTION; A NEAR EASTERN POTTERY PRODUCTION TECHNOLOGY, 8000-3000 B.C.

by

Pamela Bowren Vandiver

Submitted to the Department of Materials Science and Engineering on May 3, 1985 in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

Pottery production technology was studied at six early village farming sites in the Zagros area, starting about 8000 B.C., and the pattern of development was followed to 3000 B.C. The sites include the (1) mounds of Hajji Firuz, Dalma and Pisdeli in the northern Zagros Mountains, (2) Ganj Dareh, (3) Sarab and (4) Seh Gabi in the central Zagros, (5) Chagha Sefid, Tepe Sabz and Farukhabad in the southern Zagros, and (6) Tepe Yahya on the Iranian plateau. Small study collections of pottery from other sites were also examined, including Chagar Bazar and Halaf in Syria, Merimde and Mostagedda in Egypt, and Mehrgarh in Pakistan. After the initial testing of several methods of examination and analysis, microscopy of fractured and polished cross sections and xero-radiography were chosen to study the internal structure of the pottery. Samples of raw clay from each site were characterized for working properties, and replications of hypothesized manufacturing methods were made and analyzed. In addition, a contemporary ethnographic example of the coarse ware pottery manufacture in Cumçume, southeastern Turkey, using the same method as reported and an example analyzed.

The production technology of organic tempered coarse ware was found to be the same in each of these sites and is based on a method we have called sequential slab construction. The early organic tempered coarse wares have the same composition, methods of preparation, working properties, means of decoration and construction methodology as wet mud brick architecture; that is, chineh. The pottery technology requires the same mental set or template and is structurally isomorphous with the architectural technology.

This sequential slab construction technology is conservative and carries through the development of fine wares, such as red slipped wares, black-on-buff wares, and black-on-red or -cream wares, as the prime forming method. The development of fine wares with grit temper is based on a technological innovation in the preparation of clays. Instead of mixing dry, ground clay with chaff, water and occasionally sand, as with chineh and coarse ware pottery, to produce a composite body with short working range, the fine ware clay body was mixed with water and allowed to age, producing a plastic clay body. With such a clay body, the pottery technology becomes fully independent of architectural technology, but the same forming methods continue in use even though other methods would have been more efficient.

Sequential slab construction continues as the method of building pottery through the beginnings of turning on a rotated device, whether a sherd, basket or turntable (sometimes called a tournette or slow wheel), between 5500 and 4500 B.C. Initially, the turning is used to wet smooth or form rims and for horizontal banding of painted decoration, and eventually

to shape walls constructed of slabs and strips. Technological innovation occurs gradually and incrementally and is grafted onto the traditional, conservative sequential slab construction technology. The potter's wheel (socalled fast wheel) is introduced about 3200 B.C. in the production of small beakers and is defined as the use of centrifugal force as the prime means of raising and shaping a vessel. This improvement allows more efficient production of small vessels but does not represent the sudden or major technological breakthrough which has been ascribed its development in the archaeological literature. At the same time coiling with a spiraling slab is introduced for the rapid production of some small and medium-sized wares. The introduction of rapid coiling and throwing methods relegates the sequential slab construction technology to the manufacture of large vessels.

Changes in the shaping technology are independent of developments in the chemical technology (that is, paint and slip preparation and firing, clay purification by levigation). The chemical technology is more complex than the pottery forming technology, and requires subtle controls. It is developed, lost and reinvented. In comparison, the shaping technology changes slowly in additive, incremental steps. This change is all the more slow when contrasted with the rapid evolution of stylistic traits, such as vessel decoration, which serve not only to decorate but also to identify and individualize wares. The same pattern of technological change in the pottery production methods was found at each of the sites in the Zagros area, and preliminary investigation indicates that the sequential slab construction technology may have a wider range of some 4000 kilometers.

The widespread occurrence of the method of sequential slab construction at early village farming communities in the Zagros region indicates that a complex technology, not generally found in the ethnographic literature, was used in the neolithic and chalcolithic periods. The commonality and similar pattern of change indicates a greater degree of cultural conservatism and coherence than heretofore professed. The production technology remained conservative throughout the pottery studied, although there are many innovations in ware types, form classes, decorative motives, ordering of those motives and placement on the vessels, as well as changes in the chemical technology, particularly in the composition of slips and paints and the control of their color by manipulation of firing.

Thesis Supervisor: W.D. Kingery
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I. SCOPE AND ORGANIZATION OF THIS THESIS

This thesis addresses technological innovation and change as a means of determining the range of cultural variability and interaction in ancient societies. Specifically, it seeks to determine the methods of pottery manufacture, their spatial and temporal distribution at six sites in the Zagros area of the Near East during the neolithic and chalcolithic periods. Because pottery is so well preserved due to the rocklike hardness attained by firing, pottery technology is more accessible to analysis than the clay-based architecture or metal artifacts which are only poorly preserved. Along with the domestication of animals, cultivation of cereal crops, such as wheat and barley, and degree of sedentism, pottery technology has been established as a trait of Near Eastern cultures in the neolithic period (Childe 1951:175). The map in Figure 1 shows the widespread presence of pottery at early village sites in the Near East. This technology continues to develop in the chalcolithic concurrently with the process of urbanization from a handforming tradition into a specialized craft using the rapid forming methods of wheel throwing and spiral coil forming. Although the significance of pottery production has long been as a symbol of the level of cultural attainment, no studies have sought to determine the details of the early forming technology in the Near East.

The initial stages of pottery technology beginning in the neolithic are different from extant village community pottery manufacture or from those tests which can be carried out in a laboratory to replicate an ancient process. However, by determining the properties of materials used in antiquity and by controlling the variables of materials and processes in our model system in the laboratory, we can investigate some of the same

properties of the clays, the effects of the different tempers being used, and by comparing our replications with those of ancient or modern village potters we can understand some of the problems of manufacture and some of the decisions of potters in working within the constraints of their raw materials (F. Matson 1965). Furthermore, the structure of ancient pottery can be observed and compared with pottery produced in replication of ancient vessels and interpreted by judgements based on a knowledge of the science and technology of ceramic production (W.D. Kingery 1982: 39,40,42). This study requires the development of an understanding based on investigation of the properties of raw materials, standards and criteria for the processes being used, and analyses of the effects of these variables on the observed structure of the pottery. In effect, the methods of materials science are applied to the study of archaeology.

Accomplishing these goals requires, first, determining which methods will allow the characterization of pottery production technology. Second, these methods are applied to a fairly large corpus of pottery samples from a group of early village sites, each preferably with a long sequence, sites which have been painstakingly and recently excavated, preferably published, and for which extensive work has been carried out on the stylistic attributes and variability, and for which large collections are maintained within the eastern United States and Canada, so that collections are easily accessible and can be revisited when necessary. We conjecture that there is a technological typology in the same way that there is a stylistic or formal typology of shapes, rim and base forms, decorative motifs, organization and arrangement. Third, the range of clay and pottery processing variability will be assessed, and the pattern of technological changes compared from one site to another and through time. In other words, once a technological

typology for different ware types, form classes and periods or phases is determined, then an attempt is made to reconstruct the pottery technology, assess the properties of raw materials, processes and the resultant visual characteristics which can be observed as structure and texture in the sherds, by eye, by microscope, by other analytical tools, or a combination of these. This neolithic village pottery technology can only be understood within a framework of a group of standards for pottery production technology which serve as a baseline for comparison (L.R. Binford 1981). Finally, by determining precisely how the pottery was actually made at different sites and times, that is by determining a technological typology and the patterns of change, we can establish not only sequences of pottery production technology but also derive a model for technological innovation and change in ancient societies, and place the pottery production technology within a cultural framework, relating it to other technologies and socio-economic processes.

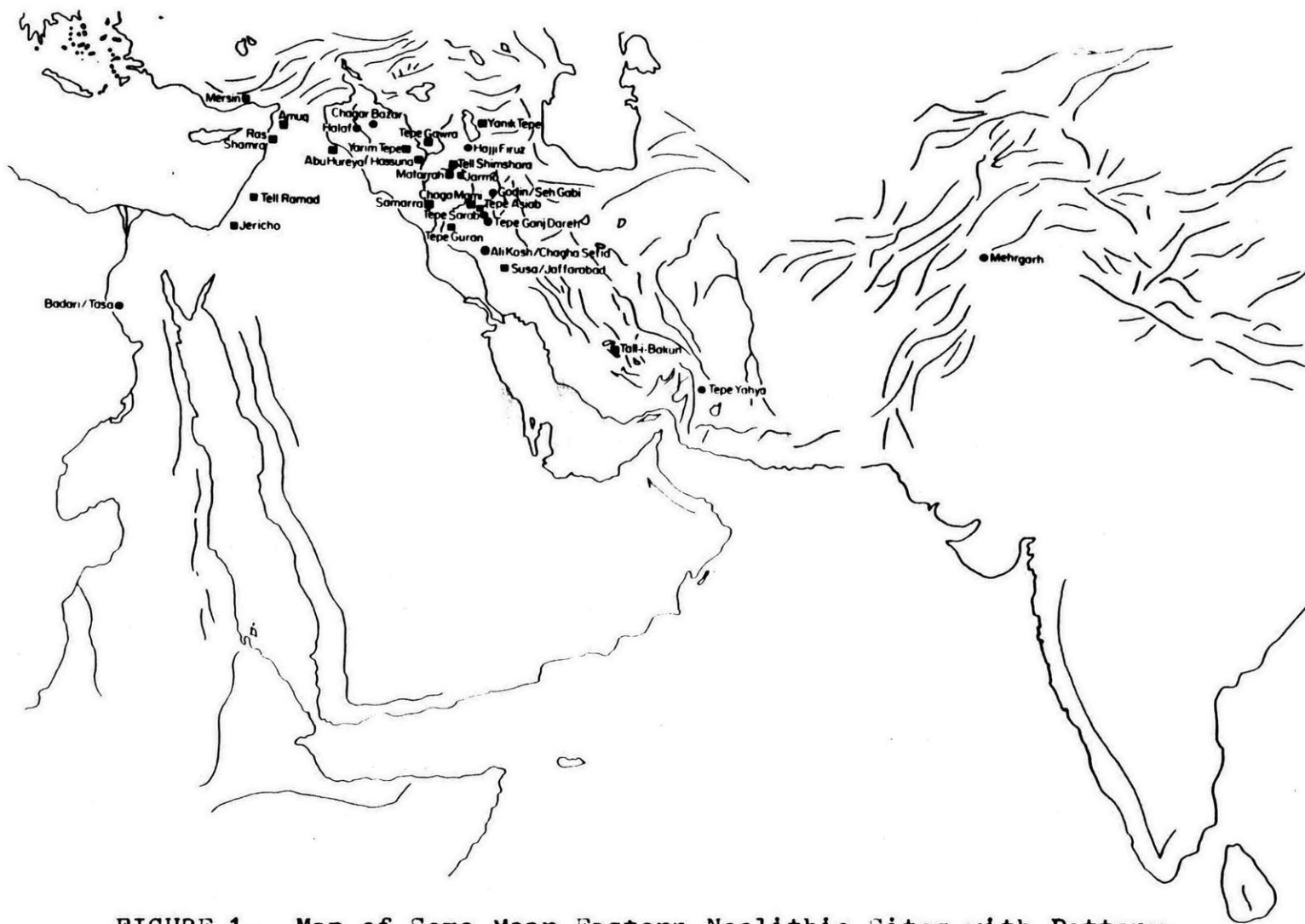


FIGURE 1. Map of Some Near Eastern Neolithic Sites with Pottery.

I. LITERATURE REVIEW

A. INTRODUCTION TO THE ARCHAEOLOGICAL SITES

Pottery from five collections of early neolithic village remains was selected for study. Each of six sites has been chosen for its well excavated, long sequence and for the care with which the ceramic collections have been organized and maintained. With the exception of Sarab, the archaeologist who directed the excavation and processing of the pottery was available for questioning and directing of my study. The early pottery represented in these collections is located in a gridlike pattern of as shown in Figure 2 which will be expanded in subsequent work. A comparative chronology is presented in Table 1, which is based on the work of M.M. Voigt and R.H. Dyson, Jr. (unpub. ms.), E.F.F. Henrickson (1985:540), G. Dollfus (1983:168), M. Prickett (1985) and C.C. Lamberg-Karlovsky (1985). Descriptions of the excavation of pottery from Ganj Dareh, Sarab, Hajji Firuz, Seh Gabi, Chagha Sefid and Tepe Yahya are presented along with a brief description of material culture, technology and subsistence. The common attributes of material culture include flint and bone tools, ground stone mortars and pestles, sundried mudbrick or chineh (wet brick) architecture, incipient agriculture, that is collecting or cultivation of wheat and barley now preserved as carbonized seeds, animal management or husbandry, plaster and pottery technologies, and trade goods, such as shell or semi-precious stones. In addition, study collections of sherds from four other sites were studied to answer specific questions of spatial extent and technological change. These sites are Mehrgarh, Pakistan, Merimde and Mostegedda in Egypt and Halaf and Chagar Bazar in northern Syria.

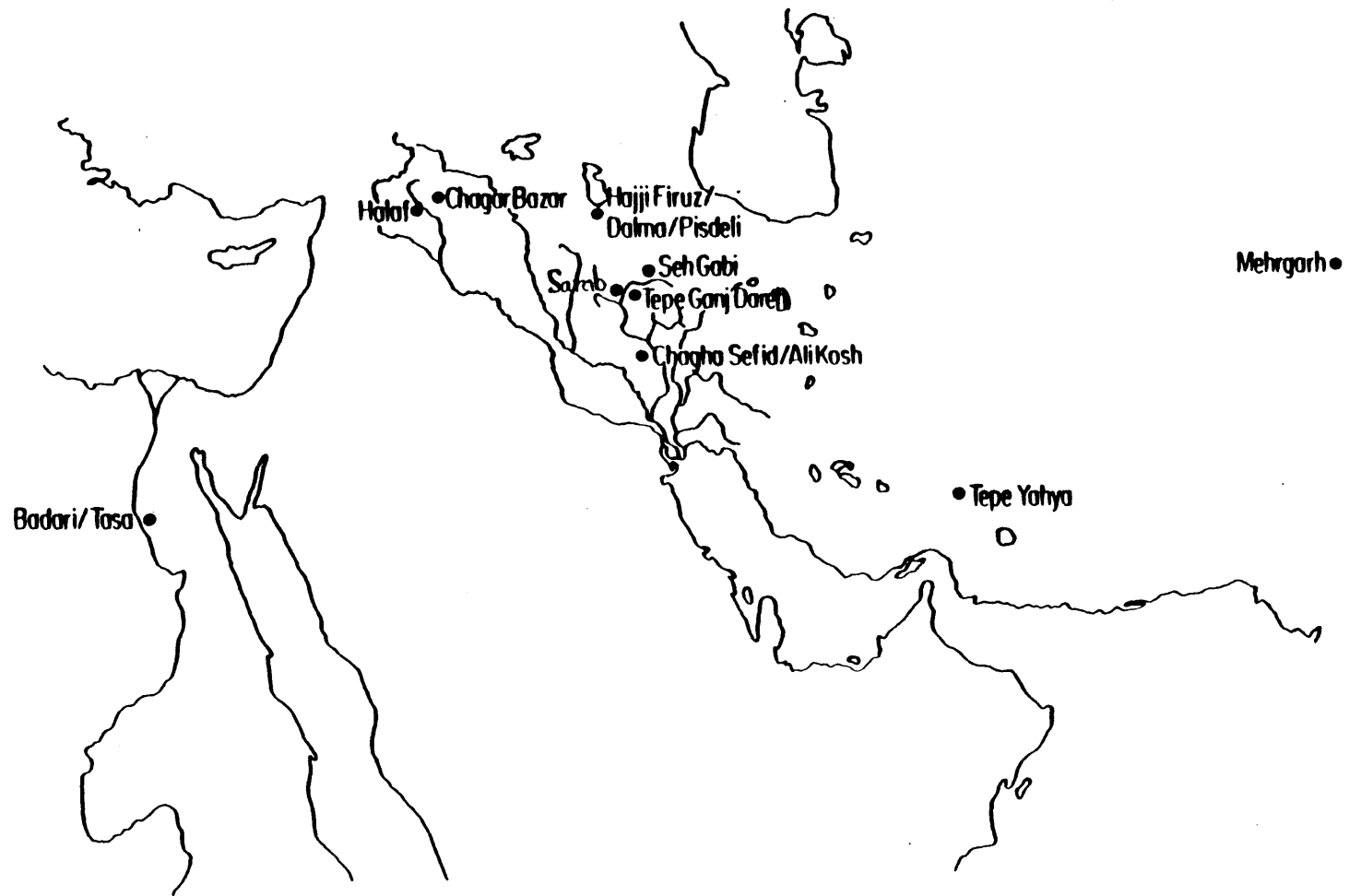


FIGURE 2. Map of Near Eastern pottery-producing sites included in this study.

TABLE 1. Chronological Summary of Neolithic and Chalcolithic Periods at Sites Being Studied as Compared with Mesopotamia

COR- REC- TION, MASCA	NO COR- REC- TION, LIBBY	Solduz Valley North Western Zagros	Mahidasht Western Central Zagros	Kangavar Valley Eastern Central Zagros	Khuzistan and Deh Luran Plain Southern Zagros	Soghun Valley Western Iranian Plateau	Mesopo- tamia Northern Plateau	Mesopo- tamia Southern Lowlands
B. C.	b. c.	YANIK EBA			SUSA ACROPOLE 14-19	YAHYA IVC1		JEMDET NASR
3000	2300							
3200	2500							
LATE CHALCOLITHIC				GODIN V/VI		GAP		
3400	2700	?					GAWRA XI	L. URUK
3600	2900	- - ? - -	- - ? - -				XII	M. URUK
MIDDLE CHALCOLITHIC				VII (AE) VIII (AE)	SARGARAB SUSA A FARUKH	GAP		EARLY URUK
3800	3100		MARAN ?	GODIN IX MOUND B			XIII	UBAID 4
4000	3300	PISDELI		GODIN X (MOUND B + XYZ)	BENDEBAL 13-27	VA		
4200	3500		SIABID			VB, VC, VIA	XIV	
4400	3700	DALMA				VIB (FW)	XV	
4600	3900					VIIA	XVI	UBAID 3
EARLY CHALCOLITHIC			J		BAYAT	VIIB	XVII, XVIII	
4800	4100	(FW)	WARE	SHAHNA- BAD (C)	MEHMEH	VIIC	XIX	
5000	4300		(FW)		KHAZINEH			
5200	4500	GAP	?		SABZ (FW)		HALAF	2
5400	4700		GAP		CMT, SURKH	YAHYA VIID	(FW) CMT	(FW) 1
5600	4900	HAJJI			SEFID MOHAMMED JAFFAR ACERAMIC ALI KOSH BUS MORDEH XXX	XXX	HAS- SUNA	SAMARRA
LATE NEOLITHIC		FIRUZ	SARAB V					
5800	5100							
6000	5300							
6200	5500	XXX						
6400	5700							
6600	5900		SARAB I					
6800	6100							
MIDDLE NEOLITHIC								
7000	6300							
7200	6500							
7400	6700							
7600	6900							
EARLY NEOLITHIC								
7800	7100							
8000	7300		GANJ DAREH					
8200	7500							
8400	7700							
8600	7900							
8800	8000							
			XXX					

? = occupation unknown, but based on incomplete survey data; GAP = gap in chronology; XXX = no occupation found after considerable survey and investigation; (FW) = introduction of fine wares

(1) Ganj Dareh, an early village located in the Kermanshah District on the border between Kurdistan and Luristan, in the Mahidasht of central western Iran, dates between ca. 8000 to 7000 b.c. (Libby) or 8700-7700 B.C. (MASCA) by radiocarbon (P.E.L. Smith 1983). The uppermost layer may date as late as 6200 b.c. (Libby). About 200 fragments of pottery, perhaps representing 30 vessels, are preserved in a variety of functional types from a small hole mouth jar, small thumb impressed beakers, to large storage jars and basins (P.E.L. Smith, pers. commun. fall, 1984). This is the earliest site in the Near East at which pottery has been found. Earlier dates of 10,000 B.C. for pottery production occur in Japan with linear relief and fingernail impressed wares from Fukui cave, Sempukuji and over 20 other sites (F. Ikawa-Smith 1980: 138). About half of the fragments from Ganj Dareh are at the University of Montreal and the rest in Tehran. The mound, measuring about 40 meters in diameter by 7 meters deep, was surveyed in 1965 and excavated in 4 seasons, 1967, 1969, 1971 and 1974, by Prof. P.E.L. Smith with the research strategy of reconstructing life in the village, the processes of sedentism, technological innovation and increasing control over food sources (P.E.L. Smith 1983: 301). About 20 volume% of the site was excavated, five levels being discerned, with A at the top and E on virgin soil. Level D is remarkable for the extensive preservation of clay artifacts because a fire in the village hardened some of the architectural structures and pottery finds.

In the earliest level (E) fire pits and no remains of architecture, lead to the conclusion that the site was probably a seasonal camp. The flint industry reveals blades with the characteristic sickle sheen from cutting grass. Evidence of hunting is present at all levels. In level D is a two-story central building complex with both plano-convex bricks and mud

architecture. Walls have been surfaced with mud plaster. Round portholes were found in the basement along with large storage vessels. Two large basins and a wide variety of other clay artifacts were found. Barley and lentils were recovered along with grinding and pounding stones. Limestone kilns were found; plaster was used in burials and for architectural purposes. In addition to hunting, some control of animals is indicated by hoof impressed brick and by the high percentage of young male sheep-goat bones. Trade goods are indicated by shell and stone beads in a necklace of an adolescent buried in level D. These people relied on a mixed economy of hunting and gathering with a certain degree of control of resources indicated. They were probably transhumant, spending winters at lower altitudes. Levels A, B and C were similar to D and represent a continuation of D, but are less well preserved. Three other contemporary sites have been located nearby.

(2) **Sarab**, an encampment probably not occupied year round, located about 30 km west of Ganj Dareh, in the Mahidasht valley of the central western Zagros Mountains, in Kermanshah Province southwest of Hamadan, western Iran, dates between 6200-5600 b.c. (Libby) or 6900-5700 B.C. (MASCA) (R.J. Braidwood 1960; M.M.A. MacDonald 1979). The pottery consists mostly of a variety of bowls, chiefly small vertical or flaired wall bowls, and some vessels restricted at the rim. This pottery has a variety of iron-clay-based slip coatings, which M. MacDonald suggested may have served for waterproofing the pottery (1979:414). There are a few sherds displaying a sophisticated decorative technology, a slipped black exterior and red slipped interior, having white paint on the black slip. This site, a low lying oval mound measuring about 150 meters in the east-west or long

dimension, was originally excavated by R. Braidwood in 1960 in two fairly large excavation units (SI to the west of 326 sq. meters and SV to the east of 160 sq. meters) from which the pottery included in this study comes and several other smaller sondings. Mary MacDonald estimated that about 10% of the excavated Sarab sherds are in the collection of the Royal Ontario Museum, well over 1000 sherds (1979:136). In 1978 three operations were carried out under T. Cuyler Young and L. Levine, with Operation 1 (to the east of SV) excavated by Mary MacDonald who supervised a group of diggers in a 5 x 5 meter square and Operation 2 (near SI) excavated by solely Seana Henrickson as a 1 x 3 meter square. Although the 1960 collection of over 1000 sherds is housed in the West Asiatic Department, Royal Ontario Museum in Toronto; the 1978 collection is still in Iran. Sherd counts and other information from the 1978 season were available, but no examples of pottery were brought back to Toronto. The pottery from SI and SV has been attributed to different levels by Mary MacDonald (1979) with SI preceding SV. SI has been dated by radiocarbon to the first half of the sixth millennium B.C. and the later phase to the second half of the sixth millennium based on artifact comparisons.

At Sarab, two occupation types are present. The early level (SI) represents a temporary settlement where herding was practiced during the spring and summer seasons. The later level SV was a more permanent settlement, occupied year round where cultivation was practiced. The level of technology involved brick architecture, ground stone artifacts, flaked chert, and pottery. Special resources in the area were exploited, such as chert, asphalt and red clay. There was no seed or bone preservation (see M.M.A. MacDonald 1979: 308f, 369f, 260f, 216f, 589f for more detail).

(3) **Hajji Firuz**, a village in the northwestern Zagros Mountains, southern Azerbaijan, in the Solduz valley, south of Lake Urmia, has been dated to 5600-4000 b.c. (Libby) and possibly as early as 6000 b.c. (M.M. Voigt 1983:6f,349f). The mound is about 10 meters above the plain and measures 140 by 200 meters at the base. The site was excavated over several seasons as part of the Hasanlu Project. Hajji Firuz is located about 2 km southeast of Hasanlu. In 1958 Charles Burney excavated two sondages, Operation I, a 2.5 sq. meter square, and Operation II, a 2.5 by 6 meter trench which was dug to the water table at 11.6 meters without reaching virgin soil. Operation III in 1960 was not completed. T. Cuyler Young, Jr., in 1961 supervised excavation of one 5 x 6 meter trench down to the water table at the base of the mound (Operation V); Operation IV was a similar trench excavated by J. Yasi of the Iranian Archaeological Survey. In 1968 Mary Voigt and R.J. Dyson supervised excavation of 9 squares, 5 meters on a side, and 6 test trenches. Phases A (early) to L (late) were isolated with the early phase just below the water table. Emphasis was placed on the research objectives of reconstruction of subsistence and economic organization (Voigt 1983: 1,3). A collection of over 1000 sherds is maintained from the 1961 and 1968 seasons at the University Museum, University of Pennsylvania.

Pottery from two other nearby mounds was studied in order to understand the pattern of change with time. Both of these mounds have only limited exposure. Dalma, a fifth millennium site dates to 4300-4100 b.c., or 5100-4900 B.C. (MASCA) (C. Hamlin (Kramer) 1975; M.M. Voigt, March 1984). This mound measures about 50 meters in diameter and rises 4 meters above the plain. Test trenches in 1958 and 1959 were made by Charles Burney, and in 1961 T.C. Young, Jr., excavated a total area of 14 x 9 meters to a depth of

about 3 meters. Pisdeli, a fourth millennium site, dates to 3500-3700 b.c. (Libby) or 4400-4500 B.C. (MASCA) (R.J. Dyson and T.C. Young, Jr. 1960; M.M. Voigt, March 1984). The mound is 110 meters in diameter and rises about 11 meters above the present plain. It was excavated in 1957 by R.J. Dyson in a small test trench of about 2.5 x 2 meters and in 1961 by T.C. Young, Jr., in two operations, an area 7 x 5 by 5 meters deep (Operation II) and a second sondage 7 x 2 meters to virgin soil. Both Dalma and Pisdeli were sampled for a representative stratigraphic column of artifacts and recovery of the architecture. The University Museum has a collection of almost 500 sherds from each site. The relative stratigraphy of these three mounds was established at Hasanlu and Hajji Firuz as there are Dalma and Pisdeli period pottery sherds overlying Hajji Firuz.

At Hajji Firuz individual house structures indicate that families each controlled their own storage facilities and cooked their own food such that the household was clearly the unit of consumption and production rather than the tribal band (M.M. Voigt 1983:295f,311f). There were two buildings with specialized functions, and there were also communal burnt pits or kilns for pottery, figurines and sealings. Many different types of clay were used, a fine silt for plastering, a fine plastic clay for figurines, a clay used in house brick brought from the southern end of the valley, and other specialized coarser clay and clay-lime mixtures (M. Voigt, pers. comm., Dec. 1984). Objects of limestone, diorite and sandstone were made of locally exploited resources, while serpentine, ochre and obsidian were imported from the northwest near Lake Van. The economy was mixed and included dry farming, cultivation of wheat and barley and the herding of pigs, sheep and goats, with herding probably as a hedge against shortages. Some hunting and gathering was practiced, but it would have contributed only a minor amount

of the diet.

(4) **Seh Gabi** is about 60 km northeast of Ganj Dareh, 6 km northwest of Godin Tepe, and to southwest of Hamadan about halfway to Kermanshah in the central Zagros, Kangavar valley. The site of Seh Gabi consists of a group of 6 mounds, labeled A to E. Mound C (MacDonald:1979,313) is the earliest dating to 4100-4300 b.c. (Libby) or 5000-5200 B.C. (MASCA), and measures about 15 by 20 meters. An area 87 sq. meters was excavated, in some areas down 2 meters to virgin soil, by Mary MacDonald under the direction of Dr. Louis D. Levine. This early village culture has been designated Shahnabad. About 6500 sherds were found, of which about 1100, those used in Mary MacDonald's thesis, were available for study at the Royal Ontario Museum. Mound B (T.C. Young, Jr., and L.D. Levine 1974) is dated to 3100-3700 b.c. (Libby) or 3800-4500 B.C.(MASCA). Mound B (S. Henrickson 1983: 156f) is about 100 sq. meters and about 7 meters high, and was excavated by a team led by Louis Levine and Carol Kramer during two seasons. A maximum horizontal exposure of 280 sq. meters was excavated, but virgin soil was not reached. Seven occupation levels were recognized, and grouped into two periods: the earlier Dalma period (Godin period X, levels 5-7) and the later Seh Gabi period (Godin period IX, levels 1-4), with level 1 at the top. This mound is contemporaneous with the deep sounding at Godin, called Operation XYZ. Mounds C and B contain a variety of pottery shapes and types, including plain slipped ware, red slipped ware and painted wares, quite similar in appearance to those from Hajji Firuz, Dalma and Pisdeli. Mounds A and E represent the later Godin Periods VII and VI, and were excavated in small soundings of 2-5 meters on a side. Seh Gabi was excavated in 1971 and 1973 as part of the Godin Project, and the entire

collection of several thousand sherds is now housed in the West Asiatic Dept. of the Royal Ontario Museum. The research objectives were (1) to obtain a stratified artifactual and architectural sequence, (2) to clarify the archaeology of central western Iran and to link this area with other regions of Iran to the east and north, and (3) to understand the early history of the major east-west route, called the Khorasan Road, from Baghdad to the Iranian plateau.

No final report has appeared to summarize the subsistence and technology practiced at Seh Gabi. Mound C was a small hamlet of 3 to 5 extended families, each an independent economic unit (M. MacDonald 1979:496f). They probably kept domesticated pigs, perhaps sheep-goats, and probably cultivated cereals and legumes, and probably were a year round sedentary population. Copper metal traded from the east, that is the central Iranian plateau, was present from the lowest levels. Other trade goods such as ochre, shell and chert or obsidian appear after the Mound C occupation. In the Dalma period at mound B, the settlement size is larger and the deposit deeper; and inhabitants seemed to practice farming and herding with a much greater degree of surity in the outcome.

(5) Chagha Sefid, located on the Deh Luran plain, Khuzistan, in southwestern Iran, is dated to ca. 5900-5200 B.C. (MASCA), or 5200-4500 b.c. (Libby). The mound measures 165 x 120 meters, and is 16 meters above the plain. About 3.5 to 5 meters of cultural remains are below the surface of the plain. Chagha Sefid was surveyed and excavated in 1968 by Frank Hole and James Neeley. Area A was a 5 x 6 meter sondage to below the level of the plain; area B comprised a 3 x 5 meter pit down to Mohammed Jaffar phase (ca. 6000-5800 B.C.) material. Areas C and D were trenches placed up slope,

5 meters wide by 20 meters long. Less than 1% of the area of the mound was excavated. The research objectives were to understand the events and dynamics of agriculture and animal husbandry and to solve problems concerning the processes of cultural development, particularly the chronological gap between the end of occupation at Ali Kosh and the beginning of occupation at Tepe Sabz, both of which had been excavated years earlier (F. Hole 1977:8,23). Of 41,000 sherds over one thousand are housed at the Yale University Department of Anthropology. Some later ceramic material from the Mohammed Jaffar phase at the nearby mound of Ali Kosh, level A, was used to supplement study of the Chagha Sefid plain coarse ware. The earlier levels at Ali Kosh are aceramic. The span of dates at Ali Kosh are 6600-5300 B.C., or 7200-6400 b.c.

At Ali Kosh the evidence suggests winter occupation by a people whose prime means of livelihood was herding of sheep-goats, but who also practiced some planting of emmer wheat and two-row hulled barley, along with hunting and fishing (F. Hole 1977:20). In the Mohammed Jaffar phase, pottery and mud brick houses on stone foundations first appear (F. Hole 1977:29,31). At Chagha Sefid, compared with Ali Kosh, herding is carried out more intensively at the expense of hunting. The mud brick houses are less substantial than at Ali Kosh. More crops are cultivated, such as almonds and wild legumes as well as six and two-row barley, but there is no evidence of irrigation. There is trade in obsidian, basalt, turquoise, specular hematite, and shell (F. Hole 1977:30). The Chogha Mami Transitional ware probably represents an actual movement of people because of the marked changes in artifacts from previous traditions (F. Hole 1977:12). At the later settlement of Tepe Sabz, which spans from 4700 to 5200 B.C. irrigation farming was practiced, cattle were domesticated and a full range of cereals,

improved by mutation and hybridization, was planted. Tepe Farukhabad, ranging in date from 3400 to 4700 B.C. spans the Dalma to Seh Gabi/ Pisdeli periods and represents a continuation and extension of the developments at Tepe Sabz (H. Wright 1981). A small selection of pottery from Tepe Sabz and Tepe Farukhabad was studied in order to provide a sequence of technological development.

Frank Hole points out the differential use of clay resources which required a specialized knowledge of different clays for agricultural and architectural use, as follows: "A striking differential distribution of sites with respect to soils was revealed...it does look as if there is a close relation between particular local circumstances and the pattern of settlement and subsequent development of cultures" (F. Hole 1977:21). From the excavation of a brick platform, Hole describes the core as soft, ashy mud bricks, and the exterior cap as dense yellow clay bricks (p. 33). Again in describing a house wall, the interior was faced with a layer of mud slightly darker than the bricks (p. 50).

(6) **Tepe Yahya** is located in southern Iran in the Soghun valley, about 115 km. or a 5 to 6 day walk inland from the Persian Gulf port of Bandar Abbas, or about 225 km. south of the town of Kerman and 30 km. northeast of Dolatabad in Kermanshah province. The early periods of Tepe Yahya are dated from about 5600 to 3900 B.C. and after a chronological gap of about 400 years, Tepe Yahya is reoccupied at about 3450-3400 (C.C. Lamberg-Karlovsky 1970). The circular mound measures 187 meters at the base and about 20 meters above the present valley floor. Tepe Yahya was excavated by Prof. C.C. Lamberg-Karlovsky in the 1967, 1968, 1969, 1970, 1973 and 1975 seasons. A series of five 10 x 10 meter trenches lettered A at the top and E at the

bottom were dug on the south side of the mound. Four squares north of A and one square west of B were also excavated. Over 50,000 sherds were excavated. Of these about 25% were kept, of which about 60%, or about 7500, are in the Peabody Museum at Harvard University, and the rest are in Iran. The research objectives were to recover the cultural history of this little known area of Iran and to understand economic exchange patterns between Mesopotamia, Persian Baluchistan, the Indus and the Persian Gulf.

Occupation at Tepe Yahya in the early chalcolithic (period VII) was based on an egalitarian social order, with individual 4 to 5 room houses densely packed around clusters of contiguous storage rooms (T. Beale 1978:425,426). The extended family was the unit of production. Local deposits of chlorite were worked to form objects with two different levels of quality practiced simultaneously: one of crudely formed grindstones, beads and arrow straighteners vs. fine art mobilier as exemplified by a head and female figurine (Beale 1978:458). Small quantities of nonlocal materials, such as semi-precious tones and shells, are evidence of trickle trade, and perhaps the seasonal movement of some part of the group to the Persian Gulf (T. Beale 1978: 454,455). In period VI the extended family becomes the economic unit of ownership as well as production. Individual houses with internal storerooms and surrounding courtyards are found (T. Beale 1978:425-432). The first fine pottery wares are introduced, and a very few hammered native copper objects are found, only seven between periods VII and VC (D. Heskell 1981:23,73). The first evidence of a rudimentary drainage system is present in period VI. In period V there is an increase in the number, type and quality of goods found within each house, evidence of an established and successful community with a limited degree of social stratification. The houses are larger and more elaborate,

rooms are differentiated by function, and several families lived within a walled compound each with its own 5 to 6 room living units, but with a central storage complex. Agriculture became more intensive; sickle blades were more numerous and their proportion relative to flint flakes increases (M. Piperno 1973:64,72). There is an increase in the number of settlements in the Dolatabad and Soghun valleys with similar artifact traits, leading to the probability of a regional trading network. Period IVC is characterized by an intrusive proto-Elamite settlement with an administrative center, which orders if not controls production of many commodities, such as chlorite bowls (P. Kohl 1974). Bricks are molded to a regular size, regular measures are used in construction, and potters' marks are found on quite uniform looking beakers (D. Potts 1980:9,11,133-4), and is interpreted as is evidence for stratification in political and economic organization.

Summary of Sites by Region:

Northwest Zagros Sites: Hajji Firuz, Dalma, Pisdeli

Central Zagros Group: Ganj Dareh, Sarab, Seh Gabi

Susiana or Southern Sites: Chagha Sefid

Eastern Site on the Iranian Plateau: Tepe Yahya

In review articles of Near Eastern chronology and material culture Patty Jo Watson (1965:82-83) and James Mellaart (1970) have documented that chaff tempered coarseware pottery is found at Near Eastern sites from the seventh millennium B.C. P.J. Watson has reported 6400 to about 6000 B.C. as the "approximate time of introduction of pottery." In Watson's chronological table the introduction of pottery occupies an almost

horizontal line in Anatolia, Syria and Mesopotamia at the 6400 B.C. level with Iran, Palestine and the Aegean later. This time period corresponds to economies based on established food production. Earlier instances of coarse burnished pottery such as at Beldibi rock shelter, level B, and Catal Huyuk, level IX-X, occurring about 7000 B.C. are not widespread nor are large quantities of sherds found. For instance, from Abu Hureyra were found only 42 sherds (Andrew Moore:pers. commun.: spring 1984). These earlier occurrences of pottery seem to be considered by archeologists as sporadic and not as important as the later widespread occurrence of pottery. From Mellaart's article and others in The Cambridge Ancient History, Part I (1970), the Table 2 was compiled. Although far from up to date or complete, this table of the approximate time of introduction of pottery reaffirms Watson's general conclusion but also points out that the spread of dates is a bit wider. For the purpose of investigating the early technology of pottery production, such a compilation also points to the importance of study of the isolated early instances in order to understand the widespread development of chaff tempered coarse ware in the seventh millennium B.C.

Table 2. Some Dates for the Introduction of Pottery;
 (based on Libby dates, b.c., with a half life of 5730)

Ali Kosh	6000-5700
Amuq A,	6200
Beldibi, B,	7000
Buqras, III,	6000-5500
Byblos,	6000
Chagar Bazar,	5300
Chagha Sefid,	6000-5700
Catal Huyuk,	6750
Chogha Mami,	5000?
Djaffarabad,	5000?
Ganj Dareh,	8000-7000
Hacilar, IX-VI,	5800
Hajji Firuz,	5400
Halaf,	5300
Hassuna,	5800
Jarmo,	6700-5900
Jericho, IX,	ca. 6000
Matarrah,	5800?
Mehrgarh,	7000-6000?
Merimde,	4300
Mersin,	6000?
Ras Shamra, VB,	6200
Samarra,	5500-5000
Seh Gabi,	4700
Tall-i-Bakun,	6000?
Tell es-Sawwan,	5800?
Tell Ramad,	6600
Tell Shemshara, 13, ca.	6500
Tepe Gawra	4700
Tepe Guran, S,	6000
Tepe Sarab,	6300-6000
Tepe Yahya,	5000
Yarim Tepe,	4800-4500

Sherds from four other sites were investigated in order to answer particular questions. Mehrgarh is a 250 hectare site in Pakistan near Peshawar of ten seasons excavation led by Prof. Jean-Francois Jarrige. This site is the eastern extent of wares similar to the software horizon Near Eastern wares but there are no sites between Mehrgarh and the Iranian plateau which, if located, might serve as cultural links (Richard Meadows 1980, and personal communication: spring, 1984). Mehrgarh has a strong Central Asian component, yet is similar to Near Eastern neolithic settlements. Mehrgarh has a depth of perhaps the 5th to 8th millennium with an aceramic basal level. Problems in the variation of radiocarbon dates have yet to be resolved. Four-room buildings were found with pit hearths in the early levels. Multiple replastering of the walls occurred, with smoking or burning before each replastering. Shell, lapis and turquoise were found from the earliest levels, with sources of lapis and turquoise believed to be nearby up the Bolan pass. Copper first appears in the early ceramic levels. Wheat and barley were cultivated in a far more temperate climate than found in the Near East (barley is native to this area but wheat is not known to be native). Goats were kept but hunting was an important part of the economy. The cultural sequence continues to about 2500 b.c. with zebu or humped cattle, sheep and goats fully domesticated by 4200-4500 b.c. A group of 30 software and early fine ware sherds were examined visually from Mehrgarh in the collection of Prof. Jean-Francois Jarrige at the Musee Guimet in Paris.

Examination of a group of sherds from the early predynastic Egyptian sites of Mostagedda and Merimde in Egypt sought to establish the eastern extent of software horizon pottery. Merimde in the southwest delta is a neolithic site dated to the sixth millennium from 4300 b.c. or 5000 B.C. (H. Kantor 1965:4,5; R. and D. Whitehouse 1975:56; E.J. Baumgartel 1976:483-4;

H. Junker 1929,1940; L. Krzyzaniak 1983:92-96). The settlement occupied a large extent of 44 acres and was composed of several layers with a continuous cultural development of about 650 years (although radiocarbon dates were obtained from stored material long after the excavation). The architecture consisted of round or oval houses with post holes, straw tempered clods of mud and matt impressions remaining. Fishing and hunting contributed to the diet and wheat was cultivated. Merimde was excavated by Prof. Hermann Junker of the Vienna Academy of Natural Sciences from 1928 to 1930. Mostegedda (G. Brunton 1937) is a Tasian/Badarian site, consisting primarily of burials, that is at the beginning of the cultural sequence in Egypt but the site is without radiocarbon dates. Mostegedda is located near Badari in upper Egypt, and has been dated to the early predynastic by artifact comparison. Study collections were examined with the advice of Dr. Edward Brovarski and Peter Iacovara at the Museum of Fine Arts in Boston, and another group of vessels was examined from Mostagedda in the British Museum. These samples of pottery was studied in order to establish the degree of commonality and possible spatial range of software horizon pottery technology to the west of the central Zagros region.

In addition, a collection of late sixth millennium B.C. Halaf fine ware sherds from Halaf and Chagar Bazar in the collection of Prof. Hole at Yale University was studied in order to determine the similarity of the methods of manufacture between the earlier Halaf fine ware from northern Syria and the later fine ware from the Zagros region. T. Cuyler Young, Jr., suggested that the painted Dalma pottery was decorated in imitation of Halaf designs, but my examination had shown that a conservative hand building technology was used in the Dalma wares, and we wished to know if the Halaf ware sometimes purported to be formed on a tournette or potter's wheel was really

made in that way or by hand building.

B. STUDIES OF POTTERY PRODUCTION TECHNOLOGY

In 1911 Louis Franchet gave a group of lectures at the Ecole d'Anthropologie in Paris which has been published under the title Ceramic Primitive: Introduction a l'Etude de la Technologie. Throughout these lectures he stressed the limitations of materials and processes on the pottery which can be produced. He stated that a knowledge of the possibilities and limitations is fundamental to observing, understanding and interpreting pottery. Furthermore, he stated that there is a necessity of having two distinct classifications of pottery: one based on technique and the other on chronology (pp. 138-139). He found that studies of pottery used form and decoration to guide classification, but this he believed was conceptually wrong.

"Composition is important because it exercises an influence over the solidity of the pottery, on the porosity, on the mode of forming, on the technique of decoration, on the determination of the point at which the firing is stopped. The composition of the body imposes on the potter the obligation to realize some forms instead of some others.

In summary the near totality of ceramic operations repose on the nature of the material. A potter can conceive no matter of form, no matter of decoration, but there shall not be the realization of the conception unless the body composition so permits by its chemical composition and physical state.

By consequence, seeing that the form and the decoration are subject to laws imposed by the properties of clay composition, one can only use as a fundamental basis for a classification, technique.

There are in effect two sorts of classifications: first, the classification of technique, second the classification of chronology.

The classification of technique has for an aim to establish divisions among the different varieties of pottery, varieties which distinguish themselves by special properties proper to each of them. The establishment of these divisions has for its object to facilitate the study of ceramics.

The classification of chronology has for an object to determine the dates of fabrication to be based not only on the physical and chemical properties of raw materials, but on diverse other elements such as the morphological characteristics of the wares, the decoration and others."

(Franchet 1911:138-9)

Franchet stated the attributes of a classification based on composition and technique and gives a brief history. In 1844 Alexandre Brongniart, director of the national ceramic manufacture at Sevres, a distinguished humanist, chemist and ceramist, established the classification of earthenware, stoneware and porcelain which is still used. Brongniart based this classification on the body composition, firing range and degree of vitrification which affect such properties as permeability, ring and degree of opacity or translucidity. Brongniart placed appearance, vessel form and decoration as sub-classes. In 1857 his successor Salvétat established an alternate classification based on optical properties, pottery without a glaze and with a glaze and subdivided into classes based on the opacity or translucidity of the body. Other classifications have been based on artifact type, such as bricks and tile, refractory products, art objects or art pottery, common pottery. Franchet believed these last two are of limited usefulness, and that the classification of Brongniart is recommended. He restated the criteria in order of importance as (1) degree of vitrification, a function of composition and temperature; (2) nature of the processing, whether glazed or not glazed and whether the body is opaque or translucent, (3) composition of the body as carboniferous, ferruginous, siliceous, phosphatic, kaolinitic, feldspathic, siliceous clay, calcareous clay, magnesian clay, or aluminous clay, or containing a fusible clay or glass. He concluded that knowing these properties, the limits of raw materials and processes are revealed, and the types of wares, shapes and decorations which can be produced are determined.

In 1936 G.D. Wu unknowingly put this classification based on technique to work in a classic study of neolithic Chinese pottery which is still cited

as the basic study of Chinese neolithic pottery wares, their characteristics and manufacture. This practical study was based on observation of the neolithic pottery, observation of potters at work in China, and experiment.

Dr. Wu states as follows:

"As to my methods, I have followed a very natural procedure. I have first studied the various pottery groups, then I have compared them. Further, I have tried to classify the wares, and finally I have constructed the chronological table. In the study of various provincial groups I have paid attention to as many as seven characteristics of pottery, i.e. color, shape, material, method of making, thickness, surface treatment, and decoration, because I believe that if many characteristics are studied, the result will be more accurate than if the study were limited to one or two.

"I am of the opinion that ancient techniques can only be identified either by experiments or by comparison with modern parallels. Within certain limitations I have followed this principle. Experiments are justified by the fact that the function of the human hand must have been the same in ancient times as it is at the present day. By using the same tools the same result will be produced. The choice of modern parallels for comparison is also justified because the Chinese people, especially the farmers, are conservative and preserve to a remarkable degree the ancient ways. In many cases, a problem of technique may be solved by comparing the ancient relics with modern equivalents.

"For the purpose of comparing I always kept in mind three principles: (1) to pay equal attention to distinctive peculiarities as well as to points of resemblance, (2) to pay equal attention to the various features of pottery, and (3) to give careful consideration to the two factors, time and space. My purpose in comparing objects distant in time or in space is to concentrate on technique. (G.D. Wu 1938:4,5).

Anna Shepard in the well known book Ceramics for the Archaeologist (1954) advocated the use of many variables and the primacy of technology. She even published photographs of textures of ceramic surfaces emphasizing the need for careful observation. Use of her approach, in my opinion, has not led to outstanding or often cited results. It is very difficult to state why this is the case. She focused attention on the use of the petrographic microscope for the identification of temper, and thus on the search for import wares, and away from an understanding of the basics of ceramic technology. She stated that it is the one sherd in many which reveals the ceramic technology and that these are scattered throughout a

stylistic typology. Perhaps she did not go far enough in insisting that painstakingly detailed description and analysis without a problem to solve will be without significant results.

Pinhas Delougaz in Pottery from the Diyala Region (1952) tried to use such technological criteria as proposed by Shepard and others for the organization of a long sequence of pottery from several sites, but concluded that in the Near East similar clay bodies and similar techniques were used over a wide geographic area and great expanse of time. The result is that he laid the basis for subsequent reports of pottery collections in which the criteria for comparison were the size and proportions of vessels and the surface finish and decoration. The result is a stylistic typology with a general description of fabric or technique of manufacture which is grafted onto formal, art historical criteria, without consideration for the underlying ceramic technology. More recent studies have added statistical interpretation to the metric data.

In addition, there have been a group of problem-oriented studies, in which the methods and point of view have been suited to a problem of limited scope. In some studies modern methods of materials analysis have been used with a sound basis in careful observation of a limited group of samples. Walter Noll (1972,1973,1975,1976,1977,1978,1979) characterized the technology of iron and manganese colored slips using scanning electron microscopy and x-ray diffraction. Diana Kamilli (1978), using petrography and electron microprobe analysis, found similarities in wares imported into several different sites and having a common origin. T. Davidson and H. McKerrell (1976) using neutron activation analysis were able to find compositional differences in clay sources for Halaf and Ubaid pottery at Arpachiyah but not at Tepe Gawra.

There has been another group of recent studies based on intensive observation of a small group of pottery or sherds which have led to new interpretations. An instance with results not envisioned in the original plan of research was the success of Denise Schmandt-Besserat (1974,1977,1983) in studying the early uses of clay and finding a possible system of accounting as the basis of the development of writing. J.-F. Jarrige's (1985,in press) study of the Mehrgarh basket impressed coarse wares, or Mary Voigt's (1983:263-267 and Pl. 25) study of basket impressed sherds from Hajji Firuz, have demonstrated baskets were used as molds in Near Eastern pottery manufacture. Janine Bourriau in Umm al-Gaab: The Pottery of the Nile Valley (1981) studied surface texture as a means of understanding manufacture of certain types of Egyptian wares, and thus grouping vessels which heretofore had been considered distinct. Don Potts (1981) in an analysis of potter's marks from Tepe Yahya inferred craft specialization. M. Voigt (1976), S. Henrickson and M. MacDonald (1984) in the determination of vessel function have isolated vessel capacity, vessel profile and such characteristics as fire blackening of the base as significant traits.

In studies which combined careful observation with replication, the yield of information about the technology is even greater. For instance, P.E.L. Smith and R. Crepeau (1983) made observation of and replicated the hole mouth jar from Ganj Dareh in order to ascertain that molding and joining had been used in the manufacture of pottery at a very early time. Joseph Veach Noble (1965), Gisela Richter (1923) and others replicated Greek black-on-red ware in order to understand the intricacies of its manufacture.

In order to comprehend what is being observed in the examination of pottery, a number of authors have recommended the use of criteria for

various types of forming, for instance the excellent book, Pottery Technology by Owen Rye (1981). Another way of trying to understand what is being observed is the use of ethnographic analogy. Examples of contemporary potters at work in the Near East are found in the publications of M. Centlivres-Demont (1971), Hans Wulff (1966), Owen Rye and Clifford Evans (1976) and Frederick Matson (1968,1984). In each of these works there is a point of view which encourages acquisition of information for the purpose of understanding historically important aspects of the craft of working with clays, as opposed to the collecting of information as ethnographically of interest in understanding group behavior. This point of view is carried much further in the work of Carol Hamlin Kramer (1982), in which activities and objects in a contemporary village were investigated in order to better understand the content and context of archeological objects and to better infer patterns of behavior.

However, none of these studies has pushed the study of ceramic technology as far as might be possible given the understanding of Franchet and Wu. R.J. Dyson (1965:217) first described an early so-called "soft wares horizon" in Iran dated to the 6th-5th millennium B.C. Many observations of these wares described the rare occurrence of a clearly defined join in the fractured edge of a sherd, and there are descriptions of piece-building from slabs (M. Voigt 1976:414) and a tongue and groove effect (Mary MacDonald 1979:361). The excavation reports from Tal-i-Gap and Tal-i-Bakun (N. Egami and S. Masuda 1962) even show some of the joins drawn into the cross sections of pottery. F. Hole, K. Flannery and J. Neely (1969:9-10,111-114) in the final report of their study of early village sites in central western Iran having an early pottery horizon dating from 6000 to 4000 B.C. choose not to deal in depth with the production technology, stating the difficulty

of isolating manufacturing methods, whether handforming or wheelforming methods.

"We are not prepared to announce the instant at which the effective wheel was put into use, and in any case we regard our evidence as suggestive rather than definite. One problem is that the break between hand-made and wheel-made pottery is not a temporal one: at one and the same time, the ancient Deh Luran villagers deemed it appropriate to make Khazineh Red and MehmeH Red-on-red pottery by hand, while they made some Susiana Plain Buff and Susiana Black-on-buff vessels by wheel." (Presumably this time dates to the MehmeH Period (4500-4000 B.C.)

"The question of the use of the wheel in early periods is still a matter of some debate." The criteria used include presence of horizontal straitions and uniformity of wall thickness. "It seems certain that intermediate stages, such as the use of a slow wheel or tournette will be very difficult to identify from the signs of the pots themselves. From the MehmeH phase onward, however, our sequence includes vessels made with a degree of fineness, uniformity, and precision that is difficult to imagine unless some sort of wheel was in use."

"Most of the vessels in our sequence were hand-made--or so we infer from the unevenness of their sides, their asymmetry, their lack of complicated profiles, and the presence of rough marks of scraping. None of the pottery shows any evidence of having been coiled. The bases appear to have been made as flat slabs, to which nearly-vertical walls were added; often the junctures of wall and base are thick in outline, like a human heel." "Another solution is to make the joint into an oblique angle or carination which is somewhat thicker than the vessel walls, because of the overlapping of the two sections" (F. Hole, K.V. Flannery, J.A. Neeley 1969: 9-10, 111, 112).

For many reasons ranging from constraints imposed by the way pottery studies have developed to a lack of understanding of ceramic technology, there has been a reluctance to directly investigate Near Eastern ceramic production technology.

III. RESEARCH PLAN

The research plan of the thesis is simply that the macrostructure and microstructure of pottery is based on the technology (Table 3). Knowledge of this structure allows one to understand and establish relationships between properties of raw materials and processes. In order to establish a technological typology and sequence of development for each site, we must establish standards for materials and processes. These methods have proven successful in the field of materials science, but have not been tried in the field of archaeology where most technical studies are applications of physics and chemistry, known as archaeometry.

Table 3. Research Plan

The Macrostructure and Microstructure of Pottery
is Based on the Technology.

The Microstructure and Local Compositional Variability
Promote the Understanding of the Properties and Constraints
of Raw Materials and Allow Interpretation of How the
Processing Has Been Optimized

We Wish to Establish a Technological Typology and
Patterns of Development

To Do This, We Need Standards for Raw Materials and Processes

This thesis is divided into sections on the methodology of studying organic tempered coarse and fine ware pottery, the results of data collection which produce a reconstruction of the technology and a sequence of technological development at each site, and a final section in which the results are evaluated, compared and interpreted within the framework of a proposed model for technological innovation and change in ancient society. In order to investigate the internal structure of pottery, a variety of analytical techniques were applied to a small sample of ten coarse and fine

ware pottery sherds from Tepe Yahya and to second group of four whole vessels for which the method of manufacture was well known. Most of the analytical techniques proved unsuccessful. Those techniques which proved successful allowed the characterization of the external and internal structure of the pottery. When combined with studies of Near Eastern clays and pottery replication, these analytical techniques allowed assessment of the properties of raw materials such that their constraints on manufacture could be determined.

Observations and measurements of the pottery production methods at Tepe Yahya showed that the organic tempered coarse wares and fine wares were constructed in a specific and efficient way by stacking on edge in overlapping joints such preformed elements as slabs, lumps, strips and coils of clay in a way we have named sequential slab construction. Several types of joints were visible in a fractured or polished edge, giving a profile view of manufacturing sequence. The spatial extent of such preformed elements parallel to the wall was determined by examination of surfaces and by xero-radiography. Other collections of pottery were then examined, using the techniques and standards developed for the Yahya and other pottery. In addition, an ethnographic example of pottery made by this same method of sequential slab construction was found in Çumçume, southern Turkey, and an example documented during manufacture was examined and analyzed.

In order to understand the implications of the patterns and changes which were being isolated, models for the cultural interpretation of technological innovation and change were investigated from the fields of history, industrial archaeology, primatology and ethnography, and a model for technological change of the pottery craft and industry in and near the Zagros region of the Near East from 8000 to 3000 B.C. was formulated and

evaluated.

A. SELECTION AND SIZE OF SAMPLE

Convincing myself that I had obtained a random sample of pottery with a normal distribution of traits from various collections of archaeological objects was not possible for many reasons. The sherds had been collected by many researchers over a long period of time during which the problems and field methods of archaeological research have changed. The research strategy, amount of site excavated, methods of collection, proportions of sherds retained, organization of collections varied from site to site and often with season as methods were refined. A sophistic view held early in this study that from the available sample, generalizations could be made about the earliest pottery manufacture or pottery representative of a region or period, or even the possibility of testing the probability of obtaining a random sample, soon proved fruitless. Instead, compared with the richness of culture and amount of life present in the neolithic and chalcolithic, we are confronted with a problem similar to trying to describe the diversity and complexity of a mountain range by a single sample from each of a few of the highest peaks. Prof. Hole suggested that trying to test the randomness of each sample would not add to the credibility of the conclusions (pers. comm., Nov. 1984). One had to accept the sample as all that is available and try to discern patterning in the available sequence. Like Voltaire's *Candide* one assumes that this is the best of all possible worlds as no other is available for study. Questioning archaeological premises could only lead to circularity before data on technology was acquired or results understood--an unwise practice.

Thus, it is assumed that the samples are biased in many different ways. However, they have a high probability of being representative of what was produced in a known place and interval of time because of the duration of cultural sequence in which the interval and context are embedded and because of the independent check provided by the comparison of two sites which overlap in time, that is because of the fabric of archaeological results. What can be established is the pattern of change, as a summation of the nature, rate and direction of many smaller changes, in a group of characteristics.

B. TECHNOLOGICAL TYPOLOGY

The more important task is to specify the goals of research and to establish whether the means chosen are appropriate and sufficient to provide the required information. The goals of this thesis are (1) to determine the details of forming processes, (2) to assess whether this technology was the same or different within a site, from site to site, and through time, (3) to describe how it varied and in what way it remained uniform, and (4) to find out what else, if anything, varied with processing technology and how they were similar or dissimilar.

Just as a description of characteristics of the shape and decoration of an object can be ordered into a typology, so can the technological characteristics. David Pye in The Nature and Art of Workmanship (1968) has described the elements of such a typology. Below an attempt is made to isolate and restate what is necessary to establish and understand the elements of technological style based on Pye's conclusions:

(1) An overall technical understanding of the process; that is, recognition of the general process of making which is based on a tradition of working a material in certain ways and on the constraints imposed by the materials and processes;

(2) Knowledge of the details of the processes; that is, in Pye's terms, assessment of the subtle lack of uniformity as contrasted with the uniformity found in mass produced goods, and evaluating this diversity in an object as those elements of texture just on the threshold of resolution and recognition which give the details of making that object;

(3) The degree of control and how it was obtained; that is, the degree of risk found in an object such that the quality of the result is continually at risk during the process of making vs. the degree of certainty found in an accepted process where a large quantity of goods are produced using templates, molds and other means of standardization or efficient repetition such as division of labor, machinery or design specifications (as for instance, a model like an imported object for which the desire to copy or reproduce is present); another way of getting at the degree of control is to try to establish what are the rate limiting steps in the processing;

(4) The standards of production and how a particular objects fits; that is, the degree of finish, strength, precision, durability or beauty necessary and sufficient to the quality and function of the object, and how an object fits into this range of like objects or how it is odd; another way to evaluate such standards is to think about the cognition or understanding of natural processes which underlies or is implied by the technology;

(5) The level of technology: (a) from the craftsman's viewpoint, the degree of dexterity and practice required in workmanship from the artisan or what the object required in special knowledge or skill of the craftsman; as well as (b) the sophisticated or complex knowledge required to arrive at a finished form, that is what is required in the way of special materials or tools or techniques or processing or thoughts.

Heather Lechtman (1977:4) has emphasized the anthropological significance of technological style as the formal expression or extrinsic manifestation, on a behavioral level, of an intrinsic, cultural patterning, which usually is not known cognitively by members of a community.

C. USE OF STANDARDS

With the lofty goal in mind of establishing a technological typology for early pottery, it is then necessary to figure out what characteristics are important, how to measure them, how to check their validity, and how to

interpret their range of variability, as L. Binford has demonstrated in the study of prehistoric bone working (1981) and W.D. Kingery and P.B. Vandiver in the study of paleolithic pigments (1985). Cyril Smith (1981) and David Pye independently have shown and concluded that in the surface texture and structure of the object is a whole story of how the object was made--the cultural values, amount of time and energy, special skill and materials, degree of precision of execution, the gradualness of the process and the deftness and economy of effort of the artisan, the experienced judgment and the lively, particular deviation which may represent a decision to deal with a problem of something went awry. Cyril Smith has emphasized that looking at texture on one level of scale can at a finer level of scale reveal a structure. He also states that finding heterogeneities will often allow one to understand how one thing transforms into another, and why each looks the way it does.

The problem of elucidating pottery production technology first involves using the external visual appearance of pottery sherds, which to the unaided eye appears as texture, but at a higher magnification, so as to reveal their structure, and then looking at the internal structure of that pottery for characteristics of the technology. Once the methods and characteristic structural elements are established, the patterns and heterogeneities are searched. However, in order to make judgments and interpret what is being seen it is necessary to have firsthand knowledge of the appearances and implications of those appearances for the technology, and this is impossible without standards and analysis of replication attempts. Such standards provide an experimental framework without which interpretation is hindered if not impossible.

IV. THE FEASIBILITY OF VARIOUS EXPERIMENTAL METHODS

Observations and descriptions of the textures of the edge fractures and surfaces of a group of 800 sherds from the long cultural sequence at Tepe Yahya pottery were made in glancing light with naked eye, 10x magnifying glass and low power binocular microscope. These observations resulted in a conjecture that sequential slab construction was the early method of pottery production and that this conservative tradition perservered through the development of fine wares to the introduction of the potter's wheel. Other traditional means of investigating ancient pottery (such as description and classification of variations in rim and base forms, profiles of shapes, volume measurements, color, hardness, amount and type of temper or surface treatment) did not reveal or demonstrate pottery production technology.

Observations of textures of the edges and surfaces of broken pot sherds reveal the external structure or macrostructure. Using criteria observed in pottery of known manufacturing method, these observations of macrostructure can be used to support various ways of making the pottery. In order to demonstrate that the observations of external textures relate to manufacture, it is necessary to find a means of observing the internal structure, or microstructure, of the pottery. If both the macrostructure and microstructure of a pot sherd support the criteria established by observing characteristics of pottery of known manufacturing method, and if the method can be demonstrated to apply to a group of pottery, for instance a form class or ware type, then the conjecture about manufacturing method is creditable.

One difficulty was that ways of looking into the internal structure of pottery at a proper scale to reveal manufacture had not been thoroughly

investigated. Several possible analytical techniques were evaluated in order to determine the feasibility of revealing and resolving the internal structure. The difficulty was to find techniques which would reveal structure or heterogeneities in the fabric at a scale which can differentiate the interactions of the potter's hands with the alignment of clay, pores and temper, and also show the places where clay was joined. The following techniques were investigated:

Table 4. Analytical Techniques

Those which were not useful:

- Dye Penetrants
- Fluorescent Dyes
- Thin Section Petrography
- Scanning Electron Microscopy
- X-ray Diffraction
- Radiography
- Ultrasound
- CAT Scan

Those which were useful:

- Low Power Microscopy
 - Surfaces and Fractured Sections
 - Polished Sections
- Xero-radiography

A. EVALUATION OF THOSE TECHNIQUES WHICH WERE UNSUCCESSFUL

1. Dye Penetrants and Fluorescent Dyes for Crack and Pore Determination

The use of dye penetrants to detect pores and cracks in metal objects is well known but has not been tried on ceramics. This technique should reveal joins, cracks or pores in fairly dense, well sintered wares. Two dye penetrants (Crown, Hebron, Ill., 1012 penetrant and 1013 cleaner and developer, and Magnaflux Corp., Chicago, Ill., Cleaner SKC-NF/2C-7B, Penetrant SKL-HF/S, and Developer SKD-NF/2P-9B) were used on polished cross

section samples of fine and coarse wares from Tepe Yahya. Once a coating of the penetrant is allowed to set, the developer is applied to remove the surface dye, as shown in Figure 3.1. All sherd surfaces were stained a bright red because of the large amount of porosity. The attempts to apply dye penetrants to polished cross sections of earthenware were unsuccessful.

Application of fluorescent dyes had the same result. A fluorescent penetrant testing system (Phillips, West Germany, Fluro Finder FL-50 and Fluro Developer FD-33) was used with both long and short wave ultra-violet light. There was sufficient porosity in both types of wares that the entire surfaces glowed such that no structural detail was revealed.

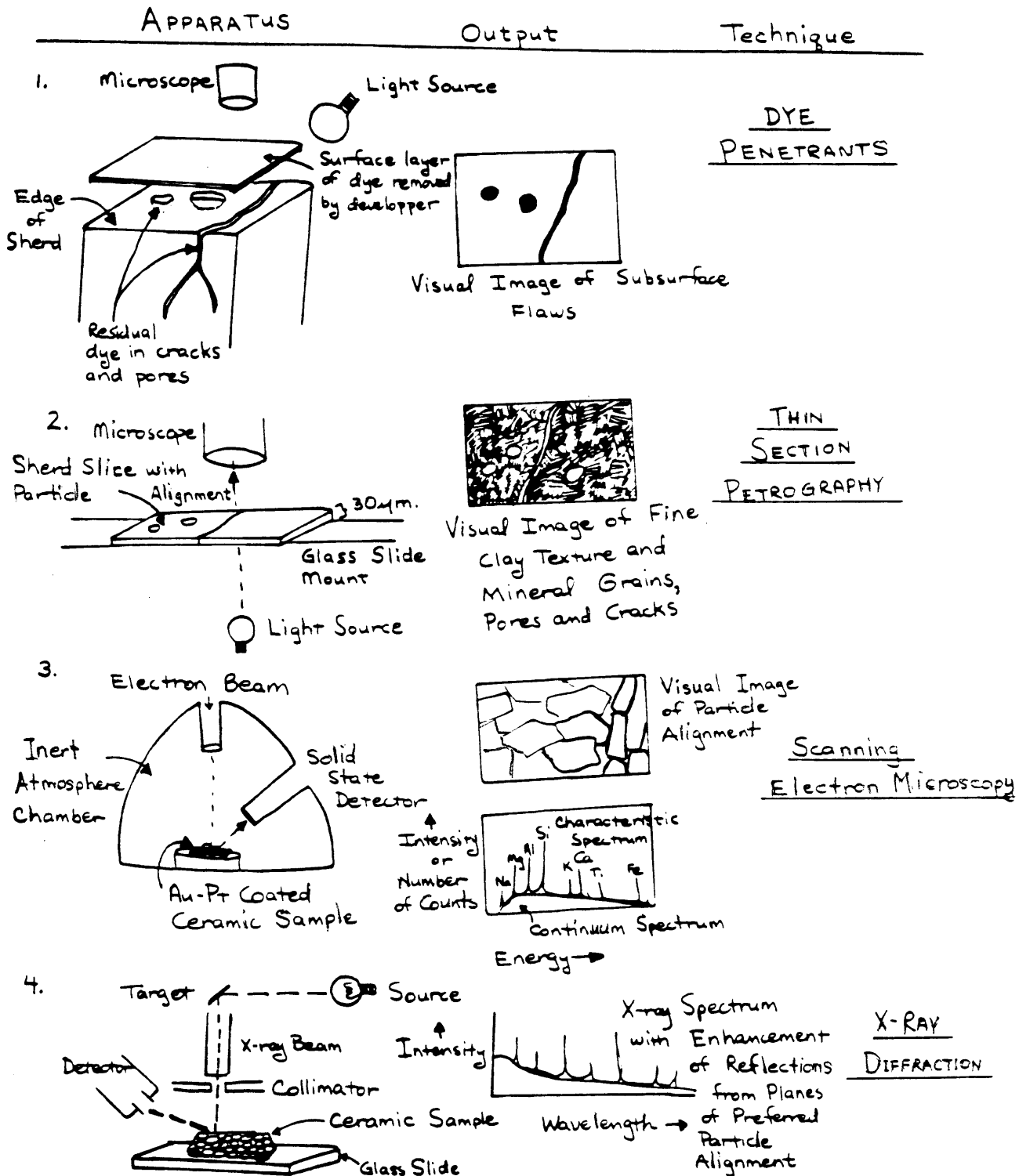


FIGURE 3. Analytical Techniques Used to Study Near Eastern Pottery

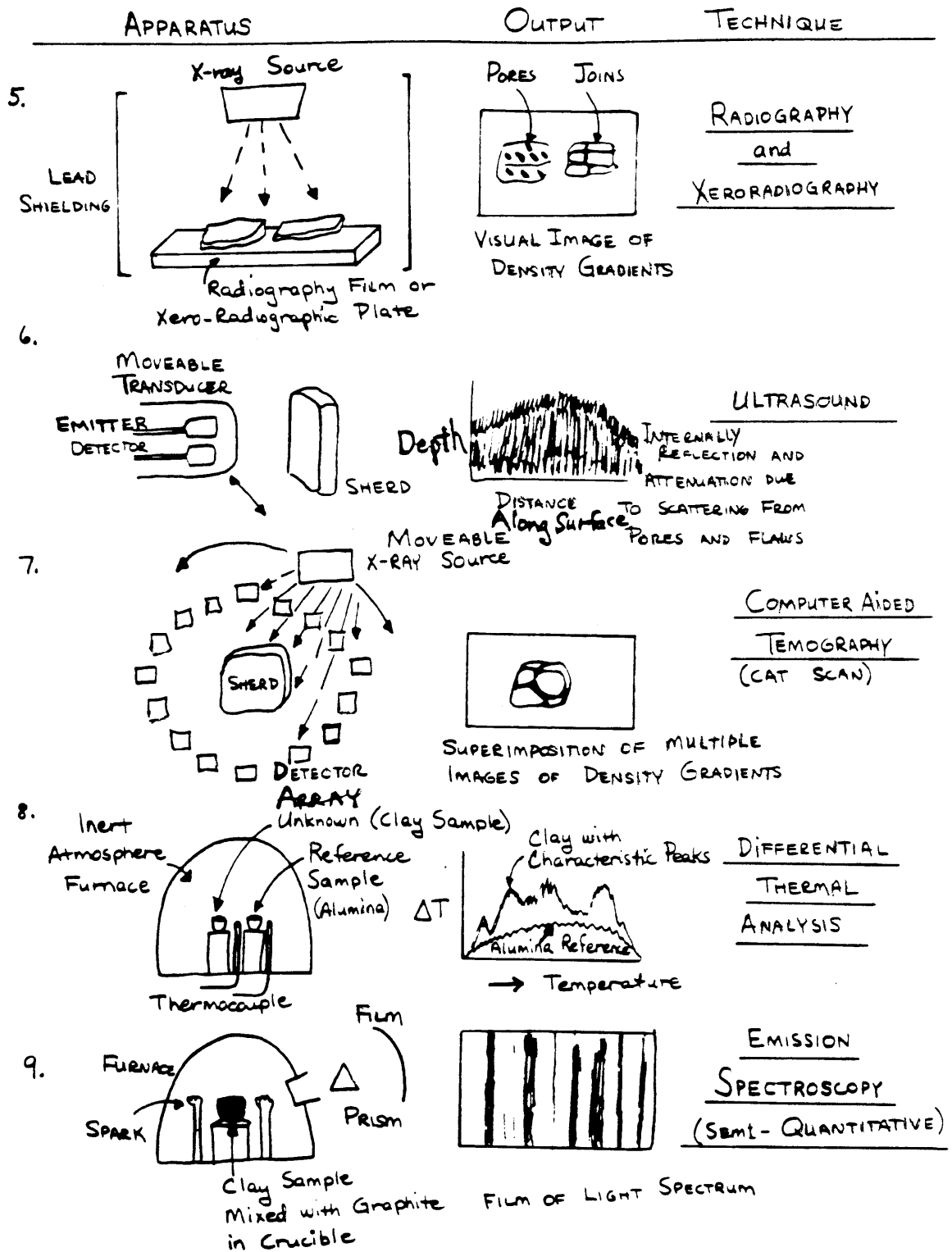


FIGURE 3. Analytical Techniques Used to Study Near Eastern Pottery, continued

2. Thin Section Petrography of Clay Textures

Preparation of thin sections requires grinding and polishing a section of clay to a thickness of about 30 microns so that it is transparent to light. If the section is oriented across a join between two pieces of clay and if this join has not been well worked together, then the structural detail of the process may be revealed in the alignment of pores in the clay and the alignment of clay particles seen as a texture, as in Figure 3.2. There are two problems: one is that clay particles are fine, in the micron size range and opaque, so that a section should be as thin as possible to reveal alignment textures, and second, that in making thin sections of highly porous, so-called software pottery, there is a great danger of surface damage, that is of pulling out mineral inclusions and enlarging the size and altering the shape of pores, and even introducing fractures into the surface during the process of diamond sawing a thin slice. Even when the criteria of being sure no damage of the sample has occurred and that what is being examined was present in the original can be met, the lengthy sample preparation limits the number of samples which can be investigated.

In the coarse ware pottery examined, samples were chosen with a join apparent in the fractured cross section. In the thin section the clay texture tends to align parallel to the joins such that it is very difficult to detect where precisely the join has been made. In addition, the organic temper which was added and which has burned out leaving elongated pores is often surrounded by complex swirling clay textures in which the clay can be seen to have delaminated from the original organic temper and to have been compressed and further distorted during the joining process. The alignment of pores, on the other hand, tends to be parallel to the wall and to change direction where joins have been made, as shown at the bottom of Figure 8

(about p. 93). Because pores are more important in understanding the software pottery than clay alignment, the method of polished sections was employed in which the problems associated with sample preparation are not so great.

In the fine ware pottery, again the alignment of pores proved to be a more important criterion for the detection of joins than the alignment of clay. The clays of the Near East are particularly fine, being about 0.1 micron. Use of thin sections in examining clay textures for manufacturing method met with success in early British wares where the particle size is larger and where coiling has been the preferred method, and thus a repetitive pattern of concentric alignment translated along a wall has been established (Ann Wood:personal communication, Nov. 1984). A comparison of thin and polished section pore alignment is given in Figure 6d (about p. 76).

3. Scanning Electron Microscopy of Particle Size and Alignment

The scanning electron microscope (Cambridge Stereoscan IV, Cambridge Instruments, England, and AMR 1000, Massachusetts, each run at 20 KV and 125 ma.) can image topography of surfaces at magnifications ranging from 50x to about 20,000x. In addition to imaging surfaces at a higher magnification than a light microscope, the S.E.M. has a greater depth of focus than a light microscope. However, the samples must be made small enough to fit into the evacuated chamber, and ceramic samples must be made conductive with a vapor deposited metallic layer in order to produce a clear image, as shown in Figure 3.3. Samples in this study were cut with diamond saw or tin snips to the a maximum size of 2 cm by 1 cm. and coated with an evaporated film of gold or palladium.

The lowest magnification (20x) is too high to image the cross section

of a sherd; thus, a composite image must be mapped, or made by translating the sample under the beam and taking photographs at intervals which are then pieced together. Sample preparation and examination is a lengthy process which limits the number of samples which can be investigated. The drawbacks are that only black and white images are available and there is often a difficulty in getting the metal coating into pores. The result is a white rim at the pore which can obscure its size and shape. However, the major drawback is that not enough of the sample can be visualized at a time.

This technique was used for special problems, such as imaging montmorillonite clay particles or slips or paints, but not for the routine examination of sherds. The availability of an energy dispersive x-ray attachment (KEVEX with Tracor-Northern instrumentation) allowed the simultaneous identification of elemental composition for an area of sample as small as 3-5 microns. Thus, the amount of lime (calcium carbonate) mixed with a clay could be estimated using standards of known composition. In the fired sherd samples, identification of clay type is not possible, because the clay has transformed to other mineral phases and glasses, unless the firing temperature was very low (about 400-600°C) and the sample can be autoclaved to reconstitute the original clay mineral.

4. X-Ray Diffraction of Anisotropic Clay Particle Alignment

For some of the very low fired wares in which ash or residual organic temper is found, or in the very few vessels which do not appear to have been fired, taking a small 10 mm. square sample parallel to a suspected join and mounting on a glass slide, will when irradiated give an x-ray diffraction pattern with abnormally high intensities for those peaks diffracted from planes of preferential orientation, as shown in the schematic block diagram in Figure 3.4. The differences in alignment on either side of the join or

with the center of a manufacturing element, such as a coil or slab, can be compared. This technique works on only a very small sample of pottery, and is not applicable to most well fired sherds.

5. Radiography of Sherd Faces and Cross Sections

The radiography facilities in M.I.T. Soil Engineering Lab are optimized to image clay and sand cores from deep sea drilling operations. A Phillips MG151-160kV constant potential high voltage generator and beryllium window x-ray tube in a lead shielded enclosure, as diagrammed in Figure 3.5, was run at 150 kV, 3.8 ma input current, at a distance of 6 feet from the samples. Exposure times were 1/20 sec. to 3 minutes, with developing times of 7-10 minutes using Kodak radiographic film.

The advantage of this technique is that sherds can be placed directly on the film plate with no prior preparation. The image shows differences in density in the sherd as differences in contrast, as shown in Figure 4. The more dense the material to x-rays, the greater the absorption, and the lighter the negative appears (Figure 4 has been printed to have the same dark and light pattern of the negative although the contrast has been increased). Thus, an image is seen of tempering material which is more dense than the surrounding clay matrix and which appears white on the film, pores and cracks which pass the beam of x-rays to the plate and which appear black, and subtle variations in contrast which are caused by manipulating the clay and forming joins. The disadvantage of the technique is that the texture of the surface of the pot is superimposed on internal structure, so that finger impressions or streaks from shaping or smoothing, or marks from scraping the wall, can be seen. Samples which have weathered or have a flaking or pitted surface are thus unsuitable. Deposits of calcium carbonate on the surface also show up, precluding this technique being used

on encrusted samples. For whole pots the variations in thickness of the wall can be seen in cross section, but in views parallel to the surface the two sides of the pot are superimposed on each other with the upper side being out of focus.

In those cases where the radiograph of the face of a sherd had a clear view of the internal structure, cross sections were sliced (like a loaf of bread) to confirm the type and placement of the join from one interval to the next. Thus, for instance, coiling can be differentiated from slab construction. Sherds were sliced with a diamond saw to have about the same thickness as the wall of the pot, about 2 to 20 mm. Examples of such cross sectional views but using another technique of radiography are shown in Figure 12.

Radiographs give a great deal of detail about the structure of pottery, but most of the detail is present as very small variations in grey tonality. The resolution is limited only by the film. High resolution film produced a better quality image (Figure 5), but does not improve the contrast. To interpret much of this detail, a great deal of image enhancement is necessary. For these reasons, the technique of radiography has not been found useful in the study of pottery production methods. The variations in density in painting pigments and metal objects are much greater, and in their examination the technique of radiography has proven useful. An alternate technique of xero-radiography produces an image of lesser resolution, but one which preferentially increases the contrast at edges and joints, and which is preferable to radiography for the study of pottery production. The technique of xero-radiography will be described below and compared with radiography.

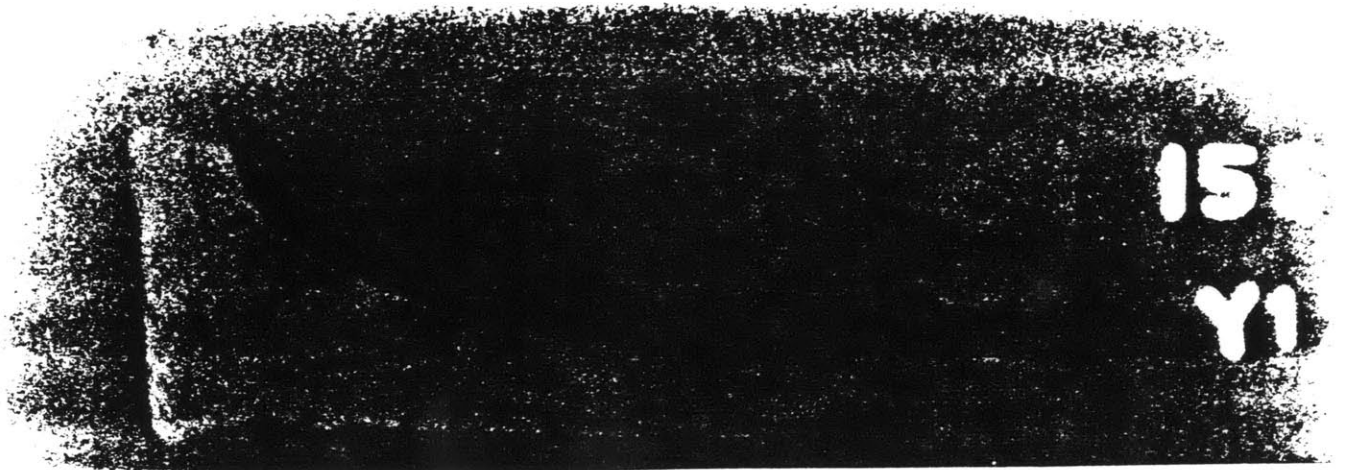


Figure 4a. Film Radiograph of Cross Sections of Tepe Yahya Coarse Ware Pottery. The same sherds are shown in Figure 6a, top and bottom, as a black and white print. The sherd on the upper right is shown in Figure 12, lower left, as a radiograph in order to facilitate comparison of these methods of visualization.

Figure 4b. Film Radiograph of the Cross Section
of a Seh Gabi Cook Pot Shown in the Radiograph in
Figure 12.



6. Ultrasound to Reveal Density Differences at Potential Joints

Ultrasound is commonly used to detect differences in density using high frequency sound pulsed at about 60 MHz (Panametrics, Waltham, Mass., Hyscan System with 5600 Wideband Ultrasonic Pulser Receiver). The echo from density gradients is detected, tuned, amplified and plotted as a depth profile as the transducer is scanned along the object of interest, as shown in Figure 3.6. The frequency of the signal can be tuned to exceed the damping capacity of most materials. Recent advances in computer software, focusing and scanning mechanisms and electronics used to tune and modify the echo, have allowed the resolution of ultrasound to less than 0.001" and the production of three-dimensional images of flaws in multilayer materials. This is a nondestructive technique which can be used to examine large numbers of samples in a short time.

However, the problem in applying ultrasound to earthenware pottery is that internal porosity reflects and scatters the incoming signal so that sound attenuation is rapid and the earthenware appears opaque to the signal. A decrease in the porosity to near perfect density is necessary for the evaluation of flaws in pottery.

7. CAT Scanning as a Means of Three Dimensional Visualization

The advantage of computer aided tomography (CAT scan) is that, instead of an image being averaged through the entire thickness of a vessel wall, sequential images are obtained for several sets of planar coordinates without destruction of the sample. When superimposed on a computer screen, these images give a three-dimensional view of the structure of an object, an advantage over radiography or xero-radiography.

This technique at present is limited in resolution to 1-3 mm. depending on the density of the base material. This resolution is insufficient to use

in the imaging of joins in pottery sherds. Inclusions of 3 mm. have been imaged in a meteorite (J.R. Arnold 1983:383), and we were able to image the cracks but not the joins in the base of a coarse ware sherd.

B. APPLICATION OF THOSE METHODS WHICH WERE USEFUL

1. Low Power Microscopy of Surfaces and Fractured Sections

Most earthenware pottery sherds from excavations still retain dirt adhering to surfaces, in pores and cracks. This added material was cleaned by intermittent immersion in tepid water in an ultrasonic cleaner (Bransonic 1/2 gallon #221 with a built in heater) for periods up to five minutes followed by brushing using toothbrushes of varying hardness. Where fugitive paints and slips had been used, sherds were not cleaned because of the possibility of loss of decoration.

The first question to assess was the extent to which what was being seen in the sherd was present in the original artifact. Scratches from cleaning, marks from picks, soil encrustation, or other residues, post-excavation treatment, restoration or wear during shipping had to be evaluated and discounted. The separation of acquired from original characteristics involved questioning archaeologists about types of soil, excavation methods and subsequent treatment, as well as microscopic looking at marks made on sherds in the laboratory from each of the conjectured post deposition processes.

Observations of the surfaces and edge fractures were made using a 10x loupe, a binocular microscope with a continuous range of magnification from 10-70x (Bausch and Lomb Stereozoom) and the unaided eye in high intensity glancing or raking light. Lighting conditions were varied through various glancing angles to increase contrast in surface features. In addition, the sherd was rotated to reveal possible joins from a variety of angles.

Criteria for the recognition of joins are given in Figure 8 and some examples of joins are photographed in Figure 5a and b. The occurrence and types of joins present in a sherd were recorded. The size of manufacturing elements was also measured as the length between the center of joins and average wall thickness. Measurements were made with a millimeter scale and recorded for each ware type. For coarse wares in the early phases of the appearance of pottery these parameters were measured for each period or phase. In order to compare the many sizes of pots, the ratio of length to width was plotted versus the occurrence. In many cases, the cleaned edge fracture had a pattern of joins which could be reconstructed from visual examination and drawn as a profile of the cross section to show the shape of joins and length of individual manufacturing elements, as well as the presence of slip coatings or layering of wall or bases. Comparisons were made between the two vertical wall exposures of the sherd. However, to be sure of the type and placement of a join, it was necessary to use at least ten power to follow the direction of pores, burned out organic material, and the changes in color of the clay due to firing and occasionally to composition.

In the visual and low power examination of coarse and fine ware pottery, there are other clues to technology which can be sought. A view of the surface texture in the faces of a sherd with about a 45° glancing light will show such features of manufacture as the operation (throwing, wet smoothing, scraping, burnishing, etc.) and sequence of operations where one type of mark can be found to overlay another type. With the light held almost parallel to the sherd surface, it is often possible to see the shape of the individual manufacturing elements, such as lumps, strips, coils and slabs, used to construct the vessel. Often there is a thickening or

thinning of the cross section at such joins.

Once a number of sherds had been examined, roughly 50 to 100, other more subtle features of technology could be described. Some of the aspects which could not be quantified were the range of variability in method of manufacture, quality of craftsmanship and the sequence of manufacture. The defects in manufacture and attempted repairs of various defects could also be seen. The most common defect in the chaff tempered coarseware was the joining of new clay to an already quite dry wall which caused a crack to grow during drying at the join. Frequently, such joins were reinforced with other bits of clay. Other manufacturing variables, such body formulation and preparation, clay shrinkage, degree of vitrification, permeability and porosity can be evaluated qualitatively during examination. However, it is extremely important to evaluate how the present collection is related to what was actually present at the site. Thus, questions about sampling strategy and differences in the populations of samples were asked.

Variations in the dryness of the pottery during which different processes were carried out can be detected with a microscope from characteristic surface textures. In addition, the group of movements required to form and finish a vessel or a particular form can sometimes be reconstructed from characteristic surface textures and overlapping sequences of these textures. The nature of the fractured edges can tell how high fired the clay was, as the fracture appears more glassy the higher the firing. Most chaff tempered coarse ware was fired to a low enough temperature that very little glass was formed, such that fractures tend to follow the construction lines. In addition, there was very little extension of the body once a join was made. In the fine wares, the firing temperature was higher, more glass was formed, walls were often extended after

construction, such that joins are very difficult to detect in the fracture. In addition, the fine wares are without the aligned pores from burned out organic temper which serve to outline the joins in coarse wares.

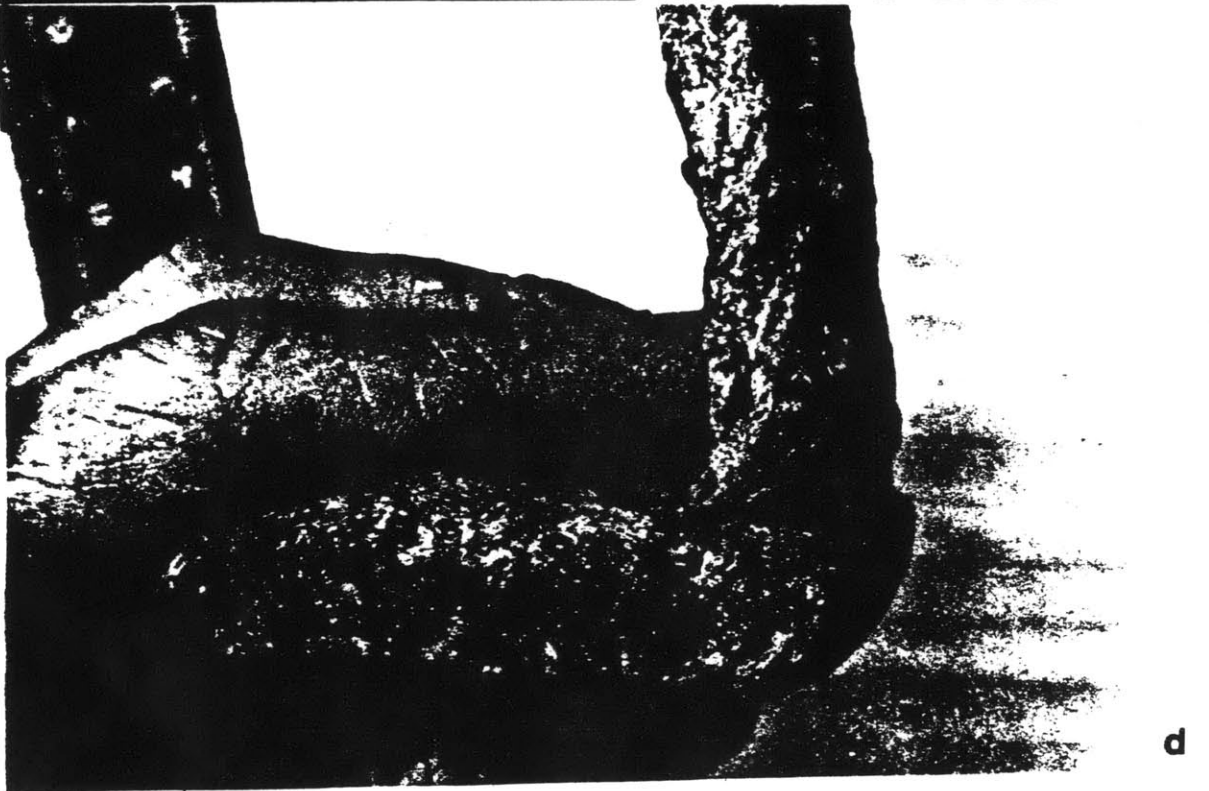
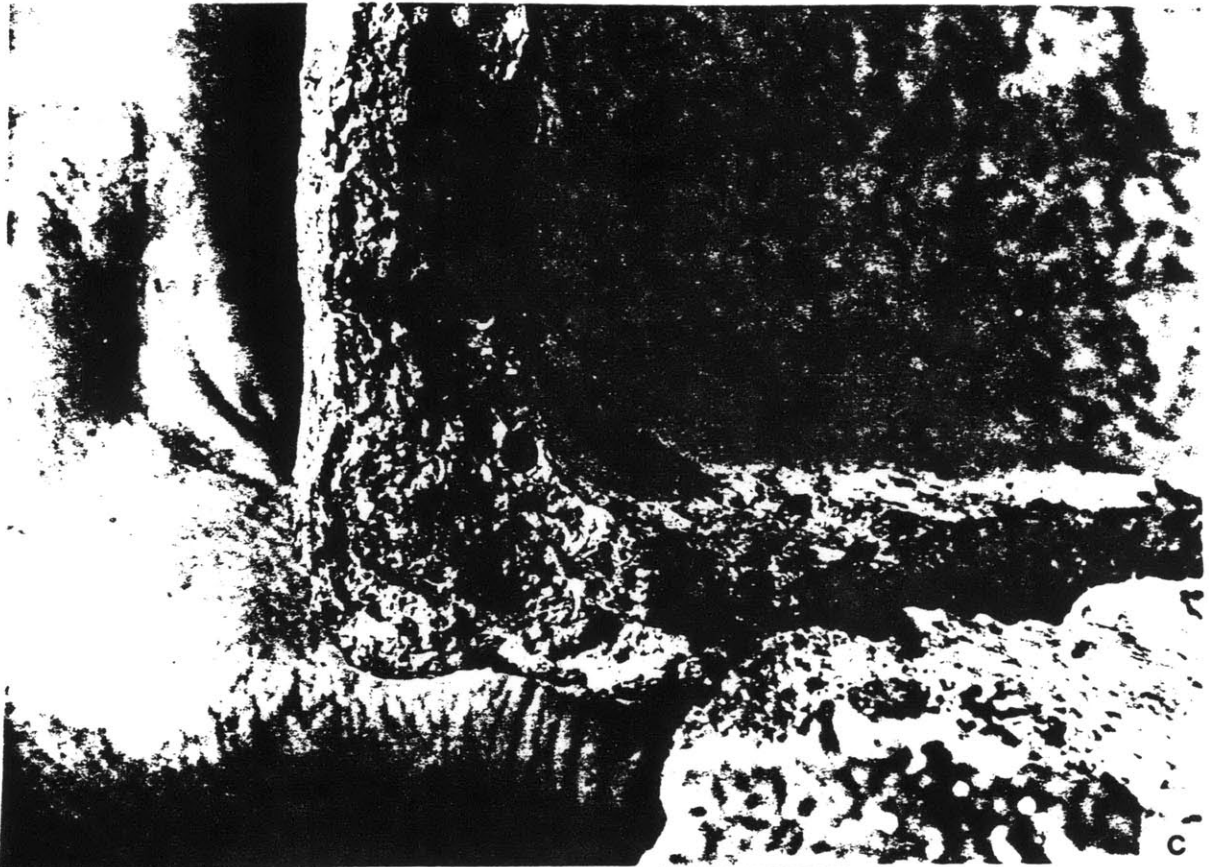
Figure 5a. Edge Fractures of Tepe Yahya Coarse Ware Sherds Showing Joins in the Body, Rim and Base: Cross Section Photographs. All scales are in millimeters.

- a. Small bowl seen in profile, 2 1/2 inches high, low fired, and built with a double wass, having the base reinforced and constructed of smaller slabs (C TT5 (7), Period VII). Probably formed inverted over a convex mold, because of the pattern of fissures and open pores on the interior surface. There are many finger impressions on the exterior surface, but not on the interior surface.
- b. Base fragment shown from surface, made of two layers, each of which has broken in a different place. When seen in profile, there is a step fracture. Voids left by burned out organic temper can be seen in the surface (XC 8N '71, Period VII).
- c. Carinated storage jar fragment showing join at carination which can be seen in the upper wall where voids made by burned out organic temper are aligned in a diagonal direction to the wall surfaces. The whole vessel is extant (C-7 (9)(10), see C.C. Lamberg-Karlovsky, 1970, Plate 42a).
- d. The same storage jar mended at the carination where the slabs were originally joined when the pot was fabricated.
- e. Oval tray fragment with a coiled loop handle (C (8) '69, Period VII). Base built in three layers with a skim coat, or thick slip layer applied over the surface. The wall was constructed in two coil or strip elements.
- f. Lower wall of carinated storage jar below the carination is formed of a three layered wall. Large pores at the join of the two center slabs can be seen between the thumb and center finger.
- g. Upper wall of the same carinated storage jar is much thinner and formed as a single thickness wall. The joins can be seen where the wall thickens just below the crack and above the finger joint near the rim.
- h. Base fragment constructed in two layers with a coil added to form a base ring (E TT3 (12)'69). This ring was added after the pot was formed and after the pot was inverted. In places the coil has shrunk away from the base and cracked off showing the join between the base and wall in which the wall was placed around the outside of the base.
- i. Interior surfaces of rim sherds (both from B TT1 (3)(1)'73). The one on the left side was coated with a thick slip when quite dry, because the slip has shrunk as it dried and cracked, leaving a fractured surface. The one on the right was constructed with a strip added at the rim. The join line can

be seen just above the widest part of the sherd.

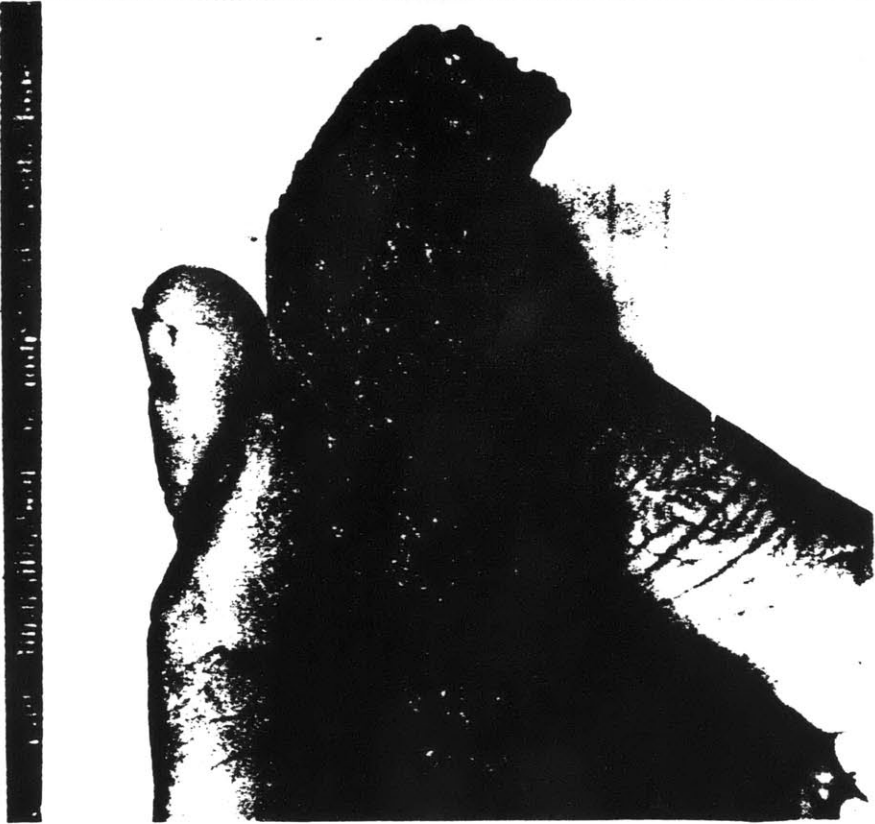
j. The same sherds in Fig. i are shown enlarged here in cross sectional view. The double wall of the left sherd in Fig. i is barely detectable in the upper cross sectional view. On the lower left side the thick slip layer is visible. The double wall in the sherd to the right in Fig. i is clearly visible in the lower cross sectional view. About half way along the upper layer a butt join between two slabs is shown.



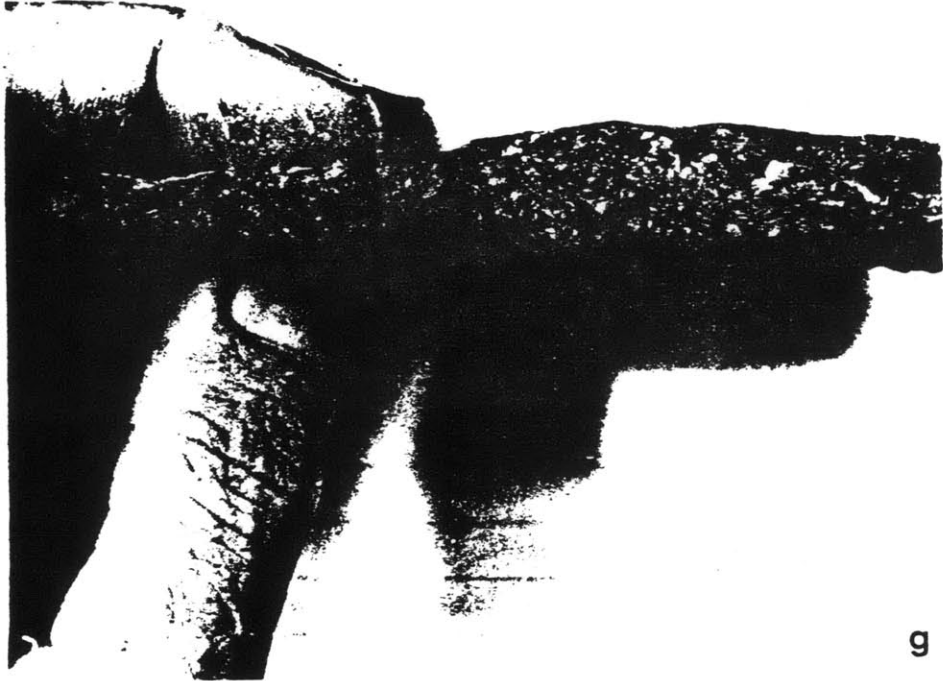


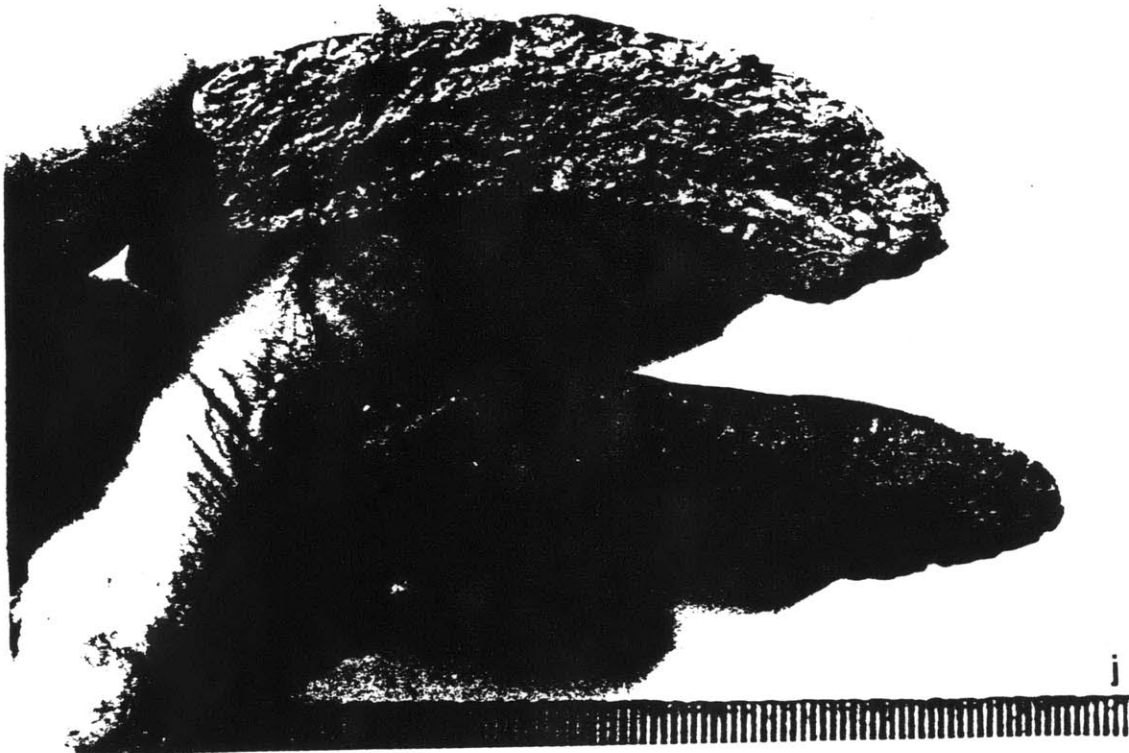
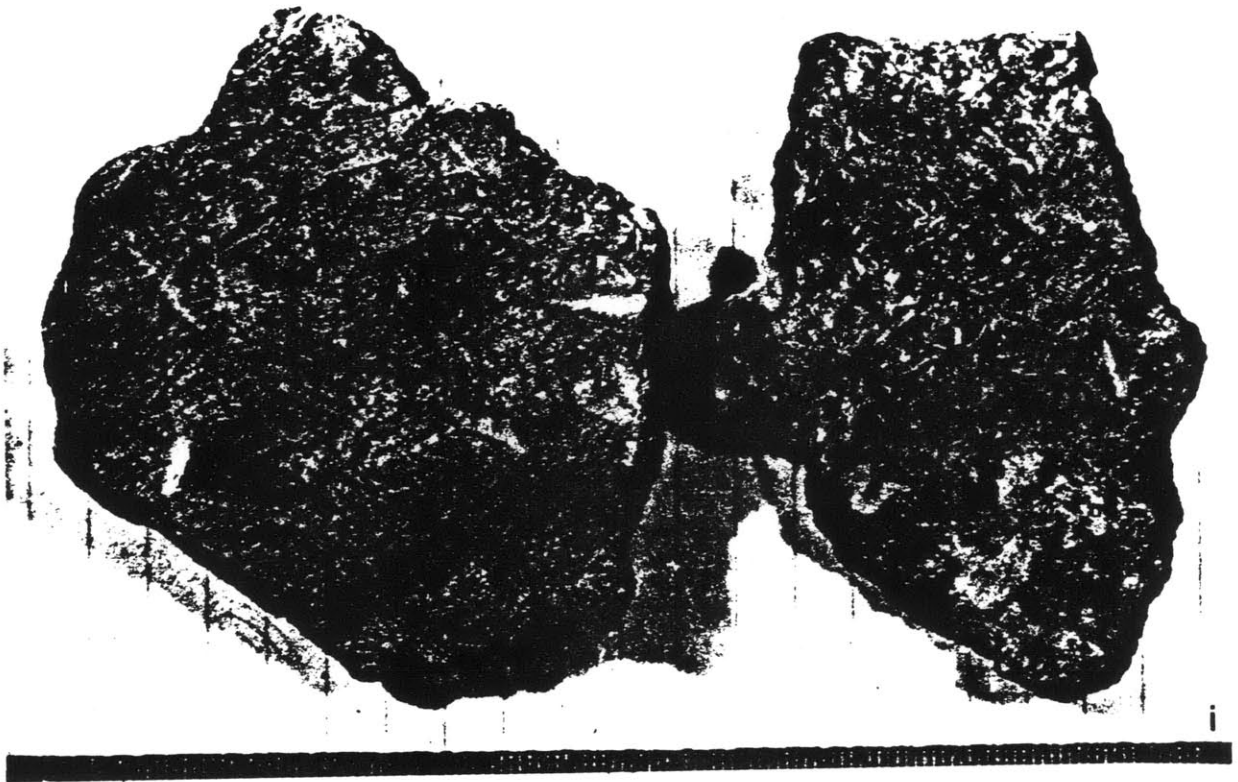


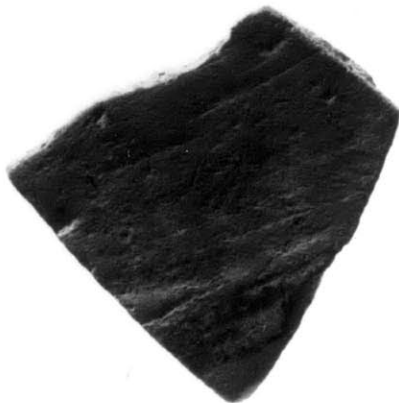
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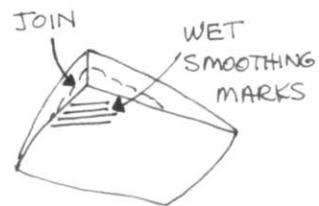
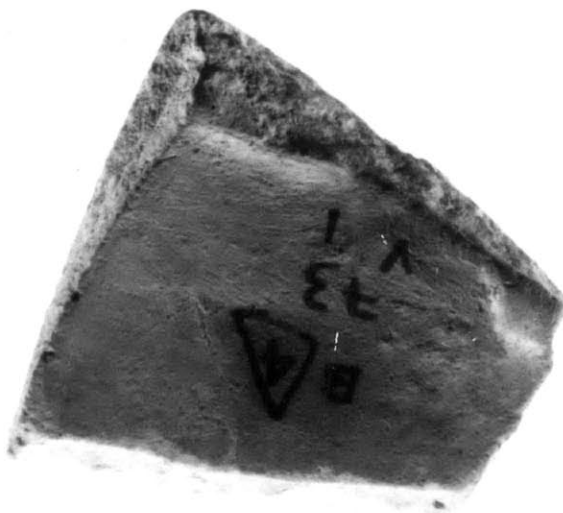
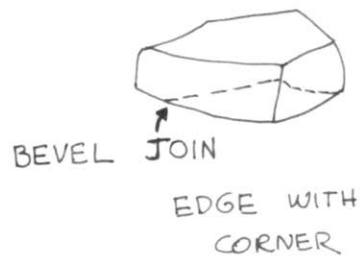
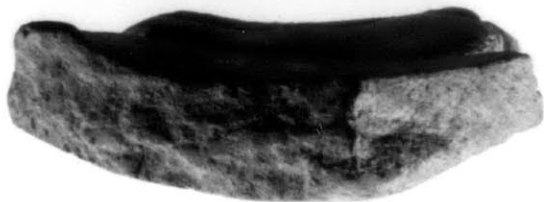
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OUTER SURFACE



INNER SURFACE

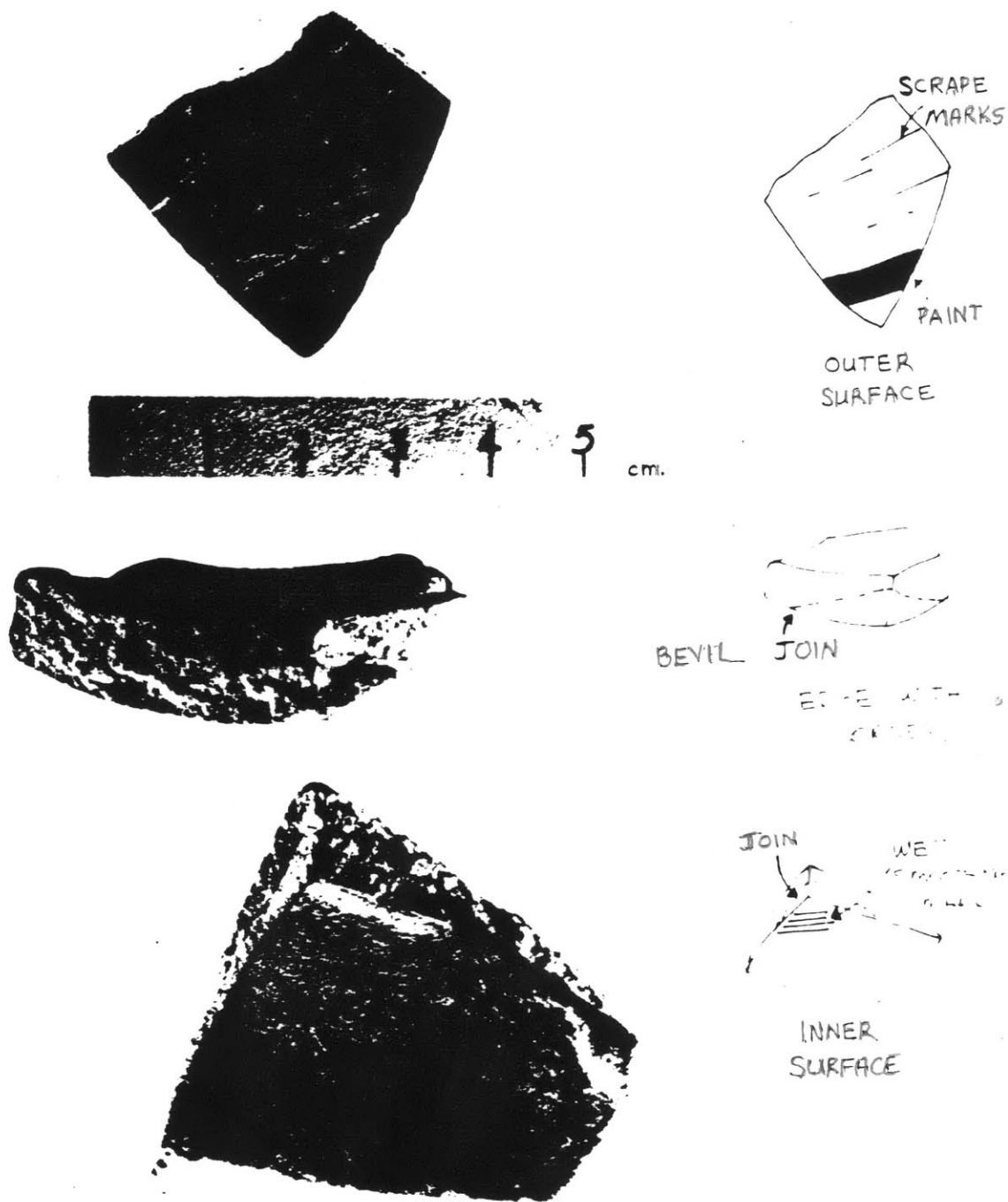


Figure 5b. Edge Fracture and Surface of a Tepe Yahya Grit Tempered, Fine Ware Sherd Showing a Bevel Join Which Continues Around a Corner (B(4) '73, Period VI). The top, edge and bottom views are aligned at the corner. The scale applies only to the upper sherd. Black-on-buff ware.

2. Low Power Microscopy of Polished Sections

Polished cross sections of both fine and coarse wares were examined with a low power microscope in order to examine the alignment of pores in the clay walls. There are two sources of pores in fired sherds, from air pockets in the clay left during preparation of the body and from burned out organic material added to the clay body or present in the original clay source(s). The air pockets and organic material will align in the direction of extension of the body during forming, and will be rounded when two pieces of clay are joined, as shown in Figure 6b. If the two pieces of clay are well worked together, the material may be reoriented in the direction of the join.

Using a fractured section, it is difficult to visualize the shape and size of pores. Grinding and polishing a smooth cross section allows the characterization of pores. This technique is particularly important for the fine wares where the size of pores is small, an example of which is shown in Figure 6.

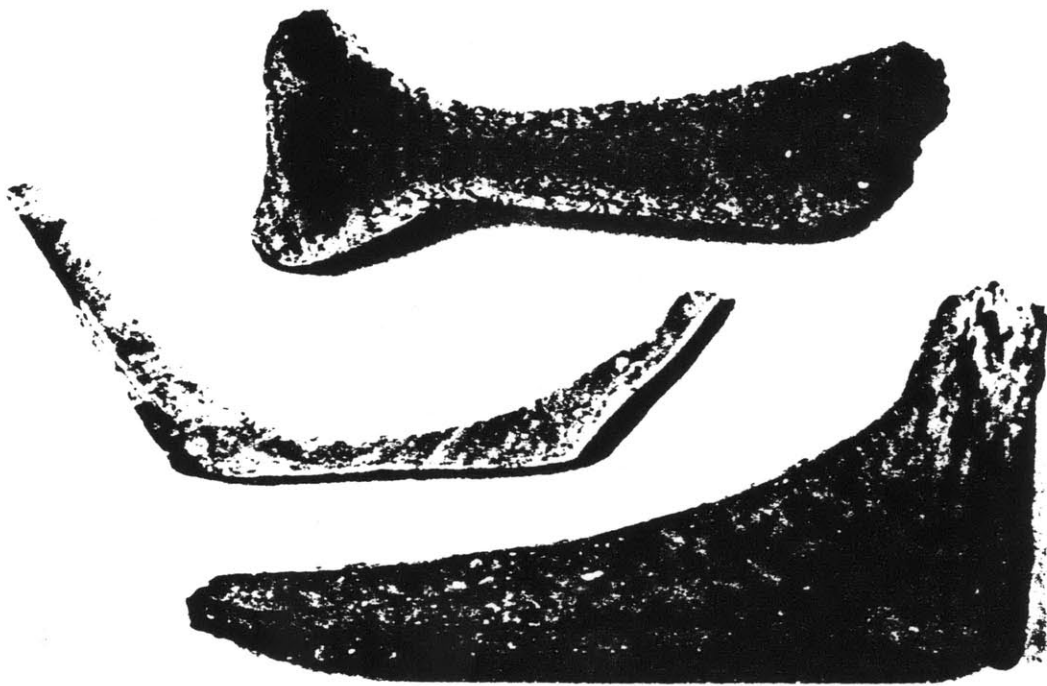


Figure 6. Polished and Thin Sections Showing Joins in Fine and Coarse Ware Sherds from Tepe Yahya:
 (a) Coarse ware base fragment made of two layers, with added coil at the base (same as Fig. 5A(#h)),
 (b) Fine ware base of beaker, black-on-red ware, (XCE 1-2 NVA.1-NVA.2), (c) Base fragment with side wall slab placed on top of base and reinforced with interior strip. In a and c the black core is darkest surrounding pores from burned out organic material. No core is present in the fine ware sherd (b). Black core indicates incomplete burnout or a fast, high firing in which pores are closed off. (c) is the most porous of the three sherds and comes from C TT1 (8) '73.

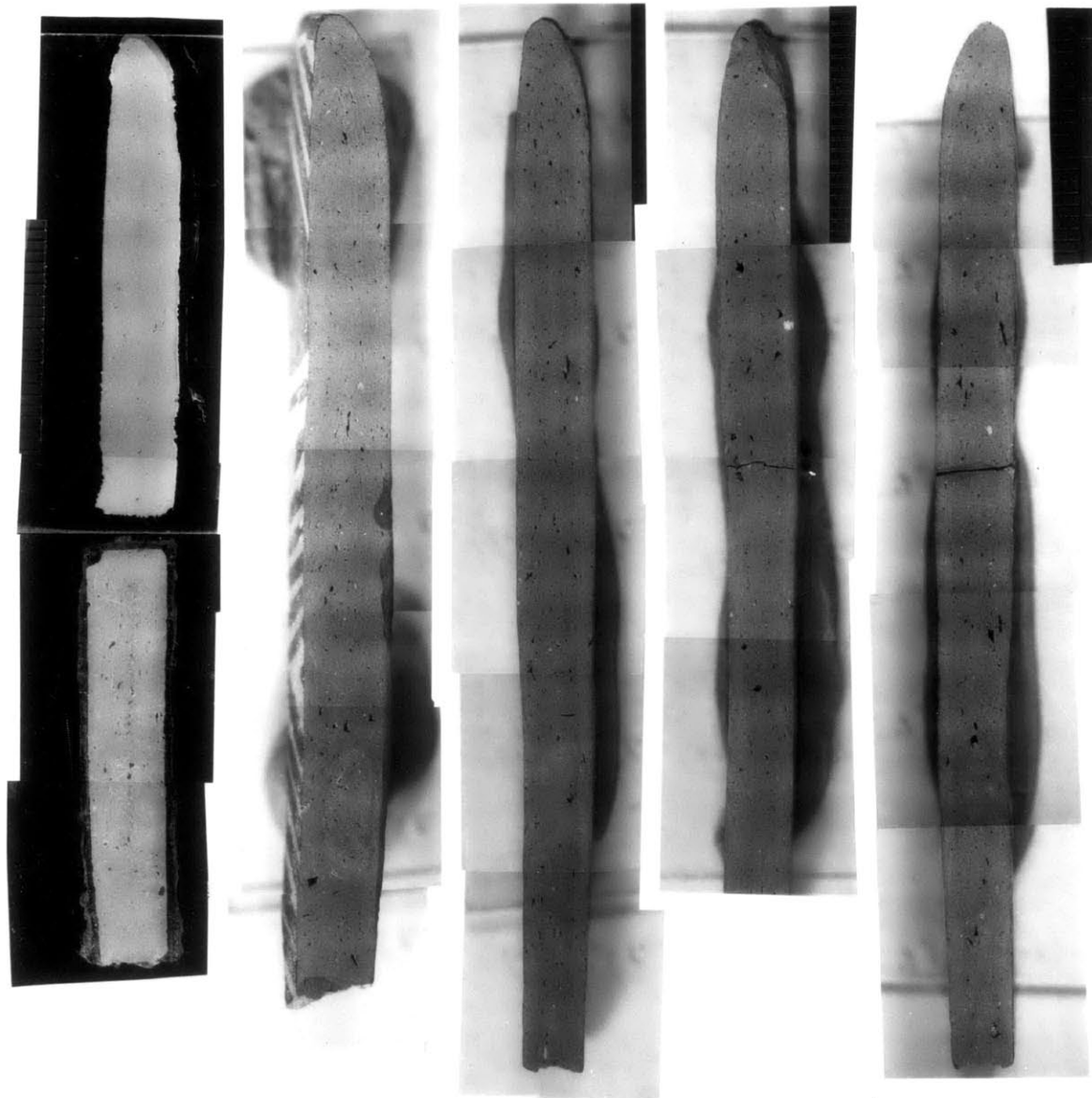




Figure 6(d). Left is a thin section showing joints indicated by arrows. The four composite polished sections to the right are slices from the same black on buff sherd (B (6)'73). The joints are indicated by arrows. The zigzag design motif is visible on edge of the first polished section to the left. Scales are in millimeters. These 5 consecutive slices cover a distance of 30 mm. circumferentially.

3. Xero-radiography

In order to visualize the spatial distribution of manufacturing elements drawn and measured in cross section, and occasionally discernible on the surface in a raking light, a Xerox Corporation process used in mammography was employed. The advantage of this method is that image enhancement of edges and joins allows greater contrast than found in traditional radiography film. A charged selenium plate irradiated with an x-ray source run at 50-65 kV, 100 kV for very thick vessel walls, and at 150 to 400 milliamp.sec (mas). The focal distance is about 36-40 inches. A block diagram of this process is shown in Figure 3.5. At the University Hospital, University of Pennsylvania, Philadelphia, a Picker GX 850 X-ray was used with Xerox Corp. imaging cassettes and developing equipment and Xerox 125 transfer paper. At Cambridge Hospital, Cambridge, Mass., a General Electric 350 x-ray generator was used during the early stages and a General Electric MPX 1050 x-ray generator was used during the later stages. In Toronto at Women's Hospital and at Varad, Inc., in Montreal, similar equipment was used.

Xero-radiography has been applied to pottery by R.E. Alexander and R.H. Johnston (1982:145-154), by W. Glanzman (1983:163-169) and by G.V. Foster (1983:179-181) to obtain information on shape, temper and manufacture. William Glanzman in his study of Iron Age ceramics has coupled replication to allow detailed interpretation of his results with the study of thick cross sections cut in profile from vessel walls and xero-radiographed in order to reveal coiling as the initial forming method of a vessel which was subsequently thrown to shape and confirming in other ware the upside down forming of bases conjectured by H.J. Franken and J. Kalsbeek (1974,1975).

A group of pottery of known manufacturing methods were subjected to

xero-radiography and are illustrated in Figure 7. The pottery has not been reproduced at the same scale. Reference to the black and white photographs of the pottery can provide a sense of scale. These standards consist of a variety of methods; three are contemporary pottery, and two are ancient examples. Illustrations of manufacturing methods include whole vessels made by (1) throwing on an electric wheel in an example made by the author where very little force is necessary and the grooves from turning are shallow. The white-appearing rounded bubbles are in the glaze. Two parallel lines have been incised at the neck by banding, or rotating on a turn table. A crack in the center of the base which radiates out from the center is caused by the slower drying of the base where water pools during throwing and initial drying. The base tends to dry last and thus is the last part to shrink. Coil building (2) at San Ildefonso, New Mexico, is illustrated in a pot by Tonita Martinez, in which the coils are well worked together, but the wall thickness is not even and stress cracks occur near the base. The top view shows some elongation and alignment of pores in a horizontal direction. A square cross section vessel (3) made by a contemporary Japanese potter was said to have been made in slabs. I thought that slabs were used for each wall and were joined at the corners. The radiograph showed that instead smaller strips were placed one on top of another and pinched together. A second view showed that the strips continued around the corners.

These samples were later supplemented by two other standards: one a fragmented base and wall section from a Godin period III jar (4) mended by Dr. Robert Henrickson and from a group characterized in his doctoral thesis as thrown, in which the circumferential grooves from throwing are visually prominent on the internal surface due to the force exerted by the potter using a kick or hand turned potter's wheel in which the centrifical force is

neither so great nor constant as in an modern electric powered wheel. In addition, the air pockets which appear white in the radiograph have aligned in an upward spiral or diagonal direction caused by the upward direction of forming the wall.

A second ancient example is a neolithic Chinese jar from the Yangshao culture manufactured by coiling and then formed by a paddle and anvil technique. The individual blows of the paddle and anvil are visible as diagonally aligned diamond shapes. The coils are 10-15 mm in diameter, are the same size in the lower wall as in the neck and can be seen most easily in the lower wall. In addition, there is horizontal alignment and elongation of the pores. The handles were added in a wetter state than the body and the differences in shrinkage are visible in crack at the base of the handle which is not visible on the surface of the vessel. A top view of the pot shows that the neck was added as a section to the body of the pot because a join line can be seen around the neck which is irregular and shows the working together of the two parts.

In the group of radiography standards we have a representation of a wide variety of processes, coiling, building in strips, joining of sections, paddle and anvil shaping, molding of the rounded base of a vessel which leads to diagonal stress cracks, uneven shrinkage of the clay body at handles and in the wet base of a pot, throwing with an electric and manually powered wheel. Each of these processes is readily apparent in xero-radiographs, which add to our knowledge of processing by adding information on internal cracks, shape, size and alignment of pores as well as variations in the density of clay packing, wall thickness and surface textures.

Figure 7. Xero-Radiography of Standards for Pottery Production.

(a) Stoneware pot thrown on an electric potter's wheel, incised at neck with a trimmed foot ring, made by author. Circumferential ridges from throwing on the surface and in profile are apparent in the black and white photo and xero-radiograph. Bubbles in the thick areas of glossy red and grey glaze appear as patches of white dots. A radial S-shaped shrinkage crack from excessive wetting of the base occurs in the center of the base. Wall is even thickness in horizontal section.

(b) Coil built earthenware jar with black slip glaze, made by Tonita Martinez, San Ildefonso, New Mexico. The base was formed in a puka or concave earthenware mold and has stress cracks where the flaring body extended over the lip of the mold. Wall thickness is irregular in horizontal and vertical sections. There is some horizontal alignment of pores where coils have been joined, shown by arrows.

(c) Slab built stoneware bottle with ash glaze and incised decoration, made by a contemporary Japanese potter from strips which were pinched together.

(d) Chinese Yangshao culture earthenware jar from about 5000 B.C., collection of the Peabody Museum, Harvard University, made by coiling and formed by beating. Coils and horizontal pore alignment at joins can be seen near the base and at the neck to have the same diameter, as indicated by arrows. The joint between the neck section and body of the pot is indicated by double arrows. Shrinkage cracks at the handles indicate they were added after the body had begun to dry. 50.1961(D2661)

(e) Small jar, measuring about 4" in height, from Godin, Period III, mended by Dr. Robert Henrickson. The vessel was thrown on a potter's wheel. The evidence consists of spiral circumferential ridges and diagonal elongation of pores, as shown by the arrows. In addition the rounded grey patches are a concretion of lime which has adhered to the pot during burial.

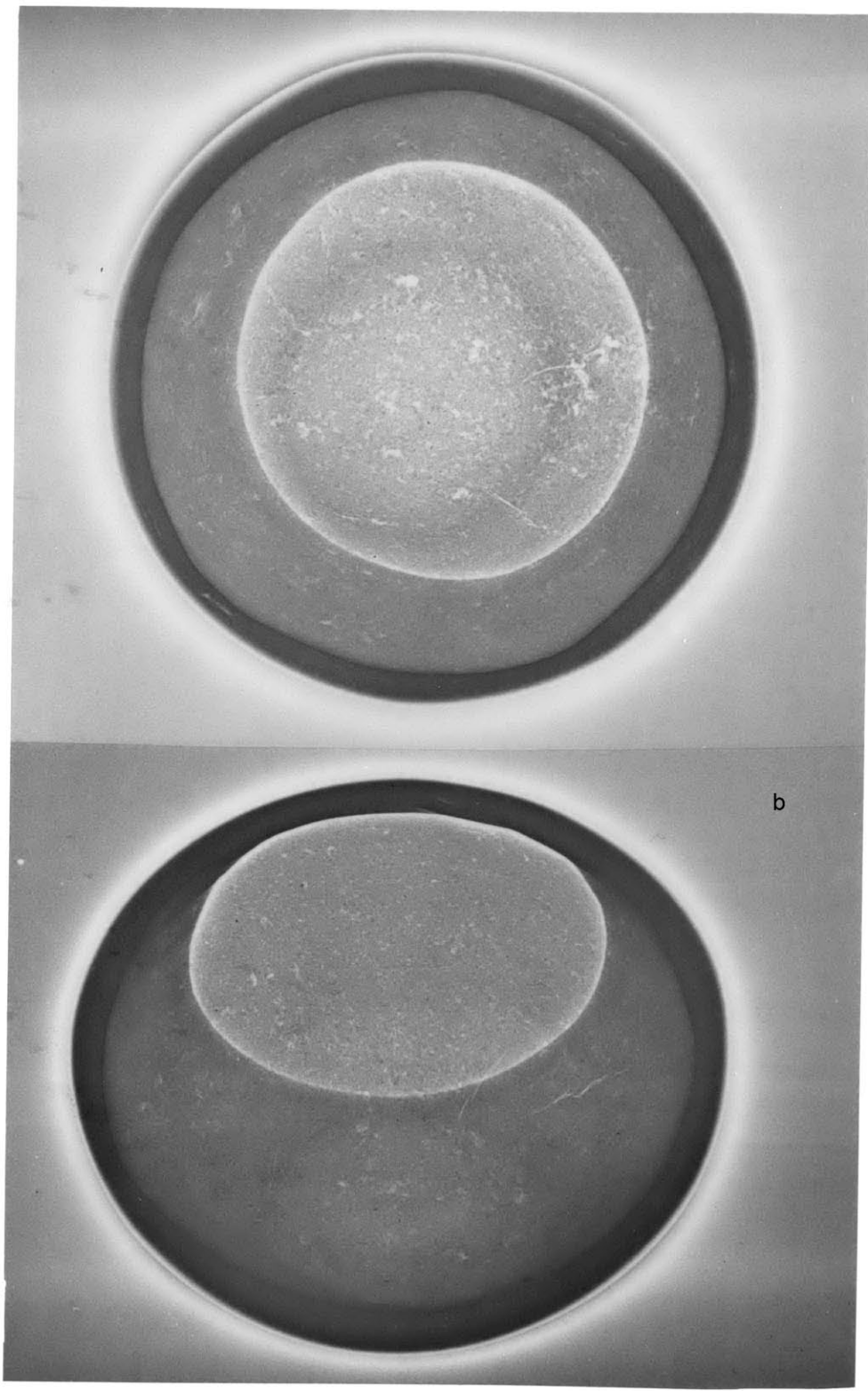


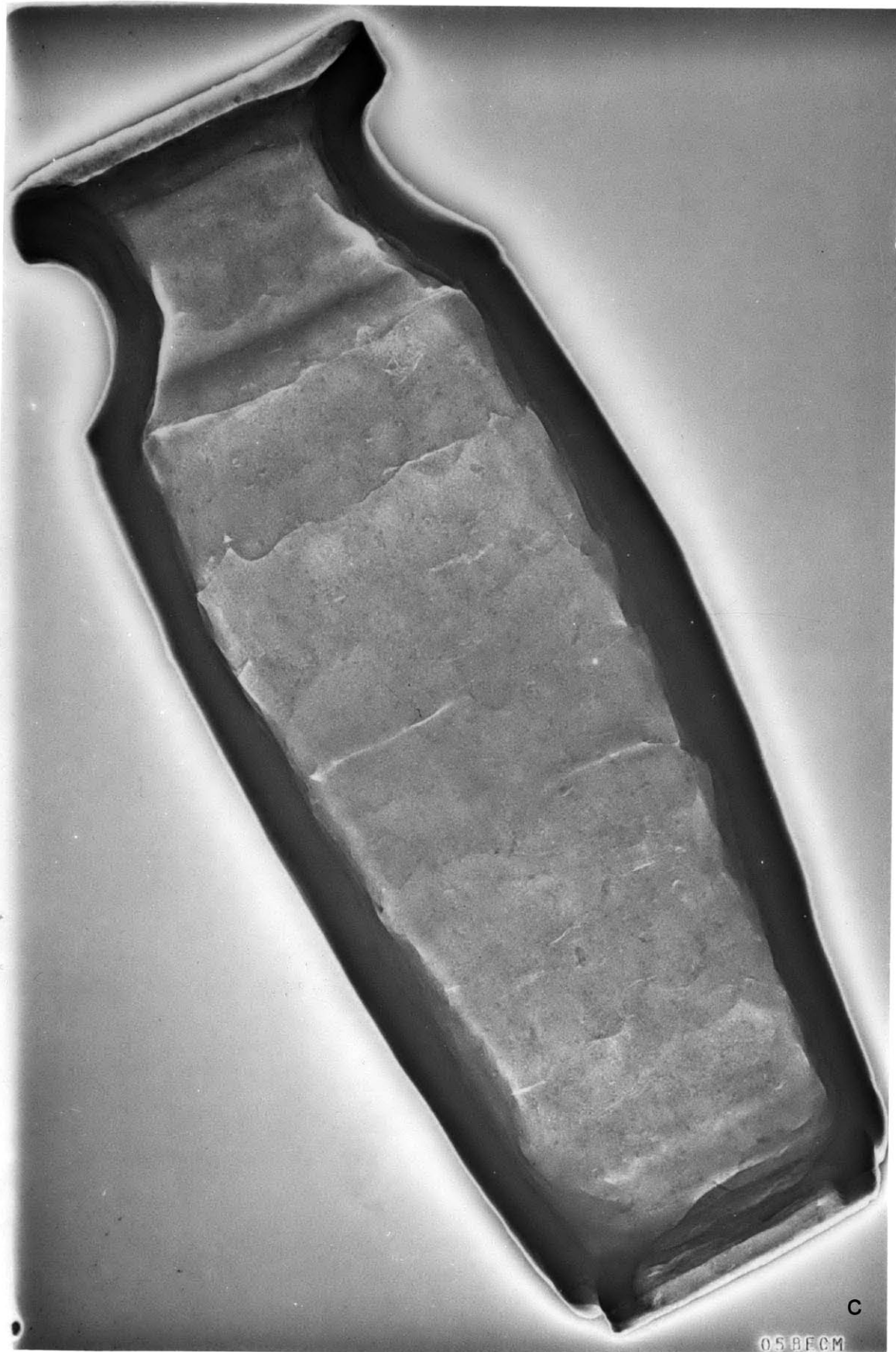
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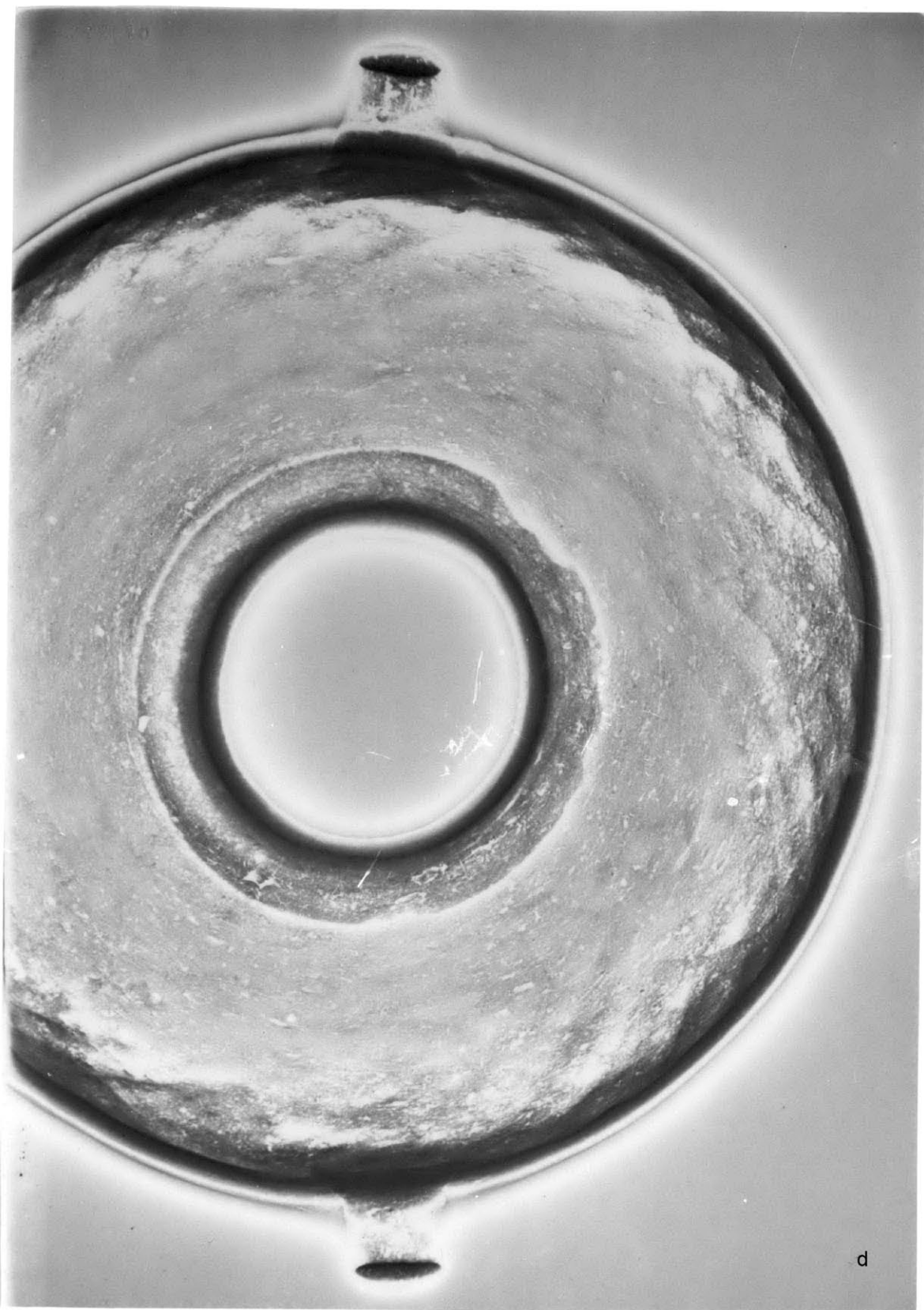
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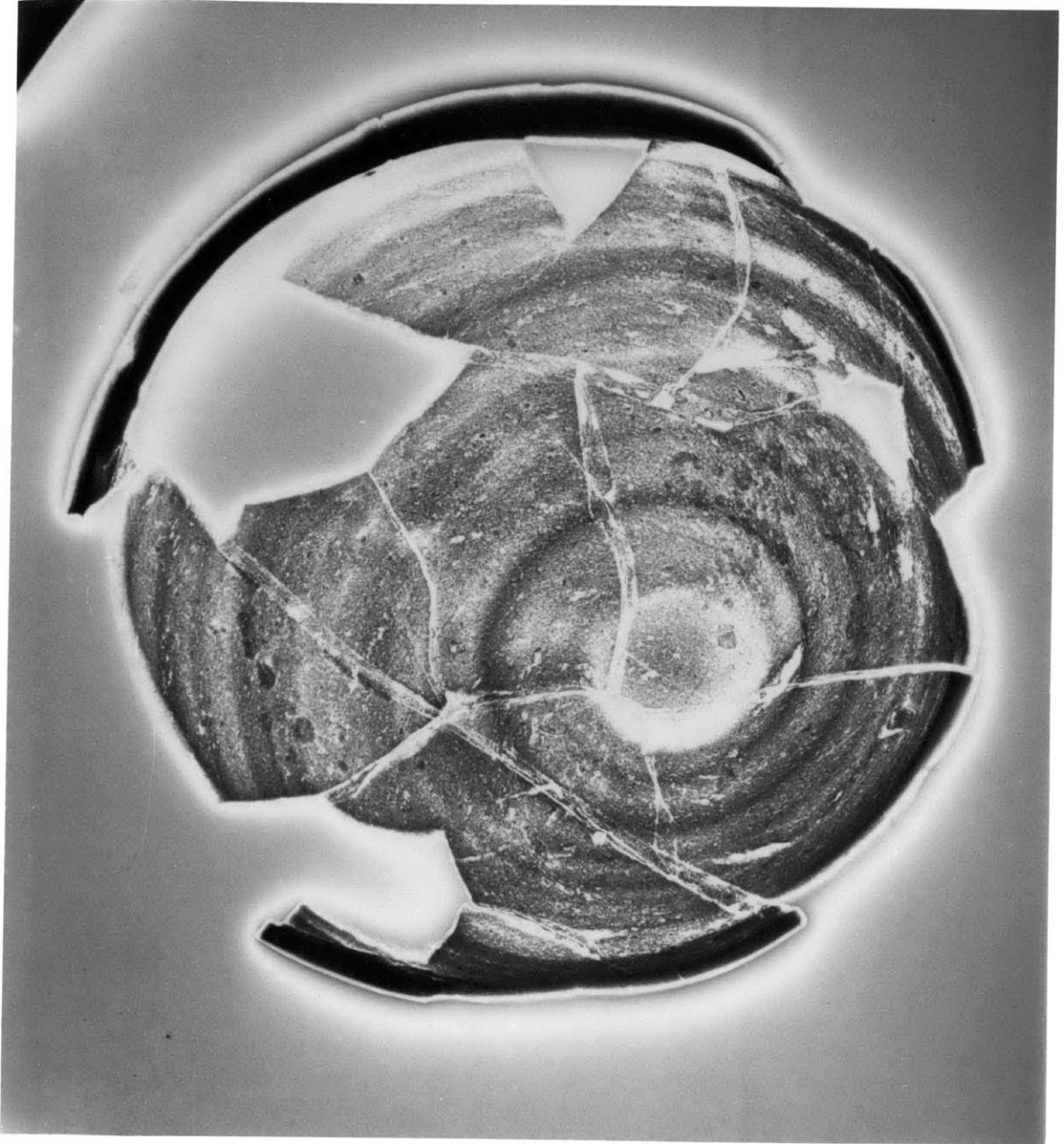


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V. CONJECTURED PROCESSES OF NEOLITHIC AND CHALCOLITHIC
NEAR EASTERN POTTERY PRODUCTION AND STANDARDS
APPROPRIATE TO THEIR STUDY

A. STANDARDS USED TO ESTABLISH A TECHNOLOGICAL TYPOLOGY

1. Types of Joins

From an initial six week microscopic examination of 800 Tepe Yahya coarse ware and fine ware sherds, there were several different sorts of evidence that joins in the walls were present. For instance, as schematized in Figure 8, a crack might be present at a join, particularly where a carination or base to wall join was present. Because the wall of a pot can only support itself to a certain height when wet, a time for stiffening and partial drying occurs before adding the next level. Joins of wet clay to partially dry clay are more evident than joins between two lumps of clay of the same wetness, because the wetter clay shrinks more than the drier clay. Earthenware clays typically shrink 5 to 10% during drying, so the mismatch can be substantial. A crack is often present at the join on the interior of the body, even though there is not crack on the exterior surface where the potter has worked the join. Often where a join has been made there is a void where one bit of clay has not completely mated with or covered another, as shown in Figure 8. Other evidence for the presence of joins is the presence of a crack on the surface which can be followed around an edge, an indentation on the surface which follows a pattern around the pot or around bits or coils of clay used to construct the vessel. Another indication is a fractured edge with a stepped fracture, in which one bit of clay has broken in the middle of a join with another. I have tried to schematize these criteria for the recognition of joins in Figure 8. In the chaff tempered coarse ware, bevel joins have chaff or rather burned out elongated pores

which show alignment on a diagonal, as shown at the bottom of Figure 8. If there has been extension of the join the same diagonal alignment occurs. In butt joins in coarse ware the pores are perpendicular to the wall, and where extension has occurred the pores are fairly symmetrical around the centerline of the cross section forming a "v" shape, as shown in Figure 8 near the bottom. Fine wares do not contain the chaff temper and the elongation and alignment of air pockets in the clay is used to delineate joins. Pores round where joins have been made in a diagonal or perpendicular pattern as opposed to their elongation in the bulk of the slab. These differences in elongation are often reinforced by differences in the color of clay, surface variations and other features by which joins can be recognized. This evidence is present not only on wasters. These sorts of indications of joins are seen on almost every coarse ware sherd, but are much less common on fine ware sherds, perhaps one in twenty; an example is given in Figure 5.

Drawings were made of the joins seen in cleaned cross section profiles of Tepe Yahya sherds. A limited number of join types were found, some of which seemed to be specific to certain parts of vessels. For instance, there were more layers of clay and more complex joins in the base than in the walls or rims. Again in the examination of sherds from Hajji Firuz, the same sorts of joins and regularity in their distribution was found. These observations led to establishment of five join types as shown in Figure 9: butt joins, bevel joins, a two layer wall with a join in one of the slabs, a double layer wall joining a single layer wall or rim, and a reinforced join or the overlapping of three manufacturing elements, and a sixth category in which a join was present, but the details were sufficiently obscured that the type was undecipherable. If this study were conducted again, the double

layer wall with a join in one wall would be divided into those with butt or bevel joins in the one layer. Figure 10 shows the relative amounts of the different joins in coarse ware sherds from Hajji Firuz made during the early phases (F2-L).

CRITERIA FOR RECOGNITION OF JOINS :

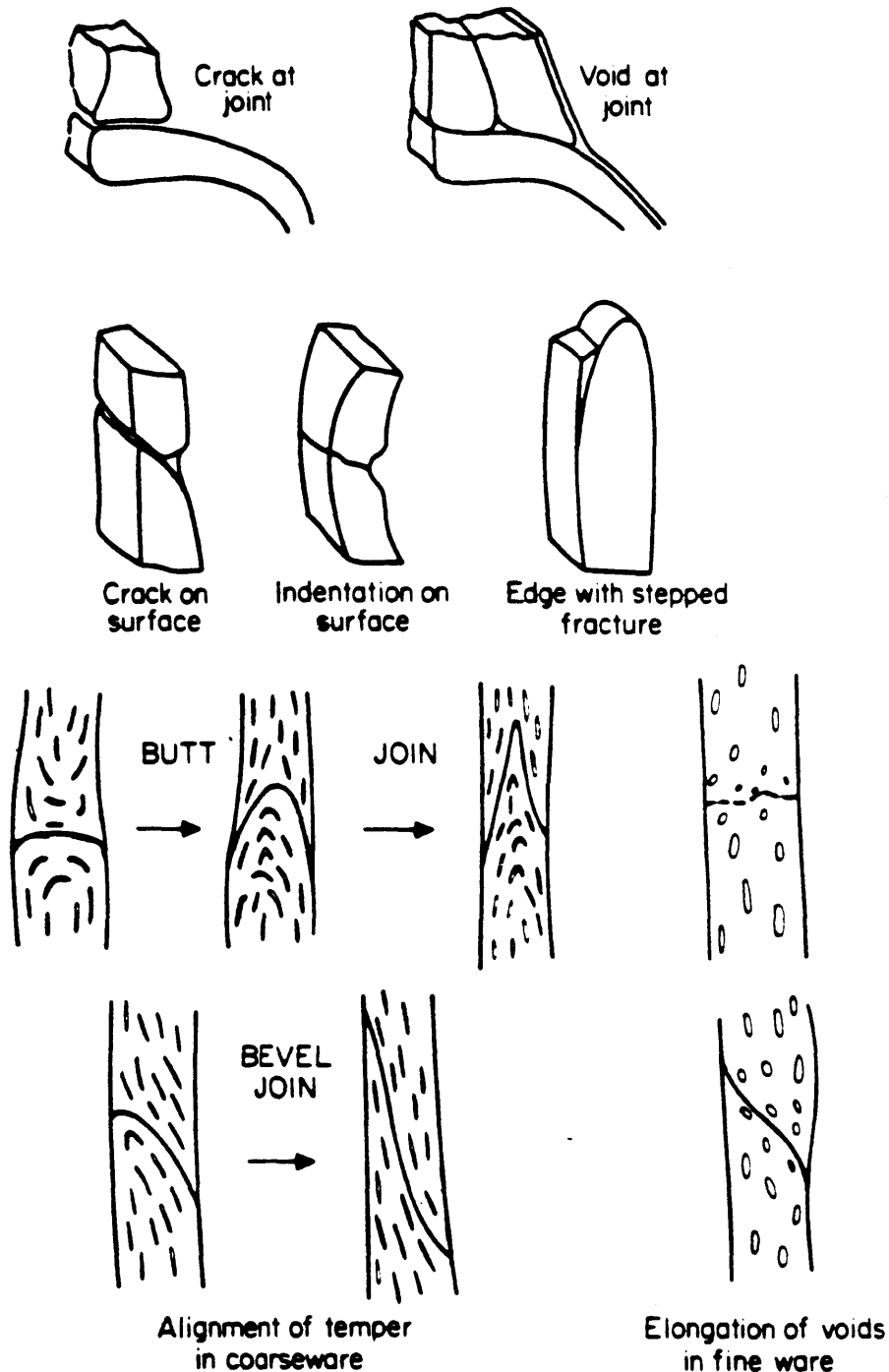
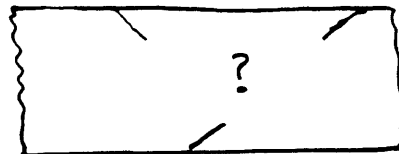
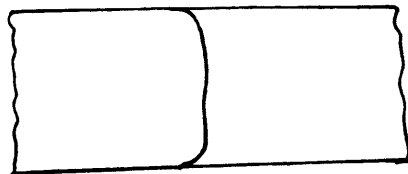


FIGURE 8. Criteria for Recognition of Joins in Coarse and Fine Wares. Surface features are shown above, such as cracks and voids at joints, cracks and indentations on the surface, and stepped fractures where two elements have been joined together. Alignment of temper in coarse wares and rounding and elongation of voids along the join in fine wares are indications of joins, as shown below. The effects of extending a join are shown for the coarse ware by arrows. The effect is to elongate the join and the pattern of organic temper burnout.

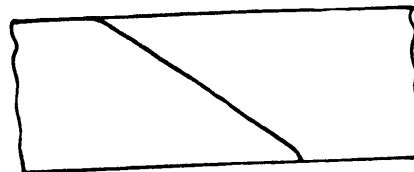


Undecipherable Type of Join

SIMPLE JOINS

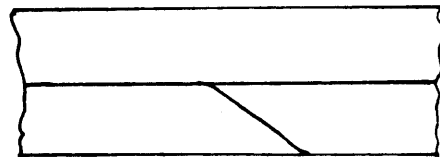
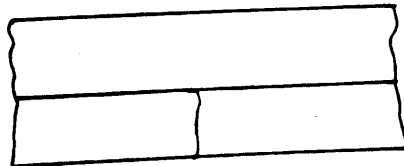


Butt Join

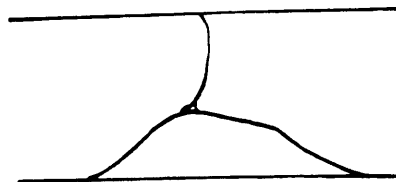


Bevel Join

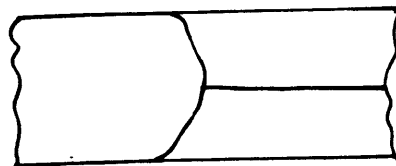
COMPLEX JOINS



Double wall with a butt or bevel join in one layer



An overlapping join of three manufacturing elements



A single element which joins with two elements

Figure 9. Types of Joins Found in Near Eastern Pottery which has been Constructed from Coils, Strips, Slabs and Lumps.

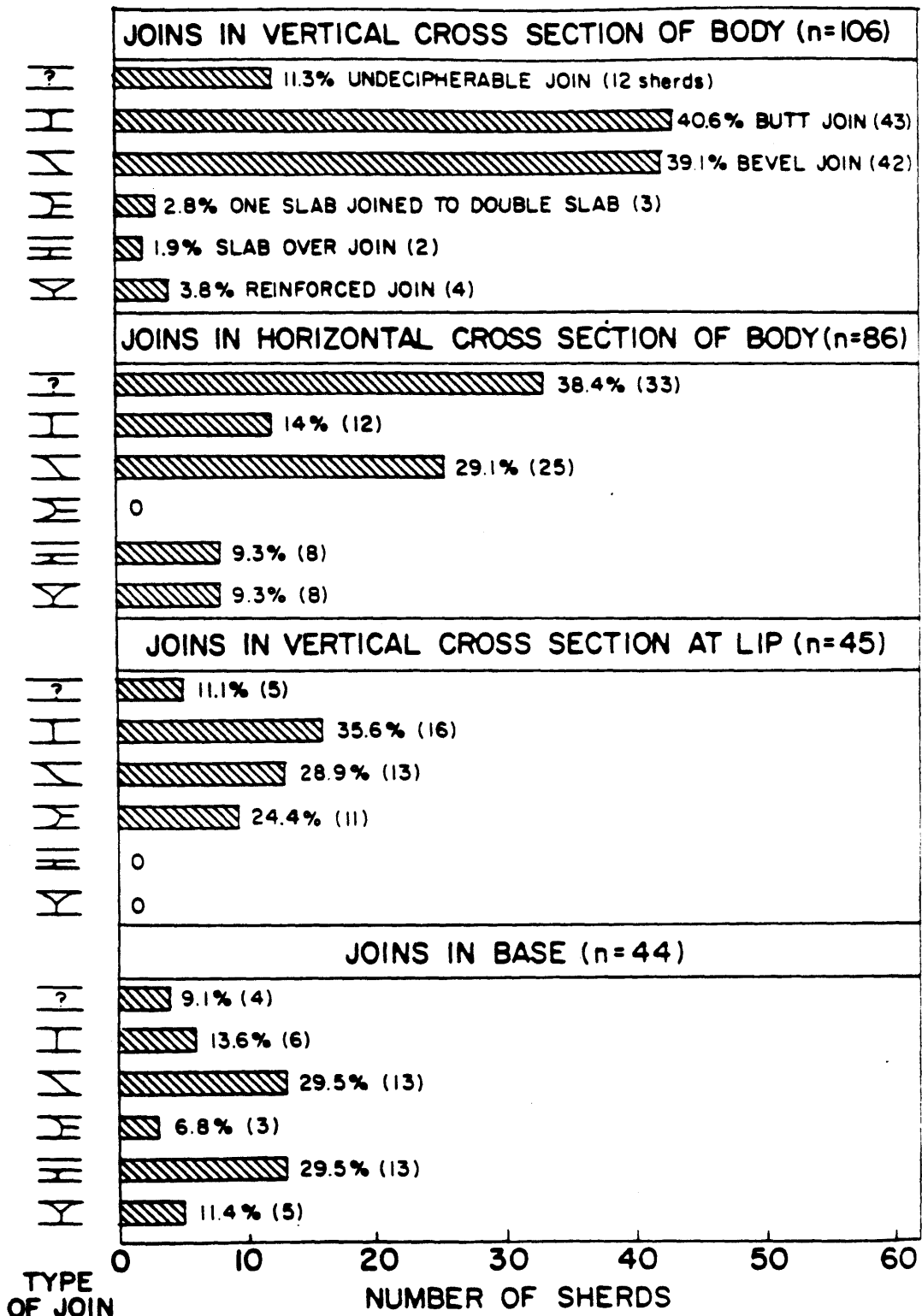


FIGURE 10. Frequency and Type of Join in 195 Hajji Piruz Sherds, all over 50 mm. in length from Operation V(1961), Phases P₂-L (Early Phases).

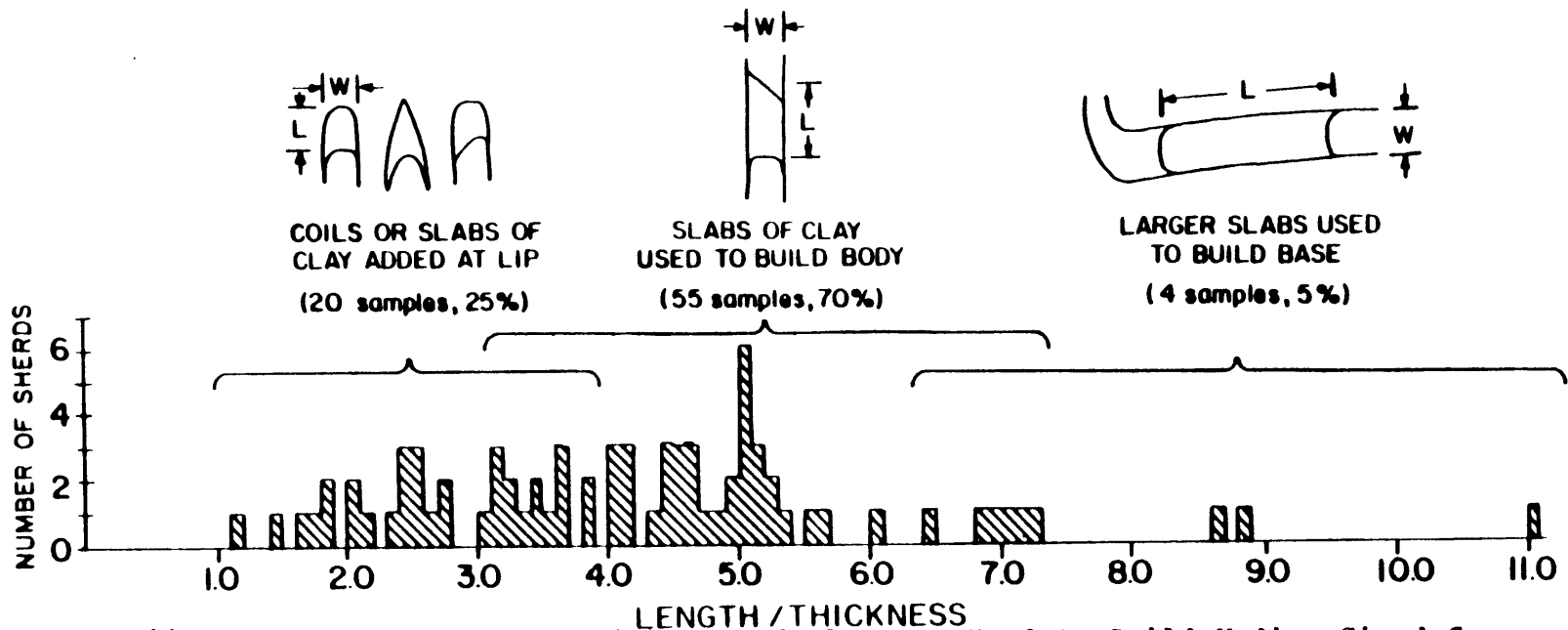


FIGURE 11. Ratio of Length to Thickness of Elements Used to Build Medium-Sized Coarseware Vessels from Hajji Firuz. Sample included 79 samples, 50 mm. minimum sherd length, from G11 (3)(2), Phases A and B.

2. Size of Manufacturing Elements

Figure 11 shows the measurement of manufacturing elements at the rim, body and base used to construct coarse ware vessels from Hajji Firuz of medium size, that is roughly about a foot in diameter, larger than an individual serving dish and smaller than a reasonably sized storage vessel, about the size of a cook pot, small storage vessel or family-sized serving dish. The sample included 79 samples from the late phases (A and B) at Hajji Firuz, with all sherds measuring 50 mm or more in one direction. The width was measured as the average thickness, and the length of the manufacturing element was measured from the center of the join. In order to compare vessels of different sizes, a ratio of length divided by thickness was taken and the number of manufacturing elements was counted. In some graphs, the number of manufacturing elements is labeled number of sherds incorrectly.

The results of the tabulation of the sizes of manufacturing elements show that with the exception of pottery from Ganj Dareh, there is a clear intent by potters to use larger slabs to build the base, having a ratio of length/thickness of 5-10, that smaller lumps, strips or slabs are used in the walls to form the body with a ratio of 3-8, and that bits or coils are added at the lip with a ratio of 1-5. That this patterns holds can be seen in the mean values for element sizes and displacement of the relative size of basal manufacturing elements relative to bodies and rims, which can be previewed by thumbing through graphs in the results section which are described there in detail. These ratios are not discrete populations, but represent a thought pattern of constructing a pot from larger to smaller elements. This is very different from the Chinese neolithic Yangshao pot shown in Figure 7 in which the same size coil (with a ratio of 1-1.5 the

width being equal to the length) is used throughout and can be seen at the bottom of the wall and in the neck.

Radiographs and xero-radiographs of walls and bases show the spatial extent of such slabs in both a surface and profile view as shown in Figure 12. When coupled with drawings of the edge fracture made independently of the radiograph, a picture of the construction of a particular sherd or vessel can be established and documented. Photographs of the surfaces in raking light further reinforce this picture. In Figure 12a a Tepe Yahya basal coarseware sherd (C TT1 (1)71) and rim (C (1)(7)71) show slab construction in profile. Two slabs are used to construct the base; at the corner a slab of clay is set at right angles to the base and another is used to brace and reinforce the join on the inside. The wall is then built with smaller elements used on top than at the base. In Figure 12b, a Mound C, Seh Gabi, cook pot (73 AA21302) is constructed sequentially with slabs placed one next to another and joined with overlapping joins and having the next layer placed over the join of the lower elements, up to a height of about two-thirds of the wall where there is a major break in construction which can be seen as a horizontal line. The pot was allowed to sit until stiff enough to support further weight. Then smaller elements were added to complete the upper section or layer.

Often bases and rims of coarse ware Near Eastern pottery are reinforced with a double layer of clay. In some bases three layers of clay are used. Some joins are reinforced with extra clay. And the surfaces are usually coated with a layer of slip as a facing coat which is either wet smoothed or burnished or both. Thus, compared with the whole pottery vessel standards we have examined, the processes of forming of Near Eastern coarse ware pottery represents a special technological style of making pottery which is

different in detail from processes which are commonly used today or from those which are found in other ancient pottery. We have called this method of making pottery sequential slab construction (s.s.c.).

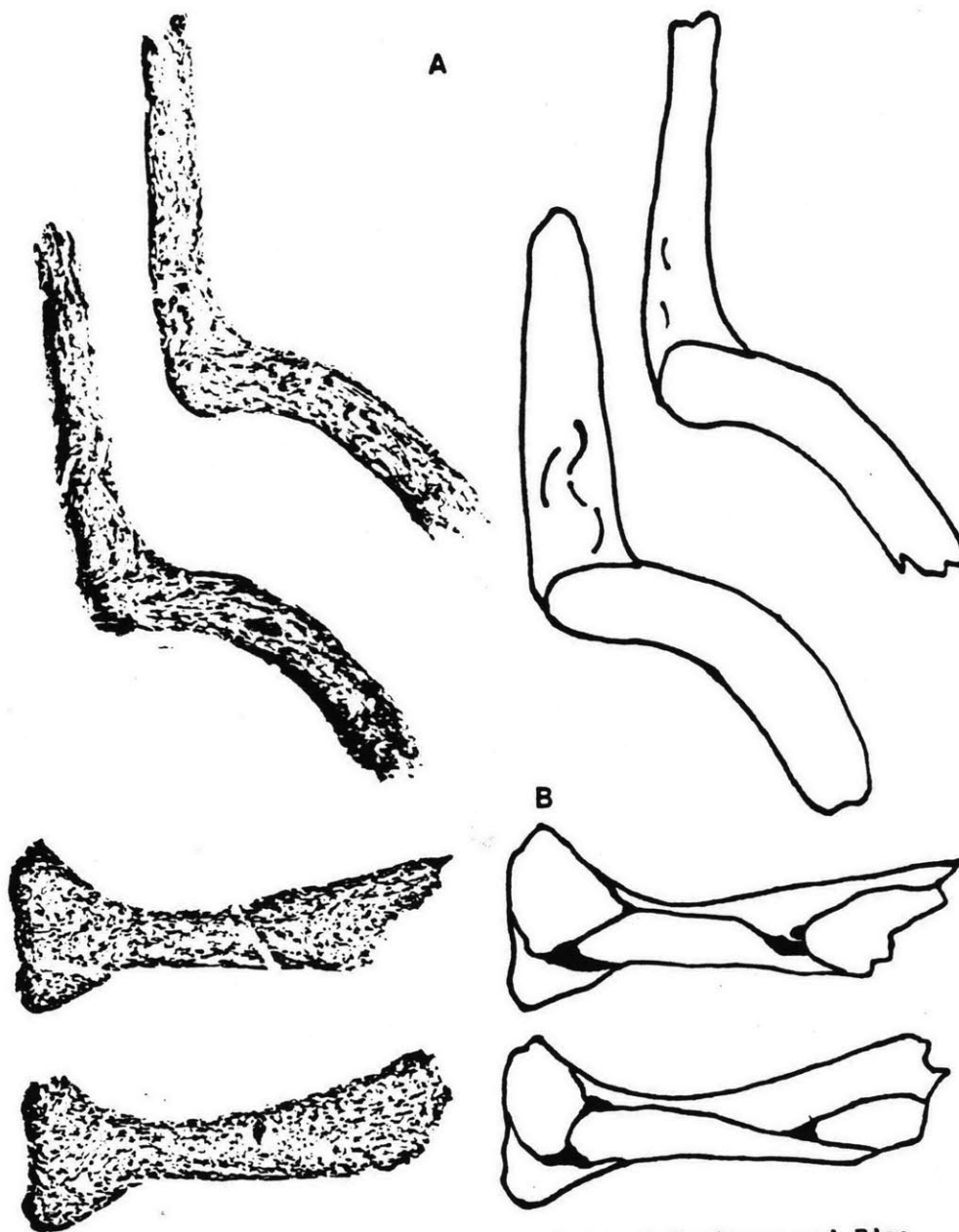
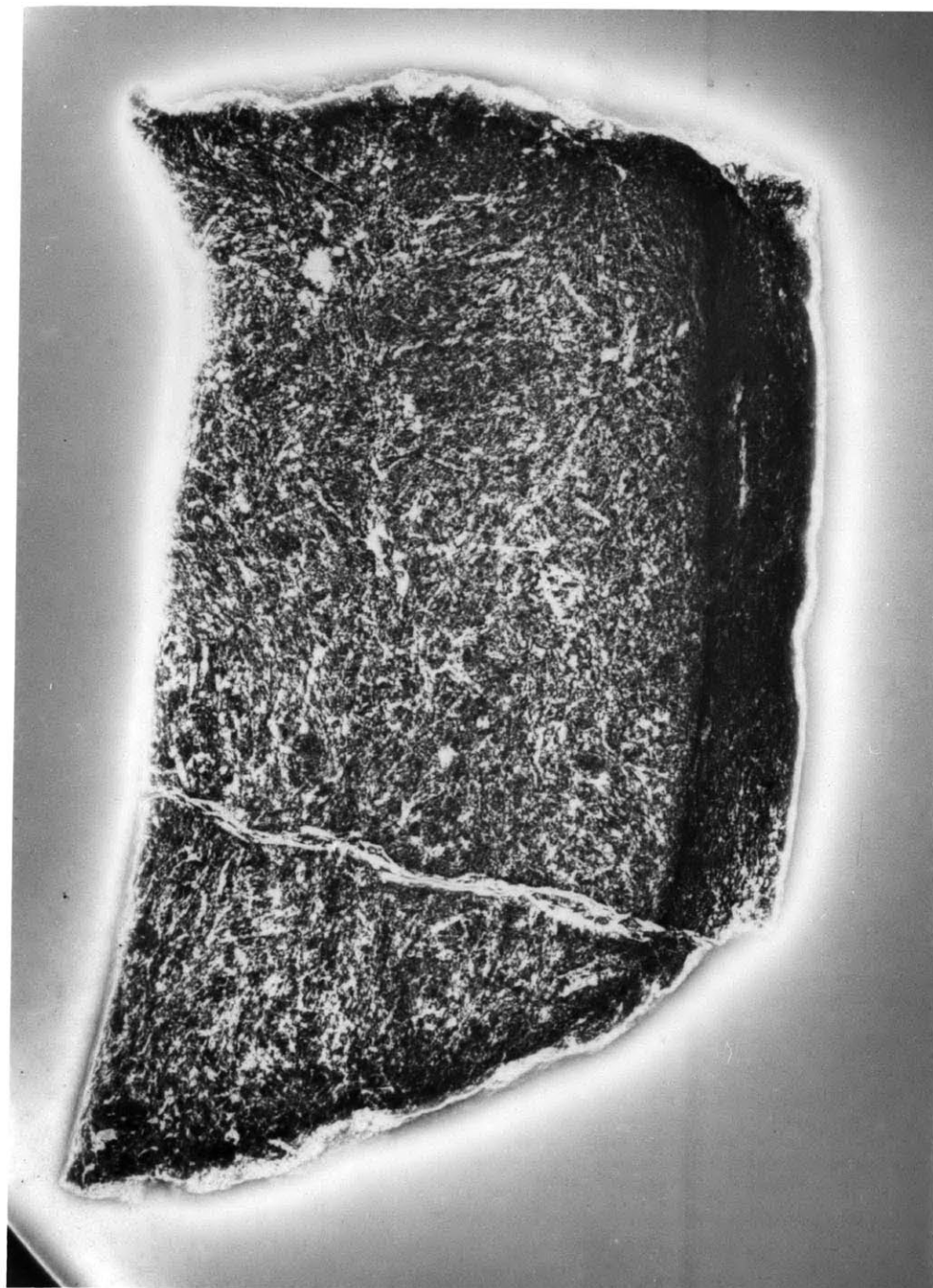
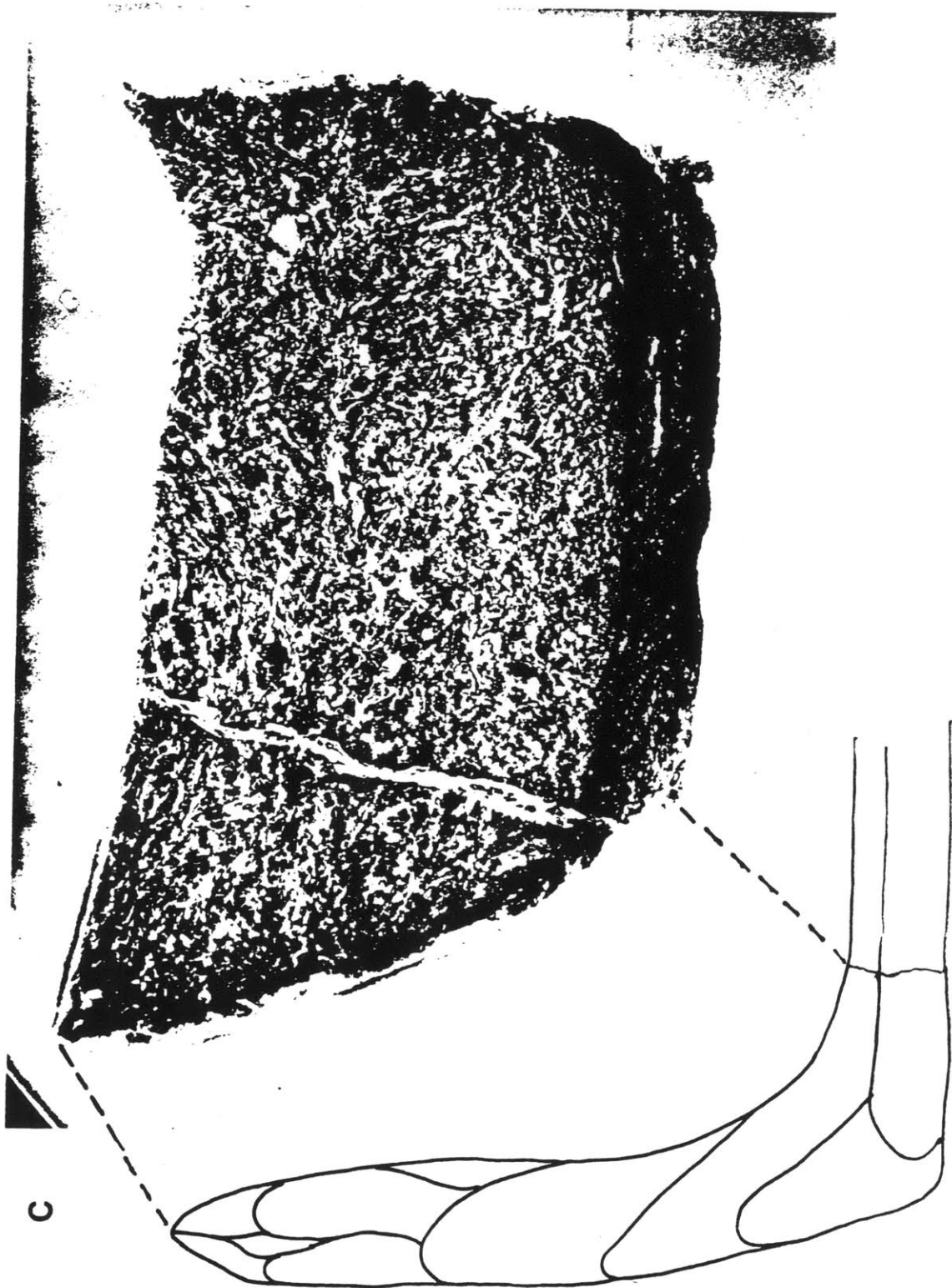
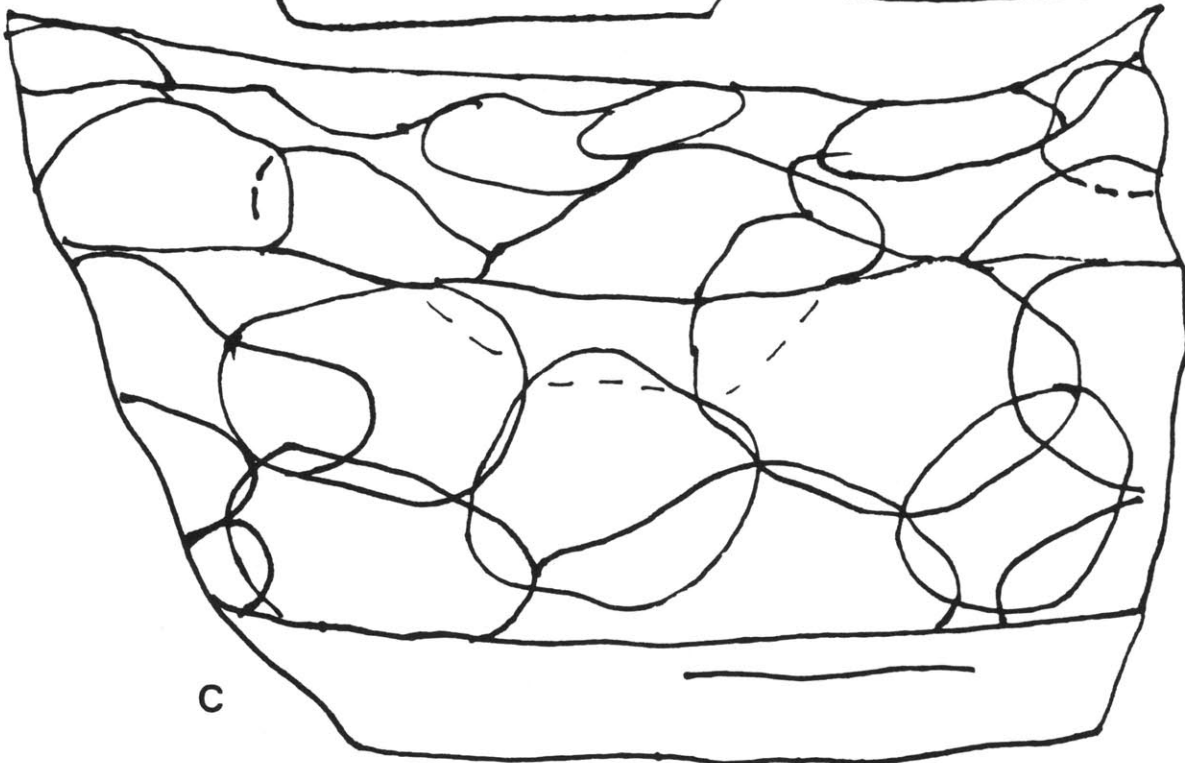
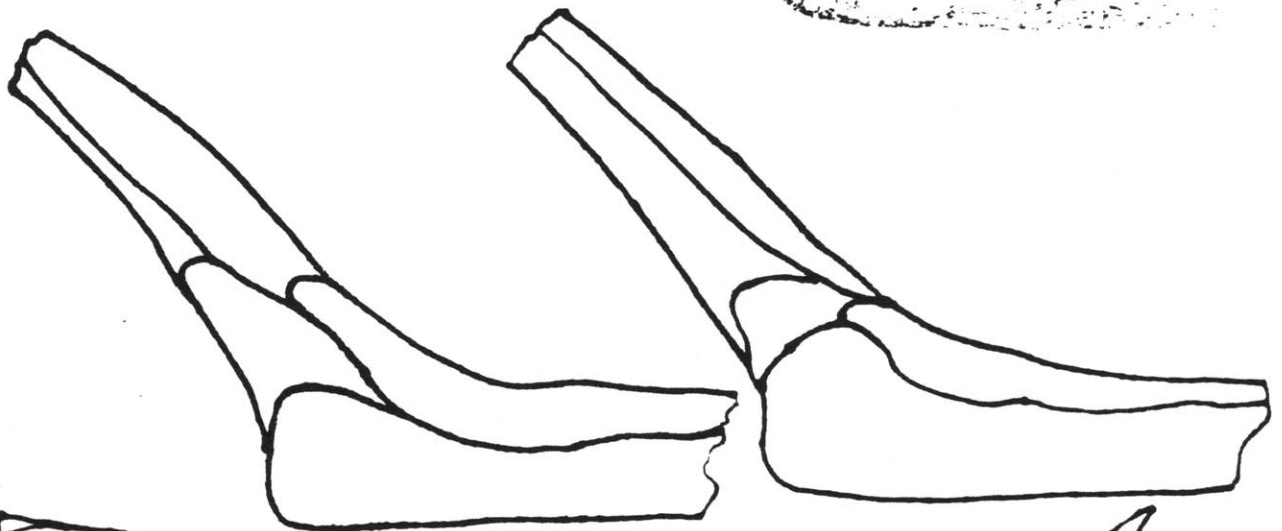
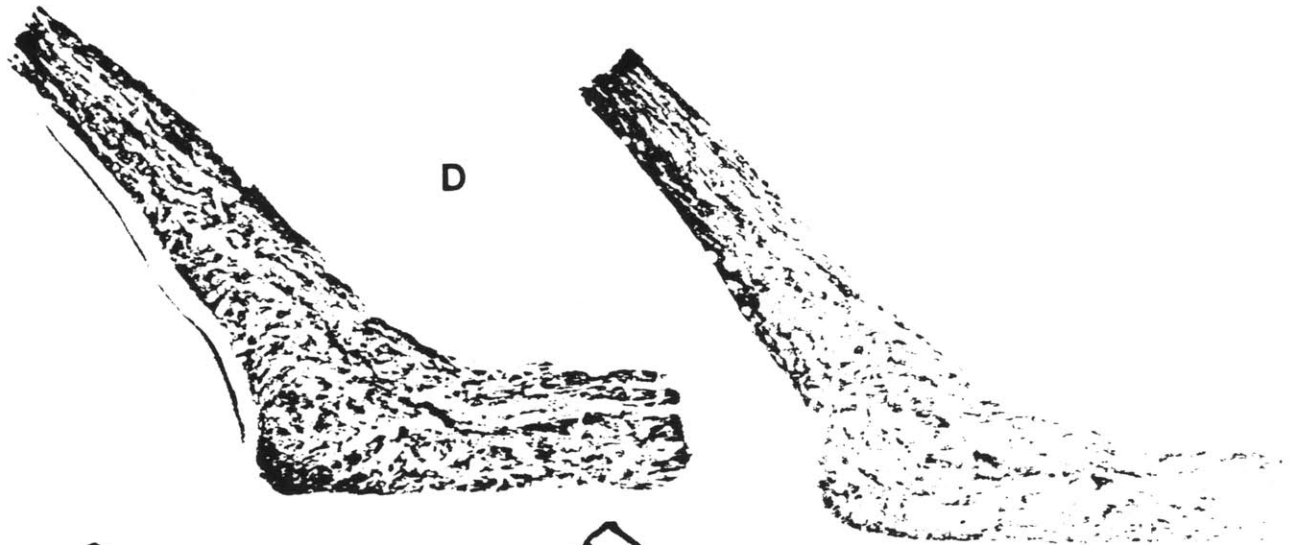


Figure 12. Xero-Radiographs and Drawings of Surfaces and Edge Fractures to Determine Spatial Distribution of Manufacturing Elements: (a) Carinated storage jar with buckling in lower part of slab, Yahya, C-7 (9)(10), (b) Base with added foot ring, Yahya, E TT3(12), (c) Cook pot made in two sections of rounded preformed slabs, smaller at the top than near the bottom, Seh Gabi, '73 AA21 302, (d) Base of bowl with variation in shape of slabs.







3. Criteria for Various Types of Processing

From a conceptual point of view, the processing of clay can be simplified to three kinds of topological manipulations: one-, two- and three-dimensional processing. One-dimensional forming involves the use of linear elements, such as coils or strips, to construct a vessel and is a process akin to construction by stacking, tying or binding of linear parts of a structure or to the construction of log cabins or trusses. Two-dimensional forming involves construction with two-dimensional elements, plates and shells in engineering parlance, like slabs, which are set on edge and joined, or the piecing together of flat pre-molded parts. Three-dimensional processing involves forming a concave-convex or hollowed out shape from a single lump. Examples of forming a vessel from a single lump are the modeling of a clay lump without adding material by pinching or by application of a shearing force to extend the material, the throwing a vessel on a wheel from a single lump of clay or pressing a single slab of clay into a mold, or the excavating a pottery shape by removal or subtraction of material from a wet or dry single lump of clay. The engineering required to build these three sorts of structures is different (S. Crandall and A. Dahl 1972). The technical understanding of materials and processes which each implies is different. In a general sense, the manipulative and thought processes involved in each type of forming are different. An example of the activities and inferred thought processes found in a culture with the widespread use of linear element construction in architecture, weaving and in myths and rituals is found on the island of Sumba in Indonesia (M.J. Adams 1977:21-53). The argument for these three types of pottery forming processes is akin to structuralist arguments found in writings of C. Levi-Strauss (1964) and others which are compelling but

virtually impossible to adequately demonstrate as one attribute of an assemblage of interrelated cultural traits.

Keeping such a construct at the edge of consciousness, we will try to establish concrete traits for various pottery forming processes. Rye (1981:58-95) has established criteria for primary or building operations and secondary shaping and finishing operations. To Rye's discussion, this thesis adds criteria for the recognition of joins (Figure 8). The presence of such joins is evidence for construction by a one- or two-dimensional forming process. From the regularity and size of such joins, the differences between coiling and slab building should be recognizable. In contrast with slab building, coiling is a well established technique in the ethnographic literature primarily because of its widespread occurrence in the New World. The American Southwest has been easily accessible. The pottery is beautiful and has been collected since before the turn of the century. From well documented collections and excavations, the long history of this pottery has been established as having a conservative craft tradition.

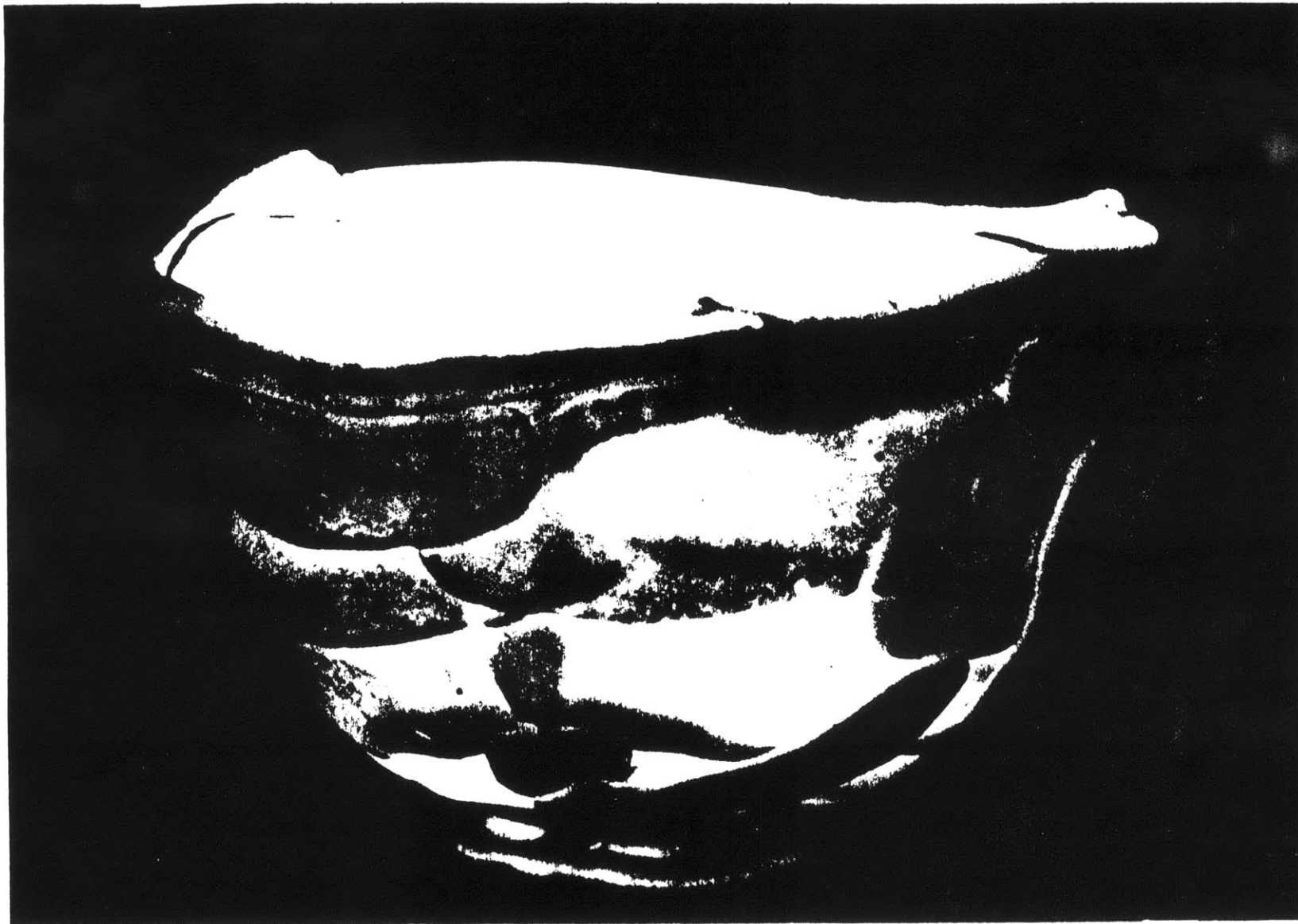
In addition, the method of using strips of clay has been documented by observation of fractured profiles in British prehistoric pottery and in neolithic pottery from northern Eurasia encompassing the area from the North Sea to Bering Straits according to Sir Lindsay Scott in Volume I of Charles Singer et.al, A History of Technology (1967:384-385). Scott did not document the spatial distribution of strips by observation of successive fractured profiles, but assumed each strip formed a ring around the pottery vessels.

Slab building on the other hand is much less well known, but it is a technique still used today. The author has built pots up to six feet high

and weighing 500 lbs. using slabs; coil building could not have produced this result because of the large number of joins, each of which serves as a potential source of initiation of a crack. Rye reinforces this view by stating that slab building is primarily used for the manufacture of large vessels. In Figure 13 is shown a contemporary, translucent porcelain bowl by Rudolf Staffel handbuilt with slabs. There is a similarity between the structure of this modern 4 1/2 inch high bowl and the 5 1/2 inch high cook pot from Seh Gabi, Mound C, shown in Figure 12.



Figure 13. "Light Gatherer", by Rudolf Staffel,
Translucent Porcelain with Interior Sulfur Wash, Handbuilt

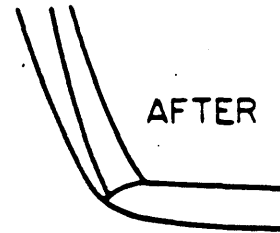
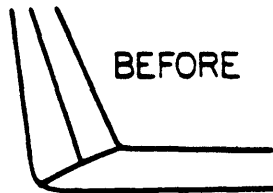
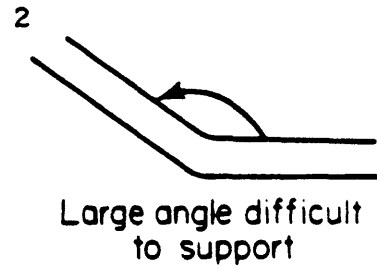
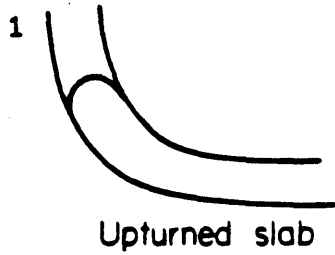


Using ideas put forth by Pye that the degree of risk in making an object is limited by the use of templates and the labor intensive quality of workmanship is lessened and made more efficient by the use of templates, we would expect to encounter templates or molds in all periods and the problem is to determine to what extent they were used. Criteria for molding and for the potentially more efficient methods of throwing and spiral coiling have been set forth, and the differences from traits found in sequential slab construction have been anticipated. During examination of coarse ware, evidence of such improved methods was sought. One would expect to encounter such methods once pottery is a successful craft for which there is an established demand. The uniformity of craft tradition and need for efficient production does not necessarily imply specialization of task or labor, only the invention which is necessary to making a more pleasing, refined, skilled or controlled shape or a lighter weight, thinner wall for easier handling.

Short of finding molds in a work area, the evidence for molding shown in Figure 14 is circumstantial. Possible evidence for molding in a concave or female mold consists of (2) walls which are flaired with a large angle to the base such that they are difficult to support, (1) rounded bases especially those with an upturned slab which would have needed support before the next element could have been added, (3) an irregular contour of the base such as a dimpled base which would be difficult or impossible to form without support, or a (4) mold impression evident in the profile or the (5) negative impression of a basket in the base and wall. The presence of join shapes which are inverted or the appearance of a plug in the base would be indicative of forming over a convex or hump mold (6). Another evidence for molding is a particular surface texture which appears uncompacted, has

open pores usually with irregular edges, and the edges of the pores have right angles with the surface, as if the clay were pushed up against a surface without being smoothed. This surface is difficult to photograph, and because of the great amount of wet smoothing, burnishing and slip coating in the Near Eastern pottery corpus studied here, only two examples were isolated. One the Ganj Dareh hole mouth jar and a small bowl from Tepe Yahya, both of which are described in the results section.

EVIDENCE FOR MOLDING :



Part of base scraped away leaving incomplete slabs is counter evidence for molding

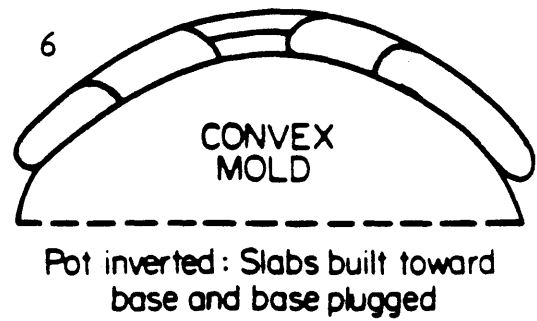
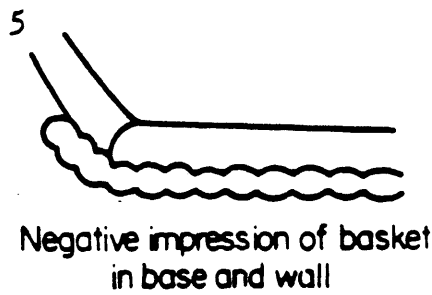
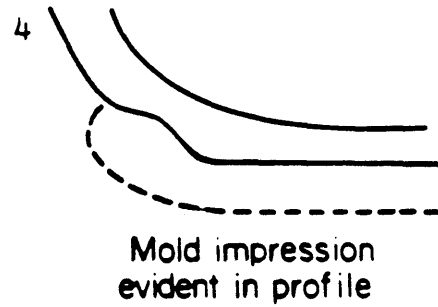
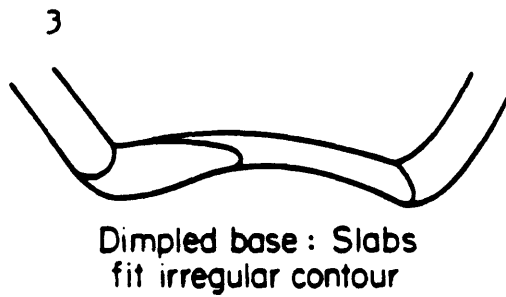


FIGURE 14. Evidence for Molding of Pottery.

Criteria for methods requiring a turntable or potter's wheel are set forth below in Table 5. It is expected these methods would be introduced for small vessels where the processes can be well controlled rather than in larger vessels where there is greater risk of failure and already proven methods would have been used. Also, presumably there was need for a greater number of smaller than larger vessels in household activities such as serving and preparing food as elaboration of such activities might be expected with time. In addition, the use of particularly well made or beautiful serving vessels might have indicated a degree of social stratification.

Coiling, it will be explained further in the next section, is difficult to use with the organic tempered coarse ware body and does not represent an improvement in pottery making practices over s.s.c. In forming a coil with the composite organic tempered clay body, the straw fibers elongate and then the clay delaminates with further extension; then the coil necks down and breaks. Coiling is useful with grit tempered clay bodies, and the efficiency can be improved with the technique of spiral coiling. Building in a spiral is a rapid means of forming vessel wall, as a hand sized lump of clay is pinched and extruded from the hand and joined to the wall with the other hand placed on the interior. The lump of clay can fit in the palm of the hand held with the smaller fingers or can be elongated and partially rest on the wrist and arm.

Table 5. Criteria for Rapid Forming Methods

Throwing on a Potter's Wheel

Definition: The centrifical force of the wheel is used to raise the wall of the vessel

External Characteristics:

1. Circumferential ridges slightly less than the width of a finger spiral continuously from the center of the base upward past the maximum diameter of

the body;

2. Fairly symmetrical shape such that the lip is more or less centered over the maximum diameter of the body and over the base;
3. Shapes tend to be rounded in a flowing curve from base to rim with no flat, indented or pointed parts;
4. Sticky, wet appearance of the surface, especially the ridges or other uplifted surfaces and at the interior of the base which is an indication of the water used as a lubricant during forming;
5. Wall which is thicker in the lower wall than at the lip and which gradually thins if a large pot or which has even walls if small, depending on the skill of the potter;
6. Reworked base because thrown pottery is almost always thicker at the base and therefore most well made wares are trimmed (that is, turned with the excess clay removed with a tool similar to those used with a lathe) or scraped;

Internal Characteristics:

7. Diagonal alignment of temper and pores in the wall when viewed normal to the surface;
8. No evidence of joins in fractured edges of sherds, or if a join is found it may be where two sections were joined as for instance at a neck to body join; such a join should then be found consistently within a form class and ware type.

Spiral Coiling from a Lump or with a Strip

Definition: Use of a linear element, either preformed or pinched out of a lump of clay held in the hand, to build a wall rapidly which is being supported on a turntable and rotated slowly beneath the hand; the wall is constructed by adding the element in a spiral

External Characteristics:

1. Spiral join line indented in the surface, in which the height of the coil is about 2-5 times the thickness of the wall, such that the number of joins and thus sources of cracks are minimized;
2. Indentation (usually from a butt join) or thickened region (usually from a bevel join) at the joint where coils were added one to another;
3. Shapes which tend to have vertical or near vertical or slightly flaired walls;
4. Coil length of about 6-18 inches depending on the size of the pot, such that the size of the coil corresponds to a handful of clay, an amount which can be easily controlled and manipulated from the one exterior hand while the other hand secures the join from the interior;
5. Even wall thickness, with no evidence of trimming or reworking the base;

Internal Characteristics:

6. Evidence of joins in a fractured cross section profile at regular intervals of about 2-5 times the wall thickness
7. A polished cross section profile and surface view with consistent elongation and alignment of pores and alignment of temper parallel to the spiral direction, which may be more horizontal than in a thrown vessel;
8. In a fractured cross section, the exterior surface is uplifted relative to the internal surface.

Neither of these methods work efficiently for the production of large vessels, such as pithoi. Slab construction is the most rapid method of constructing large vessels.

B. CHARACTERIZATION OF CLAYS TO ESTABLISH CONSTRAINTS OF RAW MATERIALS AND CHARACTERISTICS OF FINISHED PRODUCTS

In Man Makes Himself (1951:76-79), V. Gordon Childe presented the following view of pottery making in the neolithic of the Near East.

"Building up a pot was a supreme instance of creation by man. The lump of clay was perfectly plastic; man could mold it as he would. In making a tool of stone or bone he was always limited by the shape and size of the original material; he could only take bits away from it. No such limitations restrict the activity of the potter. She can form her lump as she wishes; she can go on adding to it without any doubts as to the solidity of the joins."

"...Moreover, pots were generally made by women and for women, and women are particularly suspicious of radical innovations. So the earliest pots are obvious imitations of familiar vessels made from other materials--from gourds, from bladders, membranes, and skins, from basketry and wickerwork, or even from human skulls."

"Thus the potter's craft, even in its crudest and most generalized form, was already complex. It involved an appreciation of a number of distinct processes, the application of a whole constellation of discoveries...The shaping of the pot itself is not so easy as it sounds. Quite small vessels can, of course, be kneaded and molded, mud-pie fashion, out of a lump of clay...Or a coating of clay can be spread over an open basket or a half-gourd; when it has dried, the form can be removed, and you have an open dish or platter ready for firing."

"But if anything larger is desired, or a vessel with a narrow neck like a bottle or jar, such elementary processes no longer suffice; the vessel must be built up. In neolithic Europe and Asia this was generally done by the ring (coil) method."

The conjecture of this thesis is that this hypothetical picture of early pottery making is wrong. We contend that clay is worked in a limited number of ways and that the clay is not perfectly plastic. There are many problems in forming pottery: both constraints of the raw materials and the processes which are used. The raw material limits the possibilities and processes which can be discovered. Neolithic and chalcolithic pottery does

not obviously grow out of imitations of other vessels but out of the constraints of the technology of working with the very particular properties of particular clays then being used for other purposes. Small pots were not made by simple methods and larger pots by different methods of construction. Instead, the processing is part of a technological style of working with particular clays and tempers, regardless of size, as is described in the examination of small and large pottery from Yahya in the results section. And lastly, the ring method was not generally used in the neolithic of the Near East because it is extremely difficult to form chaff tempered coarse ware using the ring or coil method.

In order to demonstrate the constraints of the composite clay and chaff body used to make the organic tempered coarse wares, we carried out an investigation of the working properties of Near Eastern clays. We tried to replicate preparation of raw materials and construction of coarse ware pottery using Near Eastern clays in order to find out what constraints of raw materials and processes were actually encountered and to determine the rate limiting steps as well as those requiring extra care in the process of making pottery. The use of basketry molds was also explored.

1. Emission Spectroscopy to Determine Trace Element Chemical Composition

In order to ascertain the compositional variability in Near Eastern clays, eleven samples of clay were collected and analyzed by emission spectroscopy to determine semiquantitatively the trace elements present. Each archaeologist was asked to provide one of two samples of the best clay available on or near the site which might have been used by potters to make pottery. For a group of clays collected from such a great distance of 1400

kilometers, there is unexpected homogeneity. The results are presented in Table 6.

The calcium content varies among the clays more than any other element. This has been found in other studies. For example, Prof. Ron Hancock of the University of Toronto carried out neutron activation analyses of pottery from Godin which has not been published, into which he incorporated a large number of samples representative different wares and different time periods, and was unable to make differentiations other than the general conclusion that the calcium content was not constant (pers. comm.: fall 1984). A similar neutron activation analysis study has been carried out at the University of Montreal with pottery from Ganj Dareh with similar findings of a remarkable homogeneity in clay composition.

Emission spectroscopy is a much less precise technique than neutron activation, but has been used in this study in an attempt to detect possible variations in minor (below 10% concentration) and trace (below 1% concentration) amounts of constituents without the expense and time commitment required of neutron activation analysis (D.G. Peters, et.al. 1974). Emission spectroscopy requires a 100 mg sample which is ground to a powder. Nonconductive samples are mixed with graphite and then ignited at high voltage with an arc. Elements present in small amounts are identified by the characteristic spectra of emitted light and the intensity of excitation. Most elements can be successfully excited; however, low atomic number elements will volatilize at a lower energy input than high atomic number elements. Where sufficient sample was available, the sample was excited more than once with step increases in energy. Analyses were carried out by Walter Correia, analytical chemist in the Center for Materials Science at M.I.T.

**Table 6. Results of Trace Element Analysis
by Emission Spectroscopy Showing Similarity of
Clay Composition**

No.	Si	Al	Ca	B	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	P	Sr	Ti	V
1	H	M	M	-	Ft	Vft	L	L	L	t	t	Ft	-	Ft	L	Ft
2	H	M	L	-	t	Vft	L	L	L	t	L	Ft	-	Ft	t	Ft
3	H	M	L	-	t	Vft	L	L	L	t	L	Ft	-	Ft	t	Ft
4	H	M	L	-	Ft	Vft	L	L	L	t	t	Vft	t	Ft	t	Ft
5	H	M	L	Vft	Ft	Vft	L	L	L	t	t	Vft	-	Ft	t	Ft
6	H	M	L	Vft	Ft	Vft	L	L	L	t	t	Vft	-	Ft	t	Ft
7	H	M	M	-	Ft	Vft	L	L	L	t	t	Ft	-	Ft	L	Ft
8	H	M	M	-	Ft	Vft	L	L	L	t	t	Ft	-	Ft	L	Ft
9	H	M	M	-	Ft	Vft	L	t	L	t	t	Ft	-	t	L	Ft
10	H	M	M	Vft	Ft	Vft	L	L	L	t	t	Ft	-	t	t	Ft
11	H	M	M	Ft	Ft	Vft	L	t	L	Ft	t	Ft	t	Ft	t	Ft

H	10.0%	Ft	0.001-0.01%
M	1.0-10.0%	Vft	0.0001-0.001%
L	0.1-1.0%	Vvft	0.0001%
T	0.01-0.1%		

In addition, sample 11 contained a Vvft of Zn, and sample 10 contained a Vvft of Ag.

List of Samples and Source:

1. Geometric clay disc, unfired, from Tepe Yahya, Prof. C.C. Lamberg-Karlovsky Harvard University;
2. Clay from Rud-i-Gusk, spring near riverbed between survey sites 41 and 49, Dr. Martha Prickett, Harvard University;
3. Hajji Firuz, clay sample from Wall D, F12, sample 5 (68078), Prof. M. Voigt, University of Pennsylvania;
4. Hajji Firuz jar sealing from H12(7)(3)(13) HF 68-193, 69-12-37, Prof. M. Voigt, University of Pennsylvania;
5. Sarab, SV4, soil sample, collected by R. Braidwood, now housed in Royal Ontario Museum;
6. Seh Gabi, Mound B, architectural fragment, probably from a roof, G20-21, 1971, T. Cuyler Young, Royal Ontario Museum;
7. Seh Gabi, Mound B, unfired clay sling ball fragments, G19 96(10), T. Cuyler Young, Royal Ontario Museum;
8. Ganj Dareh, virgin soil beneath mound, prehistoric soil sample #172, GD74, P.E.L. Smith, University of Montreal;
9. Ganj Dareh, soil sample #59 from the bank of a stream near the mound;
10. Mehme River clay from near Tepe Farukhabad (1969), F. Hole, Yale University;
11. Chagha Sefid, fragment from an unfired brick, SD/E12-12(434).

2. Differential Thermal Analysis to Identify Clay Mineral Type

In order to identify the type of clay mineral present in the samples of Near Eastern clays collected for characterization, differential thermal analysis was used. Montmorillonite clay was identified in each of the clays

as the chief mineral constituent. A characteristic spectrum is shown in Figure 15 for a clay sample from an unfired brick found at Chagha Sefid (SD/E12-13(434)). Lime (calcium carbonate) and quartz were also identified in some of the samples. The clays are not only chemically homogeneous as shown by emission spectroscopy, but also mineralogically homogeneous.

A Perkin Elmer DTA 1700 was used with a heating rate of 10°C/minute for a temperature range from 25°C to 1000°C in an inert argon atmosphere. A uniform heating rate of a 20 mg. sample is carried out, and the temperature of the sample is compared with that of an inert reference material, alumina in this case. In an exothermic reaction the sample appears to heat faster than the reference material and a peak is recorded as the change in temperature versus the reference material temperature. Assumptions are made that the bulk density, surface area and fraction of material which is active are the same for both samples (R.C. MacKenzie 1970:318f,479, 498,499f,505). Characteristic reactions identify different mineral phases. Endothermic peaks for the alpha to beta transformation of quartz at 573°C and the gradual decomposition reaction of lime between 800-1000°C and at about 700°C for montmorillonite were used for identification.

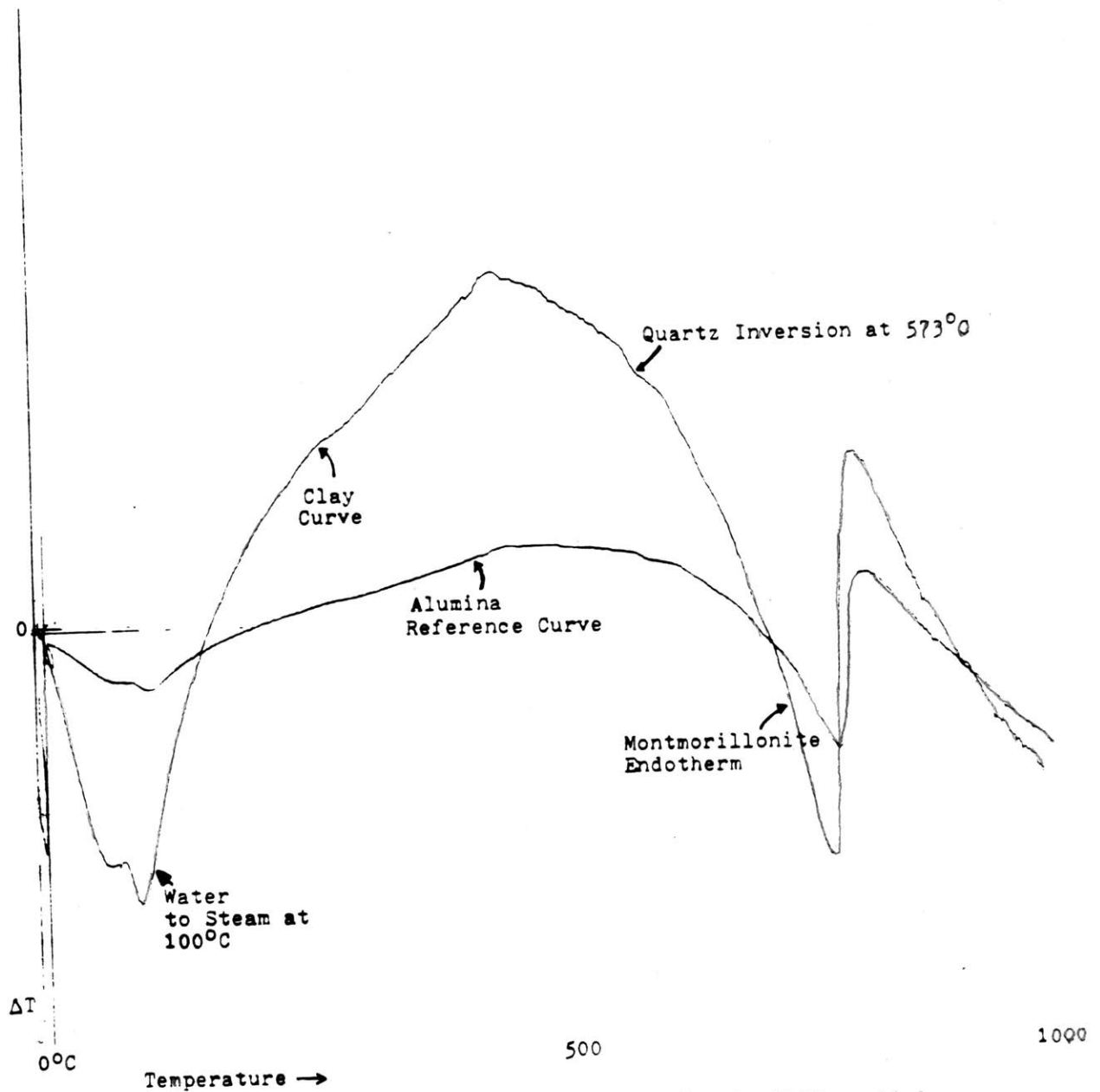


Figure 15 Clay Type Identified as Montmorillonite by Differential Thermal Analysis. This example is from an unfired brick from Chagha Sefid, SD/E12-13(434). All of the other ten clays had a similar spectrum with an endothermic peak at about 750°C.

3. Scanning Electron Microscopy for Clay Particle Size and Shape, and Degree of Vitrification

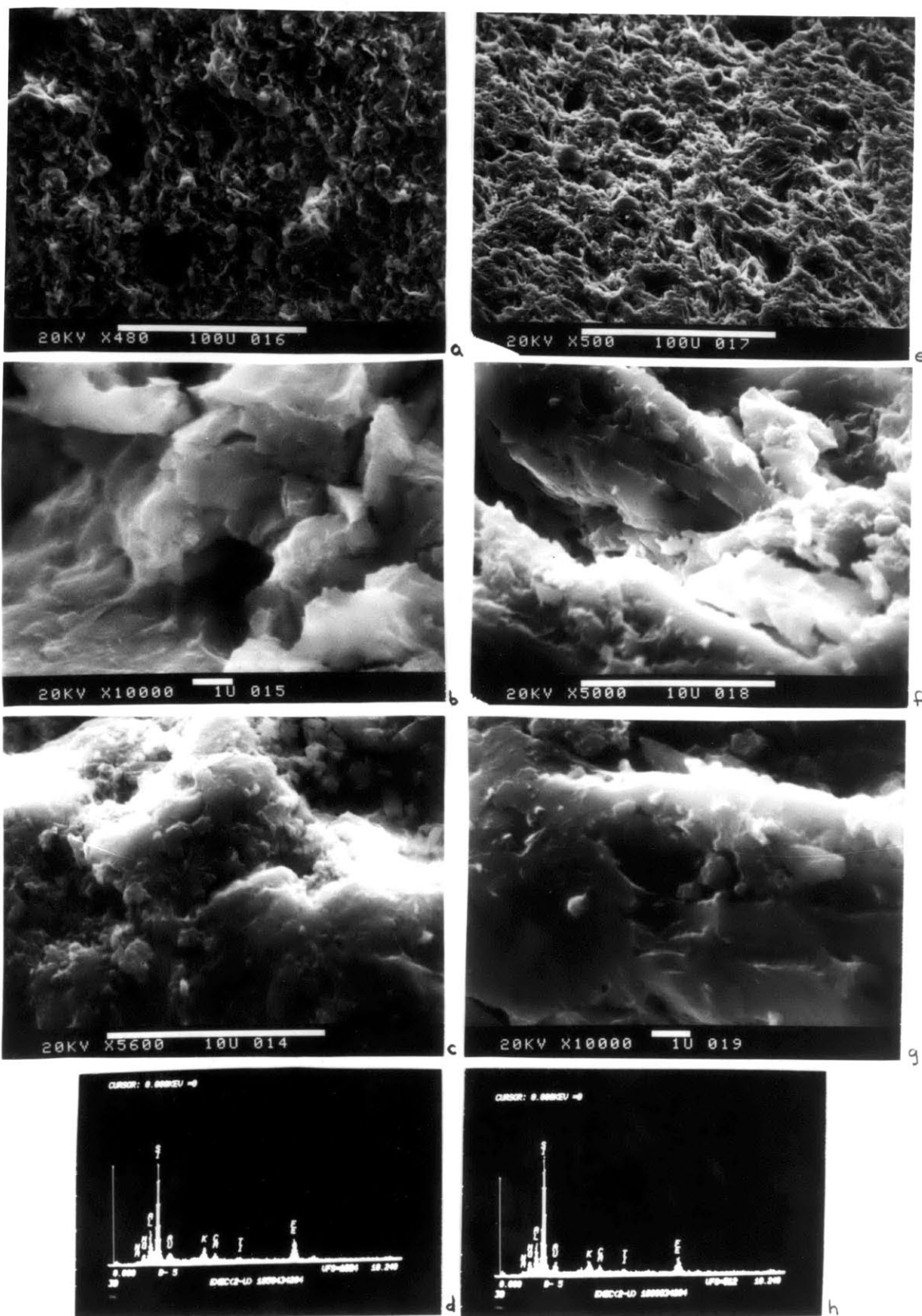
Extensive work using a scanning electron microscope has been carried out by W.D. Kingery (1974), M. Tite and Y. Maniatis (1975), Y. Maniatis and M. Tite (1981), Tite et. al. (1982) and others. This tool has allowed visualization of the fine, platy particles which slide over one another to form a plastic clay mass, the tempering materials, as well as the glass and crystals which form and cohere the clay body during firing. Montmorillonite clays are particularly small clay particles, about 0.1 micron, and are at the limit of particle size which can be easily characterized. We will therefore begin by studying two examples of fired vessels from Tepe Yahya, one a chaff tempered coarse ware (C TT1(1)71) on the lefthand side of Figure 16 and the other a fine ware (C TT3(1)) on the righthand side before trying to compare microstructures of unfired clays.

Tite (1982) has separated calcareous from noncalcareous Near Eastern clays and provided examples fired to different temperatures, and Kingery has examined a variety of earthenware sherds fired to different temperatures. Visual criteria for an increase in temperature during firing include the formation of glass first at the contact points between clay particles, known as sintering, which can be seen in a rough fracture surface of particles held together with a small amount of glass. This is followed as the temperature is increased by the formation of fine crystalline precipitates and more glass which eventually forms a continuous glass matrix and which can be seen in the microstructure as a glasslike conchoidal fracture surface. In Figure 16 the coarse ware is on the left and the fine ware on the right. In the two low magnification photos (about 500x) of the coarse and fine ware shown in Figure 16a and e, the fineware has a smoother

fracture and a more continuous matrix, whereas the coarse ware has a rougher fracture with fairly large pores and discontinuous surfaces. In the medium magnification photos (Figure 16c and f taken at about 5000x) more glass and fewer discrete particles can indeed be seen in the fine ware. In the high magnification photos (Figure 16b and g taken at about 10,000x) small particles in the Yahya fine ware can be seen to be more rounded, and the pores are also smoother and more rounded. In addition, more broken glass is present. In the coarse ware the edges of some of the fine particles are rounded but their general shape is still rough, as are the pores. This would lead us to the conjecture that the fineware was fired to a higher temperature, but we must compare the compositions to be sure that the one which appears to be higher fired has the same composition and in particular does not contain more alkalis (Na_2O and K_2O) and alkaline earths (CaO and MgO) which would flux or lower the sintering temperatures of the clay body. The spectra from energy dispersive x-ray analysis which was carried out for each magnification shows that the compositions are about the same. Thus, the fine ware was fired to a higher temperature. This general conclusion holds for examples of ware which we examined from each of the other sites.

If we then examine the individual particles of clay prior to firing in Figure 17b-f, we find that the particles are quite similar: they are very fine, less than 0.1 micron, platey, have wispy, jagged edges, tend to agglomerate in clumps of different size and are difficult to get in focus. In addition a low magnification photo of the Seh Gabi sling balls (Figure 17a) shows that these particles align in flat layers with the occasional appearance of somewhat rounded pores, as shown in the upper right of the micrograph. If we look at the compositions (Table 7), the calcium content is seen to vary considerably which is in agreement with the results of

emission spectroscopy. In comparison with the fired ware from Tepe Yahya, the calcium content of the raw clays is seen to be consistently higher. If we re-examine the particle shapes in the Mehneh River clay and the Ganj Dareh soil sample (Figure 17f,g), we see that these particles are more rounded, more equiaxed and larger than the other ones, which is a visual indication that calcite and not clay is present. The S.E.M. and E.D.A.X. data establish that there are local differences on a scale of a few microns between and within each sample in the microstructure and in the distribution of major element compositions. The S.E.M. and E.D.S. data establish that there are local differences between samples and within each sample in the microstructure and major element composition on a scale of a few microns. We can then ask what are the differences between these clays from the point of view of the potter, knowing that the clay type, particle size and shape are similar and that calcium content is the major variable.



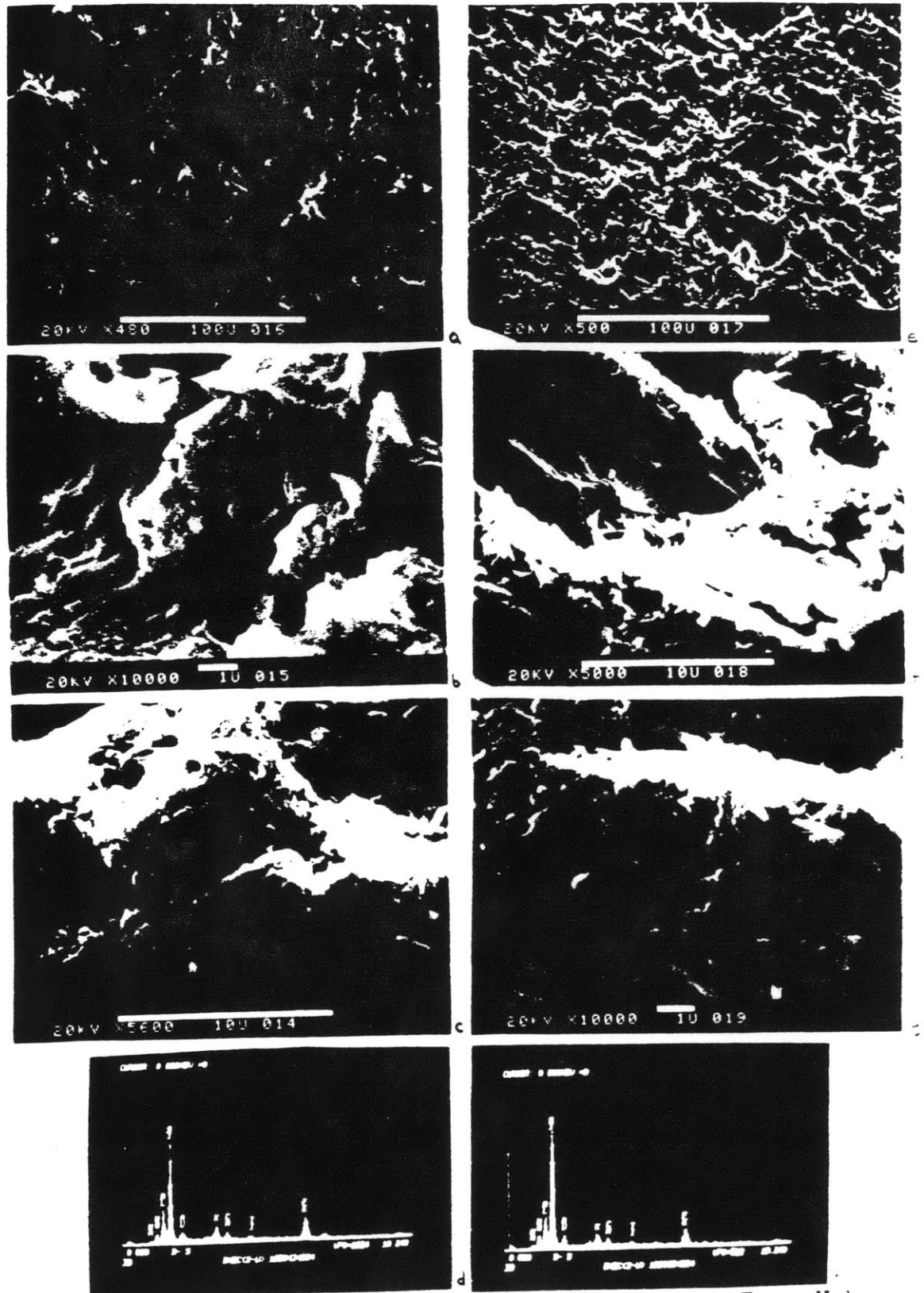
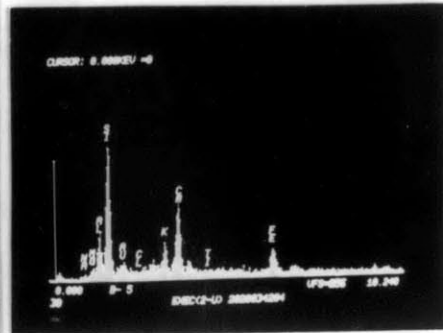
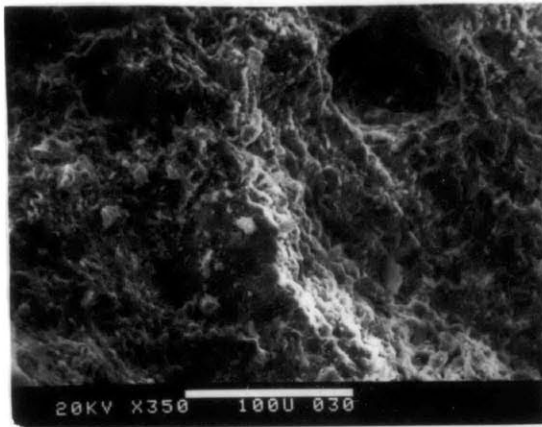
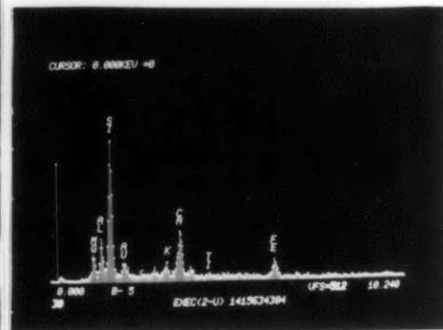
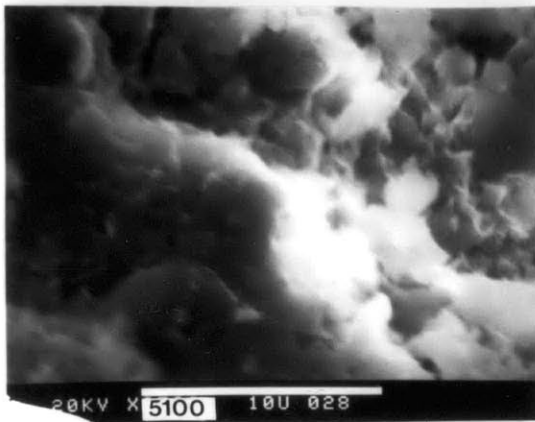


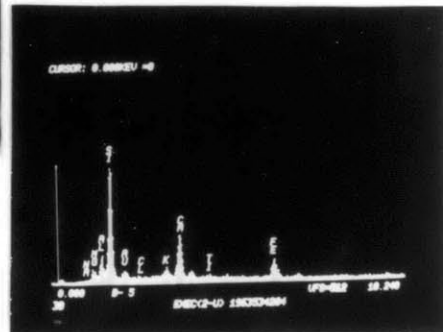
Figure 16. Fired Clay Microstructures from a Tepe Yahya Coarse (a-d) and Fine Ware (e-h)



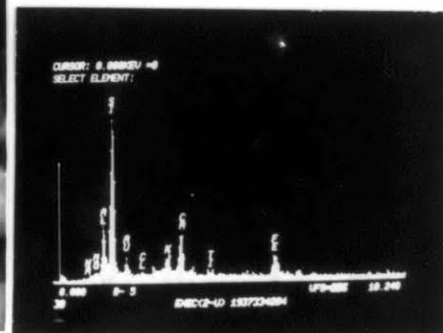
a



b



c



d

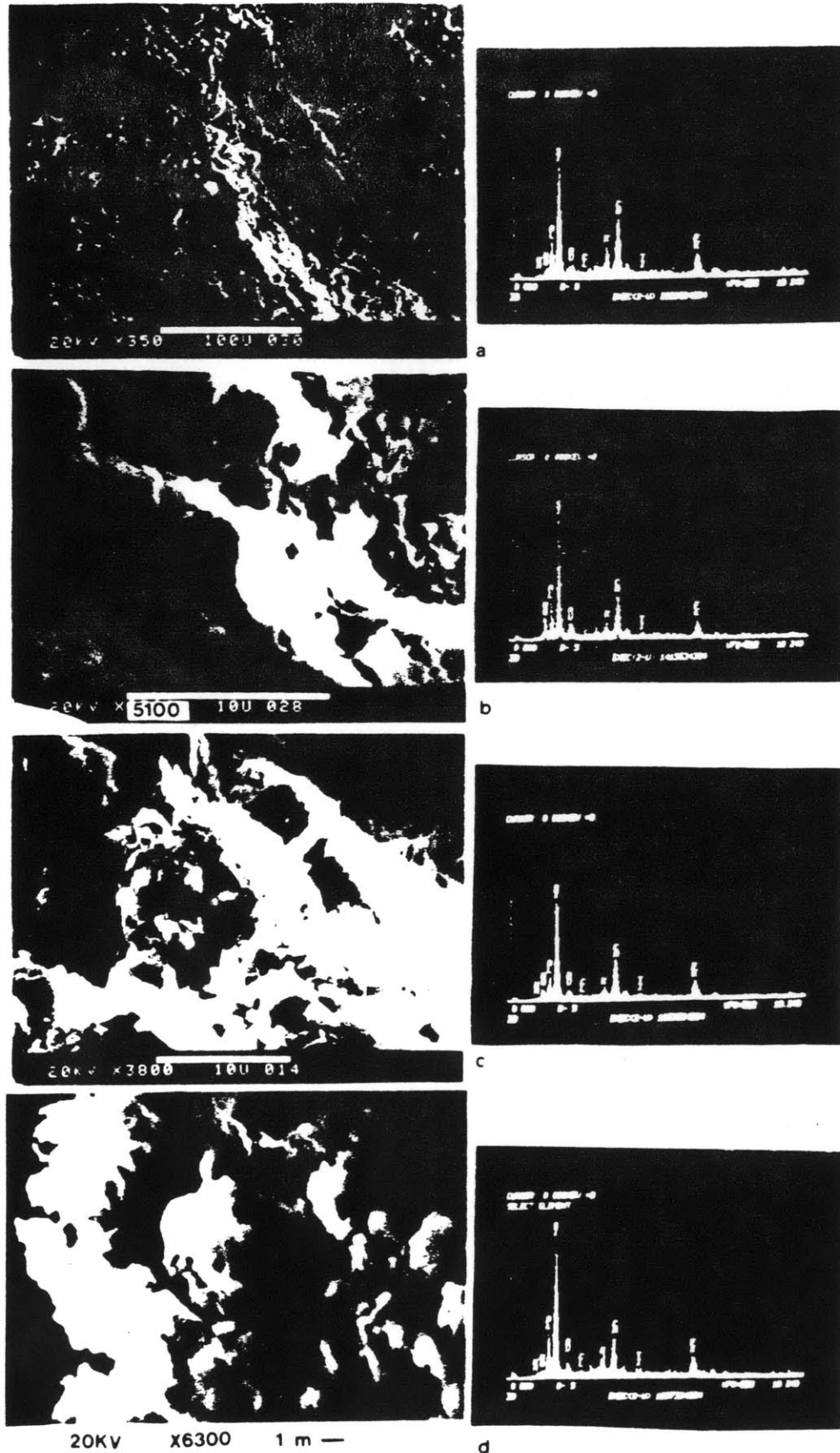
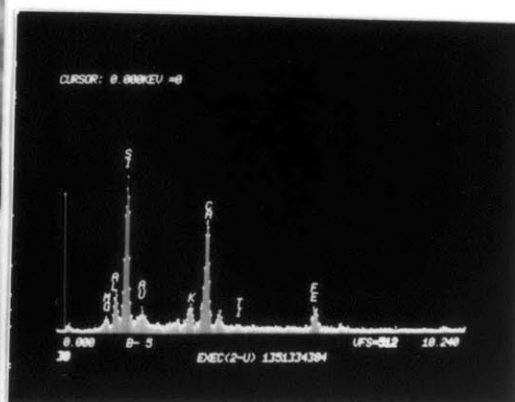
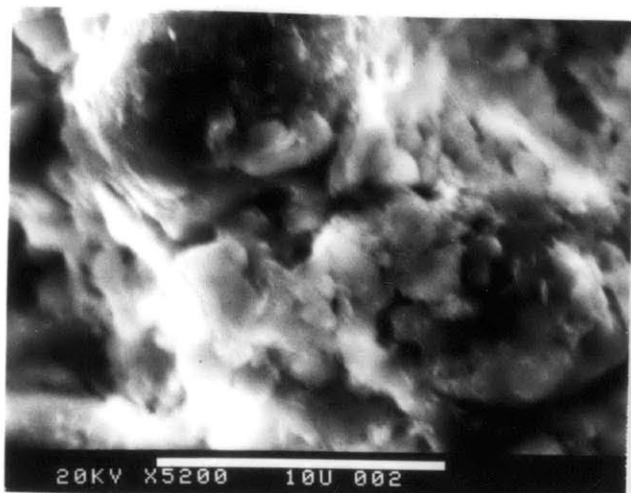
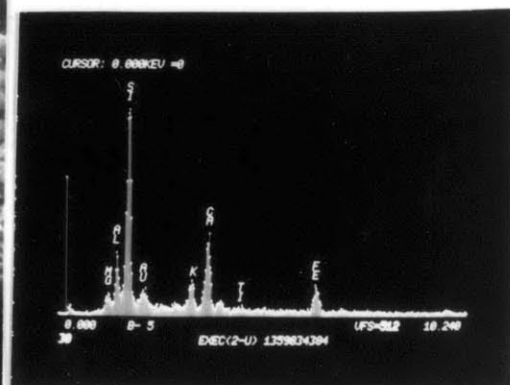


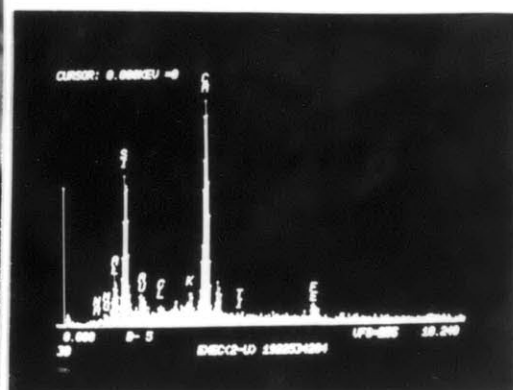
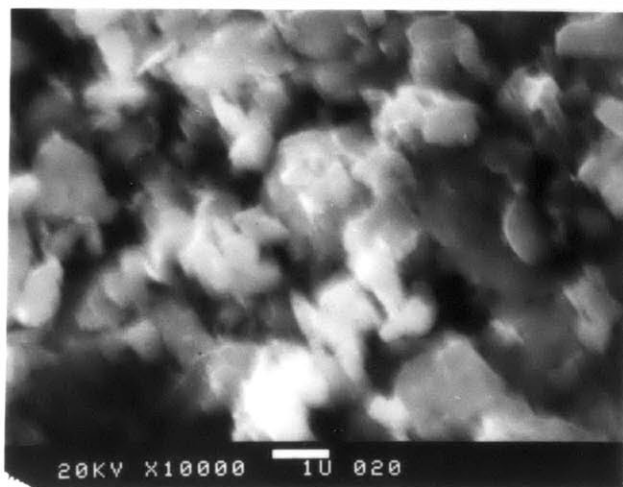
Figure 17. Representative Microstructures of Raw Clays.



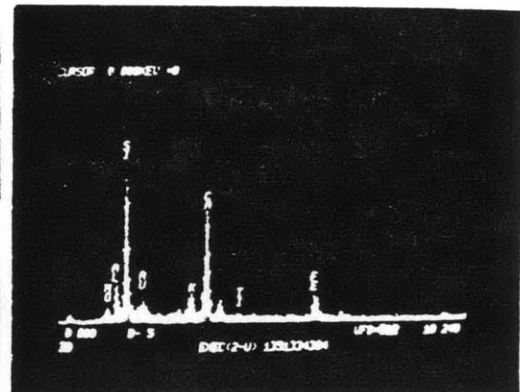
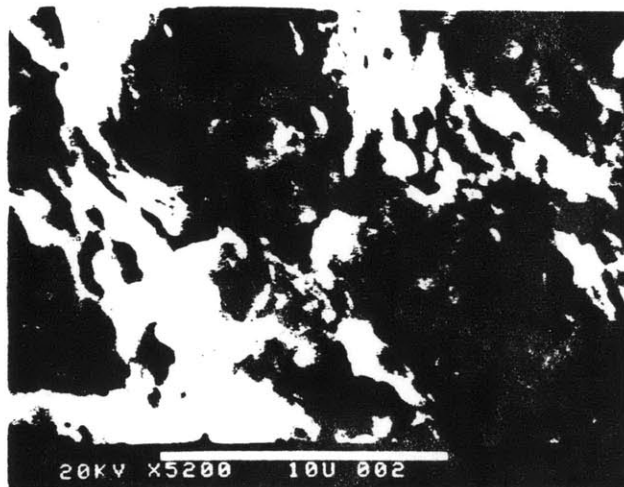
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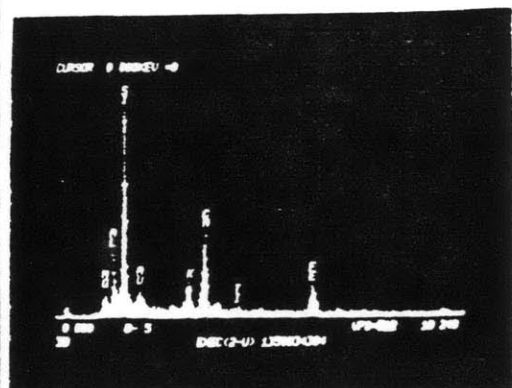
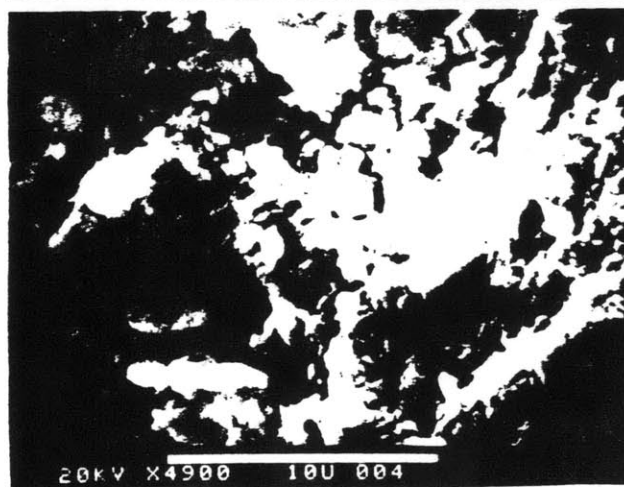
f



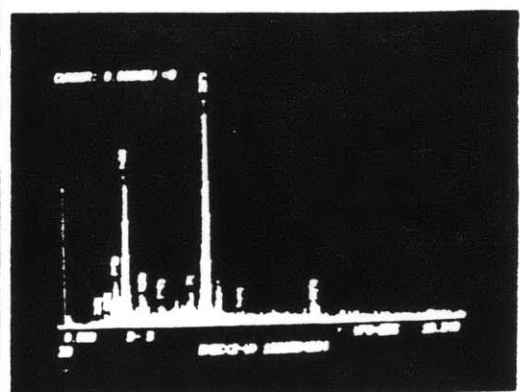
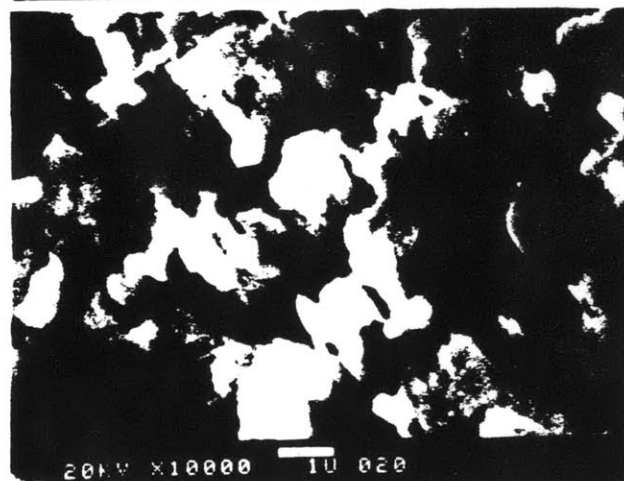
g



e



f



g

Figure 17. Representative Microstructures of Raw Clays: (a) and (b) Seh Gabi sling balls, (b) Tepe Yahya disc, (c) Hajji Firuz wall DF12, (d) Ganj Dareh sterile soil sample, (e) Sarab soil sample SV4, (f) Mehme River clay, near Farukhabad.

Table 7. Elemental Peak Height Ratios of Other Major Elements to Silicon from Energy Dispersive X-Ray Spectra

Major Elements	Si	Ca	Al	Fe	Mg	K
Pottery						
Yahya Coarse Ware	1.0	0.08	0.32	0.21	0.08	0.12
Yahya Fine Ware	1.0	0.08	0.27	0.13	0.10	0.10
Other Clay Objects from the Culture						
Yahya geometric disc	1.0	0.46	0.29	0.18	0.21	0.14
Hajji Firuz wall	1.0	0.42	0.25	0.17	0.08	0.08
Hajji Firuz jar sealing	1.0	1.32	0.32	0.26	0.16	0.21
Seh Gabi roof element	1.0	0.30	0.40	0.13	0.05	0.20
Seh Gabi sling balls	1.0	0.74	0.33	0.19	0.07	0.26
Chagha Sefid brick	1.0	1.27	0.41	0.18	0.14	0.23
Potential "Clays" Collected by Archaeologists						
Rud-i-Gushk riverbank clay	1.0	0.38	0.29	0.17	0.08	0.13
Sarab soil sample	1.0	0.39	0.28	0.14	0.11	0.17
Ganj Dareh virgin soil						
beneath mound	1.0	0.59	0.28	0.09	0.13	0.16
Ganj Dareh streambank clay	1.0	4.50	0.75	1.00	0.25	0.50
Mehmeh River clay	1.0	1.54	0.38	0.12	0.08	0.15

Note that these are not true values because the spectra have not been corrected for the differential matrix effects of absorption, fluorescence and atomic number, but are relative numbers to depict the range of variation in the major elements of these materials.

4. Differences in Working and Firing Properties of Near Eastern Clay Collection

Each of these clays was collected by first querrying the archaeologist in charge, or the one presently holding the samples who had excavated at the site, about the possibility of obtaining a raw clay sample which would have been the most likely to have been chosen and used by a potter. The usual answer was that the archaeologist did not know but on further pressing gave what he or she thought to be the best available sample. In my opinion, these are not random soil samples, but potential pottery clays which by the standards of archaeologists, working in an area and familiar with a site and its catchment area, are the best available candidates, given the pressures and time constraints of excavation, shipping and later organization.

In the laboratory a small lump of each clay, about 0.2-0.5 mm on a side, was subjected to a dilute solution of HCl acid, and observed under a microscope. Each fizzed mightily, indicating about equally the presence of calcium carbonate. The color of some of the residues was a strong yellow color indicating that iron was present and either adsorbed onto clay particles or loosely bound in the clay structure. After violent bubbling had subsided, a residue was left from each sample consisting of a fine clay which could be easily suspended in water by mixing. After resettling, none of clays had a residue containing coarse quartz or feldspar particles.

A fairly large sample of each clay, varying from 4 mm. to 10 cm. was then broken up and ground on a flat stone with a roller, mixed with water and tested for plasticity after a half hour and again after the clay had sat for a week in a damp atmosphere. Subjective, qualitative descriptions given in Table 8. Sufficient samples of the fragmented Seh Gabi sling balls which contain considerable lime and Rud-i-Gushk clays with lower lime content were

available for molding a test tile of each with a 10 cm line incised on the upper surface. During drying the linear shrinkage was 5 and 10%, respectively. The clays contained no added organic temper. The firing shrinkage when fired to 800°C in a gradual 10 hour climb was about 1/2 and 1%, respectively.

Table 8. Qualitative Evaluation of Working Properties of Raw Clay Samples

Too Fine

2. Rud-i-Gushk: really fine clay, super sticky and most plastic; doesn't have any body to form a wall; completely nongritty; perhaps use as a slip but not a clay body

10. Mehme River clay: fine yellowish white, very plastic clay; too fine to form a pot; sticky smooth texture, tastes salty; but would not hold shape

Fine Plastic Clay but Short

1. Yahya riverbed clay: good working plastic clay, but a little short, cracks when gets a little dry (this clay was found at the end of the study and was only tested by DTA and found to be a montmorillonite, but not by emission spec)

3. Hajji Firuz wall D: plastic, good working, but a little gritty and short

Good Clay

7. Seh Gabi sling balls: good plastic clay; a little fine, sticky and gooey

9. Ganj Dareh streambank clay: hard to grind; good plastic clay with a long working time, but feels a little funny

8. Ganj Dareh virgin soil: fine reddish clay, plastic with body and a long working range

Good Coarse Clay

4. Hajji Firuz jar sealing: sandy, gritty clay with lots of body; plastic and holds shape

Too Coarse to Form Well

11. Chagha Sefid brick: too gritty, cracks and is nonplastic, like Seh Gabi #6

6. Seh Gabi roof: too coarse, crumbles, but not as coarse as Sarab

5. Sarab soil sample: too gritty to form; nonplastic, cracks when deformed; works like Egyptian faience; hard to grind up; worst clay

Allowing the clay to sit for a week allowed the fine particles to thoroughly wet through with the result that the short clays had a longer working range, but the very fine and very coarse clays did not change. These evaluations were made before any other testing was carried out.

Along with the firing of test tiles, a small amount of each of the other clays was included. Three of the clays powdered after firing: the Chagha Sefid brick, the Sarab soil sample, and the Ganj Dareh streambank sample. Each of these clays has a relatively high lime or coarse particle size which prohibited sintering. The other clays were further tested by boiling for 1 hour; the Mehmech River clay decomposed into a fine powder in about 5 minutes, but none of the others decomposed. Each of these clays has a relatively high lime content or coarse particle size which prevented sintering. The Chagha Sefid brick and Sarab soil sample were each coarse and difficult to form, but the Mehmech River clay was extremely fine textured but would not hold its shape during forming, probably because of the high calcium content, in other words, being composed of equiaxed particles which would not cohere or slide over one another. Measurement of particle size in the micrographs (Figure 17g) shows they were very fine for limestone being about 0.5-3 microns in diameter. In summary, four of the clays were unsatisfactory as potter's clays because they would not fire to a durable, hard mass.

In conclusion, the clay samples had a wide variety of working and firing properties. Four of the eleven samples were unsatisfactory as pottery clays, even though they were all composed of montmorillonite clays with a similar particle size and shape and had a similar trace element composition profile (with the exception of variation in calcium content). There are local variations in the distribution and amount of major elements which affect properties, as shown in Table 9.

Table 9. Conclusions from Study of Raw Clays

Same Clay Mineral Type

Similar Trace Element Composition

Variation in Amount and Distribution of Lime, Alkali and Clay Phases on a Local Scale Gives Range of Properties

5. Conclusion: Selection of Clays Required Special Skill and a Specialized Knowledge

Even though archeologists say that clay is commonly available at their sites, the result obtained here is that they find it difficult to collect potential pottery clay samples which have the same working properties and low calcium content as the pottery found on their sites. In addition, analyses of unfired clay artifacts other than pottery from four of the sites show that a wide variation of major element composition and working properties was used for various artifacts within the culture(s), which corroborates the observations of Hole and Voigt that particular clays were used for particular functions. Evaluation of only the workability of these clays does not adequately reflect either their range of composition or firing properties. In addition, modern methods of evaluation of bulk composition, mineralogy, or trace element composition is not sufficient to evaluate the properties and suitability of pottery clays. Thus, we conclude that selecting and collecting suitable pottery clays is a specialized skill which requires a trial and error learning process, and furthermore that ancient people had a specialized knowledge of the diversity and specific uses of the many clay materials in their environment.

B. LABORATORY REPLICATION AND ETHNOGRAPHIC EXAMPLE

1. Working Properties Clay Bodies and Chaff

A ten pound quantity of clay from Rud-i-Gushk and a fifteen pound quantity from a riverbank near Tepe Yahya were used in the replication of

coarse, organic tempered pottery. Both clays were identified as montmorillonite by differential thermal analysis, and the Rud-i-Gushk clay (No. 2) was analyzed by S.E.M. and emission spec.

The organic material added as temper has been identified as grass, straw, chaff, and the more general terms of vegetal temper and organic burnout have also been used. In the Tepe Yahya and Hajji Firuz coarse wares, one hundred pores were examined with a binocular microscope which has a continuously adjustable range of magnification from 10-70x to characterize the impressions left in the clay by this material. The pores left by burned out organic materials measured from 0.2 mm to 15 mm with an occasional piece measuring 20 mm in length, and from 0.1-5 mm wide. The ratio of length to width is from 3-12. Smaller pottery had a smaller size range of pores left from organic burnout. Often parallel striations in the direction of growth could be seen in the impression. Rarely seeds could be found, and occasionally grey ash pseudomorphs from incomplete combustion of the organic material. The overriding characteristic was that the ends of the pores were blunt, either having a right angle or diagonal to the long edges of the pores. Prof. Hans Helbaek in J.R. Caldwell's Investigations at Tal-i-Iblis (1967:150) was quoted as describing the examination of a sherd as follows, "The tempering is mainly grass blades and bits of straw", but he was not sure whether it was cultivated. There is a lack of microscopic examination found in the literature, although the suggestion has been made that dung may have been mixed with the pottery to give the open, soft texture to the pottery.

In order to try to decide the nature of the organic temper, samples of chaff and straw from wheat, local wild and domestic rye grass and dung from cow, donkey, sheep and goat were examined with a microscope from 10-70x,

with the result that organic temper in pottery most resembles cut grass with blunt ends. The chaff (defined as hulls on wheat grains excluding the straw) were pointed at both ends, and the dung had pieces of grass with broken ends and cracks going along the grain, an effect of chewing. Dung from ruminants, sheep and goats, has been rechewed, the size of the grasses is smaller and has a more even distribution than found in coarse ware pottery. In addition, the dung occurs as small pellets which are time consuming to collect. In donkey and cattle dung the size the grass is not as fine, but the ends are frayed and not sharp. In Figure 18 is a drawing of the variation of size and shape in the different types of temper. My opinion based on microscopic examination of a sample of more than one hundred pieces of grass, straw and dung is that cut grass, no matter whether the grass is fresh or dried, matches best with the impressions in coarse ware pottery. As an aside, the name chaff tempered coarse ware is probably incorrect in the sense that chaff is not found in more than 3 out of 100 impressions investigated in different sherds, and that it also implies a seasonality to pottery manufacture which would have followed harvest, a time which one might guess to have been a busier time for cultivators than the warmer summer growing season which is actually a better time for the making and firing of pottery.

Cut grass was chosen as the tempering material for replications. My dull lawnmower produced frayed ends, so a half gallon bucket was filled with grass cut with scissors or a steak knife on a board in fifteen minutes. Objections were encountered from colleagues to my twentieth century temper gathering forays. Objections to the use of cut grass and straw were also heard because it was believed that a long time period would have been necessary to cut grass into such fine pieces. Sharp flint and obsidian

flakes with no retouch (the debitage of a stone working class held in Harvard's Putnam Lab) were used to cut grass against a piece of split wood or by holding a handful and slicing short lengths. I was able to produce more finely cut grass in the same time than with the scissors. Three large pots could be produced from 30 minutes work of grass gathering and cutting.

The clay was broken up and ground with a roller on a piece of wood, mixed with about one third to half the amount by volume of grass temper in order to have the same appearance as the software pottery, and then water was added to give a doughlike consistency. It is almost impossible to get an even distribution of cut grass or dung wedged into an already wetted clay body. Therefore, the clay must have been dry when the temper was added. The clay body was very short and only poorly plastic, and tended to crack very easily. Coils of clay made about the thickness of the wall cracked across the diameter and broke. Wads, lumps and slabs of clay were much easier to form and join.

The combination of chaff and straw with montmorillonite clay and water makes a composite material which has strength from the linear organic fibers which reinforce the fine particled clay. When the fibers are patted out in the clay, they align parallel with the faces, giving rigidity to the body in bending and torsion. If the body is further extended the clay delaminates from the fibers, and the strength of the body actually decreases. In making coils a considerable amount of extension is necessary, sufficient that the clay delaminates from the fibers. The result is that the coils neck down and crack into short lengths. Thus, coil building is not appropriate with a fiber reinforced body. Slab building achieves ideal working properties in this clay body. Looking normal to the surface of a slab the fibers appear to be in random orientation, but examination of fractures after the clay is

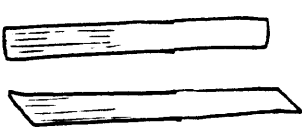

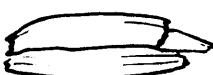
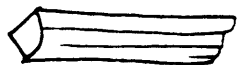
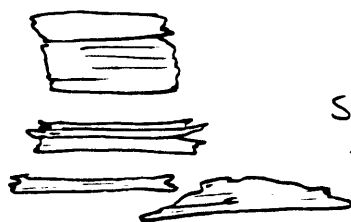
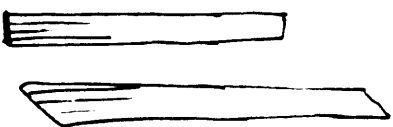
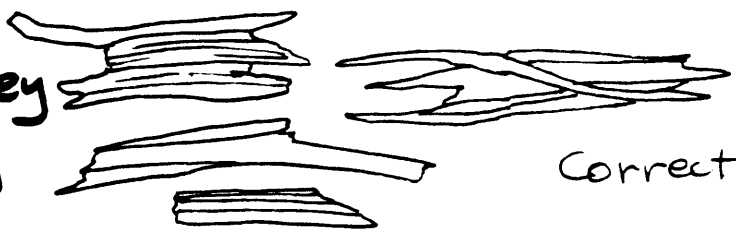
dry shows that the temper is aligned like a felted network parallel to the surfaces, giving strength in every direction parallel to the surface as well as in bending. Thus the organic temper tends to hold the body together during fabrication and to give strength to walls and prevent slumping, as well as decreasing the drying shrinkage of the clay body, which is the reason most often cited for its inclusion.

Once the clay has been allowed to sit wetted for two to three weeks, all of the clay particles wet through, and the clay achieves its full plasticity. In this state the clay is not so likely to fracture when extended, and the organic fibrous elements are not as important to its strength. The montmorillonite clay particles are very fine and because of the great numbers of them, aging is necessary to achieve plasticity. When fully plastic, coils can be made which are two and three times the length possible when made immediately after the clay (without organic temper) has been wetted. In the Near East where the climate is hot and dry, the aging of clay requires a special and intentional process of preparation. The clay must be premixed and stored, being kept moist in a shaded area or damp pit for longer than a week. Digging quantities of homogeneous, workable clay out of a stream bank is extremely difficult by comparison, as anyone who has tried it knows, and streambank clay tends to be drier than is useful for forming pottery as well as impure.

The montmorillonite clay body has the amazing property of being able to be rewetted once it is almost dry, past the leather hard state, without cracking. Thus, a vessel can be worked over a long period of time without damage. A vessel can be almost dry and still have the surface of a cracked join worked together or take a slip coat without cracking or be rewetted and burnished. Thus, some of the processing controls on the clay body are very

forgiving and not limited by the dryness of the body. However, in working with the clay, water tends to migrate rapidly around agglomerated clumps of particles because of the large capillary forces produced between fine particles. For instance, when a lump of clay is squeezed water forms a coating on the outside of the lump, much more so than with a kaolinite, ball clay or fireclay. In addition the clay tends to get overworked rapidly, to dry out and after some working to not be as plastic. It is easy to rewet the surface and rework it, to add a next section to a rewetted earlier formed section, but it is also easy to get the previous one too wet so that it deforms--so the process of making pottery is not without subtle and essential control of water content. Throwing this type of clay also presents particular problems; it is easy to overwork and crack or to overwet and loose strength in the wall thrown on a potter's wheel.

Figure 18. Sizes and Shapes of Various Organic Tempering Materials

Material	Shape (of Organic Burnout or Temper)	Size Range	Number of Samples
Pottery Temper		Large Range L 0.2 - 20 mm. W 0.1 - 5 mm. Ratio 3-12	100
Wheat Chaff:	Hull  Straw   (stalks tend to break up)	Correct L 8-10mm	50
Sheep Goat Dung		Small L 0.1-4 mm Size Distribution Too Narrow	50
Cut Grass or Dried Straw		Correct	50
Cow Donkey Dung		Correct	50

2. Surface Textures, Edge Fractures and Internal Structure Resulting from Different Processes

Surface textures from the many processes were produced with tempered and untempered, aged and unaged clay. These processes include: wet smoothing on a turntable and free hand with hand and/or piece of felt in a wet and barely damp state, burnishing in different states of dryness, scraping in wet, leatherhard and completely dry states, trimming by turning on a wheel and by hand, wheel throwing on a slow kick wheel and with an electric wheel, and incising when wet, dry and after firing were produced with tempered and untempered, aged and unaged clay. There were no surprises in the sorts of textures produced.

Wads of clay were built up into a wall, as well as slabs which had been patted out first, and slabs made of small wads of clays, all of these work well. It was very difficult to extend slabs once they were put in place in the pot; however, it was possible to extend joins and work these together, but no substantive difference could be detected in a xero-radiograph (Figure 19a) of the first layer of two pots or in a fractured cross section. After formation of the base and lower wall it was necessary to let the pot stand until it would support another 3 to 4 inches of wall. Thus the experience of building a slab pot supported the way in which the Seh Gabi cook pot (Figure 12) had been conjectured to have been made. Coiling was difficult with the unaged organic tempered body, the result was radiographed and is shown in Figure 19b. Another coil pot was made with a grit (sand) tempered, aged clay in which the coils were well worked together, and this result was xero-radiographed in Figure 19c. Some horizontal orientation of the pores can be seen in the center of the pot. In addition diagonal shaping and smoothing imprints can be seen at the neck and right side. These are on the



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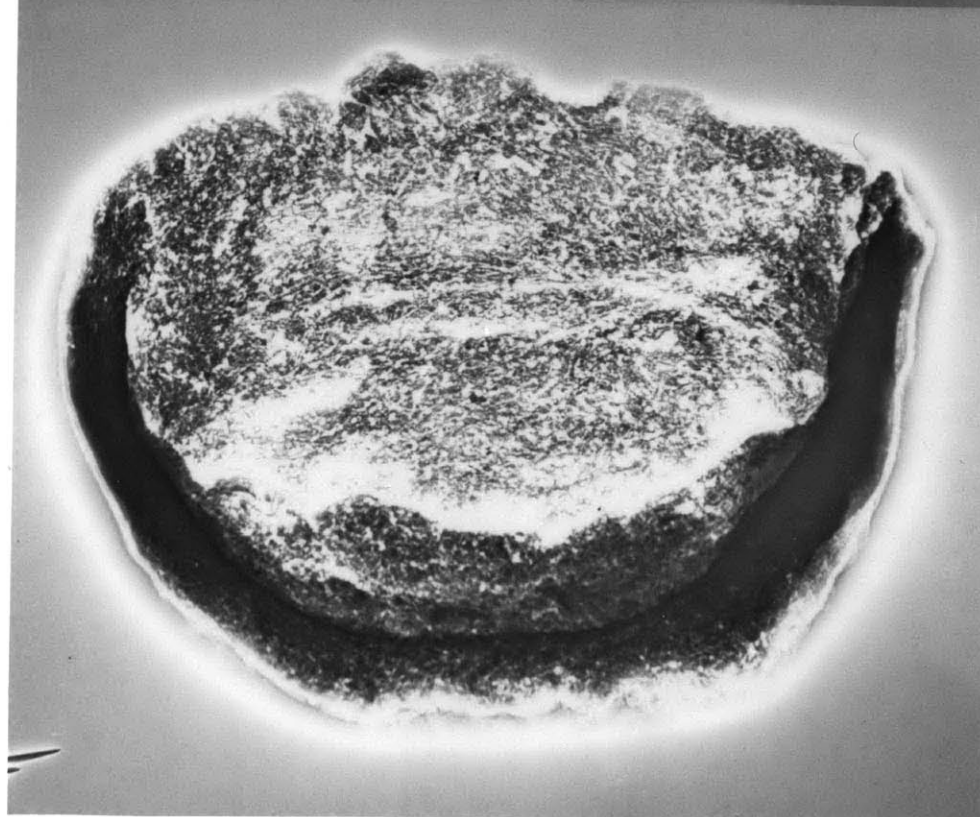
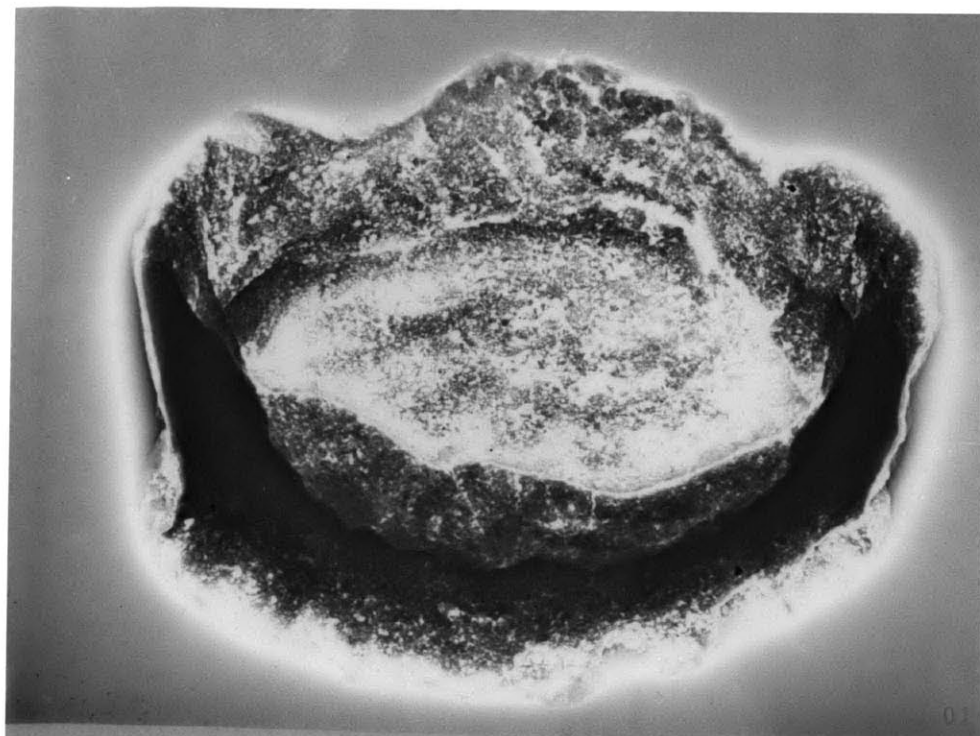




Figure 19a. Xero-radiographs of Replications Showing Join of Base with Side Wall Slabs.

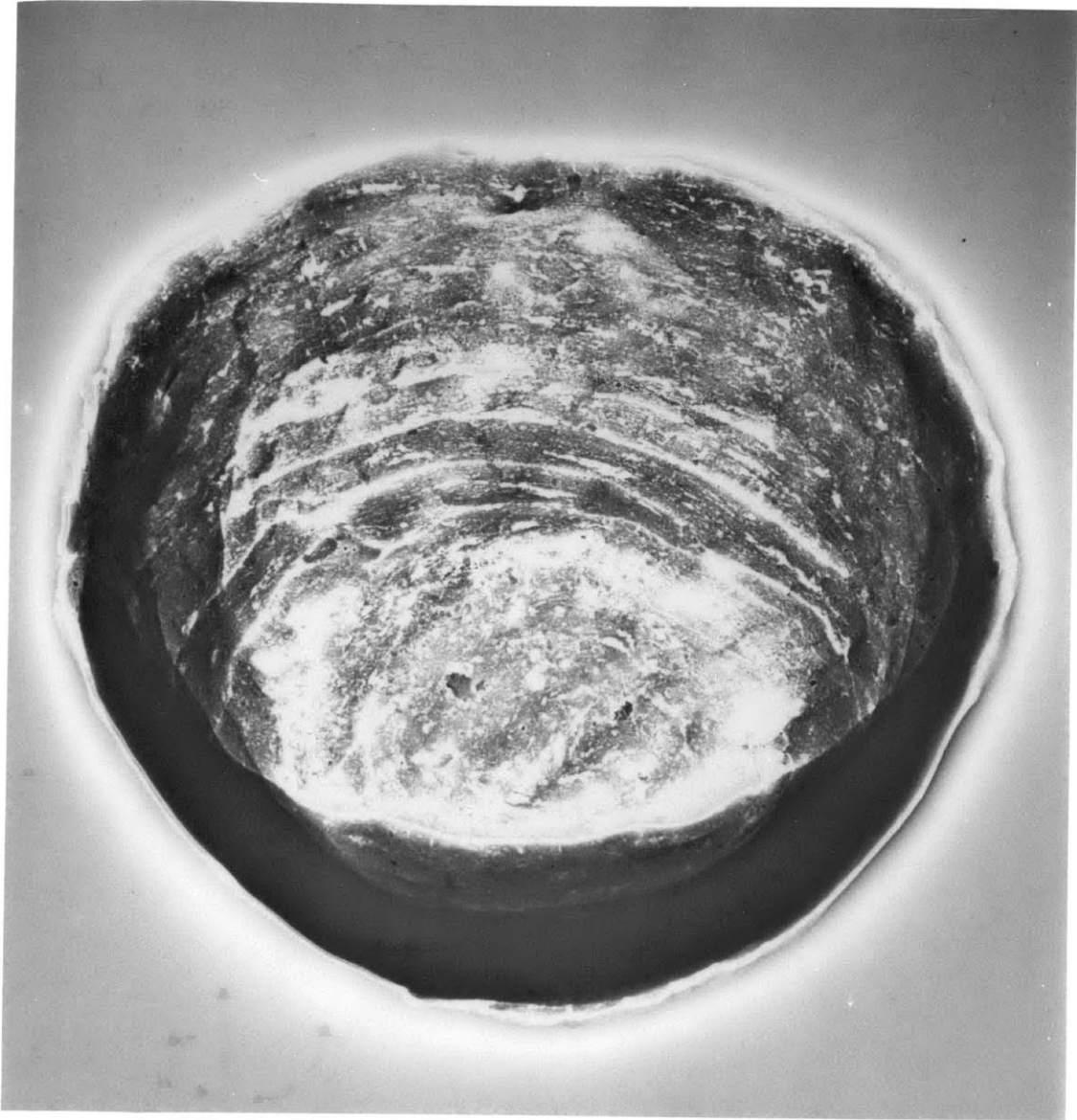




Figure 19b. Xero-radiograph of Coil-Built Replication Using Clay Body Without Chaff Temper. Horizontal pore alignment is visible in center of body.

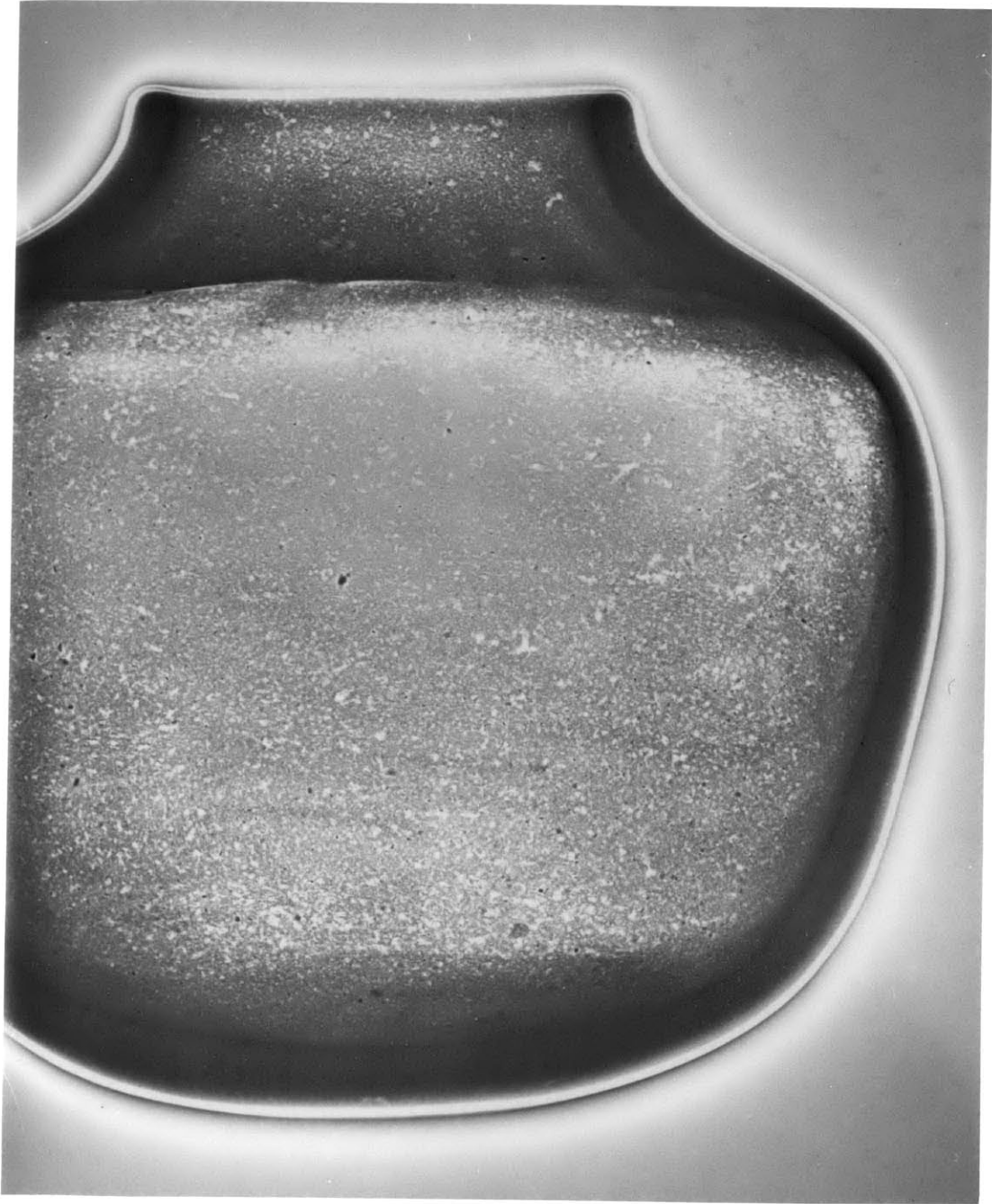




Figure 19c. Xero-radiograph of Replication Built with Coils (note horizontal alignment of pores).

3. Conclusions from Replication Attempts

One conclusion from working a grass and straw tempered montmorillonite clay body is that coiling is extremely difficult, and that using slabs, lumps and strips as building elements is a sensible, efficient means of forming a difficult to work body. In addition, this clay body is an optimally strong composite, fiber reinforced building material that is generally considered a modern engineering solution used in fiber reinforced plastics and other products of high technology. The difference is that the fibrous elements burned out of the ancient product, but the ware was still sufficiently strong to serve its purpose of storage, cooking, and serving, so there was no need for a high strength, carbon or other fiber reinforced material.

Another conclusion from working with the clay is that the only way to make a reasonable fine ware body free of organic temper is to age the clay to develop plasticity in the clay. Then the clay is a workable, fully plastic clay which can be shaped by any method, coiling, throwing, etc. The development of fine wares without organic temper requires that the clay be aged. Aging clay is a special practice requiring wetting and mixing clay and then maintaining that wetness for a week or more, optimally for two to three weeks. Montmorillonite clays have the finest particle size of all clay types and thus take longer to wet through. The aging period of two to three weeks has been considered optimal by potters, and was studied by an early head of the American Ceramic Society, Ross Purdy, as being optimal for the development of plasticity based on wetting and perhaps the development of bacteria in the clay (W.D. Kingery: pers. commun., spring, 1984). In a dry climate aging requires a pit or sheltered area where clay can be stored in a wet condition. Thus the development of fully plastic clay for fine

ware requires a technological change in the way clay is prepared.

4. *Çumcume*: Analysis of a Modern Pot from Southern Turkey

Prof. Mary Voigt in preparing a lecture for her class at Bryn Mawr looked carefully at a slide thought to be a modern example of coiling which she discovered was building a pot in strips and slabs in the same way I had been trying to describe for the Hajji Firuz, Dalma and Pisdeli pottery. Investigation of this documented ethnographic example makes the manufacture of pottery by sequential slab construction all the more credible. There is a dearth of ethnographic examples of pottery manufacture by the method of sequential slab construction. Finding this example and having it agree so closely with the method of manufacture of ancient Near Eastern pottery was surprising.

Three independent interviews were conducted with each of three researchers, M. Voigt, Carol Snow and Hilde Potts, who observed the making of three pottery vessels by the slab method over a period of three days, although not all of them were present for each day's work. One, Carol Snow, Conservator at the Walters Art Gallery, brought one of the pots back with her, which was subsequently examined and photographed by me, and later xero-radiographed by Dr. Giraud Foster at Johns Hopkins University.

Hilde Potts described the pot as being made from strips and bits of clay which were first kneaded like bread dough. The slabs were built around the pot and smoothed, but the potter did not use a lot of water. A great deal of time was spent smoothing over the pot. She walked around the pot, and formed it in a seemingly sloppy manner. Before the observers arrived, local clay had been gotten from near or at the Euphrates and dry mixed with already fine straw. Most of the straw was about 1/4" in length, with about 1/2" being the longest size. Perhaps a little sand was added, but the clay

was not gritty. The firing was not observed.

Carol Snow allowed me to use her slides, some of which are reproduced in Figure 20. Mrs. Boztepe, a Kurdish woman and mother of the cook at excavations at Gritille, agreed during the summer of 1981 to demonstrate the manufacture of pottery in the old way. Plastic, metal and other pottery containers have been substituted for locally made goods currently used by villagers at Çumçume, located in Urfa province, southeastern Turkey. The clay had been collected from a special clay source and had already been ground and the straw and chaff had been collected and prepared, although dried straw and chaff commonly is brought back to the village in large bundles shown in Figure 20.1. The clay was mixed by hand with a measured amount of chaff on a piece of plastic, then placed in a tub to which water was added (Figures 20.2 and 20.3). No dung was added to the clay body, but perhaps there was a little sand. At first the clay was very sticky and then became more like dough (Figure 20.4). Three pots were made at the same time. During the work period on the first day the base and lower wall were made. During the second day the wall was built up, and during the third work session the upper part of the neck, lip and handles were added.

A slab was patted out to make the base (Figure 20.5). Then strips were added around the edge of the base (Figure 20.6). The strips used to make the pots were sausage shaped but flattened into more of a rectangular shape. The strips went about one third of the way around the pot at the base and were worked in with water and slip by hand (Figure 20.7). The pottery was smoothed with slip from a wet area of clay in a bucket. To add more clay on the second day, the already formed edge was wetted with fingers and slightly indented, but not scored. The vertical joints were butt, not bevel joints and the horizontal joints were probably also butt joints but this is not sure.



Figure 20a. The Manufacture of a Modern Pot from Çumçume, Turkey: Gathering of Straw.

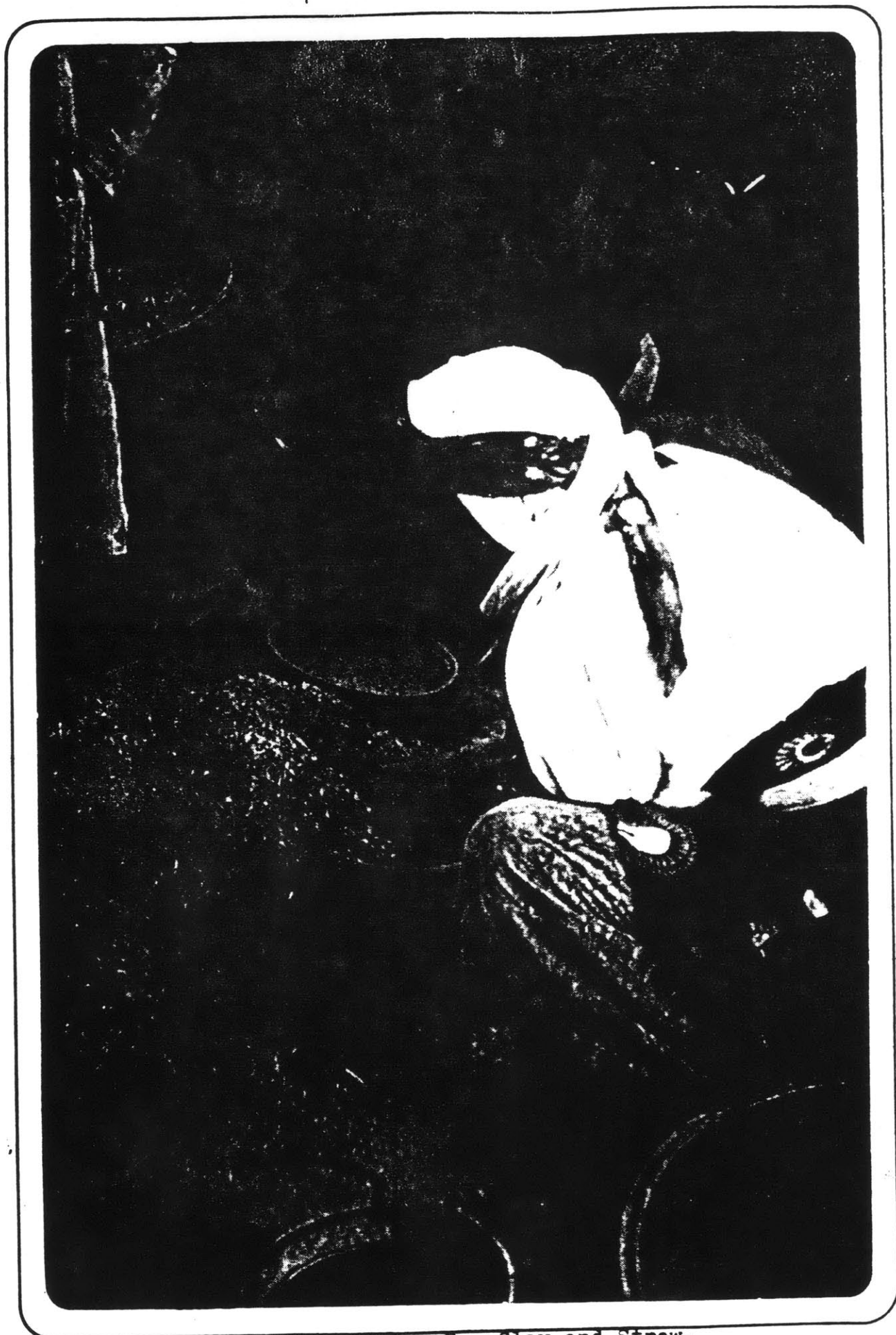


Figure 20b. Mixing Dry Clay and Straw.



Figure 20c. Adding Water to the Dry Mixture.



Figure 20d. Kneading or Wedging the Clay Body



Figure 20e. Forming a Slab for the Base.



Figure 20f. Joining a Strip to the Base.



Figure 20g. Wet Smoothing the Surface and Working the Clay at the Joint.

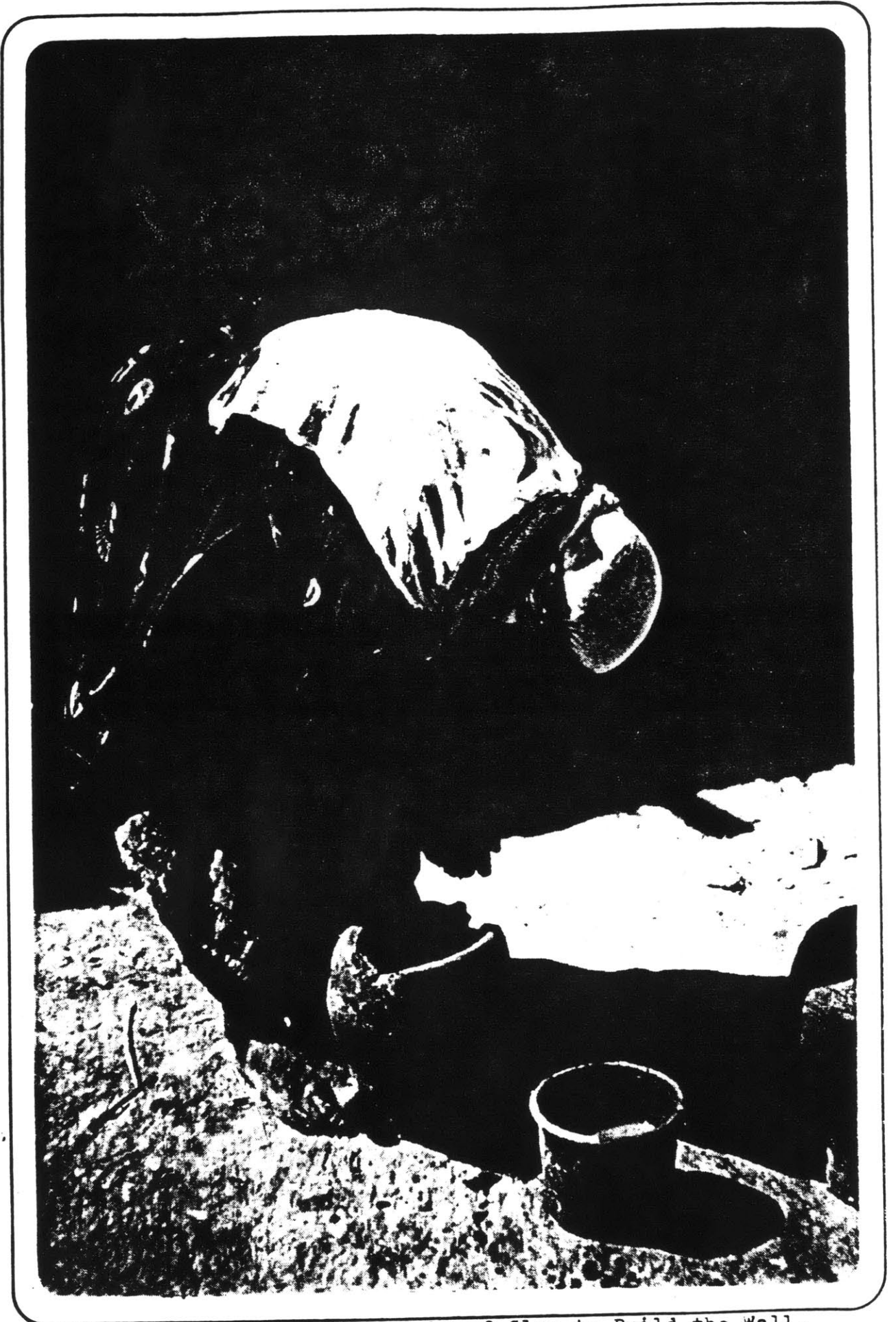


Figure 20h. Adding More Slabs of Clay to Build the Wall.

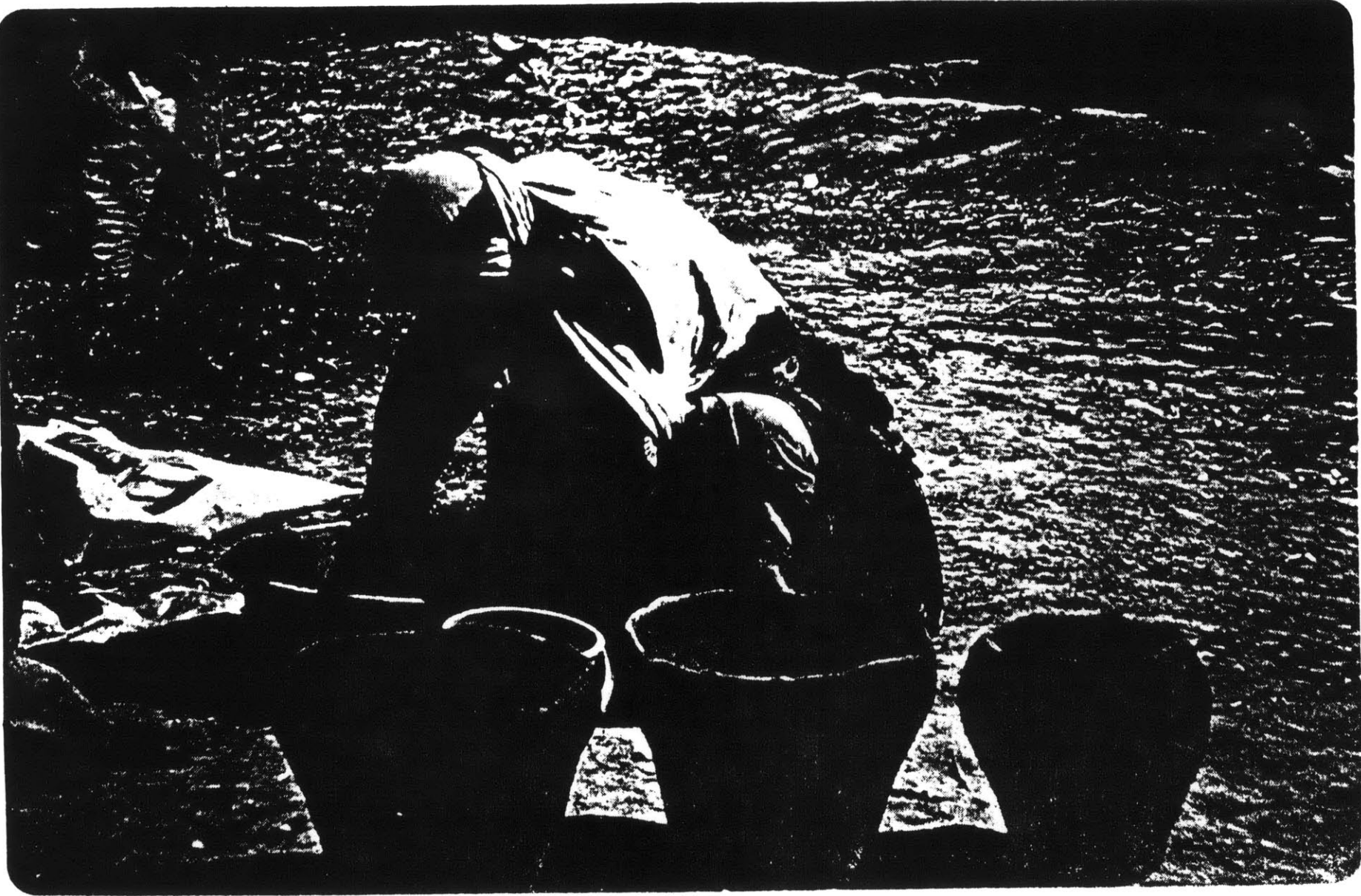
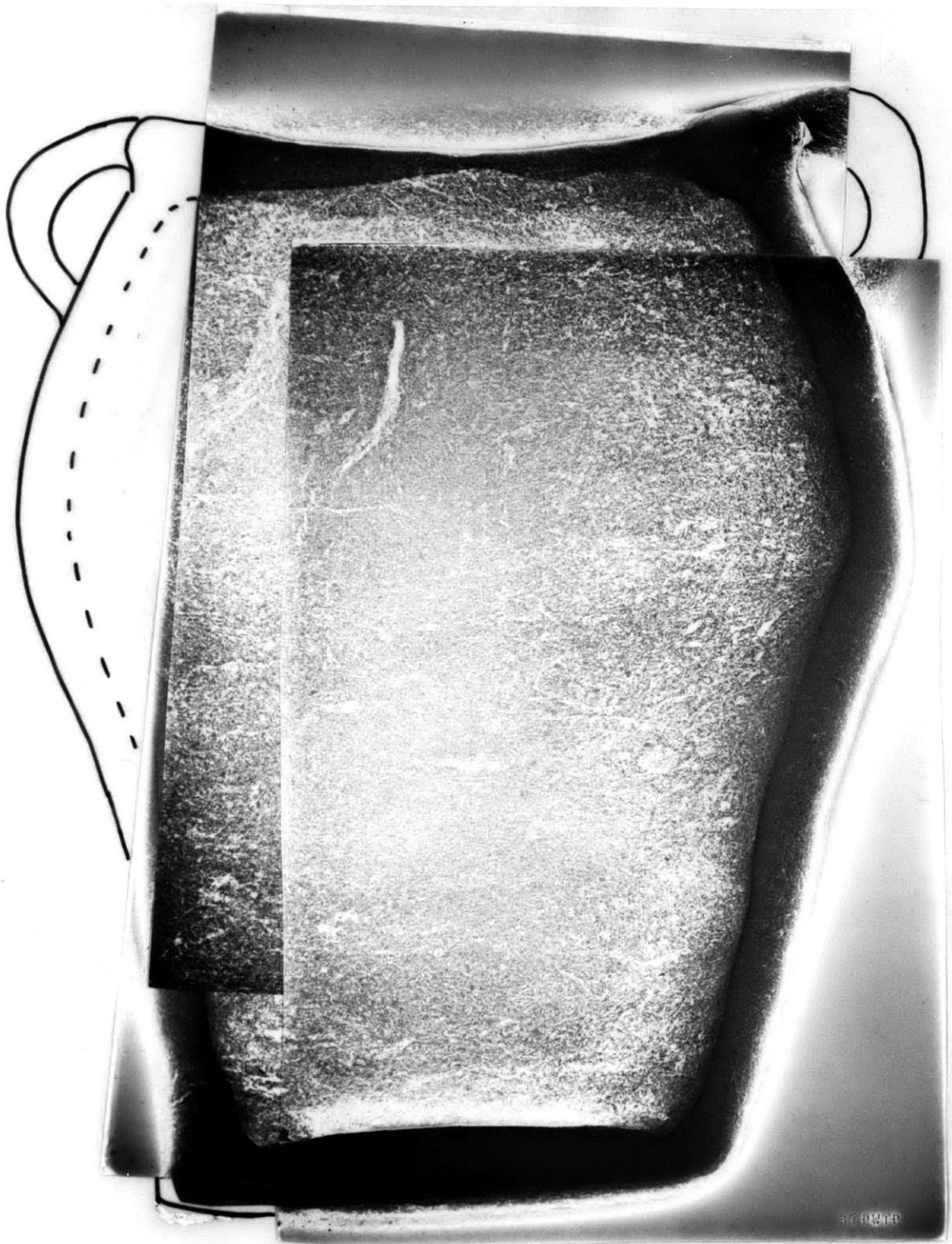


Figure 20i. Three Pots at the End of the Second Day.

One group of strips was built around the pottery, but it did not seem systematic (Figure 20.8). The next slab seemed to be thrown on top in an almost sloppy way. Just the hands were used to smooth the pottery, no rags were used. The impression is that the pottery was left to sit out in the courtyard overnight at the end of the second day (Figure 20.9). Work started on the third day before the observers arrived which is probably an indication of the need to join new clay to the thinner upper wall before it had become too dry.

The radiograph, a drawing from the radiograph and a photograph of the lower part of the body taken in a raking light, show the size of slabs used to build the wall (Figure 21). Their resemblance to the surfaces and xero-radiographs of ancient wares is striking. No broken cross sections were available for study, but if the pot ever breaks it will warrant another trip to Baltimore.



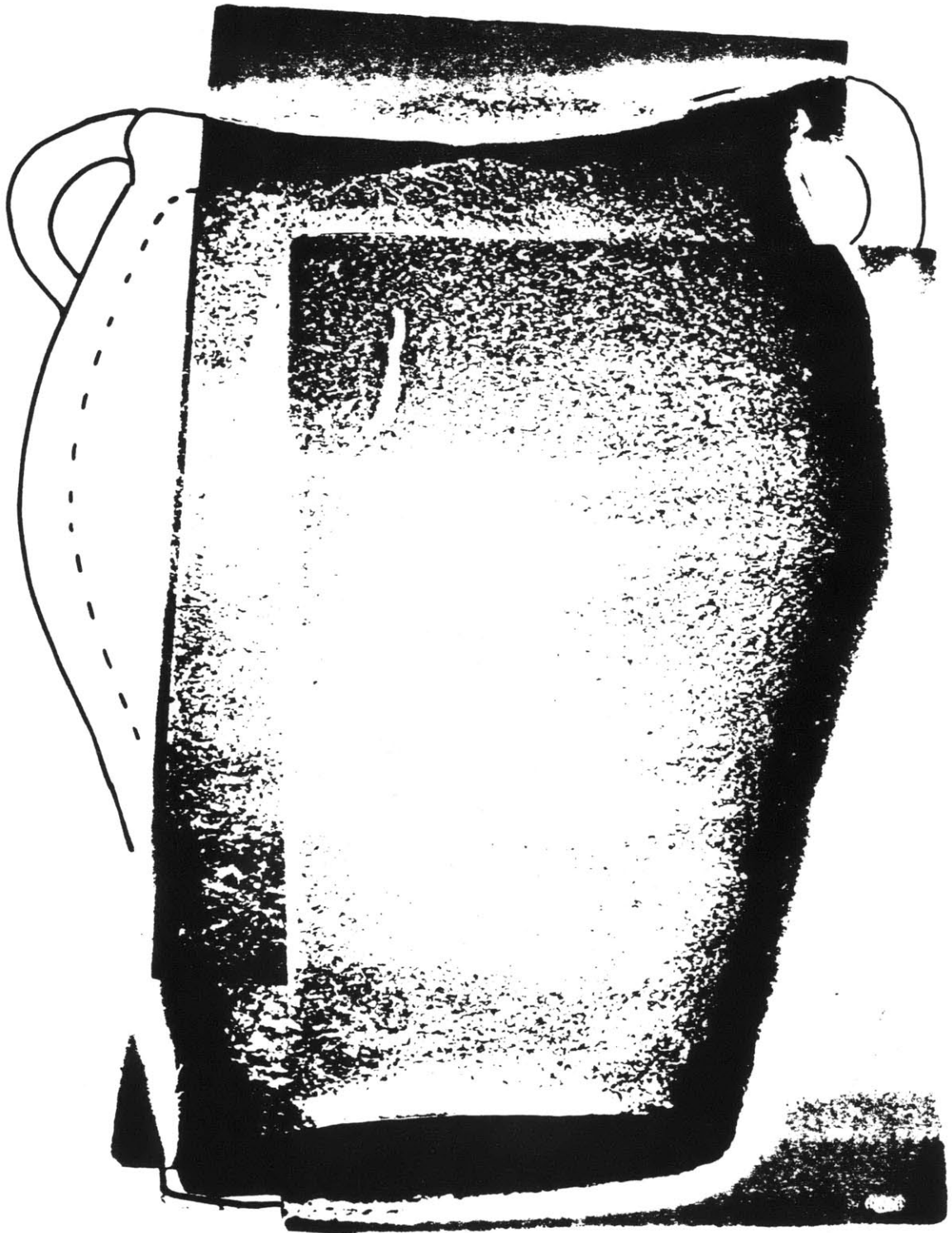


Figure 21. Xero-radiograph of Çumçume pot.

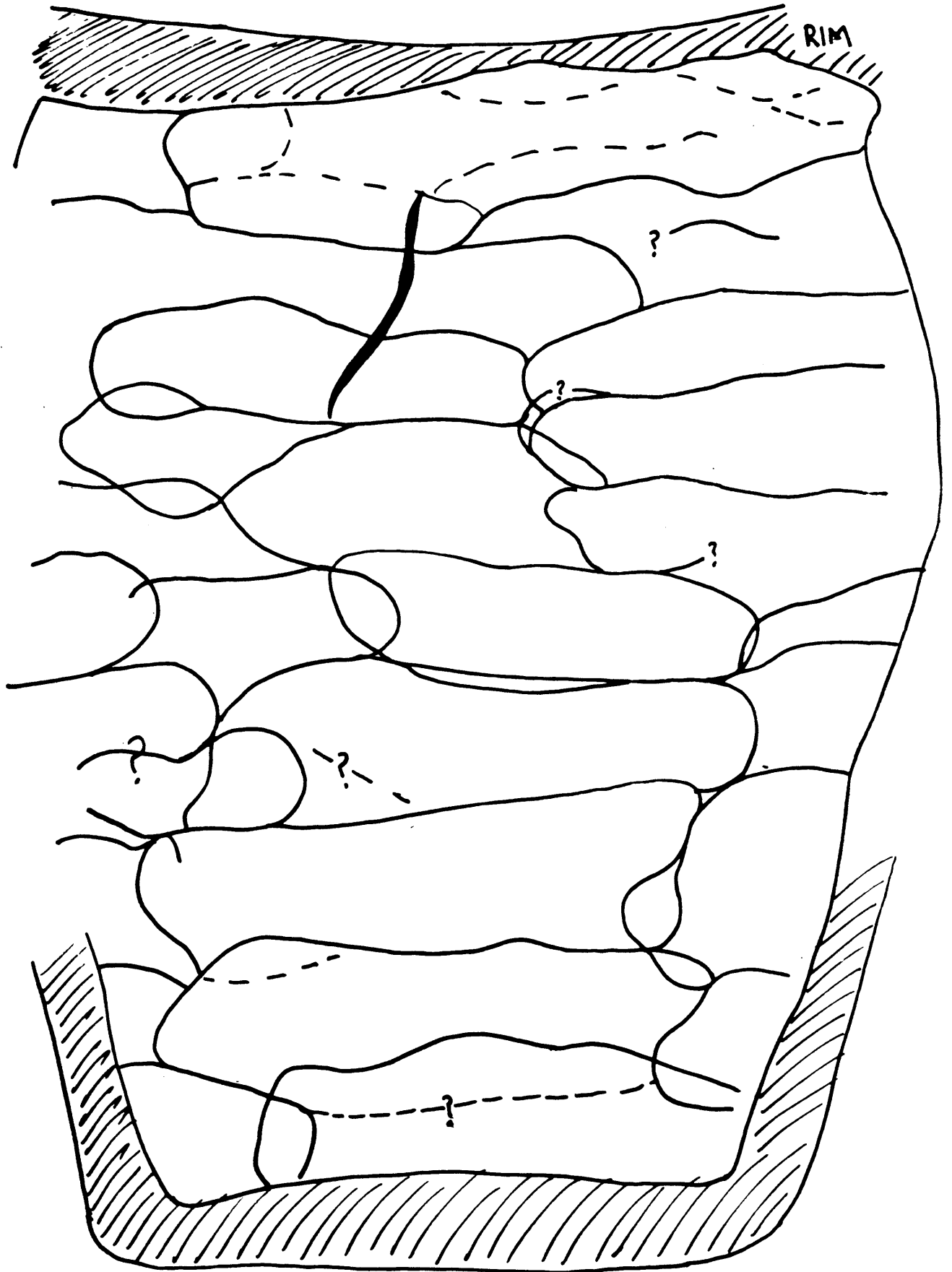


Figure 21. Drawing of Radiograph of Çumçune Pot, Continued

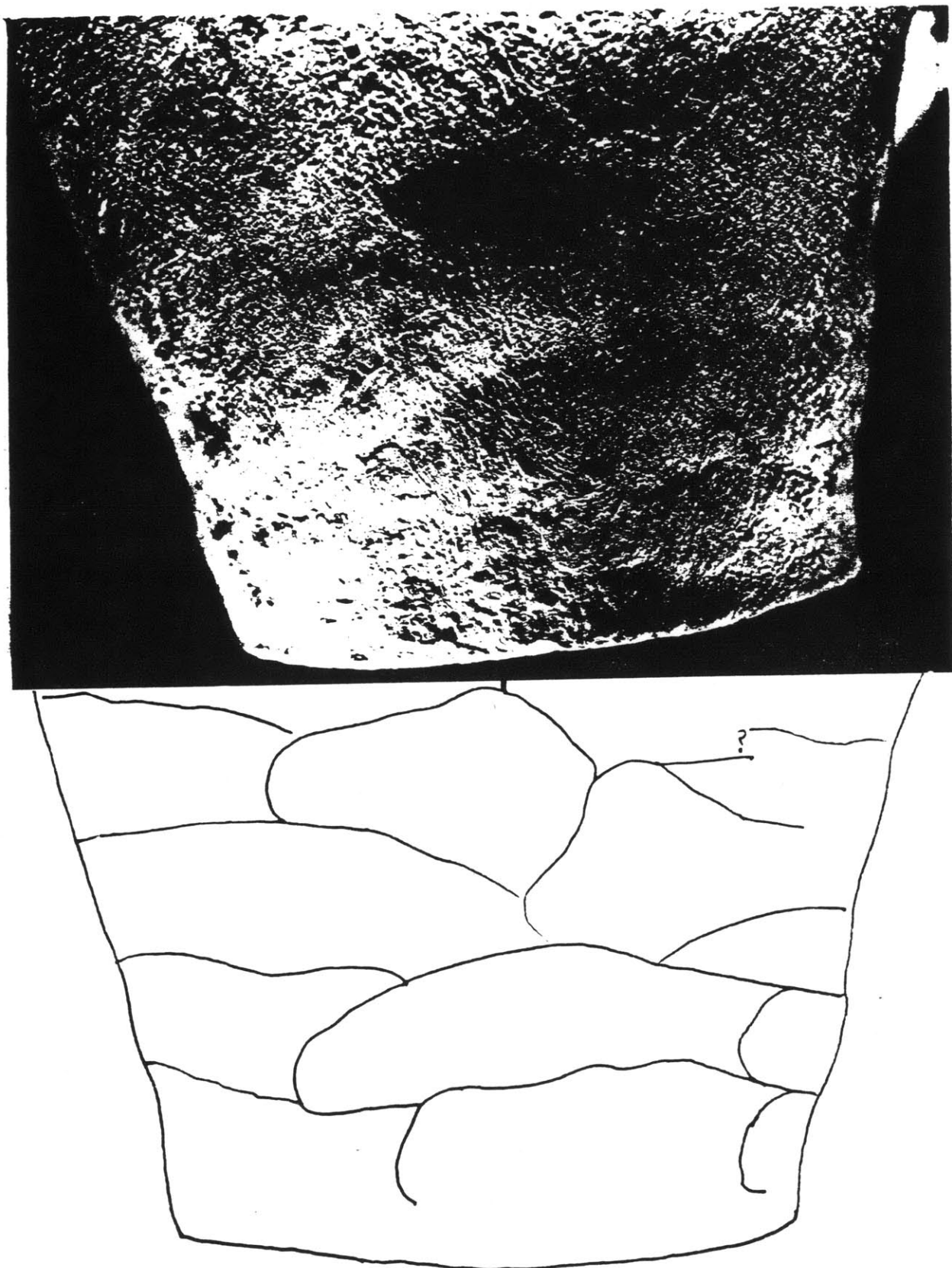


Figure 21. Photograph and Drawing of the Çumçume Pot,
Continued

VI. RESULTS

A. STUDY OF ORGANIC TEMPERED COARSE WARES AND FINE WARES

Demonstrating that sequential slab construction was the method of producing pottery in the Near East from 8000-3000 B.C. has been done in two ways: by measurement and by visual discrimination. By using microscopic examination of pottery, joins were found in all coarseware and most fineware. The type of join was determined for 4004 sherds, and the sizes of 2765 slabs or other manufacturing elements were measured. From the sherds in which the size of slabs were measured, a group of 441, about 10.5% of the total, was selected for xero-radiography. From the radiographed group a smaller group of about 1% of the sherds were documented by photography of the surfaces and then sliced like bread with a diamond saw, such that the cross sections could be radiographed in order to track the spatial distribution of slabs. All of the metric data and examples from the final group of 41 sherds are presented below by site.

Table 10. Sample Size

Site	No. of Sherds for which Types of Joins Determined	No. of Slabs Measured	Number of Sherds:	
			Xero- Radiographed	Xero- Radiographed and Sectioned
Tepe Yahya	400 fine	347 f	75 f,c	7
	402 coarse	256 c		
Hajji Firuz	373	207	42	10
Dalma	73	39	24	0
Pisdeli	112	96	24	0
Ganj Dareh	61	72	12	0
Sarab	773	528	10	3
Seh Gabi				17
C	250 c	112 e	15	
B, Dalma	305 f,c	247 f,c	57	
A and E	325 f,c	267 f,c	28	
J-Ware			30	
Chagha Sefid	292 c	213 c	72 f,c	3
	294 f	142 f		
Sabz and Faruhkabad	241 f,c	147 f,c	0	
Halaf, Chagar Bazar	103 f	82 f	25	1
Merimde	7	10	7	
Mostagedda	-	-	1	
Total	4004	2765	422	34
		69.1%	10.0%	0.8%

Note: Standards and replications, the Cucume pot, and others are not included but would add another 85 samples to those radiographed. The number of sherds examined, but not measured, as part of this study were not counted individually but the number estimated by volume is close to doubling the number measured.

Table 10 Continued. List of Samples Sectioned by Site

Hajji Firuz

Pithoi, wall carination fragment, HF G11(4)(11) (R39)
 Pithoi, body fragment, HF G11(3) (R40)
 Large open bowl, rim and wall sherd, HF V(5) (R32)
 Large open bowl, profile, HF V(8) (R29)
 Large open bowl, profile, HF V(8) (R31)
 Small jar, profile, HF V(8) (R1)
 Carinated medium size bowl, rim and body sherd, HF G11(3p) (R9)
 Medium size open bowl, profile, HF V L7(7) (R23)
 Jar, base and wall, HF V(3)F11 (R35)
 Pithoi, wall at carination, HF V(3)F11 (R36)

Seh Gabi

Base from large jar, C, SG73 EB21-305 (R8)
 Open jar, rim and wall, C, SG73, AA21-311 (R10)
 Restricted vessel, red paint, C, SG73 EB21-310 (R15)
 Jar, slipped rim and body, B, Dalma Per., SG73 F22 369(#4533) (R)
 Bowl, rim and body, B, Dalma Per., SG73 308 (#4641) (R49)
 Bowl, body sherd, black-on-buff, Dalma Per., SG73 F22 325(#4614)(R50)
 Bowl, rim sherd, black-on-buff, Dalma Per., SG73 F22 308 (#4641)(R49)
 Bowl, black-on-buff, Dalma Per., SG73 306 (#4676)(R54)
 Bowl, body with vitreous black paint on buff body, S.G. Per., SG71 G10 6(R30)
 Bowl, body fragment, S.G. Per., SG71 G20 32 (R15)
 Bowl, body fragment, S.G. Per., SG71 G? (R29)
 Bowl, J-ware, Md175-095 61 70 (R11)
 Bowl, J-ware, Md77 203 (R5)
 Bowl, J-ware, Md75 454 G2 11 (R29)

Sarab

Bowl, buff burnished slipped profile, SI 2B (R21)
 Bowl, buff burnished slipped profile, SI 2 (R8a)
 Bowl, buff burnished slipped profile, SI 2 (R6a)

Tepe Yahya

Carinated bowl, vessel wall, black on buff slip, XC(6-4)71 (R48)
 Vessel wall, Soghun plain ware, pink body with cream slip, exterior scraped, interior wet smoother, XCE 1, 2 (R46)
 Base and lower wall of vessel, wet smoothed red slip coarse ware, XCE 217? 4A (R32)
 Beaker, rim sherd, black-on-red, vertical zigzag decoration, XC TT1 (5A) 71 (R16)
 Storage jar, rim and upper wall, black-on-red, wet smoothed interior and exterior, C (6) 69 (R15)
 Open owl, rim and wall sherd, slip and pattern burnish, interior and exterior, XCE TT1 (9) 73 (R30)
 Base with ring, exterior slipped and burnished, interior weathered, D (6) 69 VII (R57)

Chagha Sefid

Small jar, rim sherd, Sefid burnished red slip on cream body, slip on interior, area A, SA/E2/189 (R38)

Large vessel, base sherd, Sefid red slip on cream, area A, SA/B4.257 (R39)
 Carinated bowl, rim and upper body, black paint on probable white slip, late
 Susiana black paint on buff body, area D, SD/D6/246 (R60)
 Bowl, rim fragment, black paint on buff body, from Tell Halaf (R86)

From Ganj Dareh, Chagha Sefid, Tepe Yahya, Dalma, and Pisdeli every sherd in each collection was handled and examined with a low power microscope or loupe, although not all were counted for types of joins or measured for slab size. From Seh Gabi, Mound C, about 90% of the collection was examined; from Hajji Firuz, Sarab and Ali Kosh about 75%, and from Seh Gabi, Mounds B, A and E, Tepe Farukhabad, and Tepe Sabz about 10-25% of each collection was studied. Collections from Tepe Yahya and Hajji Firuz were studied first during a learning period of trying to figure out what to do and these are reported first in order to relate what was learned about looking at the pottery. The other sites are reported in chronological order of the appearance of pottery and moving from north to south and away from the Zagros region.

1. Tepe Yahya: Pottery Production Methods

The methods of analysis included examination of surface textures and edge fractures for evidence of manufacture using a 10x loupe and a 10-140x zoom binocular microscope. Where accumulated dirt on the surface hindered examination, ultrasonic cleaning with water and scrubbing with a soft brush was carried out. Optical microscopy has been used to detect alignment of the temper and pores which serve as evidence for the extension of the clay body, breaks which have occurred at original joins and are evidence for manufacturing sequence, fineness of the clay matrix, slips and paints as evidence for the preparation of clay, and the texture and faceting of the exterior surface as evidence of wiping, burnishing, trimming, scraping, and other processes such as sequence of manufacture carried out in various stages of drying of the unfired clay. Color and hardness of the body have

been observed as indications of the extent of firing and the relative changes in the atmosphere across a sherd or which represent a group of sherds. Other qualitative indications of the extent of firing which were used are the ring or thudding sound made by tapping the pot and the porosity indicated by the length of time for a small amount of water placed on the surface to be carried by capillary action into the interior.

The nature of the conclusions from this study are a reconstruction of the production technology allowing for determination of the introduction of new techniques of manufacture such as the use of a turntable or potter's wheel, or the introduction of new manufacturing sequences such as slab construction being replaced by coil construction. The general picture of the ceramic forming technology which emerges in this study is schematized in Figure 22. In short, the early methods of handforming chaff tempered coarse wares are quite efficient and complex, and continue as the prime means of constructing pottery even when a turntable is introduced for decorating and finishing. They do not change until the potter's wheel is introduced where the motive force to raise the clay is provided by the centrifugal force of the wheel. These developments are not well described in the archaeological literature.

All the early chaff tempered coarse ware at Tepe Yahya is formed by sequential slab construction. There is a wide variation in the sequence and number of slabs added to form a vessel, as shown in the cross sectional drawings in Figure 23. Slabs are made as preformed elements and pressed together next to one another or in overlapping beveled joins. This is a very different technology from coil construction, although coils are occasionally found as reinforcements at joints and near or at the rims. Owen Rye (1971:58-95) describes slab building as the overlapping of

preformed slabs, rectangular units formed by pressing or rolling the clay on a flat surface or by flattening the clay between the hands, and joining them by pressing or smearing, a technique he finds well suited for rectangular shaped pots and for rapidly producing large vessels. Because chaff or other vegetal temper is added to the clay, the Yahya chaff tempered clay body has only limited plasticity; that is, once the linear organic elements are aligned, they act to stiffen or prevent further extension of the body during wet forming, just as fibers act to reinforce a modern fiber reinforced composite. The sequential slab construction forms the technological basis for the manufacture of later fine wares. There is a gradual introduction of a slowly rotated device (turntable or tournette) superimposed on the conservative sequential slab construction. The gradual development of fine wares involves (a) slow turning to smooth and form the lip, (b) trimming in vertical and diagonal strokes on the wall and circular ones on the base, followed with smoothing by rotation of the base and lower wall, all to thin the wall and to control the shape of the profile, and (c) later in time turning to shape and extend the slab constructed walls.

TYPE OF
POTTERY
MANUFACTURING
TECHNIQUES

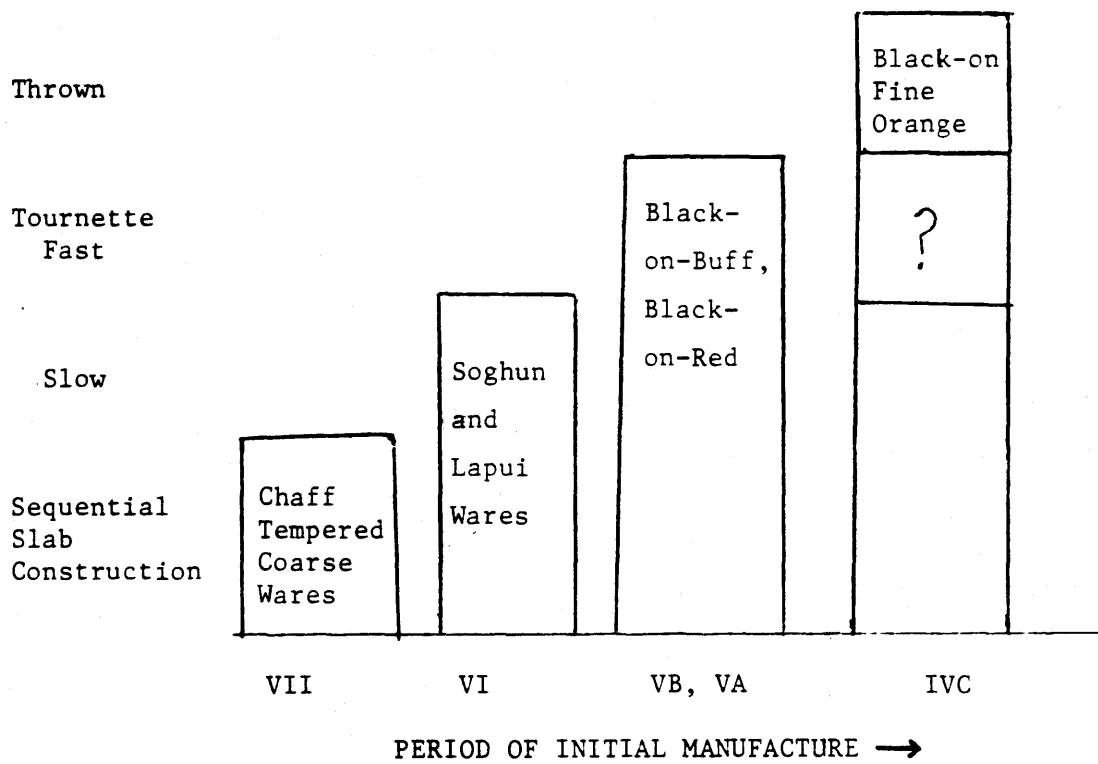


Figure 22. Technological Change in Pottery Manufacture at Tepe Yahya.

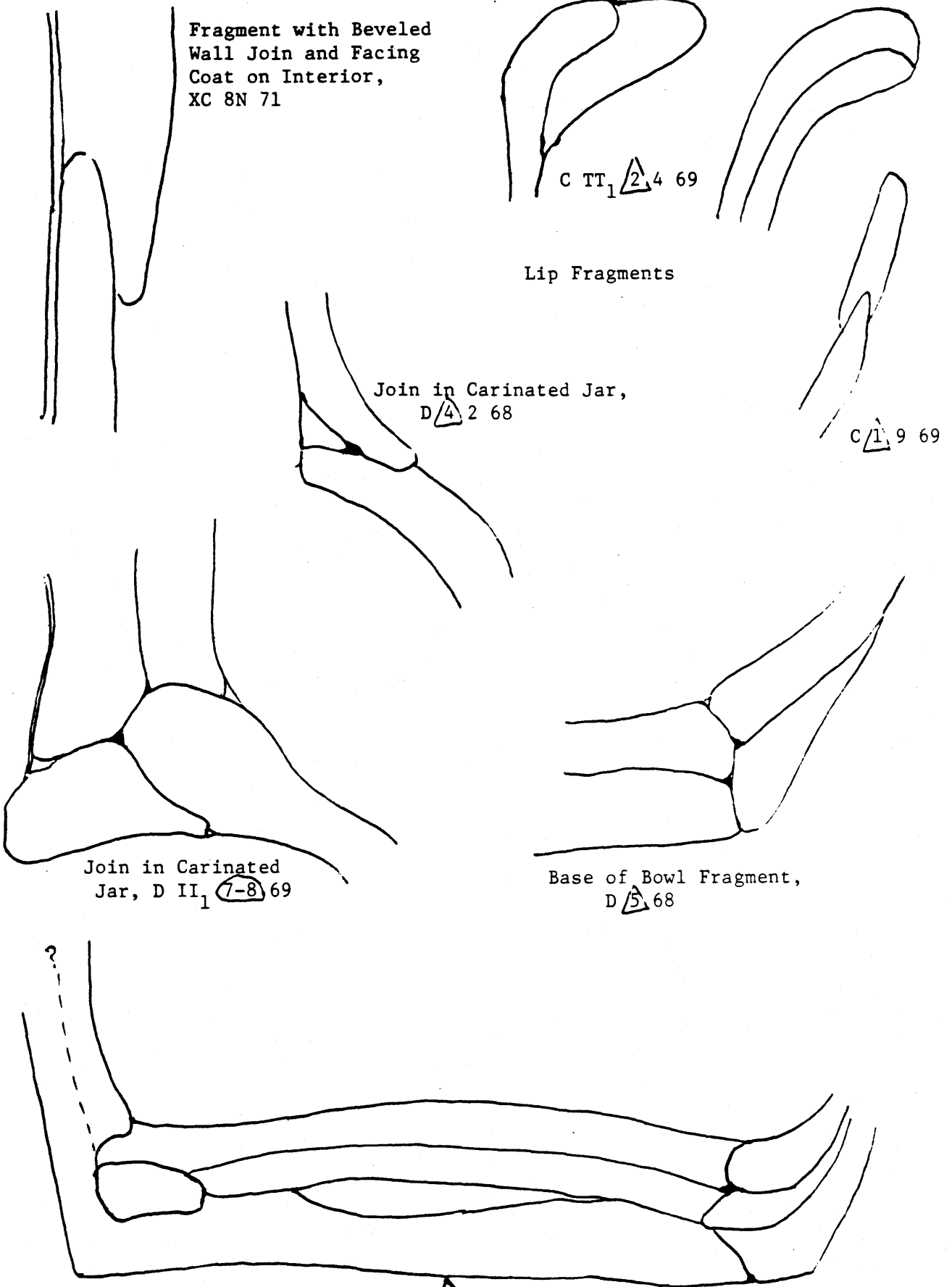
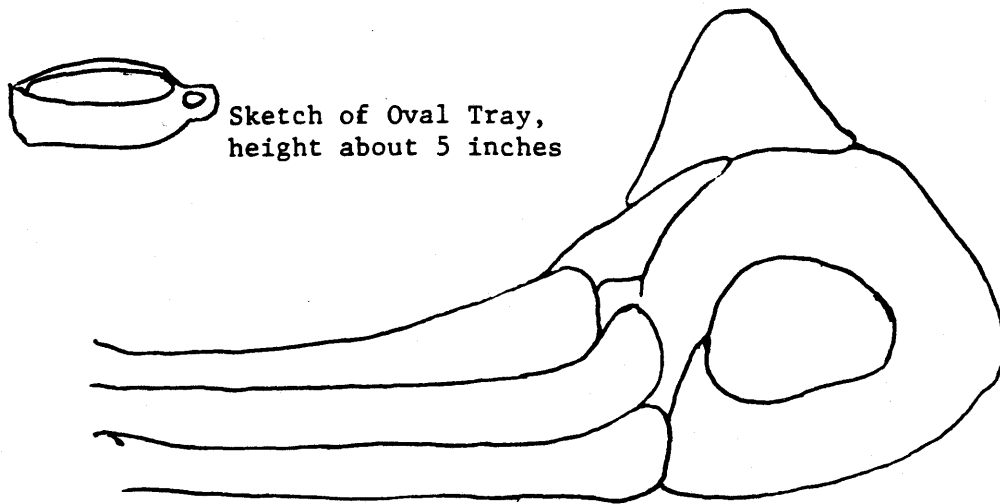
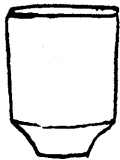


Figure 23. Cross Sectional Drawings of Yahya Pottery by Ware Type
 Period VI Coarse Chaff or Vegetal Tempered Ware

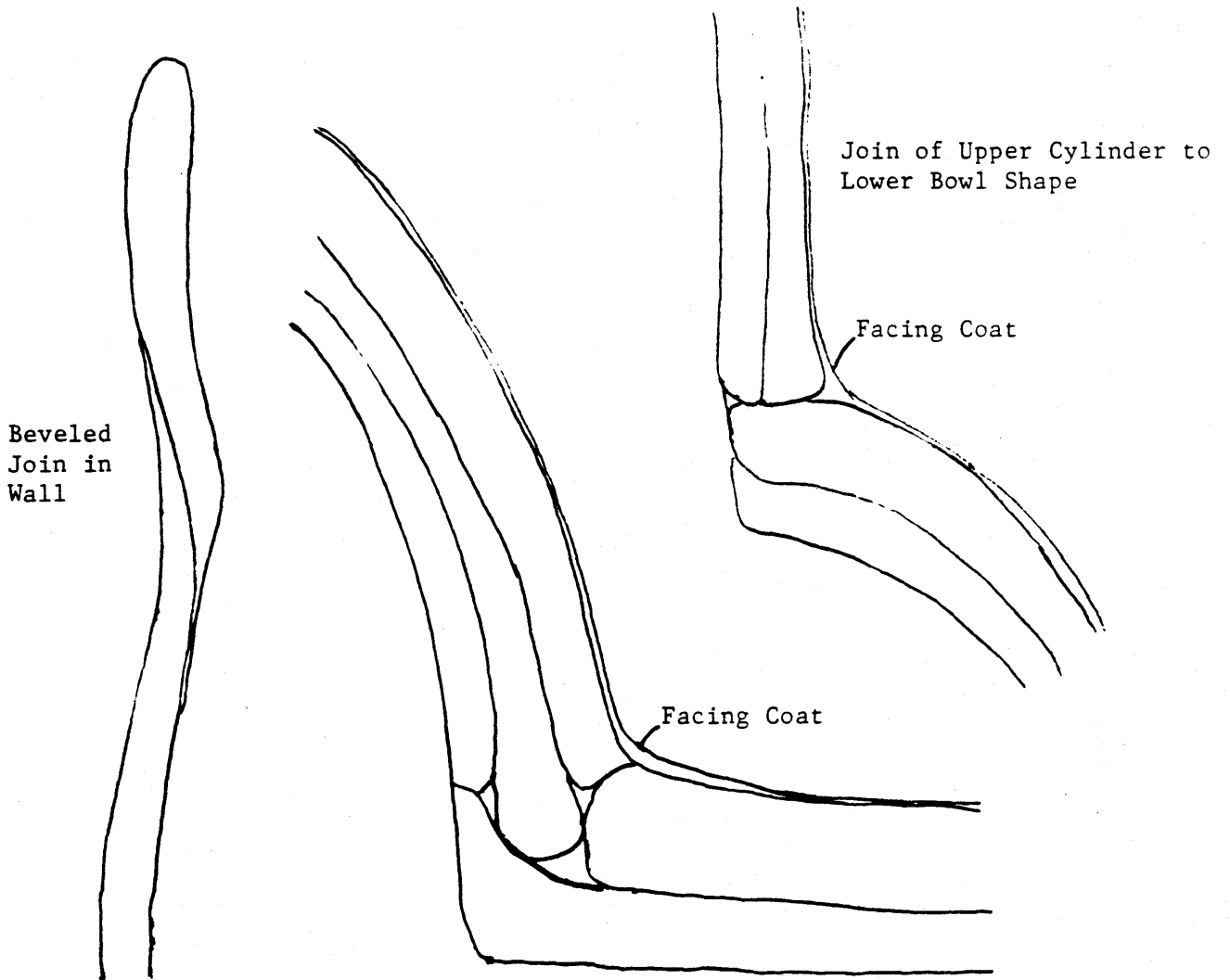


Sketch of Oval Tray,
height about 5 inches

Fragment of Oval Tray, D Δ 69



Sketch of socalled
Hassuna-type milk jar,
height about 24 inches



Beveled
Join in
Wall

Join of Upper Cylinder to
Lower Bowl Shape

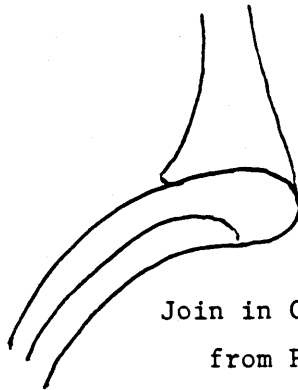
Facing Coat

Facing Coat

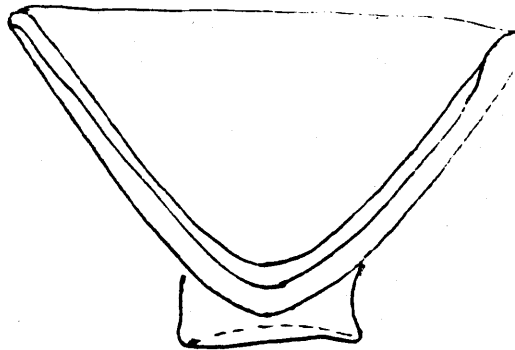
Oval Base with Facing Coat, C-7 (9)(10)
Period VI Coarse Ware Made by S.S.C. Continued



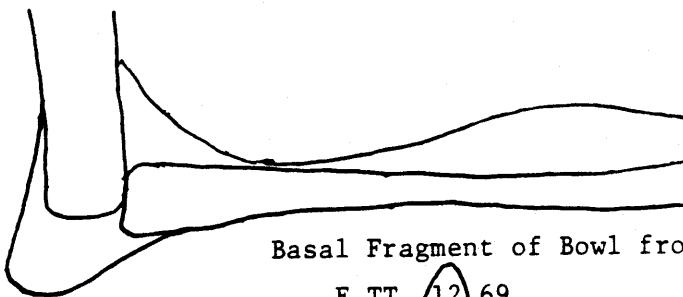
Wall Fragment
from Period VA
C TT₁₋₃ Δ 68



Join in Carinated Jar
from Period VA,
same number

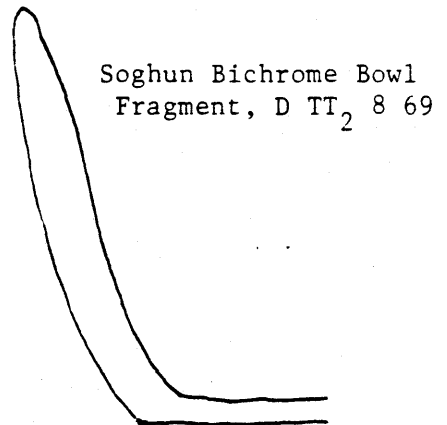
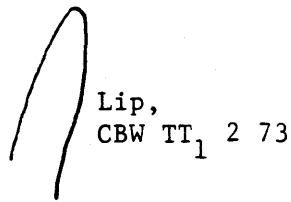
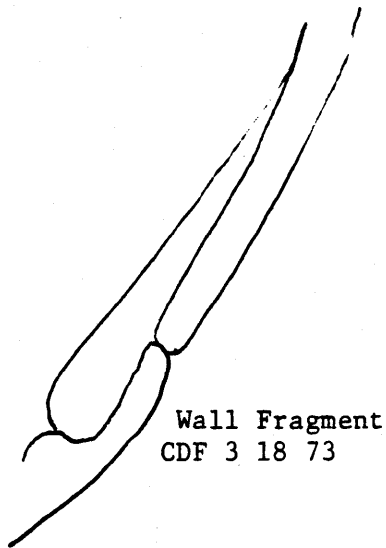
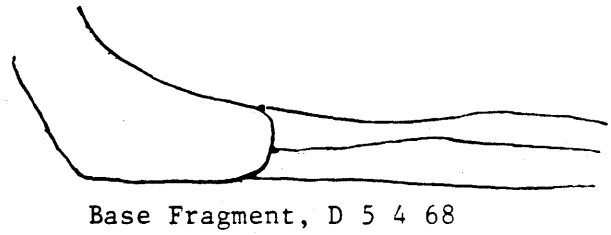
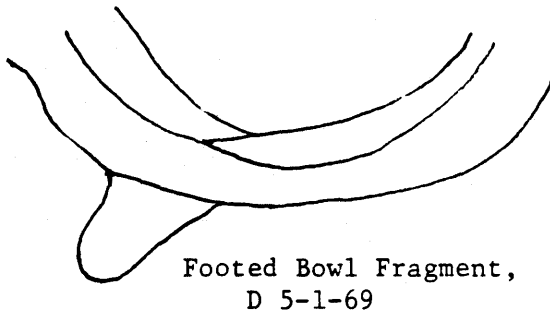
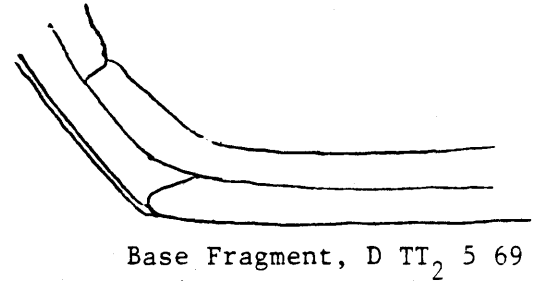
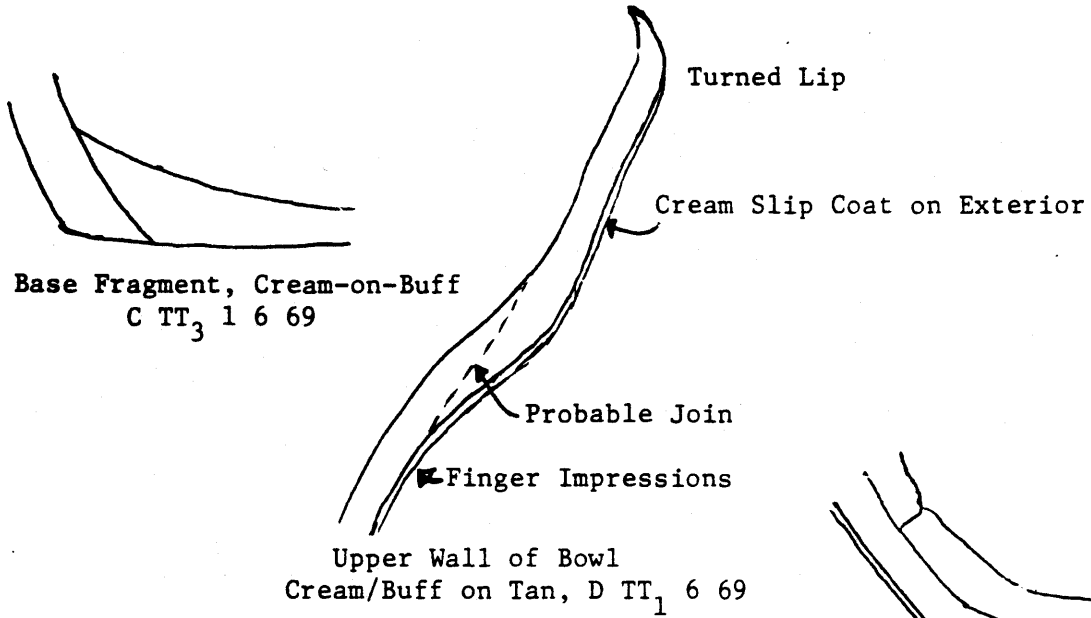


Small Bowl from Period VII, height 2 1/2 inches.
C TT₅ Δ 7

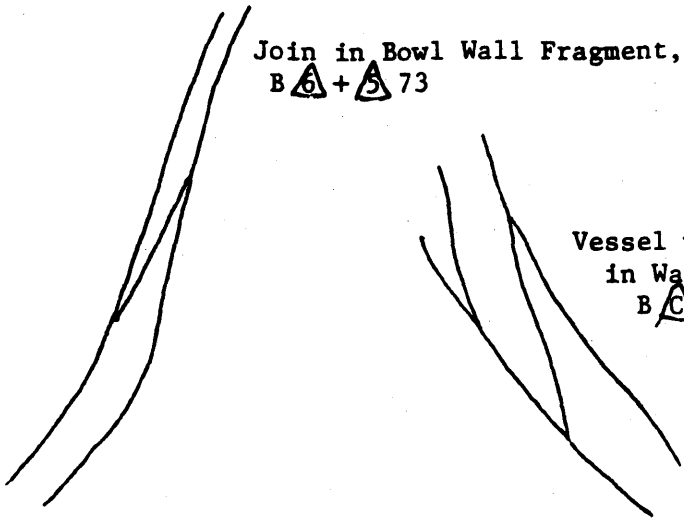


Basal Fragment of Bowl from Period VIIA
E TT₃ Δ 12 69

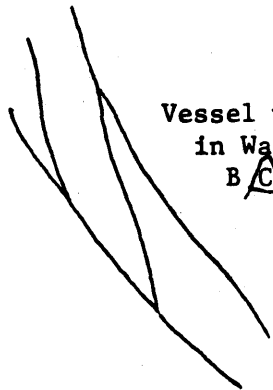
Vegetal Tempered Ware from
Other Periods Made by the Sequential Slab Construction Method



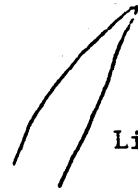
Soghun Plain Ware



Join in Bowl Wall Fragment,
B \triangle + \triangle 73



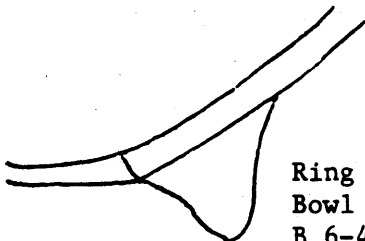
Vessel with Neck Join
in Wall Fragment,
B \triangle 73



Turned
Lip Fragment
B \triangle 73



Bowl with Uneven Trimmed Base,
B \triangle 73



Ring Base of
Bowl Fragment,
B 6-4 73



Double Wall in Bowl Basal Fragment,
B \triangle 3 73

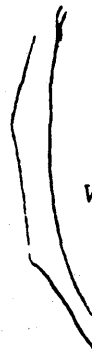


Trimmed
Exterior
Wall Fragment,
B \triangle 73



Turning Mark

Exterior has been
trimmed, B \triangle 73



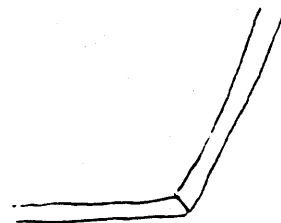
Wall Fragment with Facets
from Trimming, B \triangle + \triangle 73

Black-on-Buff Ware



Typical Surface Texture
in Wall of Beaker Fragment
Showing Considerable Upward
Extension of Outer Wall Clay

XCE 1-2 NVA.1-NVA.2



XCE 1-2



Double Wall Construction Extending
Almost to Lip

XCE 1-2

Black-on-Red Ware

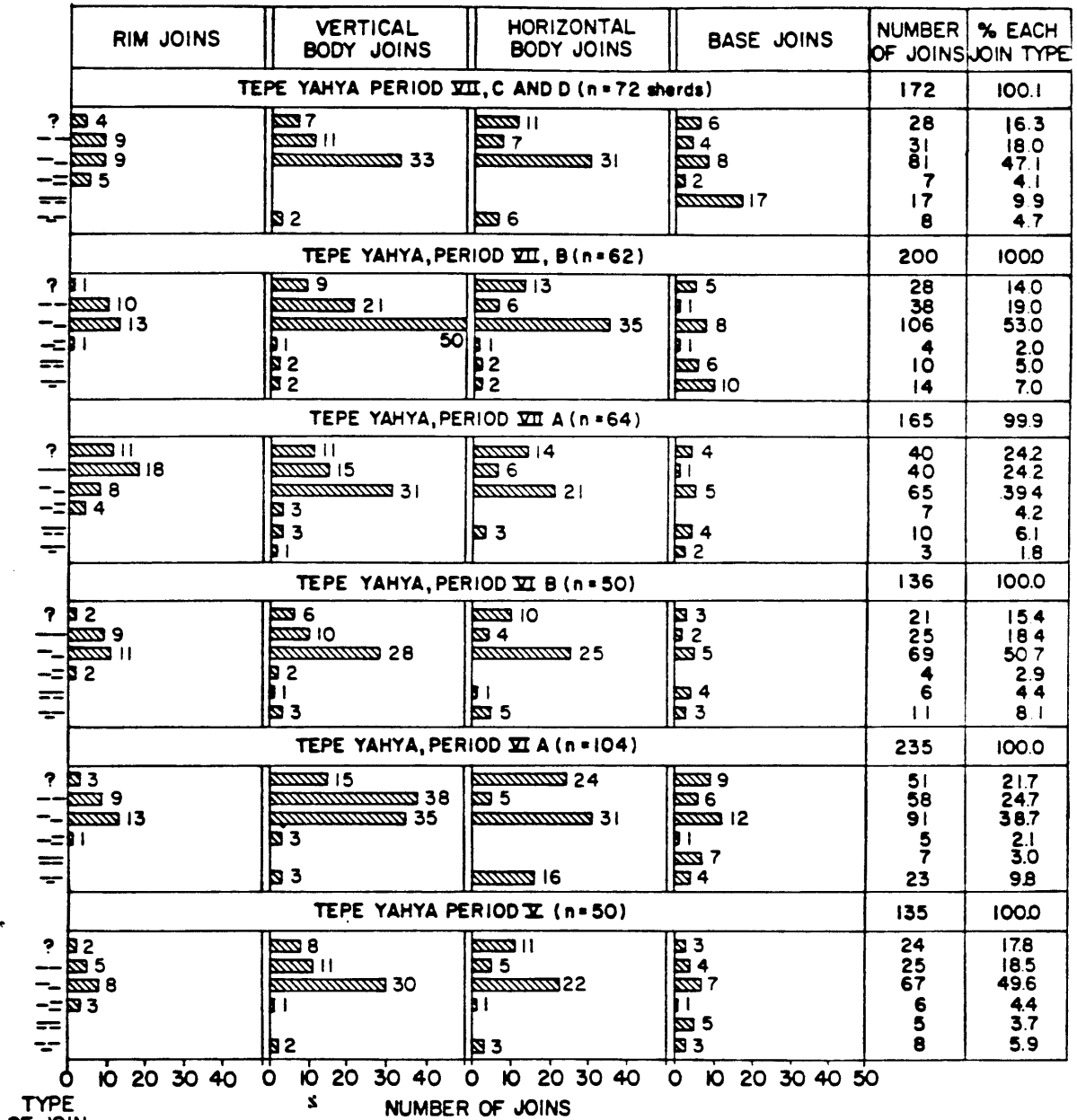


Figure 24. Type and Frequency of Joins in Coarse Ware from Tepe Yahya, Periods VII-V.

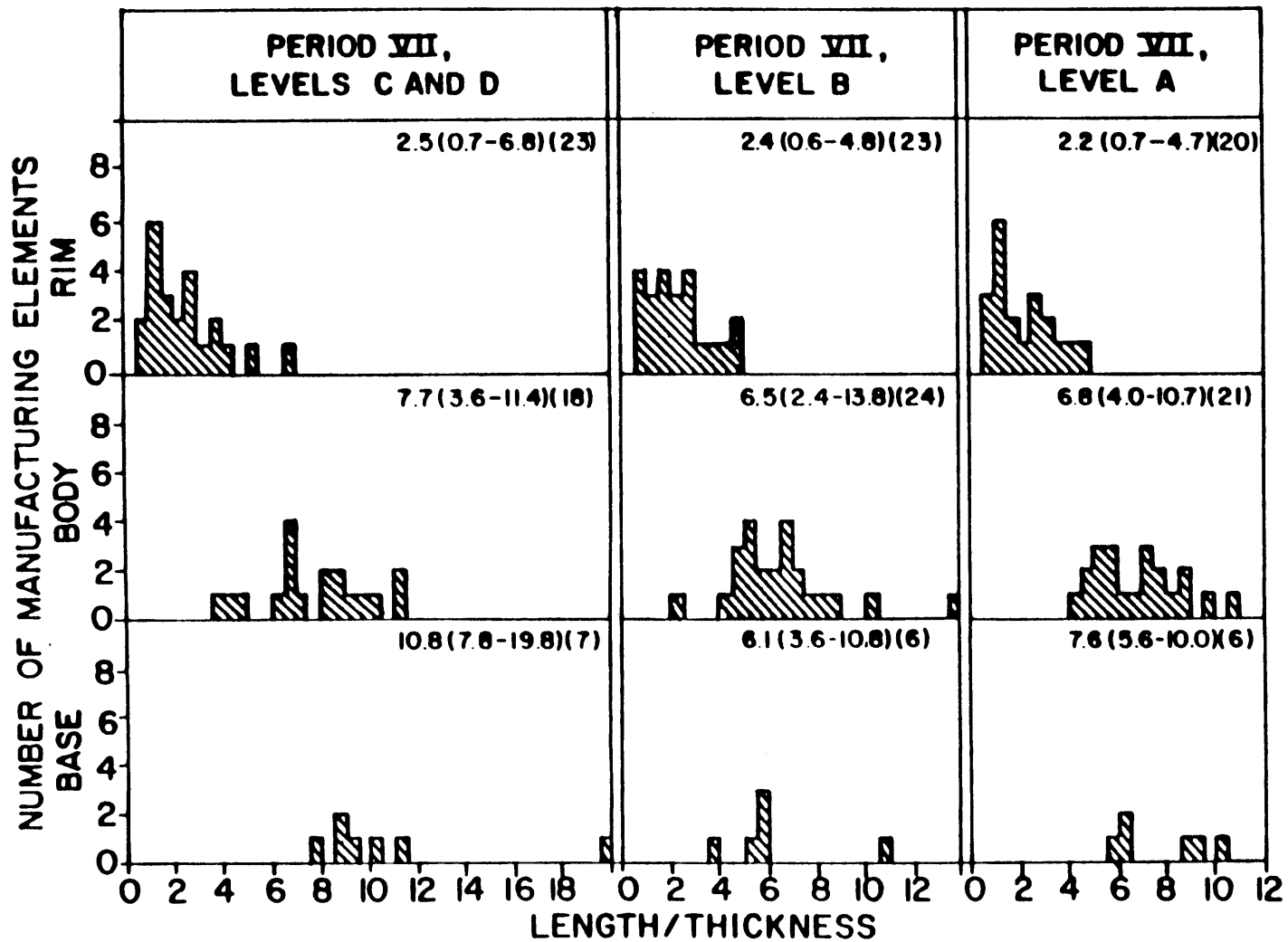


FIGURE 25. Relative Size of Manufacturing Elements from Early Period Coarsewares at Tepe Yahya, Reported as Mean, Range of Values and Number of Manufacturing Elements Measured.

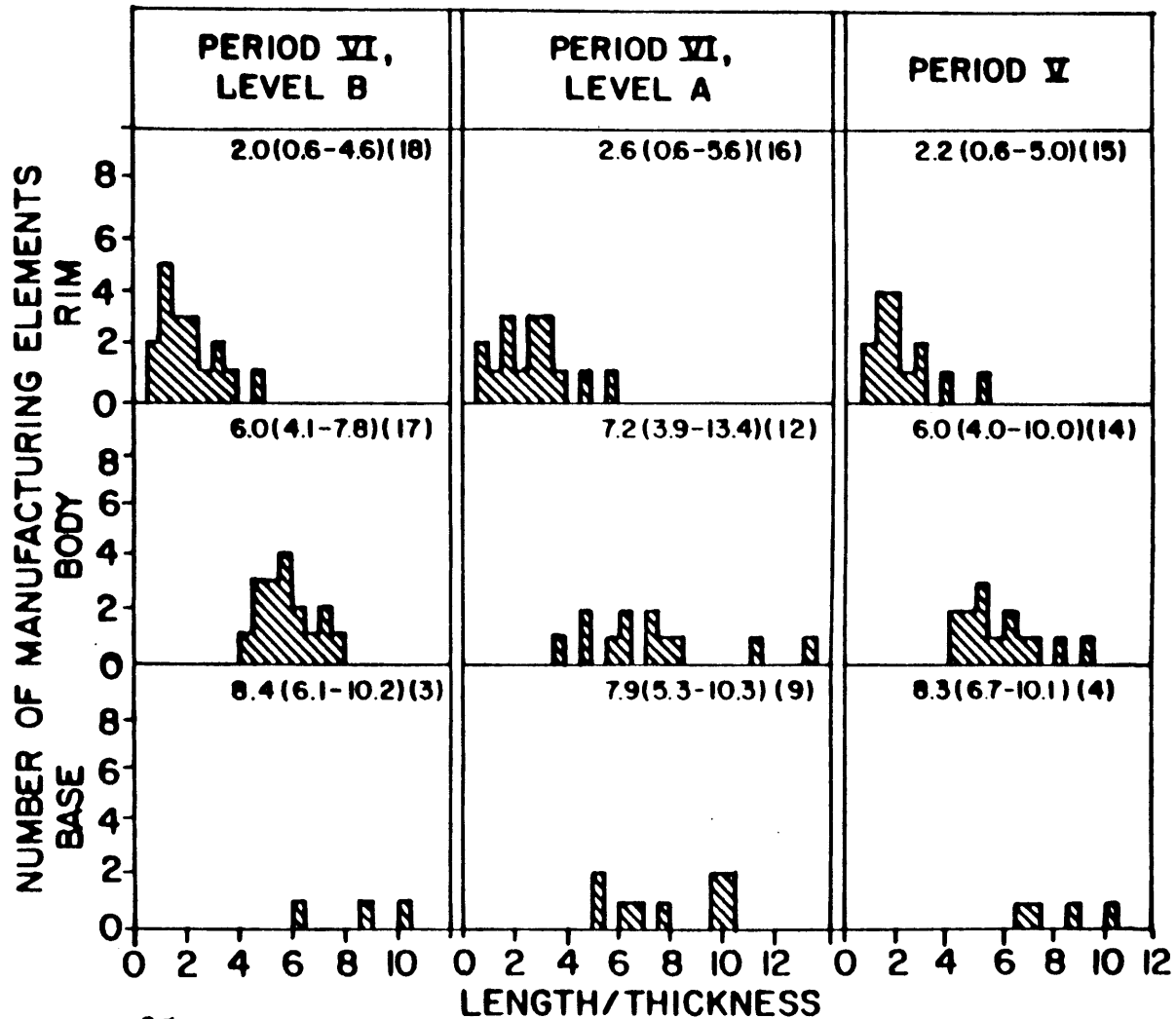


FIGURE 25. Relative Size of Manufacturing Elements from Early Period Coarsewares from Tepe Yahya, Continued.



Figure 26. Type and Frequency of Joins in Fine Wares from Tepe Yahya, Periods VII-V.

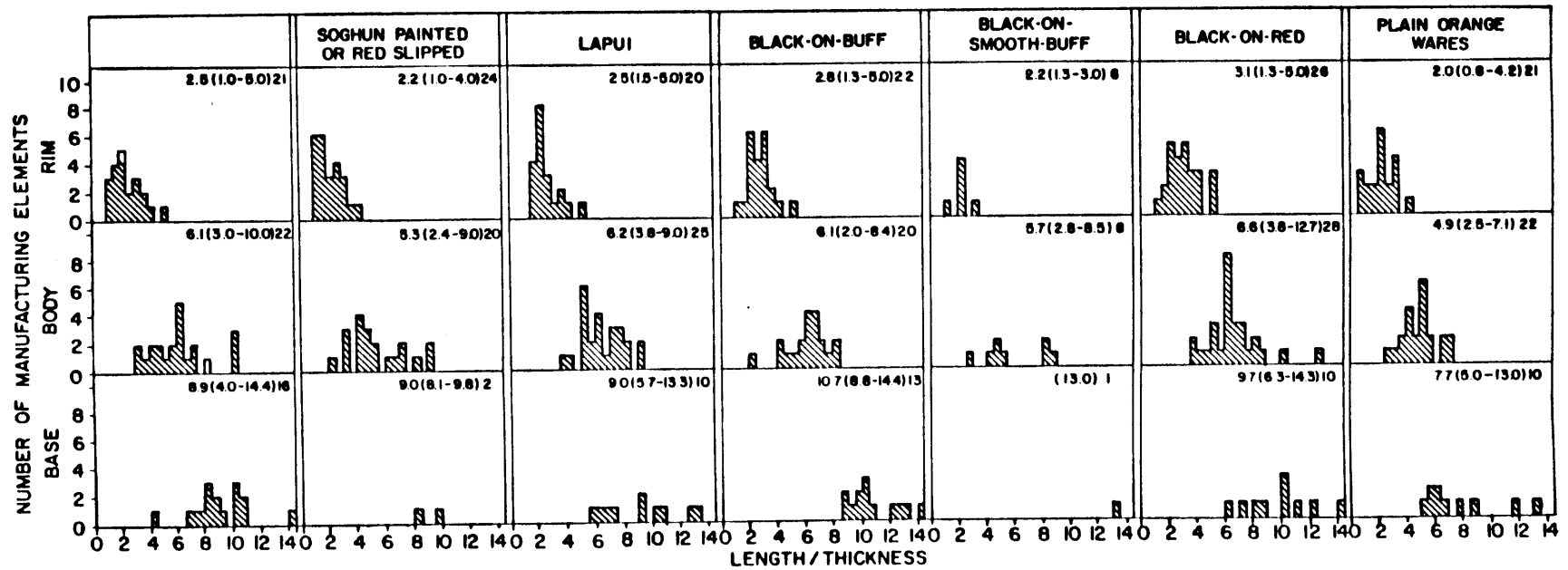


Figure 27. Relative Size of Manufacturing Elements from Tepe Yahya Fine Wares, Periods VII-V.

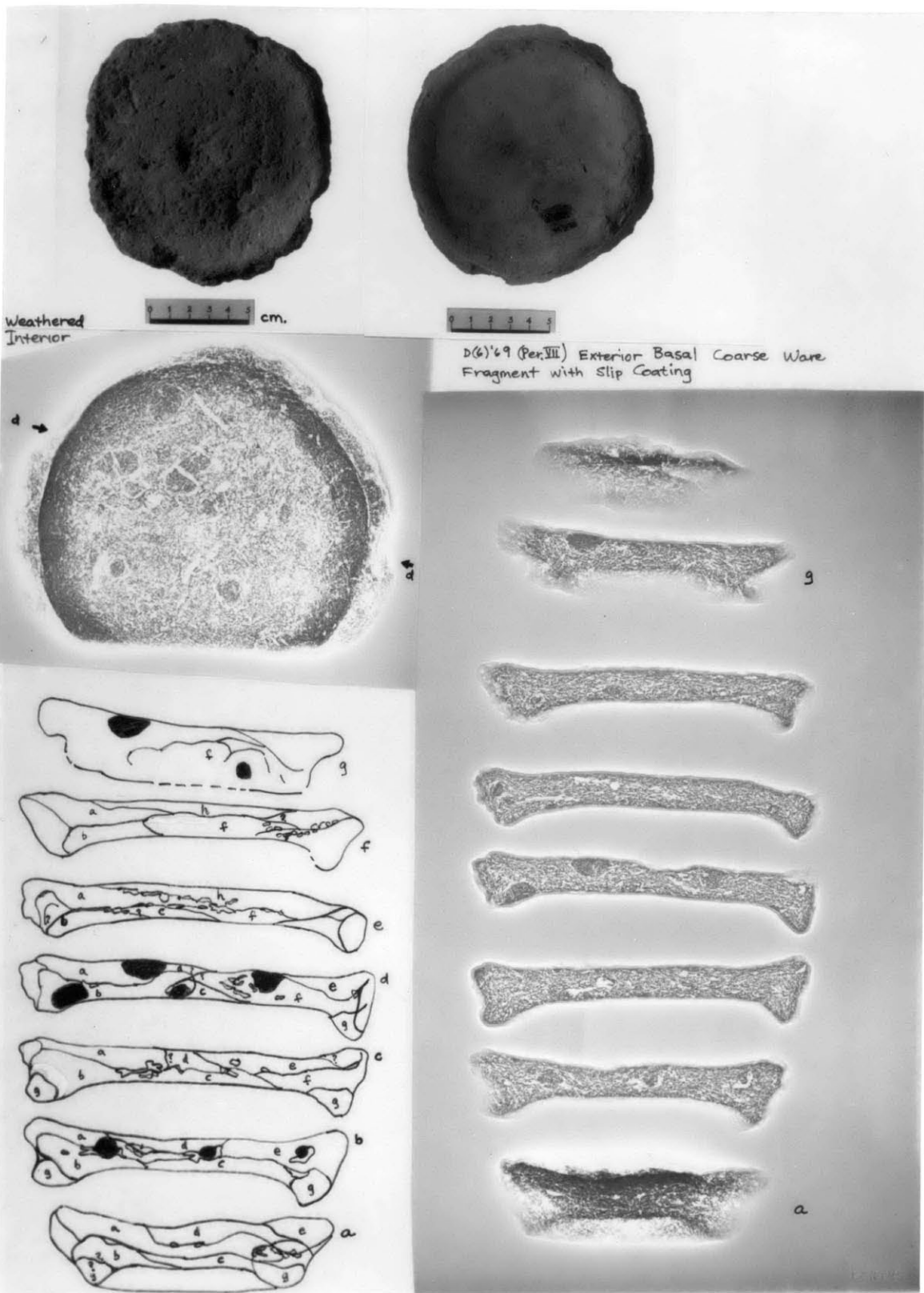


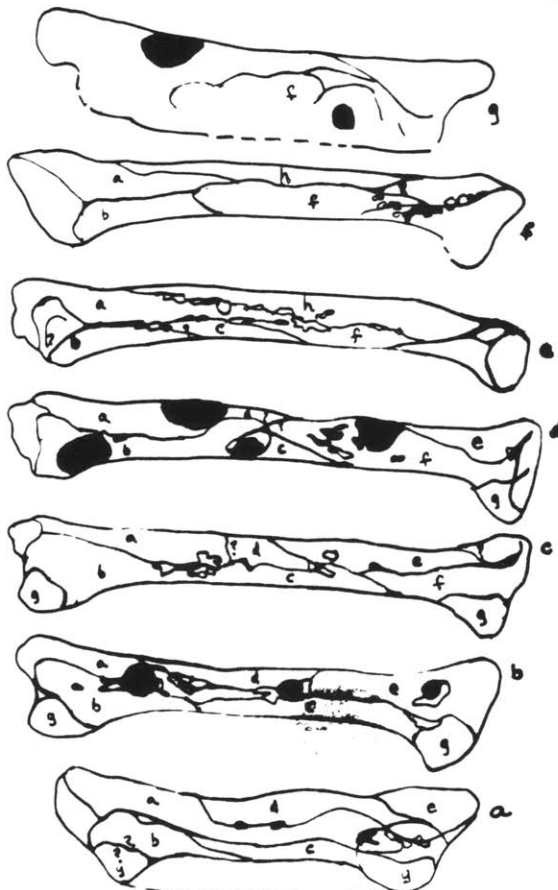
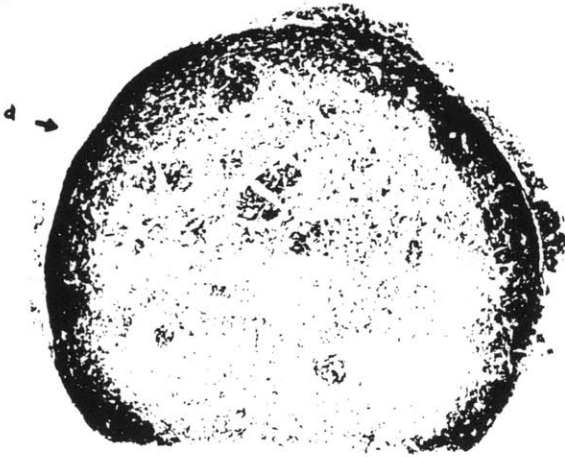
Fig. 28

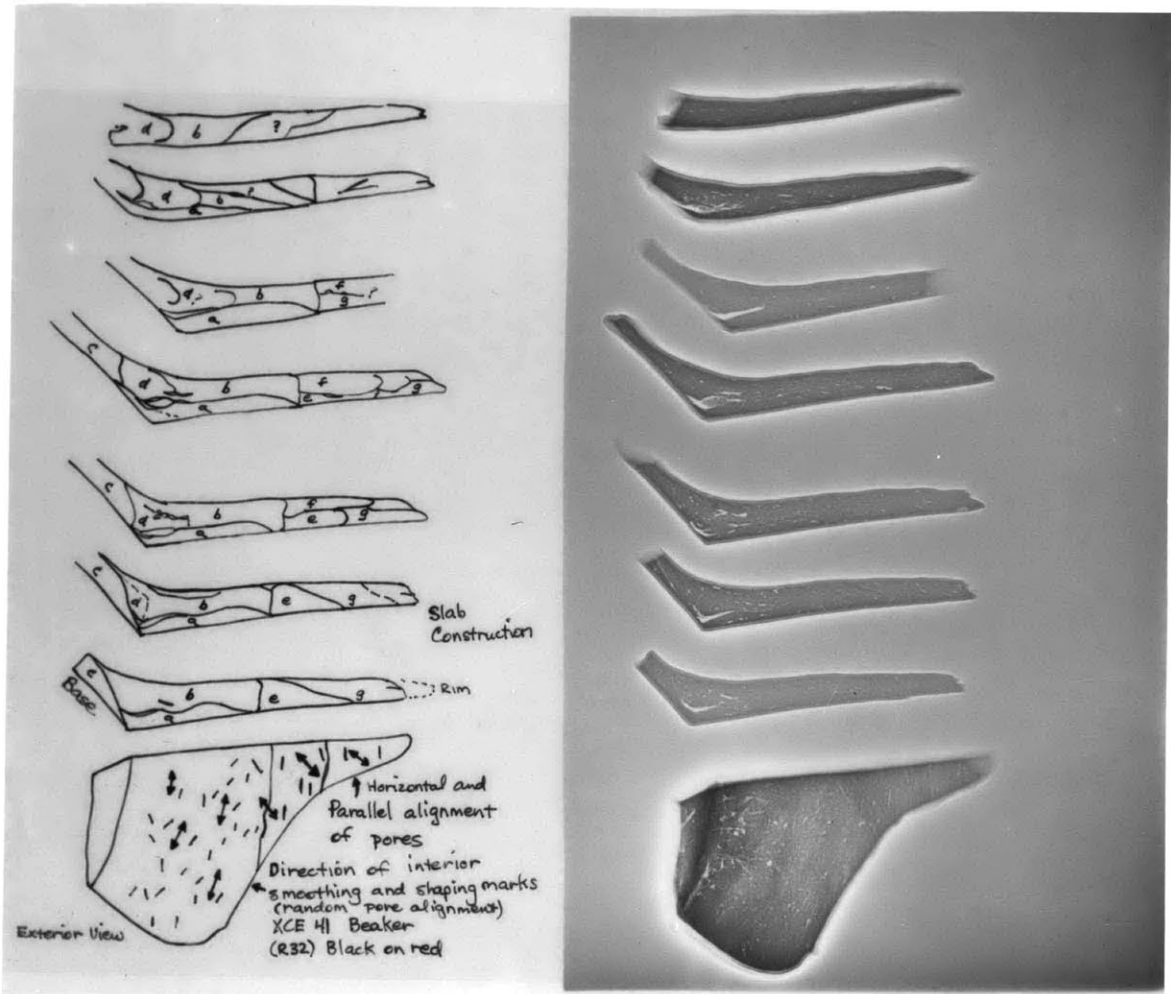


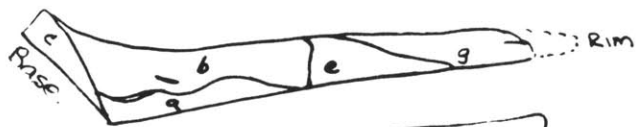
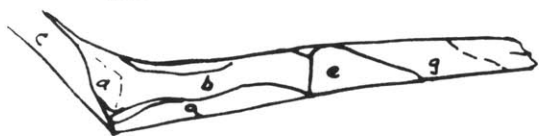
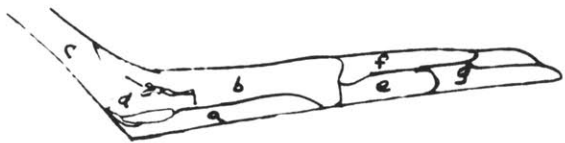
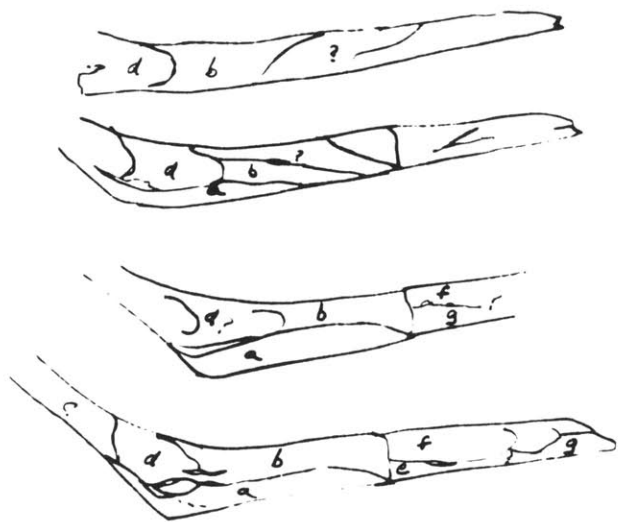
Weathered Interior



D(6)'69 (Per. VII) Exterior Basal Coarse Ware Fragment with Slip Coating







Slab
Construction



Exterior View

Horizontal and
Parallel alignment
of pores

Direction of interior
smelting and shaping marks
(random pore alignment)
XCE 41 Beaker
(R32) Black on red

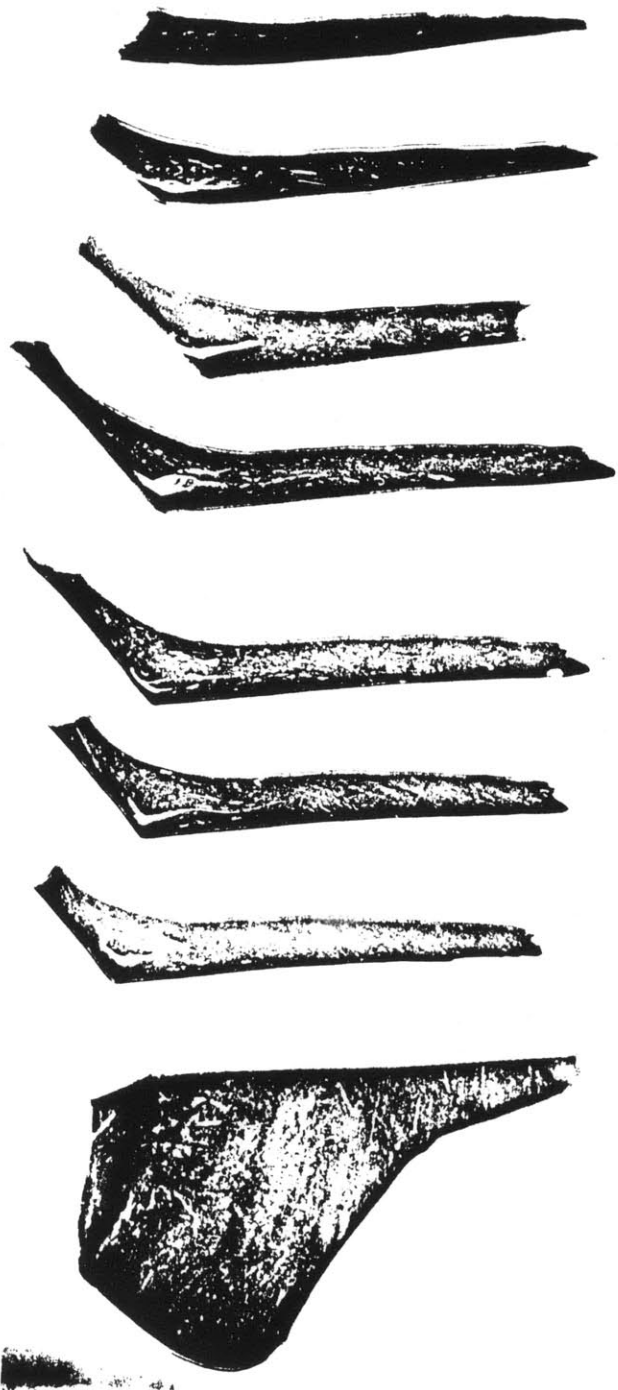


Fig. 28, cont.

The quite simple observation that sequential slab construction was used as a production method has not been made heretofore probably because of the way archaeologists conceive of pottery in terms of average profile shapes and superimposed decoration. This conception loses sight of the texture of the surface or of the fractured edge which reveal how a pot was constructed. When the pot is low fired and not much glass has formed to sinter the clay particles together, this edge fracture follows joints where bits of clay have been added to one another. In the archaeological literature, drawings of stone tools, in contrast with illustrations of pottery, emphasize techniques of manufacture because of the way in which each surface contour and texture is represented. Recently there has been an attempt to correct this problem, especially in the work of H. T. Wright (1981:28,96-97,100-101) and J. Bourriau (1981).

In Figure 24 and Table 11 are shown the frequency and type of joints in the chaff tempered coarse wares for each of the periods of its manufacture. The type of joint was determined by microscopically examining an edge fracture and applying the criteria given in Chapter V, Section A. In order to compare the construction of pottery in different form classes, that is large and small pots in particular, the ratio of the length to thickness of the manufacturing elements was plotted in Figure 25. This figure shows the relative sizes of manufacturing elements for coarse wares in the rim, body and base. In Figures 26 and 27 are shown the types of joints, the relative numbers of joints, and the relative sizes of manufacturing elements in the rim, body and bases of the different so-called fine wares (the Sogun plain and painted wares and the Lapui wares contain vegetal temper, the black-on-red and black-on-buff are grit tempered). The relative sizes of manufacturing elements are reported as mean of the length to thickness

ratios, range of values and number of manufacturing elements. The general picture of the construction of pottery is found in which the rims are smaller than the bodies than the bases regardless of ware type or form class, but the type and number of different types of joins is variable. As shown in Table 11, the rims tend to have more butt joins because the rim lumps and coils are added to smooth, even and reinforce the lip, and they tend to not be worked into the body a great deal, the bases tend to have more complex joins because they are built up of several layers, the horizontal body joins are mostly bevel joins where overlapped clay is well worked together, and the number of undecipherable joins is higher in the horizontal body because the clay is worked at the same wetness. The vertical body joins are quite variable, from about 0.3 to 1.0. In general there are more bevel joins. It is remarkable that this same general picture holds both for large and small pottery. It is significant that this same overall picture holds for coarse and fine wares and also that this picture continues from 5600 to about 3000 B.C.

Table 11. Ratios of Join Types at Tepe Yahya

	Simple or Butt and Bevel	Ratio Butt/ Bevel	No. of Complex Joins	Ratio of Complex/ Simple	No. of Undeci- pherable	Ratio of Un- decip- herable/Other
Chaff Tempered Coarse Wares						
Period VII, C and D						
Rim	18	1.00	5	0.28	4	0.17
Vertical Body	45	0.33	2	0.04	7	0.15
Horizontal B	38	0.23	6	0.16	11	0.25
Base	12	0.50	19	1.58	6	0.19
Period VII, B						
Rim	23	0.77	1	0.04	1	0.04
Vertical Body	71	0.42	5	0.07	9	0.12
Horizontal B	41	0.17	5	0.12	13	0.28
Base	9	0.13	17	1.89	5	0.19
Period VII, A						
Rim	26	2.25	4	0.15	11	0.37
Vertical Body	46	0.48	7	0.15	11	0.21
Horizontal B	27	0.29	3	0.11	14	0.47
Base	6	0.20	6	1.00	4	0.33
Period VI, B						
Rim	20	0.82	2	0.10	2	0.09
Vertical Body	38	0.36	6	0.16	6	0.14
Horizontal B	29	0.14	6	0.21	10	0.29
Base	7	0.40	7	1.00	3	0.21
Period VI, A						
Rim	22	0.69	1	0.05	3	0.13
Vertical Body	73	1.09	6	0.08	15	0.19
Horizontal B	36	0.16	16	0.44	24	0.46
Base	18	0.50	12	0.67	9	0.30
Period V						
Rim	13	0.63	3	0.23	2	0.13
Vertical Body	41	0.37	3	0.07	8	0.18
Horizontal B	27	0.23	4	0.15	11	0.35
Base	11	0.57	9	0.82	3	0.15
Fine Wares						
Soghun Plain Ware						
Rim	20	0.54	1	0.05	8	0.38
Vertical Body	41	0.64	14	0.34	15	0.27
Horizontal B	21	0.05	8	0.38	21	0.72
Base	7	0.40	15	2.14	4	0.18
Soghun Painted and Slipped						
Rim	23	1.56	3	0.13	5	0.19
Vertical Body	27	0.59	5	0.19	13	0.41
Horizontal B	11	0.00	2	0.18	8	0.62
Base	4	0.33	0	0.00	1	0.25
Lapui						
Rim	16	0.33	5	0.31	7	0.33
Vertical Body	41	0.37	12	0.29	3	0.06
Horizontal B	30	0.07	10	0.33	15	0.38
Base	7	0.40	14	2.00	5	0.24

Black-on-Buff						
Rim	30	0.25	1	0.03	15	0.48
Vertical Body	59	0.44	4	0.07	14	0.22
Horizontal B	29	0.07	2	0.07	15	0.48
Base	13	0.44	23	0.57	4	0.11
Black-on-Smooth-Buff						
Rim	6	0.50	0		4	0.67
Vertical Body	13	0.30	0		5	0.38
Horizontal B	3	0.00	0		8	2.67
Base	3	0.50	0		1	0.33
Black-on-Red						
Rim	43	0.39	4	0.09	15	0.32
Vertical Body	53	0.77	4	0.08	18	0.32
Horizontal B	28	0.08	3	0.11	27	0.87
Base	12	0.50	9	0.75	6	0.29
Plain Orange Wares						
Rim	29	0.71	2	0.07	7	0.23
Vertical Body	52	0.44	2	0.04	18	0.33
Horizontal B	36	0.03	8	0.22	17	0.39
Base	8		8	1.0	2	0.13

The development of decorative paints and slips can be seen by microscopic observation beginning in the earliest wares. The earliest chaff tempered coarse wares display a preoccupation with surface finish. Thick layers of slip were applied as facing coats to conceal joints and smooth surfaces. Many of these slip coatings also contained organic temper which remains as an indentation on the surface. It is likely that no particular preparation of the slip was involved, and that the fine clay body which accumulates in a wet depression in the prepared clay body source was used as a coating. That early attempts at colored decoration of the surface consisted of the application of a red iron oxide wash over the surface of the slip have been confirmed using S.E.M. and E.D.S. analysis. Plain Fe₂O₃ will not fuse and adhere to the pottery surface and forms a so-called fugitive paint. Later the entire thickness of the slip was colored red with iron oxide, either intentionally by mixing in the raw material hematite or by selecting ochrous earths. This practice of making a slip composition separate from the clay body composition led to elaboration of the practice of separate preparation of clays and colored earths for slips and paints, to

experimentation as shown by the diversity of early decoration on the Soghun wares (Soghun red-painted, mottled purple, bichrome and a variety of different slips) and to the widespread use of durable, uniform, technically successful and aesthetically pleasing iron-clay based paints on the Soghun ware and early black-on-buff ware, and to a limited extent on a minor number of the chaff tempered pots. However, the results are not uniform on the Soghun ware, which is an indication of a lack of control. The slips on Soghun and chaff tempered coarse ware frequently crack and peel, (Figure 5a, number 1) and the paints frequently are not very durable, indicating poor control of composition and/or application and/or firing. In addition the color is quite variable. Some Soghun wares are decorated with a selected or prepared whitish colored, fine clay slip about a millimeter in thickness, which often peels or breaks away from the body. This slip contains a higher calcium content than the body or other reddish colored slips and is evidence of experimentation. Further modification and the development of control of the slip coatings is found in the Lapui ware, a burnished ware. However, there is no apparent change in the body which can differentiate the Lapui from the Soghun wares. The Lapui wares and some of the Soghun creamy buff wares have a very fine slip coating which was chosen from a fine clay deposit or perhaps prepared by levigation. It is impossible for me to differentiate between natural and man-induced sedimentation. The color of the Lapui slips varies from red to white to a mixture of the two. The development of Lapui slips probably required a considerable amount of experimentation (at Yahya or elsewhere) to achieve the greater control. The luster is obtained by burnishing the surface which aligns the fine clay particles mechanically, thus increasing the total area of particle to particle contact and aiding in the sintering process. We

have not investigated the nature of the chemical variability in the Lapui ware. The black-on-red ware displays a fully developed ceramic paint technology in which the black is composed of manganese and iron and to which potassium, probably as plant ash, has been added as a flux that is as a chemical aid in the sintering of the black paint. No burnishing of the black-on-red ware has been carried out as the luster and durability are controlled chemically with the addition of potassia, and there is no need for burnishing. This investigation shows that the chemical technology develops differently from the forming technology.

The early coarse chaff tempered wares of Period VII and VI are made from preformed elements, slabs and occasionally coils, which are added to one another usually in overlapping or beveled joins. The limits of the working properties of the heavily chaff or vegetal tempered clay are reiterated here because they must be understood to interpret the results. The chaff acts to stiffen the clay, and in extending a lump of clay the chaff aligns with the direction of elongation parallel to the surfaces. Although F. Matson (in Caldwell 1967:150) in the Tal-i-Iblis coarse ware found poor alignment of the organic burnout, and thus found "...the clay was not further worked or wedged to any great extent, nor were the vessel walls patted and shaped and scraped much...", the Tepe Yahya software has well-aligned organic burnout consisting either of pores in the shape of the organic material or residual siliceous ash. If the slabs or coils are not well joined or if the drying of preformed elements begins before joining, then they shrink apart from one another and a broken cross section reveals the airspace at the joins, or the fracture may have changed direction along a join which would offer a path requiring less energy during breakage. These joins combined with the directional alignment of chaff allow visual

and microscopic examination to reveal manufacturing methods.

Some examples which show that chaff tempered ware is formed by sequential slab construction are given below. The large amount of chaff in the body (about 15-20 vol%) limits the plasticity of the clay, while providing stiffness during the construction of the vessel as well as a lowered shrinkage during drying. Preformed slabs are worked together in bevel and butt joints, often with more than one layer near the base and lower wall of the vessel, and larger vessels are made in parts or sections which are then joined with reinforced butt joints. There is a wide variation in the sequence and number of slabs joined to form a vessel, for instance in the join between the base and wall, shown in Figure 23.

An oval tray (D (8)'69) about 15 inches in length was built with three overlying slabs in the base, joined to a wall made of coils to which was added a coil as a handle, as shown in Figure 23. A jar (C-7(9)(10)), measuring about 2 feet in height, was made of two preformed sections which were joined together. A flaring bowl for the base, a cylinder for the top and fragments revealing joins are drawn in Figure 23. The base was formed of slabs added sequentially one for the base, one for the wall and another on the interior. The upper part of the bowl is formed in three slab layers one added inside and the other added outside the first (Figure 5a, no. f). The lower wall of the cylinder is made of a double thickness of slabs. The upper wall is thinner and formed by overlapping one slab over the other in a beveled joint (Figure 5a, no. g). The lip has been smoothed in short strokes, thus offering no evidence for the use of a tournette. A facing coat has been added to the interior and exterior surfaces of the pot, although it is much thicker on the interior surface. There are indentations about 3 cm. across above the join between the cylinder and bowl, which might

have aided in handling the pot, but which were probably made during the lifting of the cylinder to facilitate joining of the two sections. The two sections were joined without scoring in a butt join which has since broken through in some of the sherds (Figure 5a, nos. c and d). A possible reason for this quite difficult to form shape is that the lower bowl shape may have been set in the ground to promote stability and avoid being tipped over. The surface has been partially burnished in a multi-directional, so-called pattern burnish. Open vessels, an example of which is shown in Figure 23 (E TT3 '69), are made in a similar way except that the pot was turned over and a coil added to the base as a ring. A very small bowl (C TT5 (7)), measuring only 2 1/2 inches high, was constructed of 2 layers of slabs with a coil added to form a ring base. Thus the small vessels are constructed in the same way as the large vessels. Examples of cross sections from other ware types are illustrated in Figure 23.

The remarkable feature of the early Yahya pottery from Periods VII to IV is the continuity of mental set and structural sequence required to produce ware made by sequential slab construction while evolving to more sophisticated use of the tournette. Essentially, a conservative technology having many similarities to wet mud brick, or chineh, construction provides a basis of forming pottery which survives through more than 2500 years with only gradual evolution of slow turning and trimming technologies. The slip and paint technology once established in VB are maintained as a tradition of some 1000 years prior to the development of the fast wheel or throwing. An attempt to describe the development of ceramic technology from these observations is shown below in Table 12.

Table 12. Sequence of Conjectured Developments in Pottery Technology at Tepe Yahya

Period VII. Sequential slab construction of chaff tempered coarse ware.

Period VI-VC. Development of late Soghun and black-on-buff fine ware without chaff temper; use of same s.s.c. method to form a more plastic, grit tempered clay into thinner walls and still avoid cracking from drying shrinkage.

Experimentation with nondurable red iron-containing paints, and later the development of red and white durable clay-based slips in the Soghun and Lapui wares. Possible levigation or selection of calcareous clays for use first as slips and later as a clay body.

Period VB. Continuation of s.s.c. to build walls. Development of stable black paint-clay mixtures for decoration. The pigment consisted of an iron-manganese mixture which was fluxed with a potassium-containing ash.

Use of tournette to form and wipe lip rims.

Use of hand-held ribs to form bases and walls. No finger impressions and the walls are more regular, that is form arcs of circles of varying radius when viewed in cross section. The rib also may have been used as a trimming tool.

Trimming of bases and lower walls of bowls and beakers to achieve geometric profile and wall thickness as thin as 1.5 mm.

Probable development of craft specialists, in other words, from the skill required to manufacture the thin-walled fine wares, from the complexity of the manufacturing process, from the limited variability in numbers of shapes and sizes within a shape type, and from the uniformity of reasonable high temperature firing and atmosphere, it seems reasonable to suggest that the black-on-buff wares were made by only a limited group of experts, whom we may call potters, although pottery was most likely not their only responsibility.

Period VA. Continuation of s.s.c. method.

Increase in kiln temperature and change to a more oxidizing firing, as the pottery is less porous and rings more when struck. The black-on-buff and black-on-red are probably the same ware but fired in different atmospheres, reducing and oxidizing, respectively, which are possible in the same kiln.

In looking at the beakers and following the hands of the potter through the sequence of manufacture, there is almost no describable variation. For instance, the bases are ribbed on the inside with 5-8 draws of the tool all set at about the same angle. Only the tournette was rotated beneath the rib. The walls were built by s.s.c. and then extended with diagonal strokes on a tournette moving quite rapidly. The exteriors were trimmed first by vertical scrapings, the facets of which are often visible at the base, then the beakers were scraped at a near horizontal. The surface was then wiped with a fine slip. We hypothesize the development of a pottery workshop or work group with the aim of producing more cups, beaker and bowls than was sufficient for their own needs and with the aim of producing efficiently quite a large quantity by uniform methods, although we do not envision full time specialization as a necessary requirement for the rapid production of large quantities of beakers and bowls of various sizes.

Other supportive evidence comes from the use of painted potter's marks on some of the beakers (Potts 1981:107f).

First probable kiln found with underfired and overfired examples of pottery and nearby unfired and perhaps levigated clay; both black-on-red and chaff tempered coarse wares were found, indicating possibly a communal kiln which fired various types of ware.

2. Hajji Firuz, Dalma, Pisdeli: Quantification of Results

The pottery from Hajji Firuz in storage at the University Museum, University of Pennsylvania, consists of one whole restored storage vessel, several small whole pots and several boxes of sherds. The initial examination showed that the same sorts of surface textures and joins along the broken edges were present as found in the vegetal tempered coarsewares from Tepe Yahya. The size of many of the sherds from Hajji Firuz is larger than from Tepe Yahya. The edge fractures of 178 body and rim sherds from square G11, phase A, were cleaned with an ultrasonic cleaner except where there was fugitive red paint, examined with a 10x loupe and at about 40x, sketched and sorted into eight groups of different join types. Schematic drawings of each group are given to the left of Figure 29. The uppermost one has no joins present, another has joins the distinguishing features of which were undecipherable, a group with butt joins which are perpendicular to the walls, a group with bevel joins which are diagonal to the walls, a group which had an example of each type of join, signifying that a particular type of join was not a way to group pottery but variation within the manufacture of a single pot, and three more complex types of joins: one in which a single slab is joined to two slabs which form a wall of double thickness, a double thickness wall with a join in one of the layers, and a join which is reinforced on one side with an extra slab. This last type of reinforced join frequently occurs at carinations. Each sherd was examined at the larger vertical and horizontal edge relative to the original pot shape.

The largest category (26%) had no vertical joins, and joins in horizontal edges were particularly difficult to find (92%). This was

expected because joins along horizontal sections are made with clay of similar wetness, whereas joins along a vertical section tend to be made with a wetter clay placed on top of clay which had begun to dry or been allowed to set up for a period of time. The predominant types of joins are butt and bevel joins, of about equal magnitude, with complex joins occurring infrequently. To counteract the problem of a large number of sherds with no joins, those sherds with one or more joins were reexamined and found to measure over 50 mm. Those with two joins measured over 100 mm. In order to establish the size of manufacturing elements, sherds with two joins and three manufacturing elements were required.

Figure 10 (about p. 95) shows the improved results of measuring sherds over 50 mm, from Operation V (1961), phases F2-L. The category of no joins and joins of undecipherable type have been merged. Butt and bevel joins are approximately equal in number in vertical cross sections of the lip and body. Bevel joins predominate in the horizontal section of the walls and in the base by a factor of about 2. Fifty millimeters was established as the minimum size necessary for measurement of manufacturing elements in both the body and base, with greater than 100 mm. preferred.

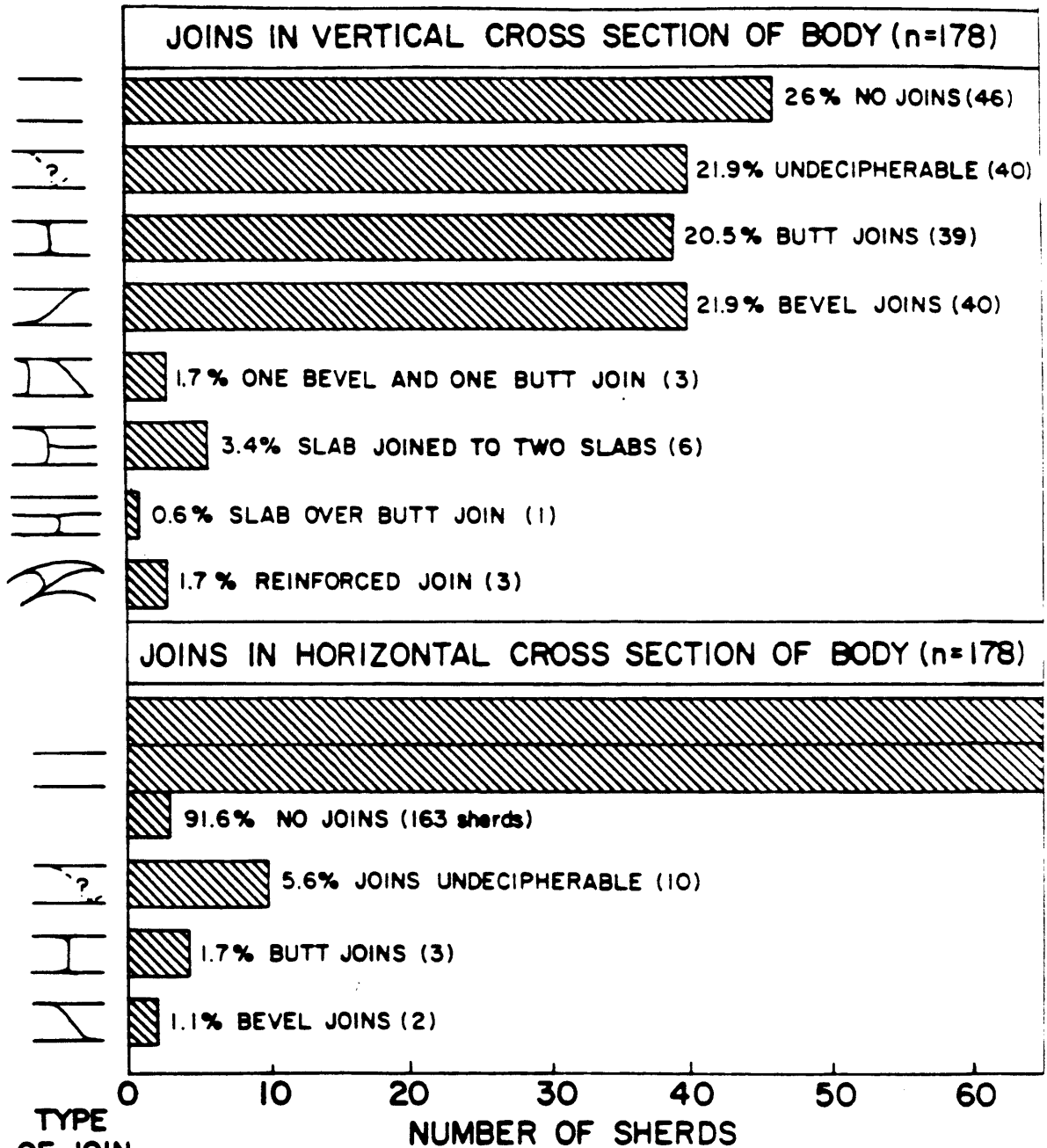


FIGURE 29. Frequency and Type of Join in 178 Hajji Firuz Body Sherds all under 50 mm. in length and from Operation V (1961), Phases P₂-L (Early Phases).

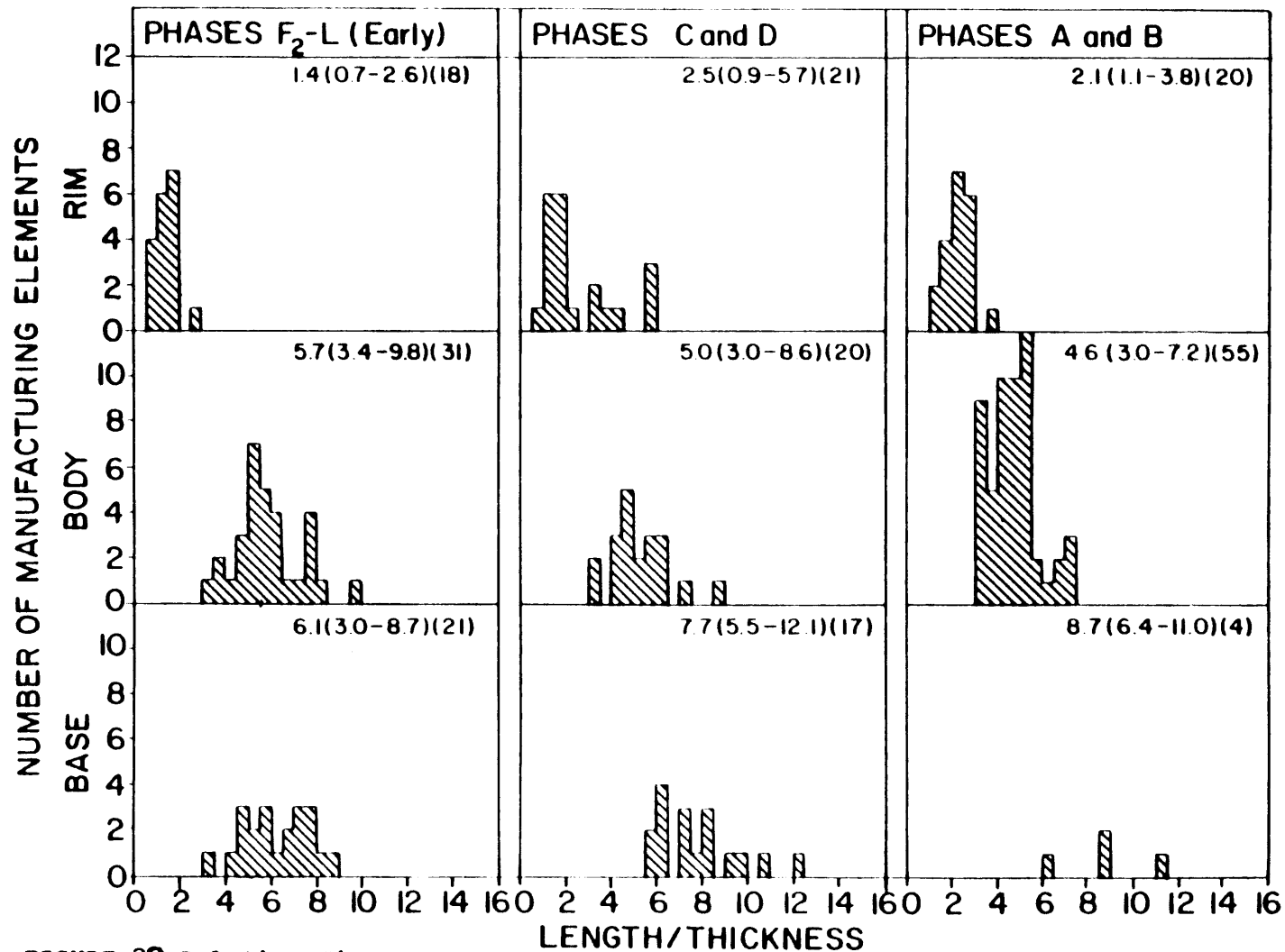


FIGURE 30. Relative Size of Manufacturing Elements Used in the Base, Body and Rim to Construct Hajji Piruz Pottery from Phases F-L, C and D, and A and B, Reported as the Mean, Range and Number of Elements. Plain Buff Coarseware Pottery with a Few Samples Having Fugitive Red Decoration.

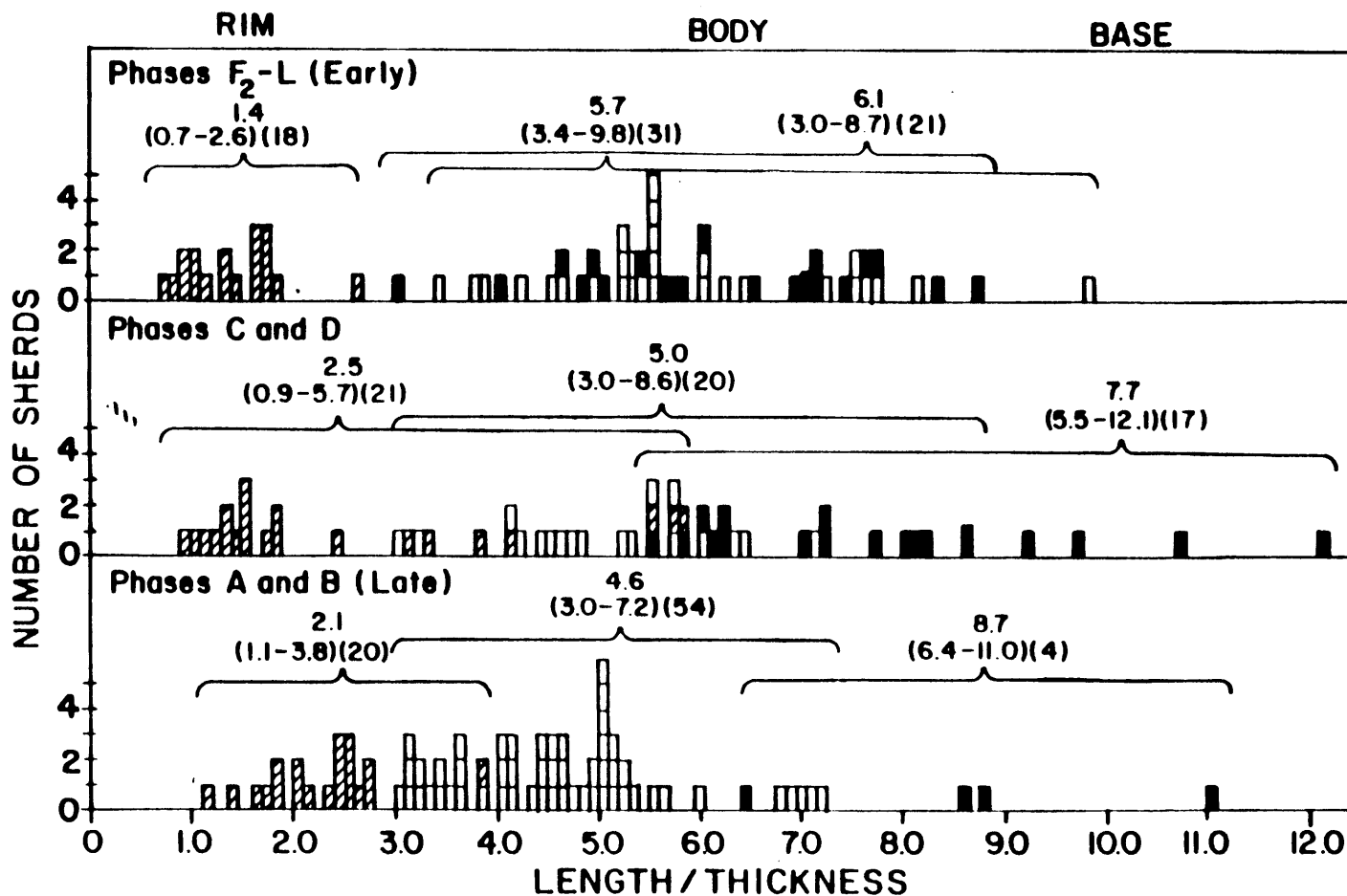


FIGURE 31. Comparison of the variation of relative sizes of manufacturing elements used in the rim, body and base construction of coarseware vessels from early, middle and late phases at Hajji Firuz. Values are reported as mean, range of values and number of manufacturing elements. In each case the length to width ratio of the rim is smaller than the body and than the base, correlating to a use of smaller elements at the rim, larger elements in the body and still larger ones in the base, with values of 1-3 at the rim, 4-6 in the body and 6-9 or more in the base.

Rim sherds of a lesser size could be used, because once measurements were made of the size of manufacturing elements at the lip they were found to approximate about 2 to 3 times the thickness of the wall, as shown in Figure 31. The elements used to form the walls were about 5 times the thickness and those of the base about 7 times their thickness, thus coiling could not have been used to manufacture the walls and bases of the Hajji Firuz pottery. Wherever a double layered wall occurred, the measurement of the manufacturing element thickness was made of only a single thickness. The ratio of element length to thickness was used in order to compare pottery of different sizes. There was no difference in the ratio for the elements used for small, medium and large pots. The size of the manufacturing elements seems to have scaled well in the size range of pottery represented at Hajji Firuz; there were no pots so large as to have been unliftable when full by one person.

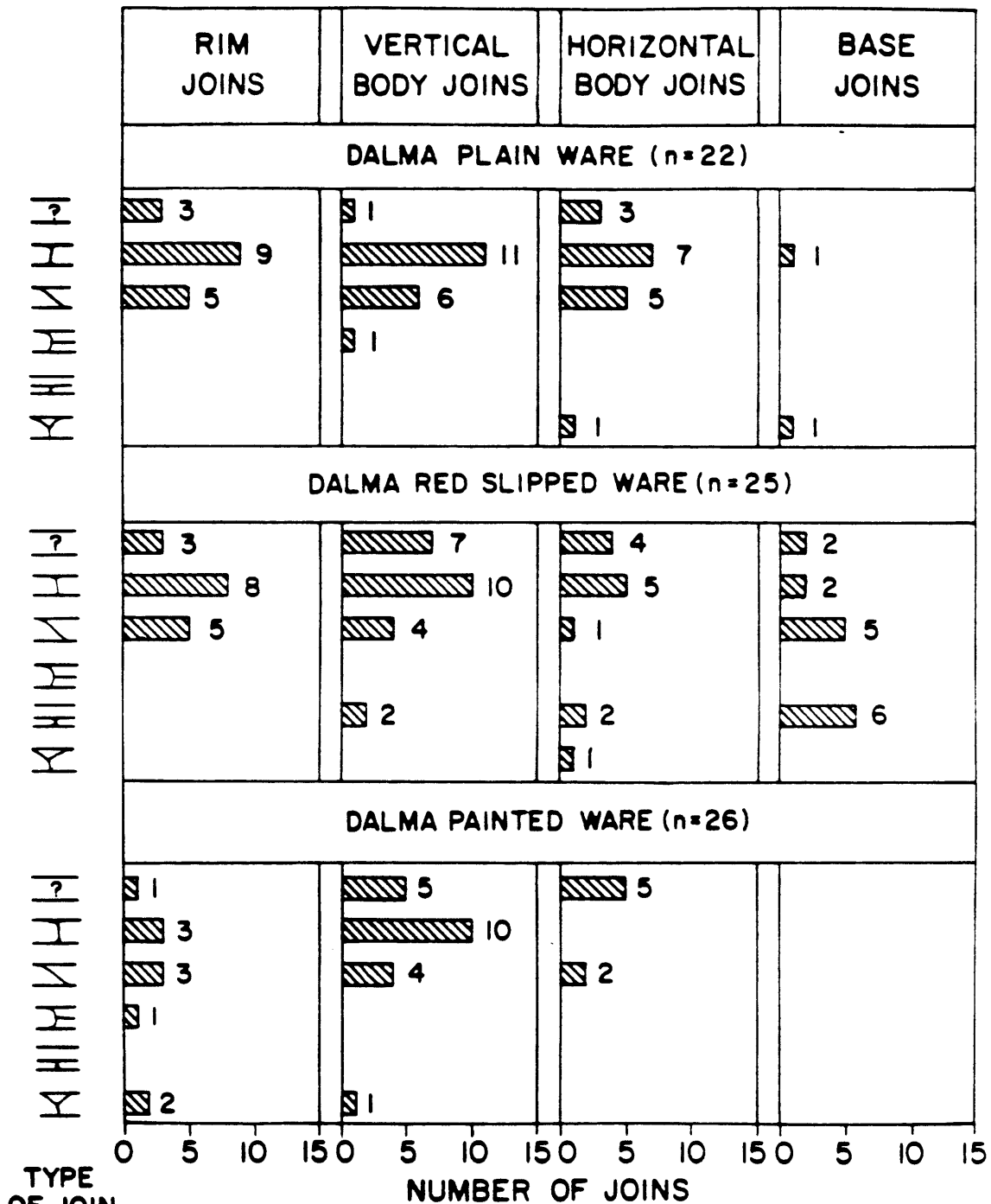
In Figures 30 and 31 are shown plots of the length to thickness ratio of manufacturing elements versus number of rim, body and basal sherds for the early, middle and late phases at Hajji Firuz. There is a considerable range of values for manufacturing elements as revealed in the edge fractures in the different parts of the pottery. This range was evaluated once the spatial distribution of the manufacturing elements parallel to the wall of the pottery was established using surface texture and xero-radiography. For instance the size of manufacturing elements in the edge fracture would be expected to vary more if the slabs approximated oval lumps than if they approximated strips, which they occasionally do. From Figures 30 and 31 we conclude that there is no change in the way pottery is manufactured during the Hajji Firuz period using the size of elements as revealed at edge fractures as an indicator.

From this examination, we conclude that a limited number of join types are present, that simple joins occur in about the same frequency and are much more numerous than complex joins, that a sherd over 50 mm. is required for base and wall measurements, although a smaller sherd may be used for the lip. We can also conclude that the pottery throughout the Hajji Firuz period (sixth millennium) was constructed with a definite plan or mental set in mind, having larger elements joined for the base of a pot, elements which resemble strips or slabs or lumps for the walls and elements which resemble coils or small lumps at the lip. Furthermore, this pattern of pottery construction is maintained for small, medium and large pottery vessels.

In addition, the fugitive red paint on the large carinated jar in M. Voigt's Plate 96c (1983:152) was identified as quite pure hematite, Fe_2O_3 . There was no difference in the clay and slip composition of this pot. No slip or paint samples of the other later wares were studied.

In the Dalma period (fourth millennium), the types of ware are more diversified, including variations in decoration and firing: Dalma plain, Dalma painted, Dalma red slipped, Dalma impressed, which are probably variants on the same ware, and a small fraction of brown or black painted on buff or white slip, referred to here as black-on-buff ware, which looks very different from the others. These sherds were excavated by T. Cuyler Young, Jr., in 1961 during Operations III and IV (C. Hamlin (Kramer) 1975). The same types of joins are found in each of these wares as in the Hajji Firuz pottery. Figure 32 and Table 13 show the frequency of join type in the first three of these wares. More butt than bevel joins were found in the rims and bodies, and very few examples of complex joins were found. The sample of sherds over 50 mm. was 73 out of an estimated 550 sherds (C. Hamlin 1975:117). Basal sherds were few in number in this collection. In

Figure 33 the same distribution of sizes of construction elements can be seen in the Dalma Period as in the Hajji Firuz period. Separate categories are shown for the body joins which are horizontal versus those which are vertical. This data restates what was already shown by the frequency of join data; that is, joins along a horizontal section are less frequent than those in a vertical section, or to state it another way, that the size of elements in the horizontal is greater than in the vertical direction. From this we infer that manufacturing elements are considerably longer than they are high, thus the pottery was not formed by taking equiaxed lumps of clay and pressing them together but made primarily of strips.



TYPE OF JOIN
NUMBER OF JOINS

FIGURE 32. Frequency and Type of Joins in Wares from Dalma Tepe. All 73 sherds were over 50 mm. in length, and this size can be assumed for all succeeding wares unless otherwise specified. Of the joins, 41.7% were butt, 25.6% were bevel, 21.2% were undecipherable, and 11.5% were complex.

Table 13. Number of Joins and Percent of Each Join Type for Dalma and Pisdeli Wares

Dalma Wares

Type of Join	Plain		Red Slipped		Painted	
	No. of Joins	% Ea Type	No. of Joins	% Ea Type	No. of Joins	% Ea Type
?	7	13.0	16	23.9	11	29.7
Butt	28	51.9	25	37.3	13	35.1
Bevel	16	29.6	15	22.4	9	24.3
2 to 1	1	1.9	0	-	1	2.7
Double Wall	0	-	10	14.9	0	-
Reinforced	2	3.7	1	1.5	3	8.1
Total	54	100.1	67	100.0	37	99.9

Pisdeli Wares

Type of Join	Plain Coarse Ware		Impressed Coarse Ware		Red or Grey Slipped or Burnished	
	No. of Joins	% Ea Type	No. of Joins	% Ea Type	No. of Joins	% Ea Type
?	22	36.7	9	37.5	15	25.0
Butt	26	43.3	7	29.2	23	38.3
Bevel	11	18.3	3	12.5	16	26.7
2 to 1	1	1.7	0	-	2	3.3
Double Wall	0	-	4	16.7	4	6.7
Reinforced	0	-	1	4.2	0	-
Total	60	100.0	24	100.0	60	100.0

Type of Join	Brown on White Slip		Brown on Red or Buff	
	No. of Joins	% Ea Type	No. of Joins	% Ea Type
?	16	40.0	12	31.6
Butt	10	25.0	17	44.7
Bevel	12	30.0	9	23.7
2 to 1	0	-	0	-
Double Wall	2	5.0	0	-
Reinforced	0	-	0	-
Total	40	100.0	38	100.0

Table 14. Measurements of Manufacturing Elements
from Dalma Plain and Red Slipped Wares

Lip			Horizontal Body			Vertical Body			Base		
L	T	R	L	T	R	L	T	R	L	T	R
(where L = length, T = thickness, and R = ratio)											
23	9	2.56	55	9	6.11	40	10	4.0	65	7	9.29
9	6	1.5	38	4	9.5	35	7	5.0	75	10	7.5
16	4	4.0	60	7	8.6	50	7	7.14	68	8	8.5
13	4	3.25	50	6	8.33	45	7	6.14	55	7	7.86
20	10	2.0	100	16	6.25	38	7	5.4	70	8	8.75
17	10	1.7	60	10	6.0	38	5	7.6	64	10	6.4
10	5	2.0	55	7	7.86	36	5	7.2	55	8	6.88
11	8	1.38	70	7	10.0	45	12	3.75	45	5	9.0
6	6	1.0	60	7	8.75	20	6	3.33	57	6	9.5
8	4	2.0	40	7	10.0	47	7	6.71	70	6	11.67
14	4	3.5	65	7	9.3	50	6	8.33	55	15	3.67
20	15	1.5	55	11	5.5	47	11	4.3	60	15	4.0
25	15	1.67	55	7	7.86	40	6	6.67	85	10	8.5
17	10	1.7	37	6	6.2	20	6	3.33	55	10	5.5
30	10	3.0	45	8	5.6	32	5	6.4	50	4	12.5
15	7	2.14	55	12	4.6	33	4	8.25	Only 15		
7	8	0.9	55	10	5.5	25	5	5.0	examples		
16	8	2.0	60	8	7.5	37	10	3.7	found		
8	6	1.75	(43	3	14.3)	35	12	2.9			
20	8	2.5	(50	4	12.5)	40	15	2.67			

() = not plotted, but averaged. This is the only plot with such a discrepancy.

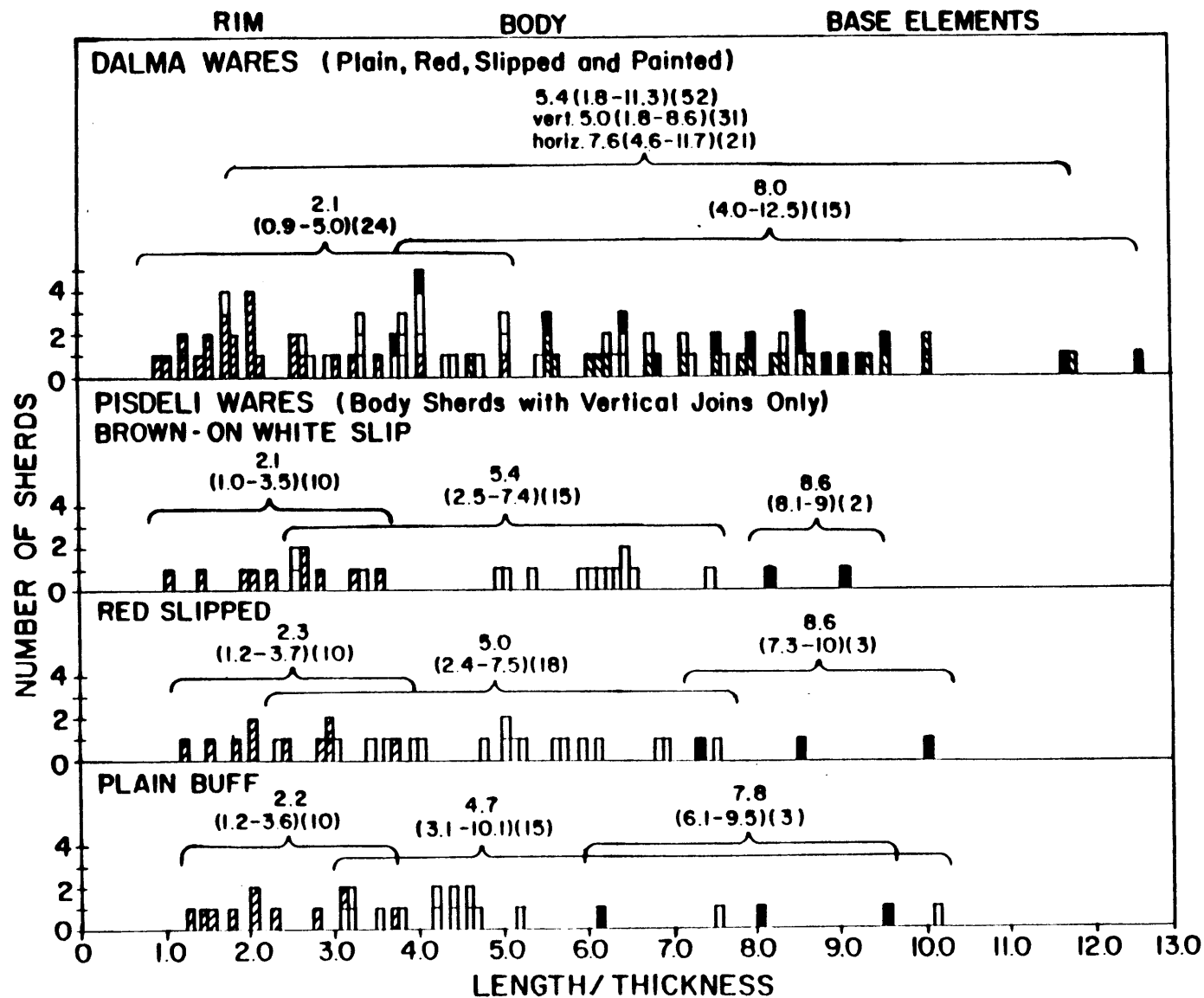


FIGURE 33. Relative Size of Manufacturing Elements Used to Construct Dalma and Pisdeli Tepe Wares, Reported as Mean, Range and Number of Manufacturing Elements. The same pattern found at Hajji Piruz is continued.

In the Pisdeli period (third millennium), the ware types are similar to the Dalma period with minor changes in the characteristics of the ware types, and a larger fraction of black-on-buff relative to the total assemblage. Another ware type is found in the black or brown painted red slipped pottery, referred to as black-on-red ware. The sherds were excavated by T. Cuyler Young, Jr., in 1961 in Operations II and III. The same types of joins are found in the Pisdeli ware as in the Hajji Firuz and Dalma wares, as shown in Figure 34, and a similar distribution of construction elements is compared with the Dalma ware in Figure 33. We have tried plotting such a distribution by ware type and cannot detect any change.

In examining the surface texture, shape and decoration of the Dalma and Pisdeli pottery, variations in the direction of wet smoothing, rim shape and presence of banded decoration suggest that a turntable or other slow rotating device was used in the forming and decorating, signaling a change occurred in the pottery technology. In Figure 35 are sketches of the rim forms, beginning with the three forms described for Hajji Firuz pottery by M. Voigt (1976:102-158): rounded, pointed and squared or flattened, and rare occurrences of flaired rims. This figure also shows the greater variation found in the rim forms of Dalma pottery and a decrease in Pisdeli pottery. There actually may have been more variation in the Pisdeli pottery which this small sample does not demonstrate. There are perhaps 12 to 16 rim forms in the Dalma pottery with one shape blending into the next. The forms to the left in the Dalma material are earlier, and those to the right are later. There is a greater variation of rim forms in the Dalma pottery, and many of the forms suggest the possibility that lids in ceramic or other material were placed on or tied to the rim. In addition, many of the rim

elaborations are faceted as one would expect from a form which has been rotated and shaped with finger tips. In a very few examples (2), one smoothed ridge parallel to the rim overlies the one next to it which suggests rotation. However, this occurrence is rare because most of the pottery has been wiped with slip and either wet smoothed or burnished. The Dalma and Pisdeli pottery has the same rim shape across the entire circumference of the sherd, while in the Hajji Firuz pottery the rim form often changes within a single sherd. If one counts the number of examples of the three different Hajji Firuz rim shapes, it is about one quarter greater than the total number of sherds. From this data, we infer that the Dalma pottery has more rim variation and elaboration than Hajji Firuz pottery and that the shape of the rim is a consciously designed part of the pot which is supposed to be and is symmetrical. There is reason to infer that a slow turning device such as a pot sherd or basket mold might have been rotated quite rapidly to form the rim. In addition, there is a considerable amount of experimentation with the shape of the rim. In the Pisdeli wares the rim elaboration is much less extensive, and the shapes and some of the surface textures suggest turning of the rim shape. A few consistent forms are made, mostly likely by turning on a slow wheel. Thus the amount of rim elaboration, the presence of turning marks on the rim and the symmetrical shape of the rim suggest turning was an object of experimentation during the Dalma period but firmly established during the Pisdeli period. Other criteria reinforce this view.

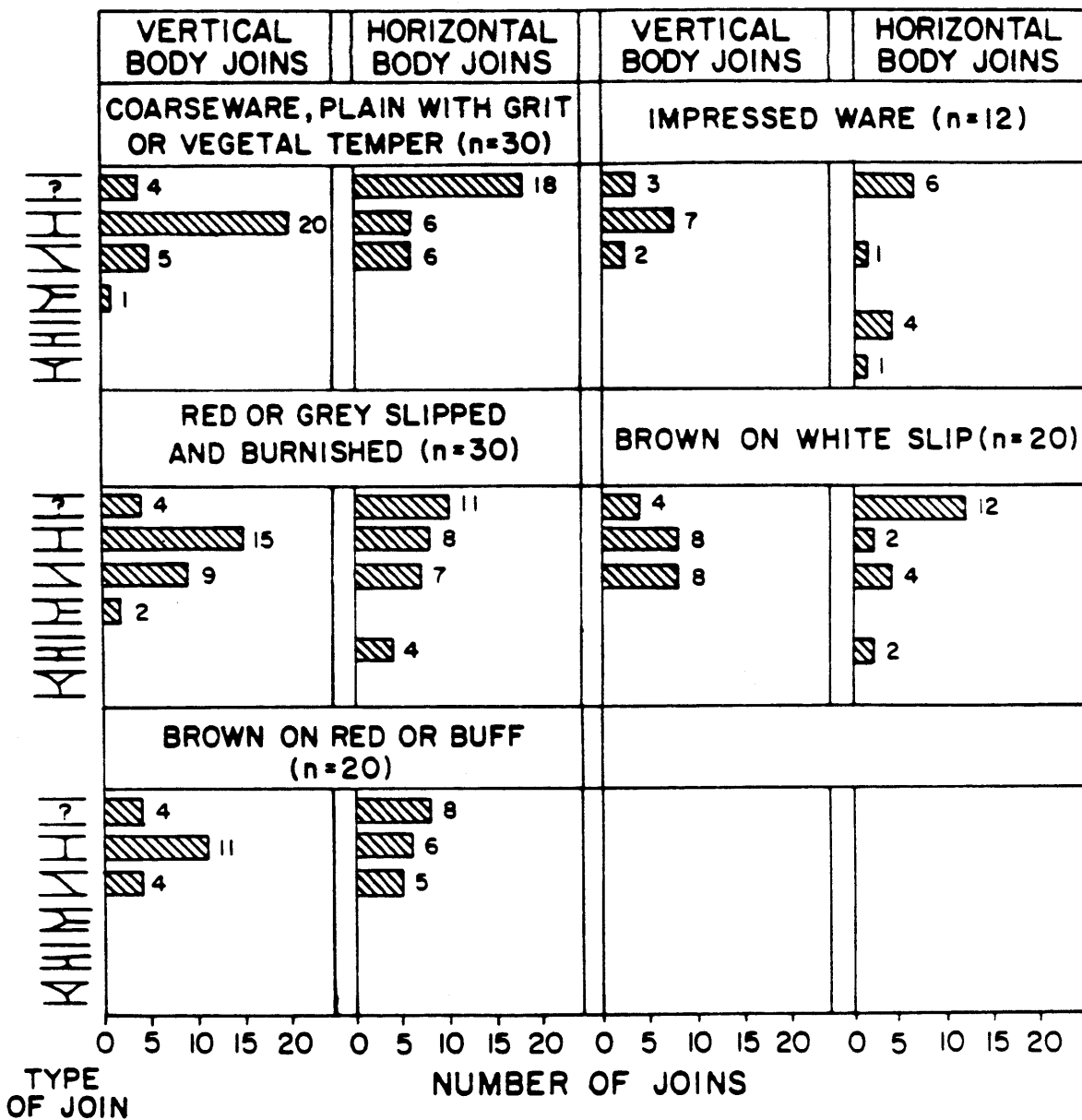
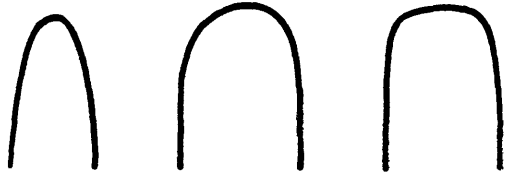


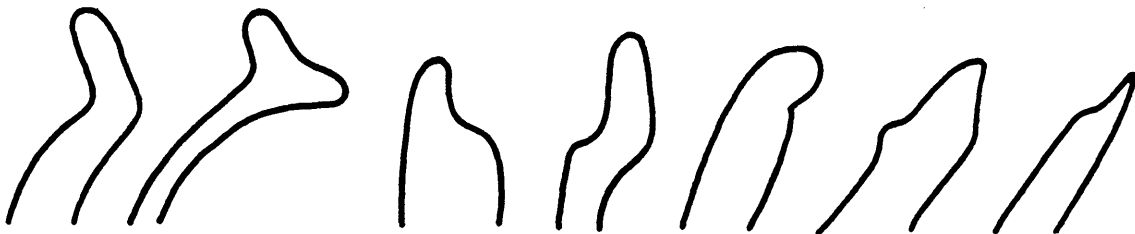
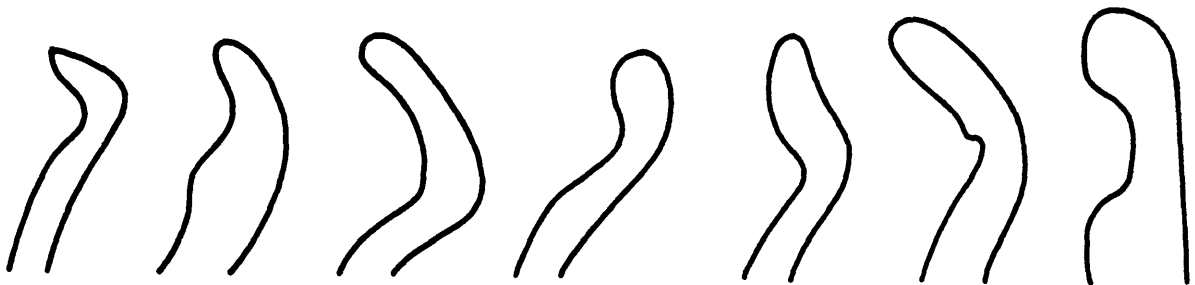
FIGURE 34. Frequency and Type of Joins in Wares from Pisdelli Tepe. Number of Sherds Measured was 112 in which 37% butt joints, 23% bevel joints, 34% undecipherable joint types, and 6% complex joints were found.

VARIATION IN RIM FORM:

HAJJI FIRUZ



DALMA



PISDELI

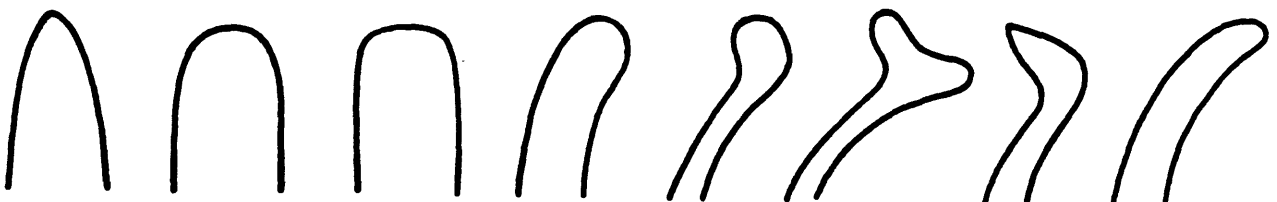


Figure 35. Variation in Rim Form of Hajji Firuz, Dalma and Pisdeli Wares.

The direction of wet smoothing as shown in Table 15 is parallel to the lip in 39% of 80 examples in the Hajji Firuz coarsewares, in 32% out of 25 examples of Dalma plain, red slipped and painted coarsewares, and in 79% out of 234 examples of Pisdeli wares. The breakdown by ware type is given for the Pisdeli wares in Table 15. The Pisdeli plain buff coarseware and painted wares have the largest numbers of parallel wet smoothing marks at the lip (84% plain buff, 82% black-on-white and 78% red or brown on buff or red). If the wet smoothing marks are parallel to the lip and if their texture is that of fine, parallel grooves and ridges and has the look of a wet, slippery clay, then rotary motion can be inferred for the smoothing of the lip. The wet texture is from the lubrication used. The wet smoothing and shaping of a rim can be carried out quite simply but with practice by rotating a pot of the proper wetness on a sherd on the ground, as for instance, was done by Dona Rosa of Coyotepec near Oaxaca, Mexico, in the well documented making of coil built water jars which are similar in body shape and size to some of the Dalma jars. The difference in environment between a fifth millennium village potter and a twentieth century one makes any other than a superficial comparison farfetched.

Table 15. Direction of Wet Smoothing Marks at the Lip

Hajji Firuz Plain Buff and Fugitive Red Painted (n = 80)

Parallel to the Lip	31, or 39%
Not Parallel to the Lip, Diagonal	49, or 61%
Unreported:	15
(too weathered to tell, no marks, or parallel inside and diagonal outside)	

Dalma Plain, Red Slipped and Painted Wares (n = 25)

Parallel to Lip	7, or 32%
Not Parallel, Diagonal	18, or 66%
Unreported	7

Pisdeli Wares (n = 234)

Grouped by stratigraphy:

Early	Parallel	32, or 84%
	Not Parallel	6, or 16%
Middle	Parallel	28, or 74%
	Not Parallel	10, or 26%
Late	Parallel	124, or 78%
	Not Parallel	34, or 72%
Total	Parallel	184, or 79%
	Not Parallel	50, or 21%

Unreported:

	61
Early	11
Middle	19
Late	31

(additional cause, too high fired to tell)

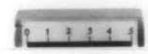
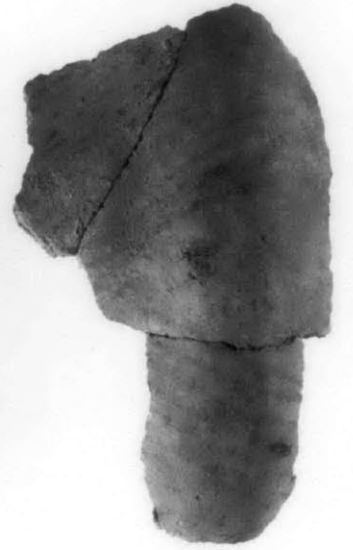
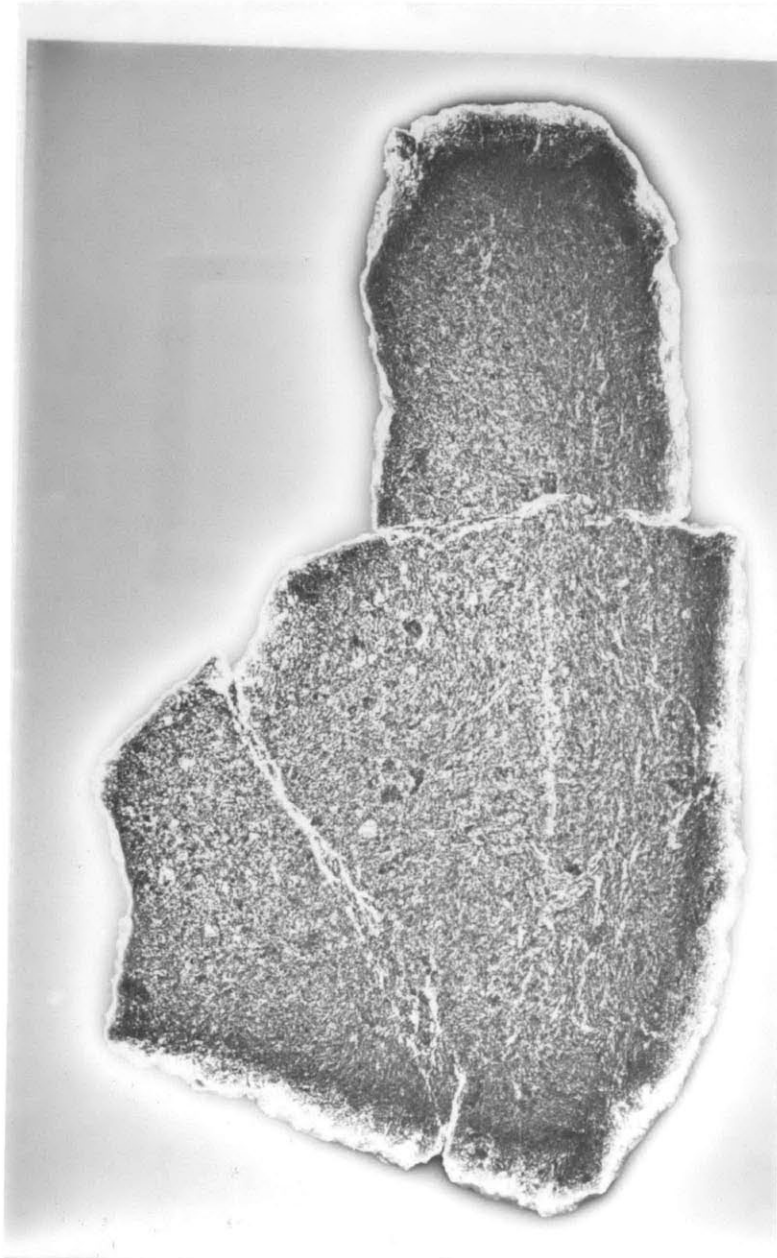
Grouped by ware type:

Plain Buff	Parallel	57, or 84%
	Not Parallel	11, or 16%
Red, Grey Slipped	Parallel	65, or 75%
	Not Parallel	22, or 25%
Black-on-White Slip	Parallel	32, or 84%
	Not Parallel	7, or 18%
Red/Brown on Buff/Red	Parallel	21, or 78%
	Not Parallel	6, or 22%
Impressed	Parallel	9, or 69%
	Not Parallel	4, or 31%
Total	Parallel	184, or 79%
	Not Parallel	50, or 21%

A final criteria for the possible introduction of rotary forming is the presence of banded decoration. At Hajji Firuz, there are 91 sherds with decoration recorded in M. Voigt's study of which there are horizontal, circumferential stripes on 32 examples of 35% of the total (1984: Figs. 74m, 93bd, 92acdfglp, 94ec, 95ace, 96(3), 97, 98 banded; Figs. 84k, and others in 92, 93, 94, 95, 96(2) not banded). Close examination using a microscope shows that many of these bands are composed of short, individual brush strokes. We will compare all of the possibly banded examples from Hajji Firuz with those having horizontal stripes from Dalma wares. Banded decoration on Dalma pottery is the prevalent type, and furthermore close examination shows that breaks in painted lines are much less frequent in Dalma than in Hajji Firuz pottery. In most of the sherds studied the banded lines cross an entire sherd without interruption. Thus, we can infer that during the Dalma period pottery is being decorated with horizontal banded decoration in 80-90% of the pottery with decoration. In the Pisdeli period the same emphasis is found on banded decoration and in addition to banding a rotated device is also being used to shape and wet smooth rims, although the same slab methods of construction are being used as in the earlier Hajji Firuz pottery. In summary, using three criteria (rim form, banded decoration and direction and texture of wet smoothing), we can state that a turntable was in use in the Pisdeli period for all three operations, and for the first two operations in the Dalma period.

In order to determine the spatial distribution of manufacturing elements in the wall of the pottery, xero-radiography was carried out on about 40 sherds from each period. Drawings were made of the surface texture of the pottery, often revealing by the pattern of grooves and raised areas the same pattern of slabs or lumps as found in the radiograph. Ten large

sherds from Hajji Firuz were then photographed to document their surface textures and cut with a diamond saw into vertical cross sections showing the profiles. The thickness of these sections was approximately the same as the thickness of the wall of the pot. Using xero-radiography to track the position of joins across the sherd, we can then map the size and shape of the slabs. Ten examples were documented, an example of which is shown in Figure 36. Figure 37 shows the same sort of slabs are present in Dalma and Pisdeli pottery. There are also some examples with anomalous patterns of pores and rock temper which occur in the radiographs of Dalma and Pisdeli wares and which might isolate some of the pottery as import ware, a poorly made or differently made local product as for instance with a beginner or person who had recently joined the village as a bride or settler, or pottery which was made in some period of stress when there was inadequate time or opportunity for clay selection or preparation.



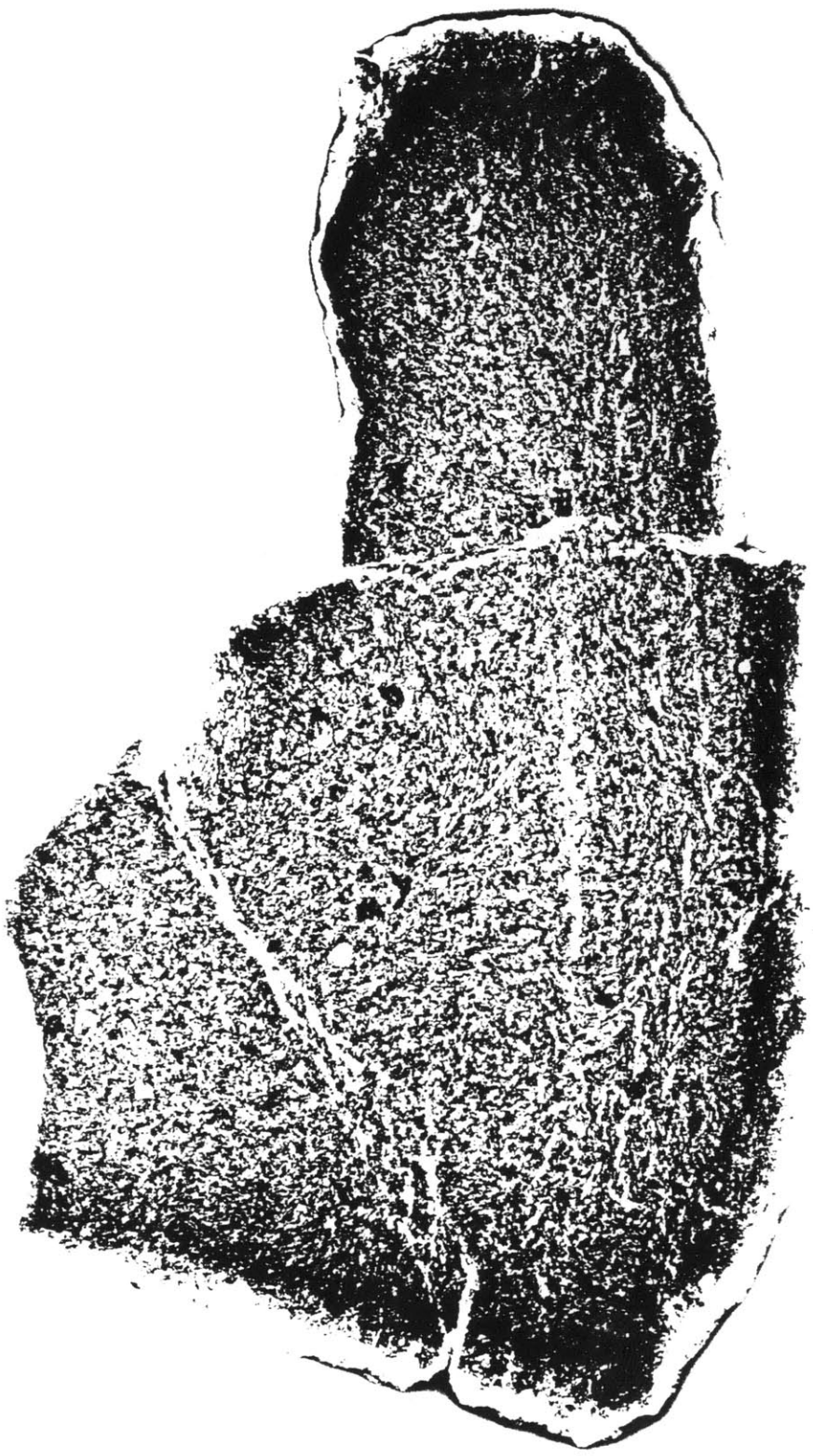
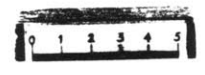


Fig. 36



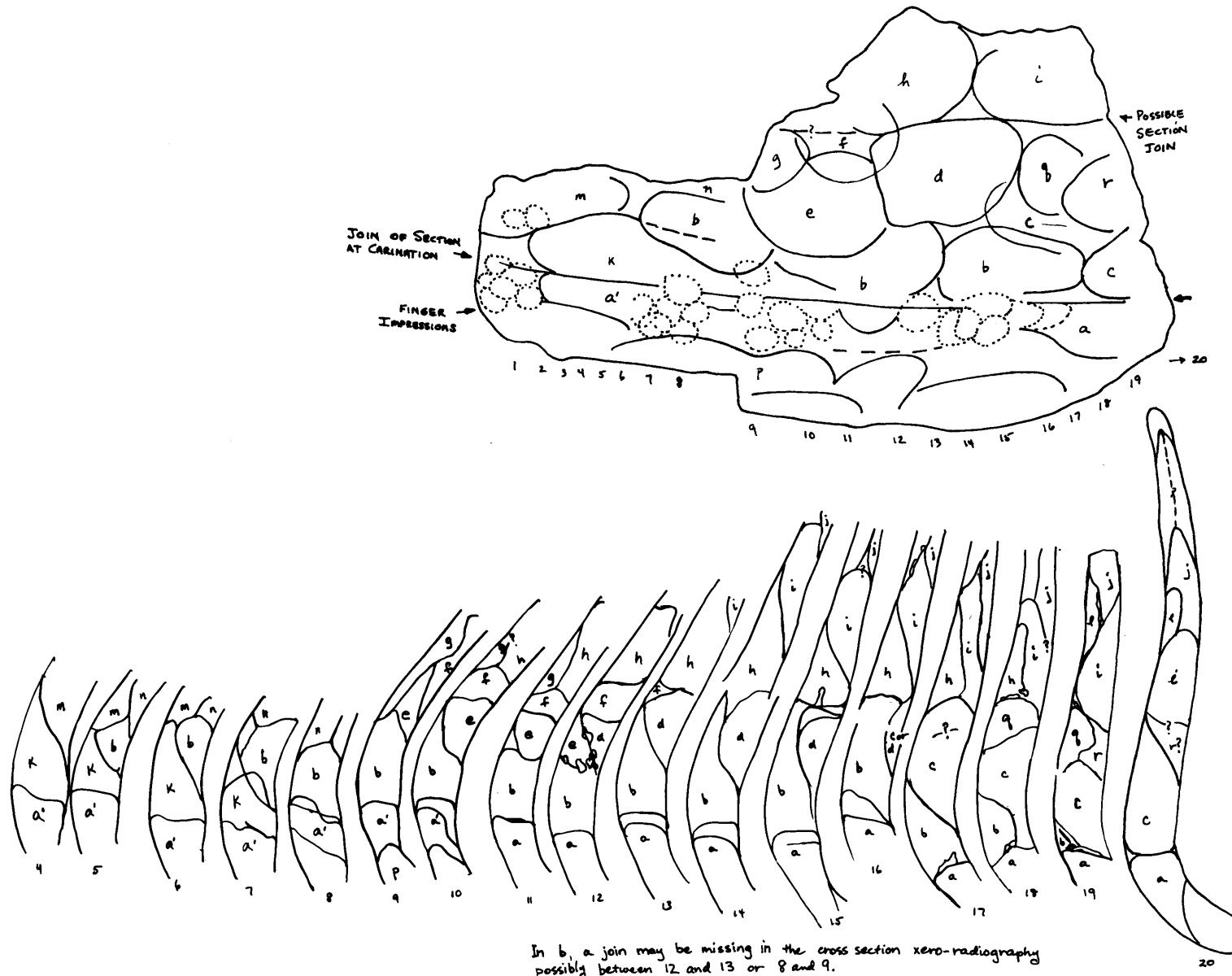
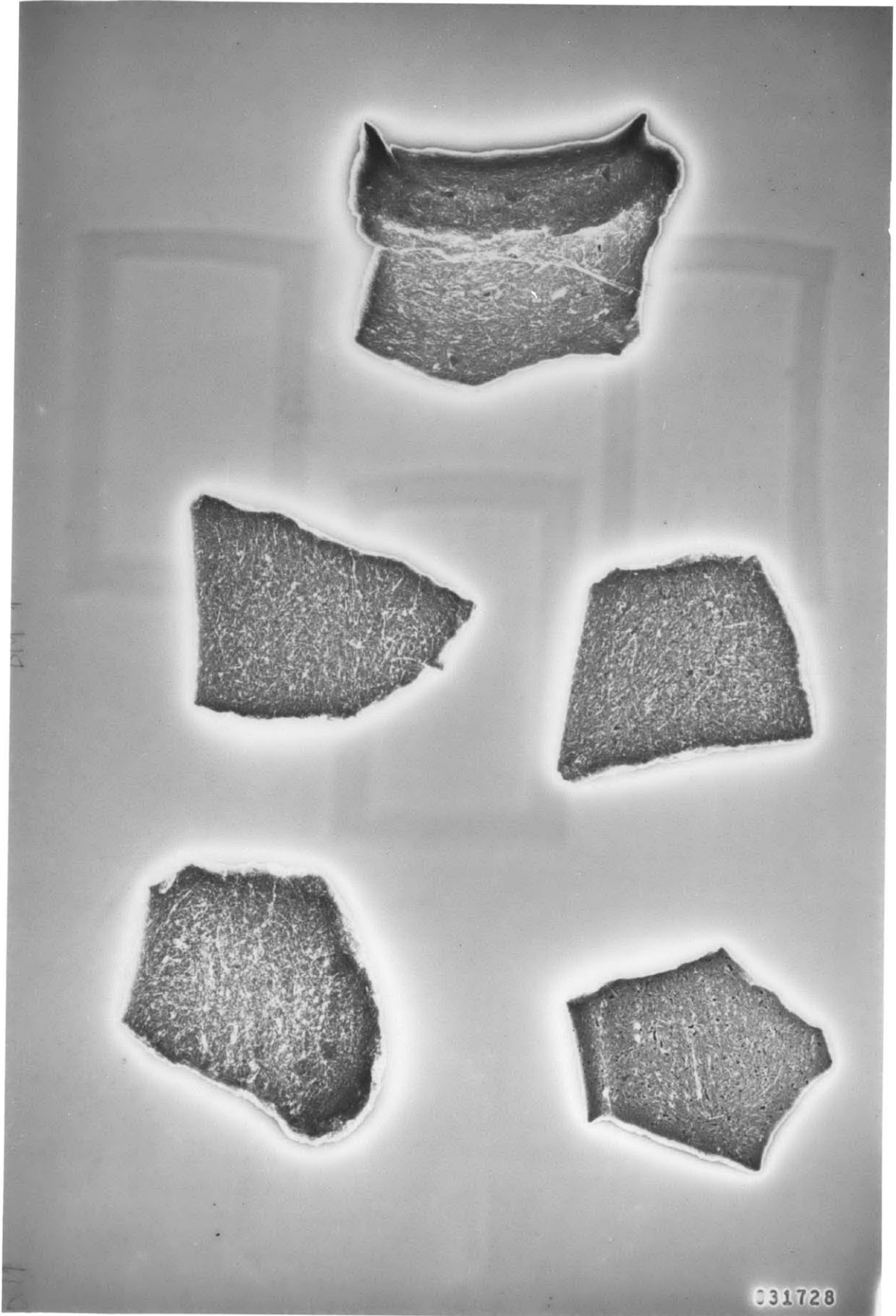
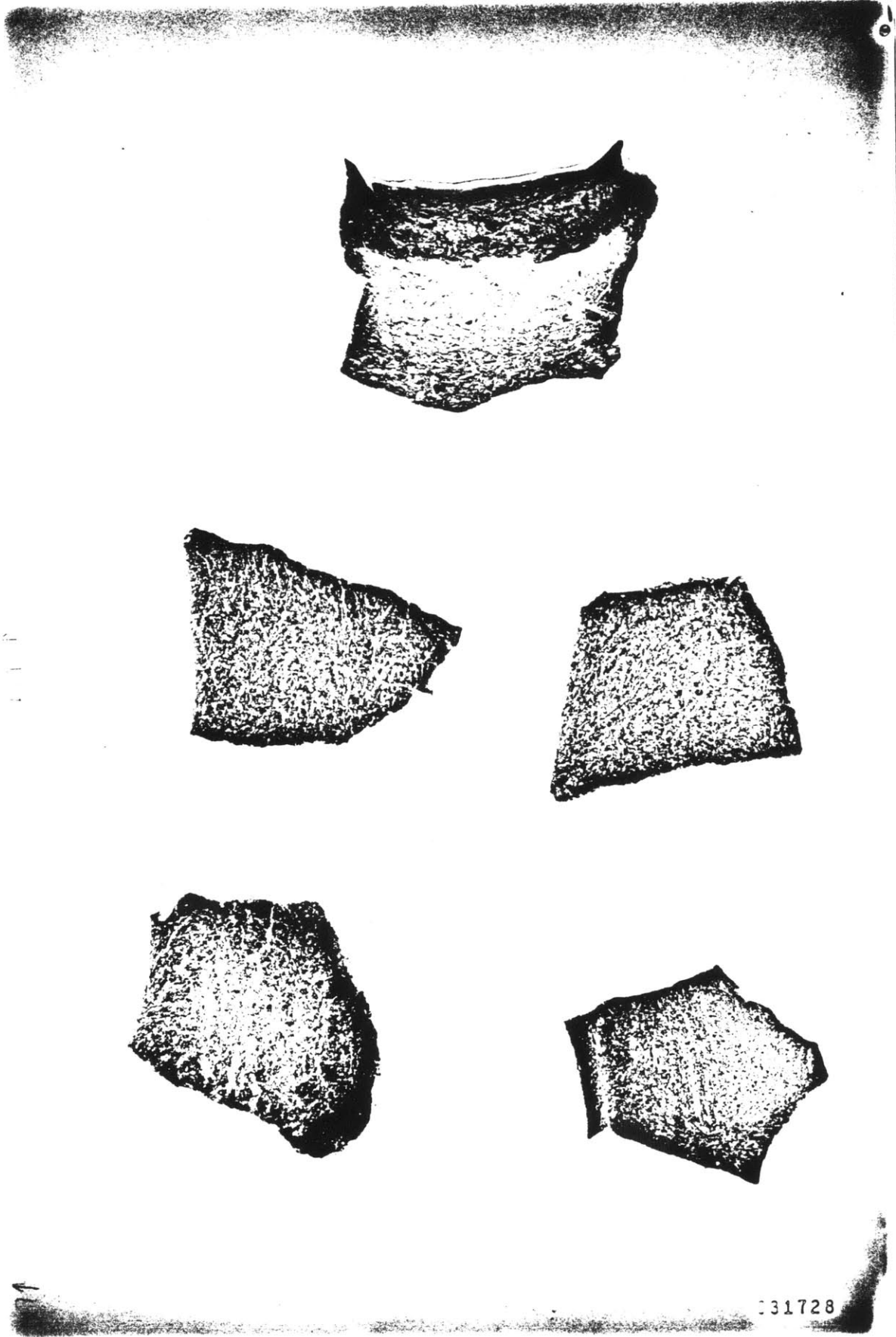


Figure 36 continued



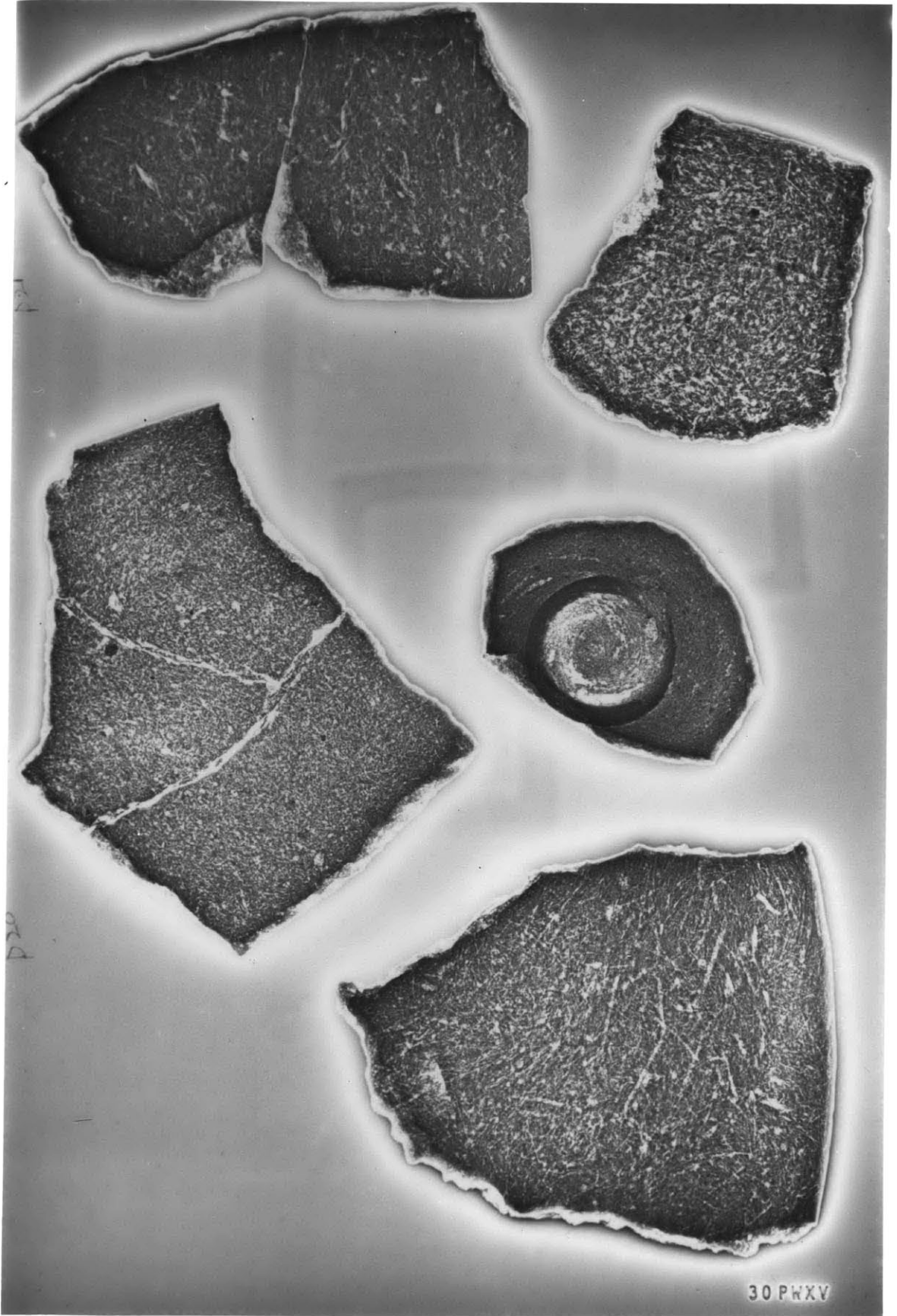
031728



Dalma Fine Ware

Fig 37

31728



P 20

P 20

30 P W X V

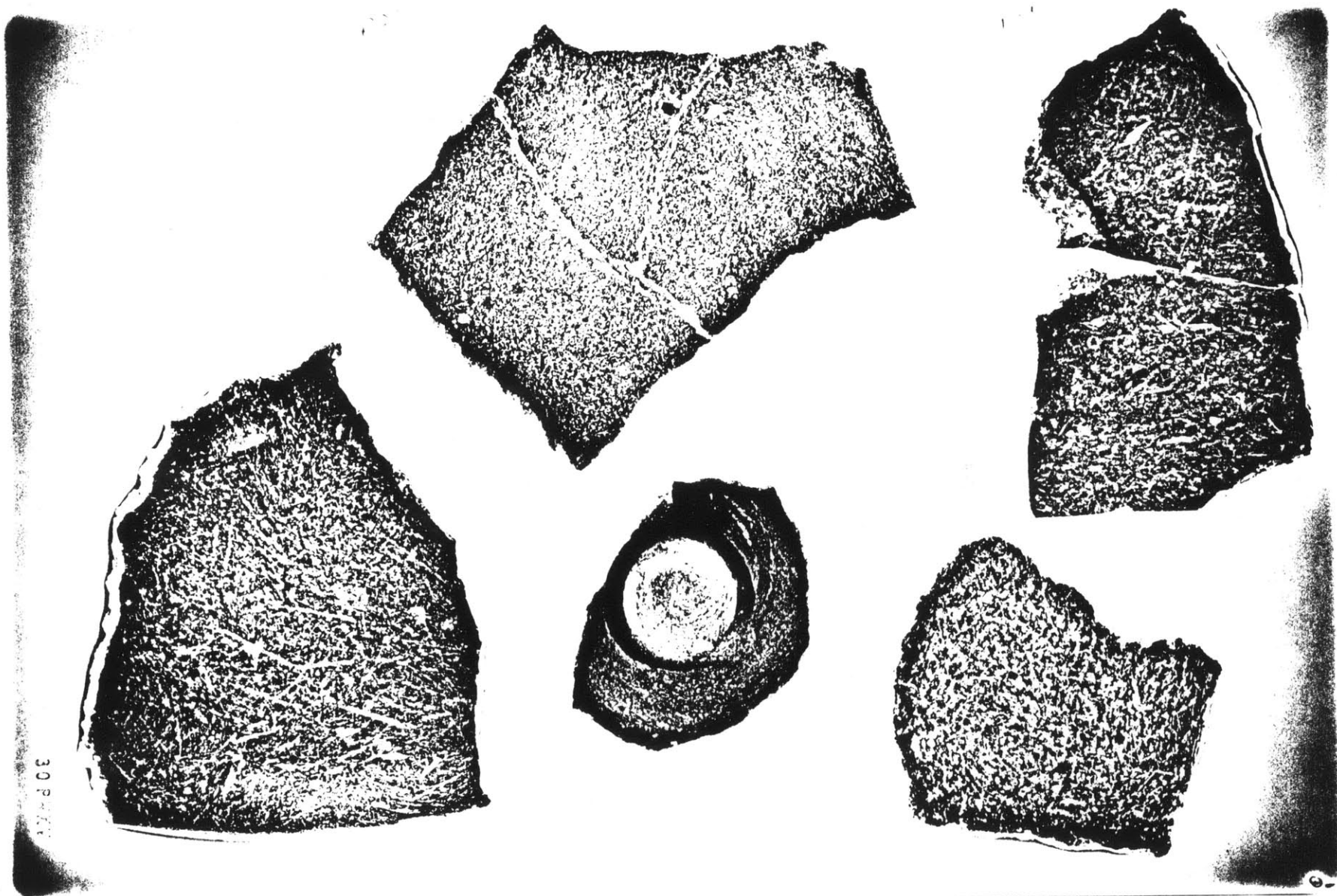


Fig. 37 Pisdeli Fine Ware

3. Ganj Dareh: Unexpected Variety in Forming and Clay Body Preparation

At Ganj Dareh there is great variety in the clays used and in the forming methods. This was unexpected because my western ideas of progress teach that a simpler technology should be followed by a more complex one. Ganj Dareh is the earliest of the sites by about 1000 years. There is unusually good preservation because of a fire in level D which preserved many structures which otherwise might not have survived. Ganj Dareh pottery is formed in slabs or lumps for both large storage vessels and small vessels, as can be seen in Figure 38. The ratio of complex to simple joins is high as the pottery was built up in many layers, as drawings of the cross sections show in Figure 40. In addition the elements used in the base, body and rim, have the same general size as shown in Figure 39, thus the pottery was constructed but not with the same pattern as found in later sites where the base elements are larger and those at the lip are smaller, as shown in Figure 39.

At Ganj Dareh there is further evidence for the specialized knowledge of clay resources. At least three clays with different working properties and different methods of preparation were used. The fine geometrics and clay figurines are made of a very fine yellowish-white clay whereas the small pottery is made from clay which has been coarsely ground and water added, but no organic temper. I believe this was a very clever way of avoiding problems with a fine montmorillonite clay body without temper; namely, the high plasticity and shrinkage and the low strength during forming. What led to this observation was the repeated occurrence of pores with irregular cross sections. Instead of being rounded, they were pointed, having two or three or five points, as if granules of clay about 3-5 mm.

across had been joined with slip. This is probably another instance of a composite body, made of barely plastic granules and slip. The larger pottery, storage vessels and basins, was made with vegetal temper. The basin was made of stacks of slabs as originally recognized by the excavator, Carol Hamlin Kramer, as shown in a redrawing of her original work in Figure 40. The large storage vessels were built of stacks of large slabs with butt joints only poorly worked together, as shown in Figure 40. The xeroradiograph confirms this slab construction.

The small hole mouth jar published by P.E.L. Smith and R. Crepeau (1983) was made in two halves. From the internal surface texture there is a roughness, with almost hemispherical pores and irregular half open pores, which occurs when the vessel is not well compressed or rubbed over by a hand, but instead poorly compressed against another surface. The two halves were joined with the surface wet smoothed but neither slipped nor burnished. Thus we have evidence not only for the specialized use of different clay bodies far before craft specialization but also a diverse and quite complex technology when one expects uniformity and simplicity.

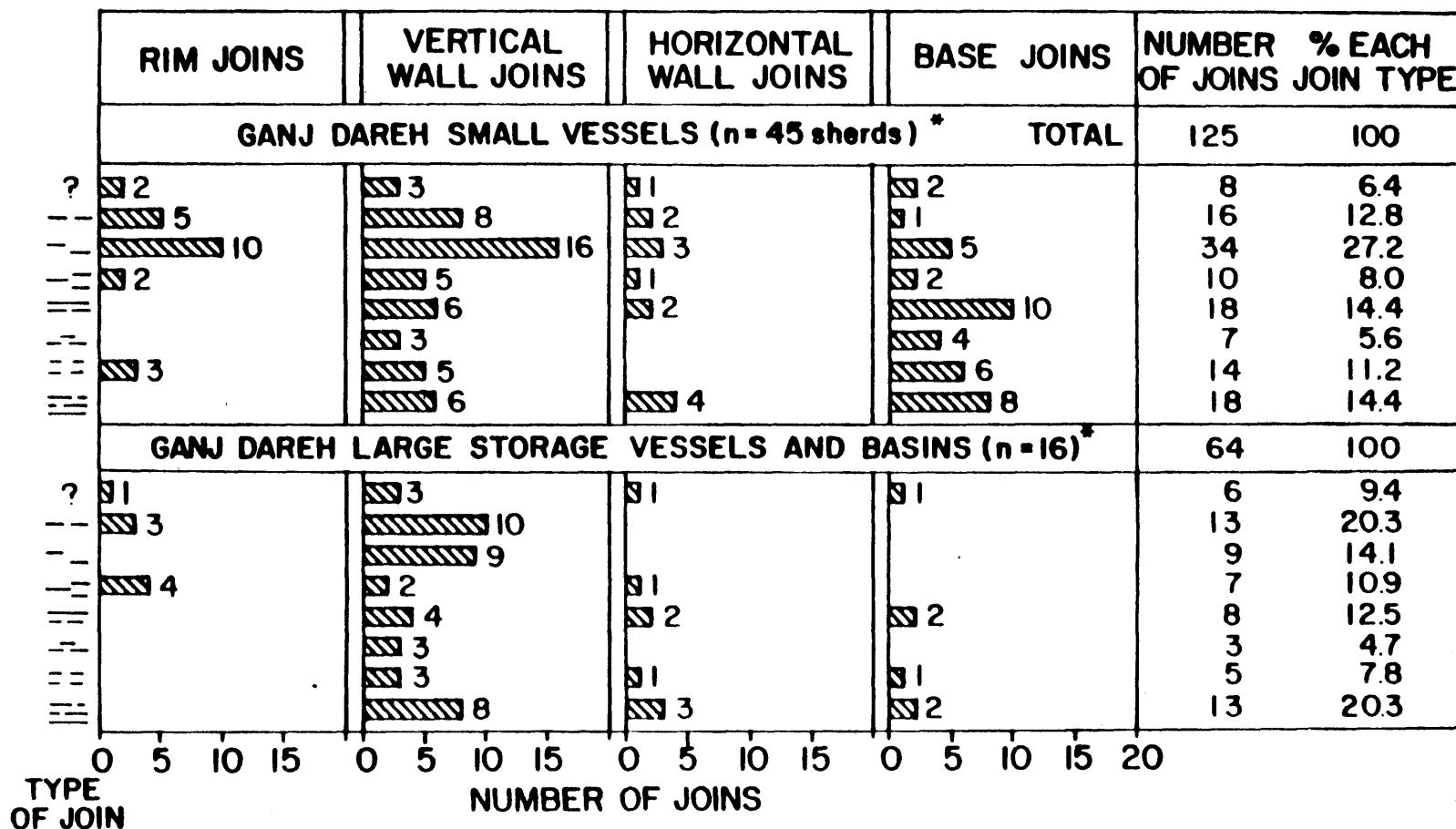


FIGURE 30. Frequency and Type of Joins in Small and Large Vessels from Ganj Dareh. The total number of sherds was 61 and the total number of joins was 189.**

* Whole pot (GD69 199 4046) and basin (GD69 321 31027) were each counted as one because of the large number of sherds from these two vessels. The other sherds reinforced the same view of a large number of complex joins as shown above and a greater number of bevel over butt joins.

** Because of the small size of manufacturing element, there was no minimum sherd size imposed.

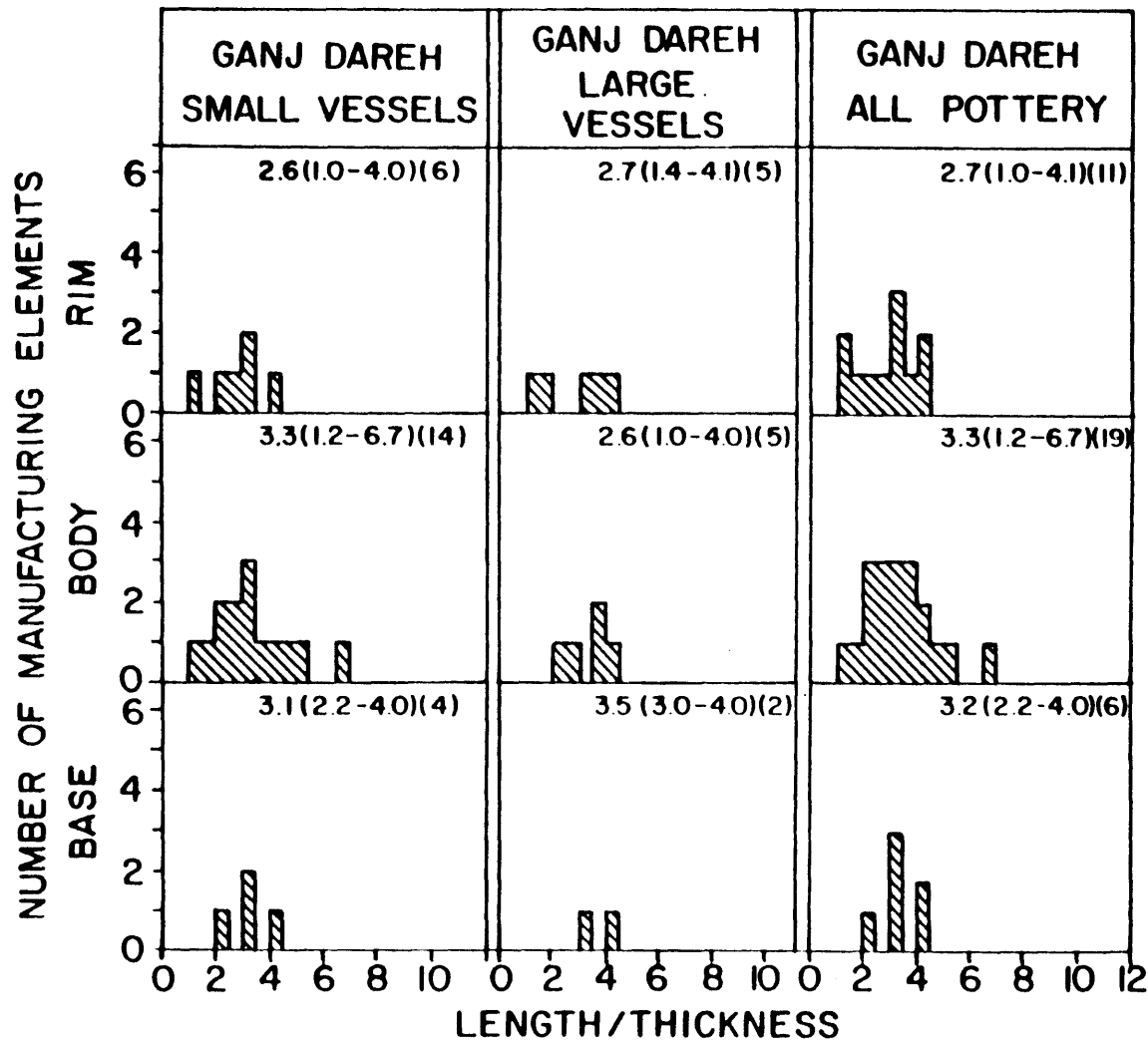


FIGURE 39. Size of Manufacturing Elements Used in the Base, Body and Rim to Construct Ganj Dareh Pottery, Reported as the Mean, Range and Number of Elements.

Figure 40. Xeroradiographs and
Drawings of Ganj Dareh Pottery



4. Sarab: Excellence and Uniformity in Pottery Making and Firing

At Sarab were found small vertical wall or slightly flaired bowls made by sequential slab construction, slipped and burnished in various buff shades during the period of level I occupation and a quite strikingly uniform bright red during level V occupation (Figure 47). Presumably these bowls of unusually high quality were serving bowls. The walls are quite thin and the joins well worked together. Given the constraint of working with vegetal tempered montmorillonite clay, these wares are refined (note the profiles in Figure 47). The uniformity is found not only in the forming but also in the firing. In the earlier period (SI), the buff colors were preferred, as shown both in sherd counts from 1978 and in the relative weights of sherds from Braidwood's excavation, in both of which 80% of the sherds were buff. In the later period (SV) red was preferred in 75% of the sherds (as measured in the same way as for SI). In the red ware, the firing was kept intentionally in oxidation at least for a period near the end to produce this visual effect. The fact that both excavations found similar fractions of the wares is good corroborative evidence that both samples are representative.

We have tried to trace the uniformity of forming by measuring frequency of joins and relative slab size, but there is a considerable amount of variation, as shown in Figures 41 to 46. What is clear, however, is that the pattern found at all later sites is established, that is the simple joins outnumber the complex joins and that the base elements are larger than the wall elements, and both are larger than the lip elements. There is no evidence of any molding, or of the variation in clay preparation found at Ganj Dareh. Instead, all of the pottery contains vegetal temper.

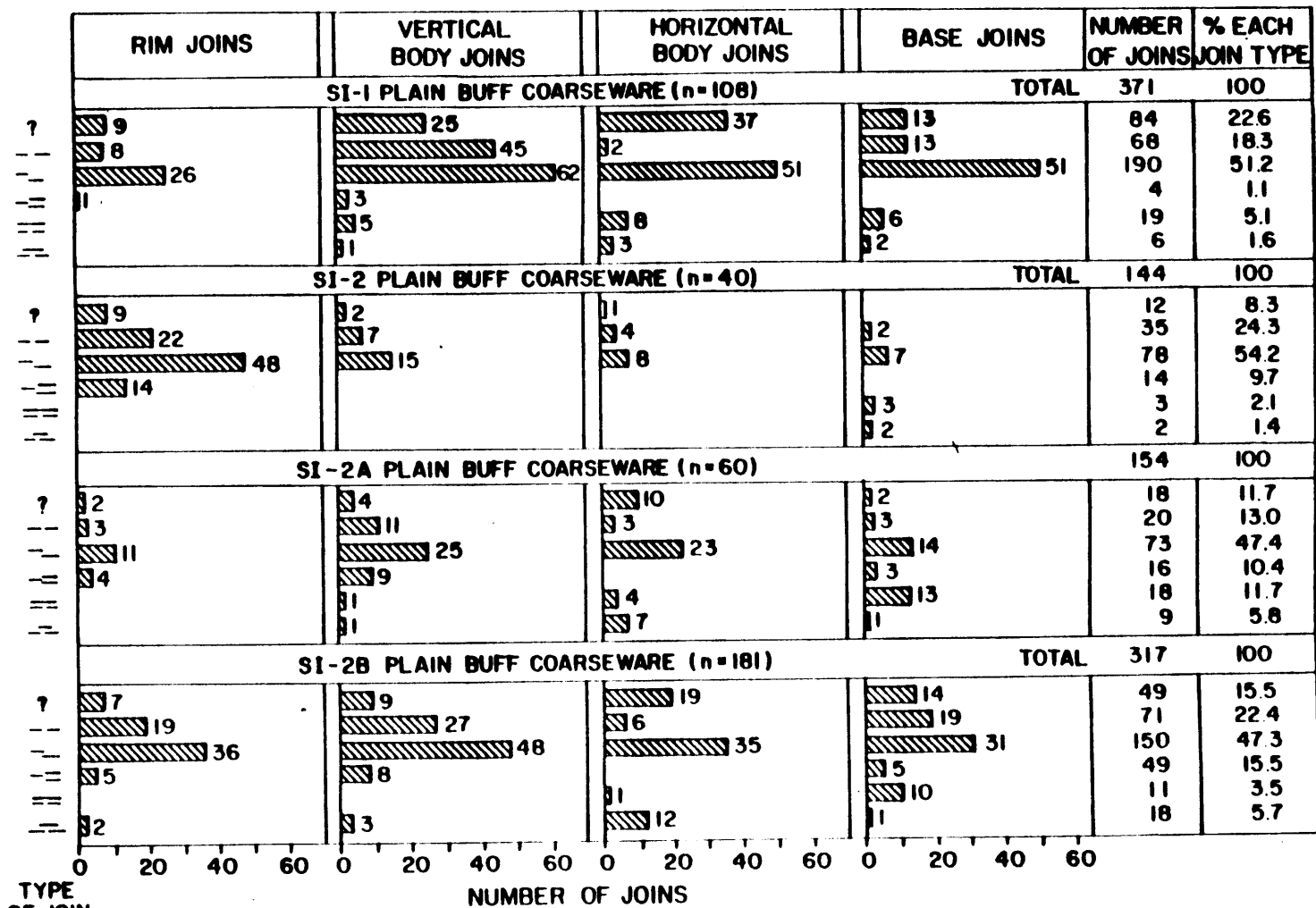


FIGURE 41. Frequency and Type of Joins in Sarab Plain Buff Coarsewares, Level I, 389 sherds total (minimum size 30 x 30 mm). This bar graph shows a consistent pattern from phase to phase within Period I.

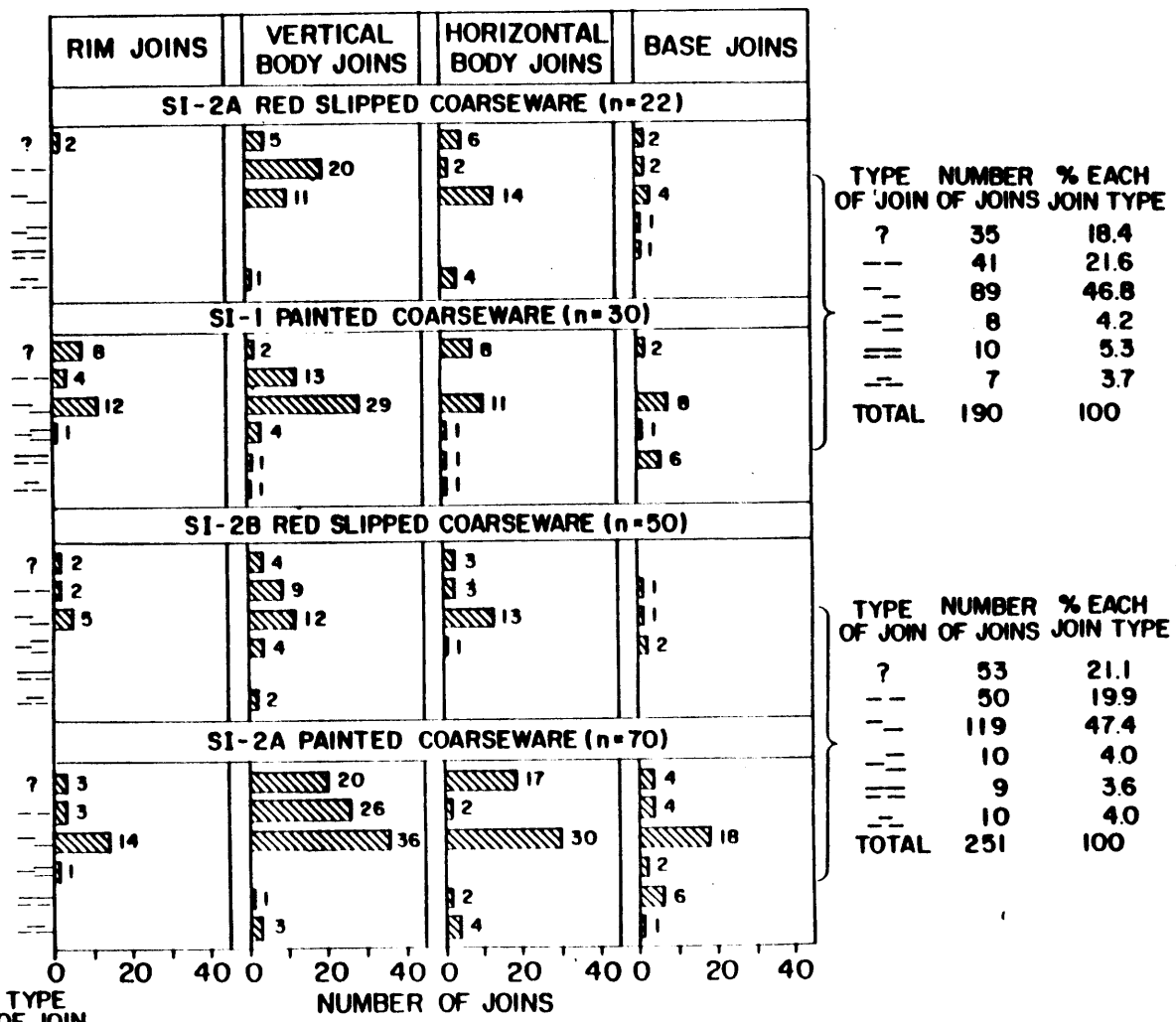


FIGURE 42. Frequency and Type of Joins from Sarab, Level I, Red Slipped and Painted Coarsewares, 172 sherds total (minimum size 30 x 30 mm.). The same pattern is found in the decorated and slipped wares as in the plain wares.

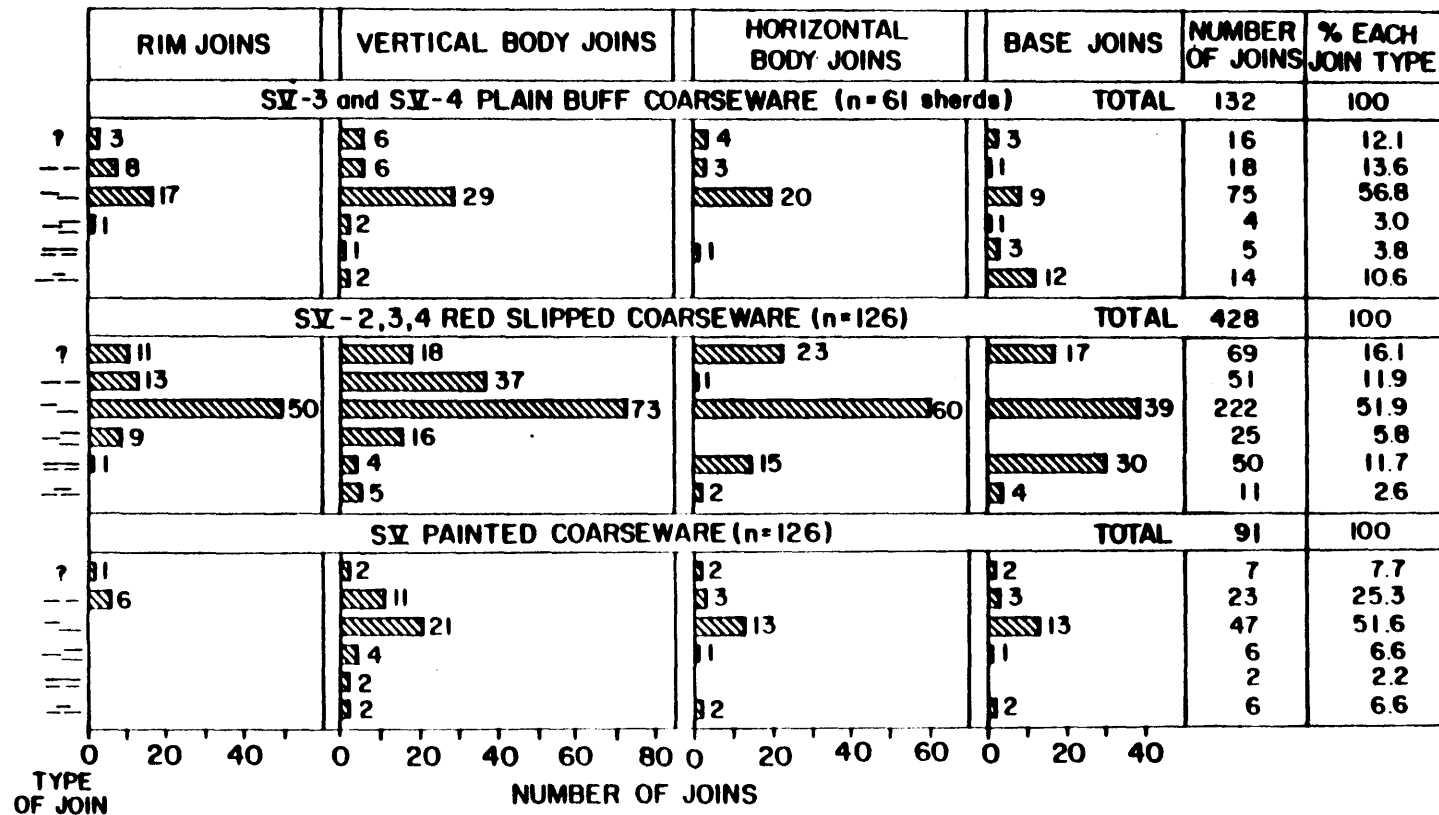


FIGURE 43. Frequency and Type of Joins in Sarab Plain, Red Slipped and Painted Coarsewares, Phase V, 212 sherds total (minimum size 30 x 30 mm.).

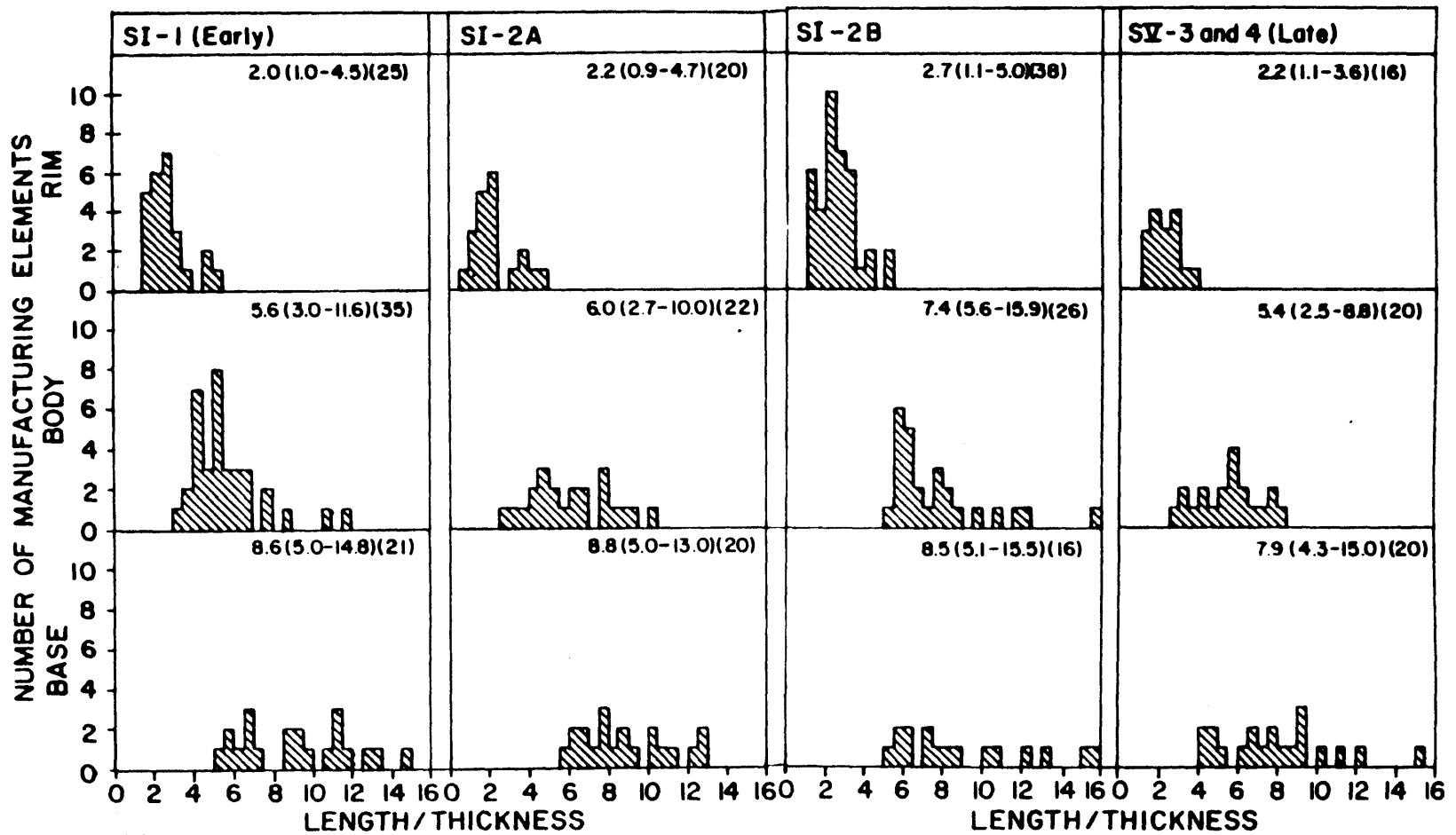


FIGURE 44. Relative Size of Manufacturing Elements in Sarab Plain Buff Coarseware Reported by Phase Mean, Range of Values and Number of Manufacturing Elements.

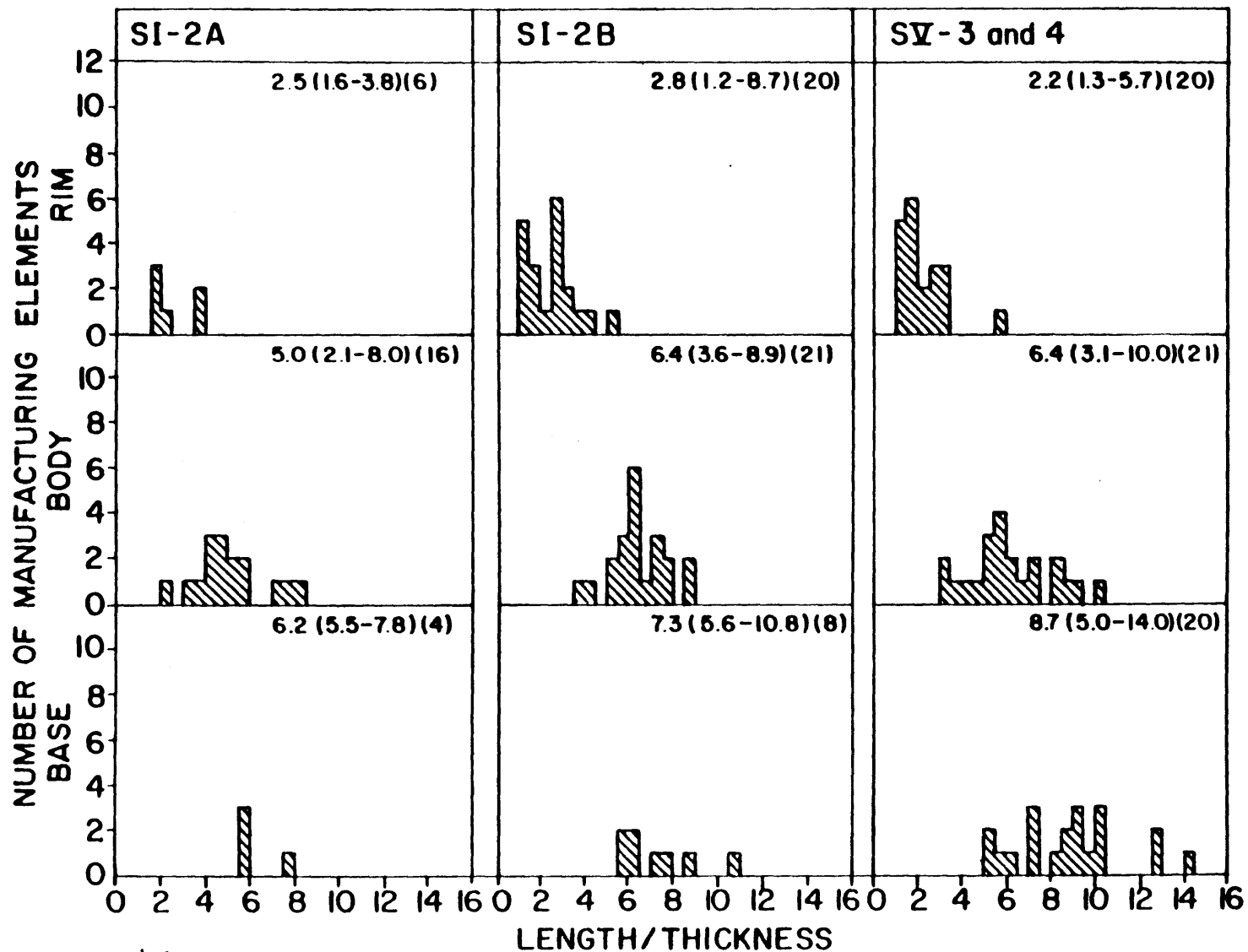


FIGURE 45. Relative Size of Sarab Red and Buff Slipped Coarsewares Reported by Phase as Mean, Range of Values and Number of Manufacturing Elements (136 manufacturing elements from 172 sherds).

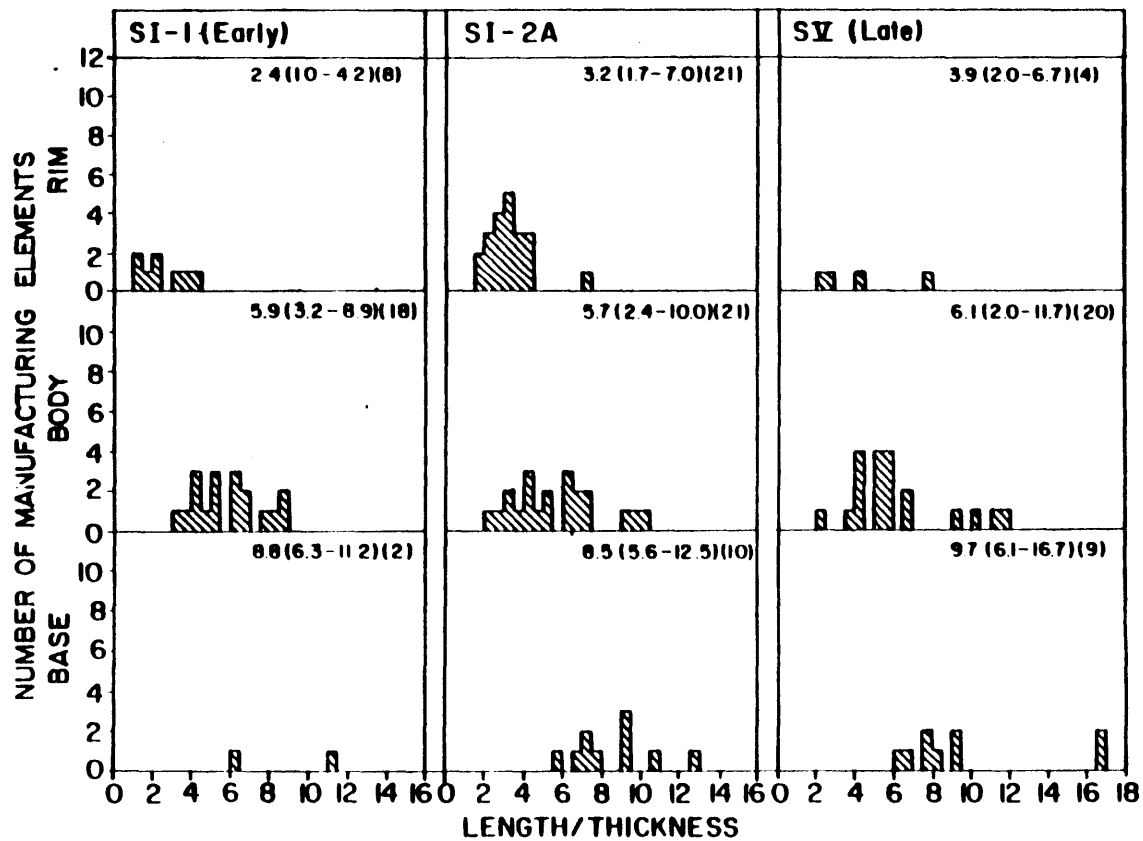
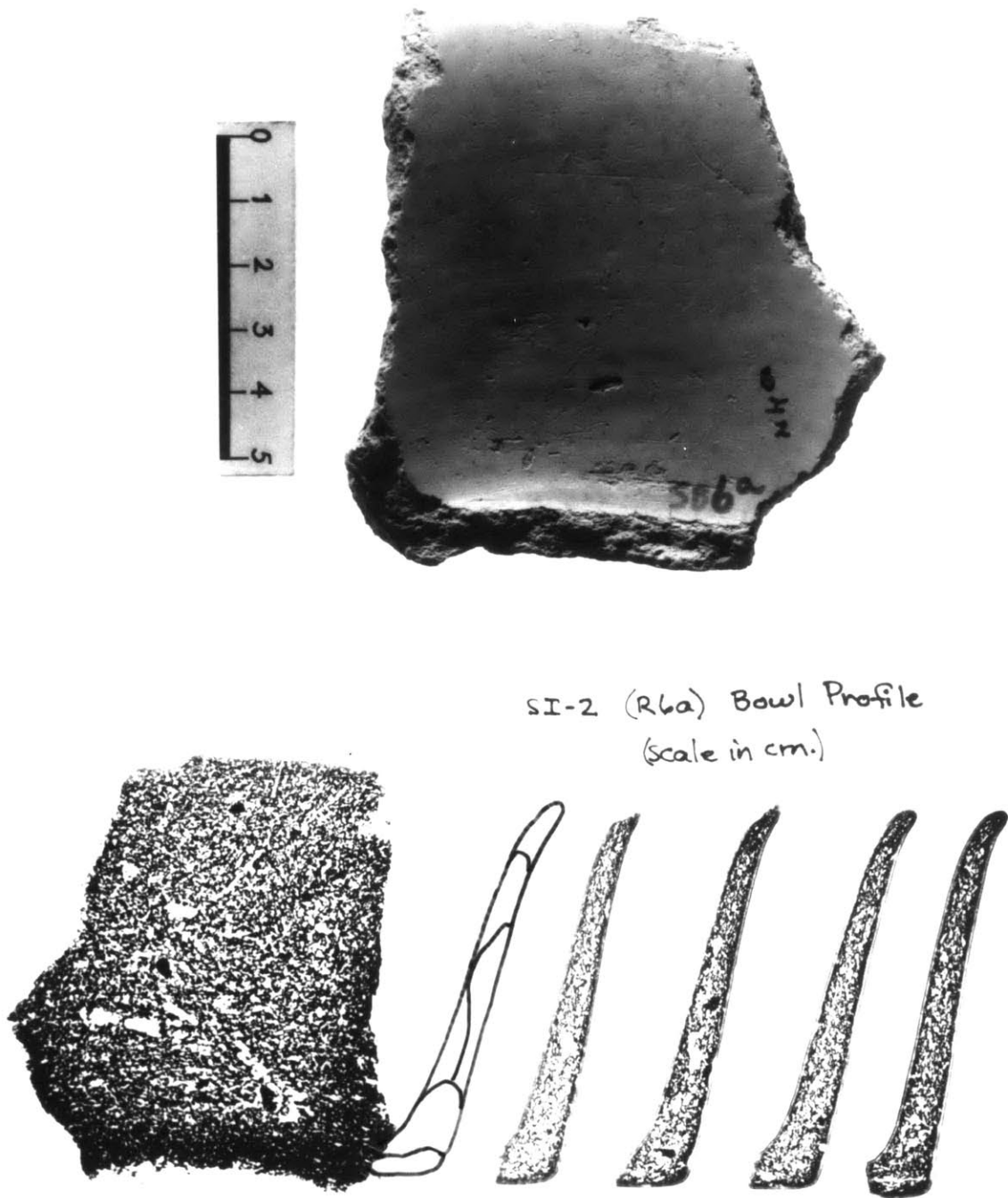


FIGURE 46. Relative Size of Manufacturing Elements in Sarab Painted Coarseware, Reported as Mean, Range of Values and Number of Manufacturing Elements (113 elements in 136 sherds).

Fig. 47. Xeroradiographs and drawings, Sarab



In order to further investigate the quality of Sarab coarse ware and to find out whether the function of the slip was decorative, or as has been suggested, that it served the purpose of making the pottery less porous, tests were made of water absorption, and the length of time for water transport across the wall thickness. Impermeability is thought to be an important property enabling pottery to contain liquids both for cooking and serving. The result was that the slip coating did not make the pottery less permeable. No little difference was found between Sarab ware which had a slip, well burnished and in good condition, and pottery with no slip coating left, nor was there a difference between the earlier buff wares and the later red wares.

Other wares were tested with similar results. However, one interesting result was that the pottery best able to contain liquid was the earlier vegetal tempered coarse ware pottery, which had the widest spread of values. Two possible explanations are that there is a greater variation in forming of the early wares or because of variations in open pit firing (instead of kiln structures or other encasing material which would produce a more even temperature). The wide range of wetting through behavior must have been appreciated if the pottery was used for cooking or storing liquids.

Table 16. Porosity and Permeability Data

Percent Water Absorption	Rate of Wetting (mm./min.)	Time to Wet Through from one side of the wall to the other with pool maintained on one side Sarab
(n = 20) 16.6% (12.8-20.6)	SI Sarab Buff Slipped (n = 14) 0.30 (0.05-0.74)	63 (18-195)
(n = 5) 24.4% (18.9-30.1)	SI Sarab Red Slipped (n = 5) 0.30 (0.23-0.35)	31 (23-35)
(n = 11) 18.4% (14-25.3)	SV Sarab Red Slipped (n = 8) 0.31 (0.17-0.53)	43 (18-108)

Ganj Dareh

By comparison much Ganj Dareh clay is very low fired. Small amounts were made available for determination of water absorption measured as weight increase after immersion in boiling water for 1 hour.

Water Absorption	Wetting Rate	Degree of Vitrification
(n = 6) 8.2% (5-12.5) but four samples decomposed and were not counted	Not Determined	(n = 10) 2 samples decomposed immediately when immersed in boiling water; 2 more fragmented within 5 minutes; 6 samples withstood 1 hour of boiling and had sintered

Tepe Yahya

Chaff Tempered Coarse Ware		
(n = 8) 23.4% (5.5-38.4)	(n = 8) 0.8 (0.3-1.3)	24 (5.5-83.5)
Soghun Plain and Painted Ware		
(n = 4) 17.4% (15.0-18.9)	(n = 4) 1.3 (1.1-1.4)	7.3 (4.5-12)
Lapui Ware		
(n = 5) 15.8% (14.2-17.0)	(n = 5) 0.8 (0.4-1.2)	8.4 (3.5-13)
Black on Red or Buff		
(n = 6) 16.1% (13.1-21.1)	(n = 6) 1.58 (0.5-3.0)	6.75 (2.0-16.5)

Seh Gabi

Mound C, Shahnabad		
(n = 4) 19% (11.5-28.8)	(n = 6) 1.6 (0.18-4.0)	15.6 (3-41)
J-Ware		
(n = 10) 15.3% (9.3-22)	(n = 4) 0.12 (0.03-0.25)	163 (24-325)
Dalma Period Red Slipped Wares		
(n = 11) 22.4% (9.9-27.8)	(n = 11) 4.2 (0.7-29.7)	10.1 (3-32)

	Dalma Period Black-on-Buff	
(n = 10)	(n = 8)	
14.4% (5.8-21)	7.9 (4-199)	0.5 (0.04-1.63)
	Seh Gabi Period Black-on-Buff	
(n = 9)	(n = 3)	
17.3% (2.6-22.9)	11.3 (4-35)	0.9(0.17-1.63)
	Later Period V, VI Coarse Buff Ware	
(n = 6)	(n = 5)	
12.8% (9.5-17.3)	16.2 (3-53)	0.6 (0.09-1.0)

Chagha Sefid

	Plain, Fugitive Painted Early Wares (n = 7)	
19.0 (13.2-30.1)	0.6 (0.19-1.8)	32.1 (5-64.5)
	Red Slipped Coarseware (n = 4)	
16.6 (14.6-18.7)	0.4 (1.8-5.0)	31.0 (13.5-73)
	Sefid Black-on-Buff (n = 3)	
17.8 (16.6-18.5)	1.8 (0.18-1.3)	26.3 (7-44)
	Sialk Black on Red (n = 5)	
20.9 (16.0-27.1)	0.76 (0.26-1.5)	15.1 (4-31)

Tell Halaf

	Black-on-Buff (n = 5)	
12.4 (10.2-15.4)	0.15 (0.03-0.32)	76 (19-161)

The uniformity of production in forming and firing at Sarab is accompanied by a complex chemical technology. A group of sherds with three colors were found which are most amazing, or at least unexpected. Their chemical technology is much more refined than expected at this period of time. The interior is red, the exterior is black and a white paint decorates the exterior. A small amount of the white decoration was scratched away and under a microscope mixed with hydrochloric acid which did not fizz. Thus lime was not present, and the paint was well cohered and thus not a post fire paint. (Aside: Lime can be held in a clay in two ways, mixed with it as fine particles of lime which would have fizzed in HCl or integral in the clay structure which tend not to fizz; if the pot has been fired sufficiently the lime transforms to a mixture of crystals and glass, none of which fizz.) Later examination confirmed that the white was a low iron, calcareous clay, about the same composition as the body. The black slip contained manganese with a small amount of iron and titanium which is different from later black-on-buff compositions, and the red was an iron-clay based slip. All three had been fluxed with a greater amount of potassia than had been found in the clay body. This is an intentional and complex paint and slip technology, which was developed in an intentional trial and error process. For the uniformity of slip color, there was a considerable control of firing. The interior iron-based red slip meets at the lip in a sharp line with the exterior, shiny black slip. Control of just oxidation state would not produce this result; it must have been combined with chemical control. These sherds represent a sophisticated chemical technology, which is not found in the previous pottery at Ganj Dareh nor in subsequent wares, for instance early organic tempered wares from Hajji Firuz, Tepe Yahya or Mound C, Seh Gabi, all have a fugitive red

paint and red slips which are not successful. Thus, the Sarab pottery is an instance of a technology which required tight processing controls of firing, forming and preparation of raw materials, and this three-color technology was subsequently lost at least in the Zagros region and was not seen again until the Halaf and J-ware black-on-buff tradition.

5. Seh Gabi Mounds C, B, A and E: Variations in Forming with Ware Type and Period

At Seh Gabi, Mound C, the pottery, as has been noted by others, is strikingly similar to that from Hajji Firuz. The metric data are also similar, as shown in Figures 48 through 53 and Table 17. Likewise Mound B with two periods, Dalma and Seh Gabi Periods, is strikingly similar to that from Dalma and Pisdeli. The same pattern of the introduction of the turntable can be found using the criteria of banded decoration, parallel wet smoothing of the rims and in the xeroradiographs the instances of horizontally aligned temper and pores in the Seh Gabi Period which does not occur during the Dalma period. Rim shape was not investigated.

In the Seh Gabi period black-on-buff ware, a most unusual glassy black was produced, which is a compositional precursor to a glassy glaze or glass. It is composed of reduced iron in a potassia-fluxed, calcareous clay. No manganese or chrome was identified using energy dispersive x-ray analysis for which the limit of detection of transition elements in a silicate matrix is about 1/2 to 1% (see section VI.B.3 and Table 19).

During Periods VII and VIII no whole vessels were found which have been thrown on a potter's wheel, but bases of stemmed cups were thrown. There is good evidence for homogeneity of production in the fine and medium fine buff wares in that there is considerable separation of the sizes of elements used for rim, body and base and these have relatively narrow distributions. In

addition the joins are mostly butt joins and not so well worked together as some of the earlier wares. One speculation about this ware is that it was produced in craft workshops.

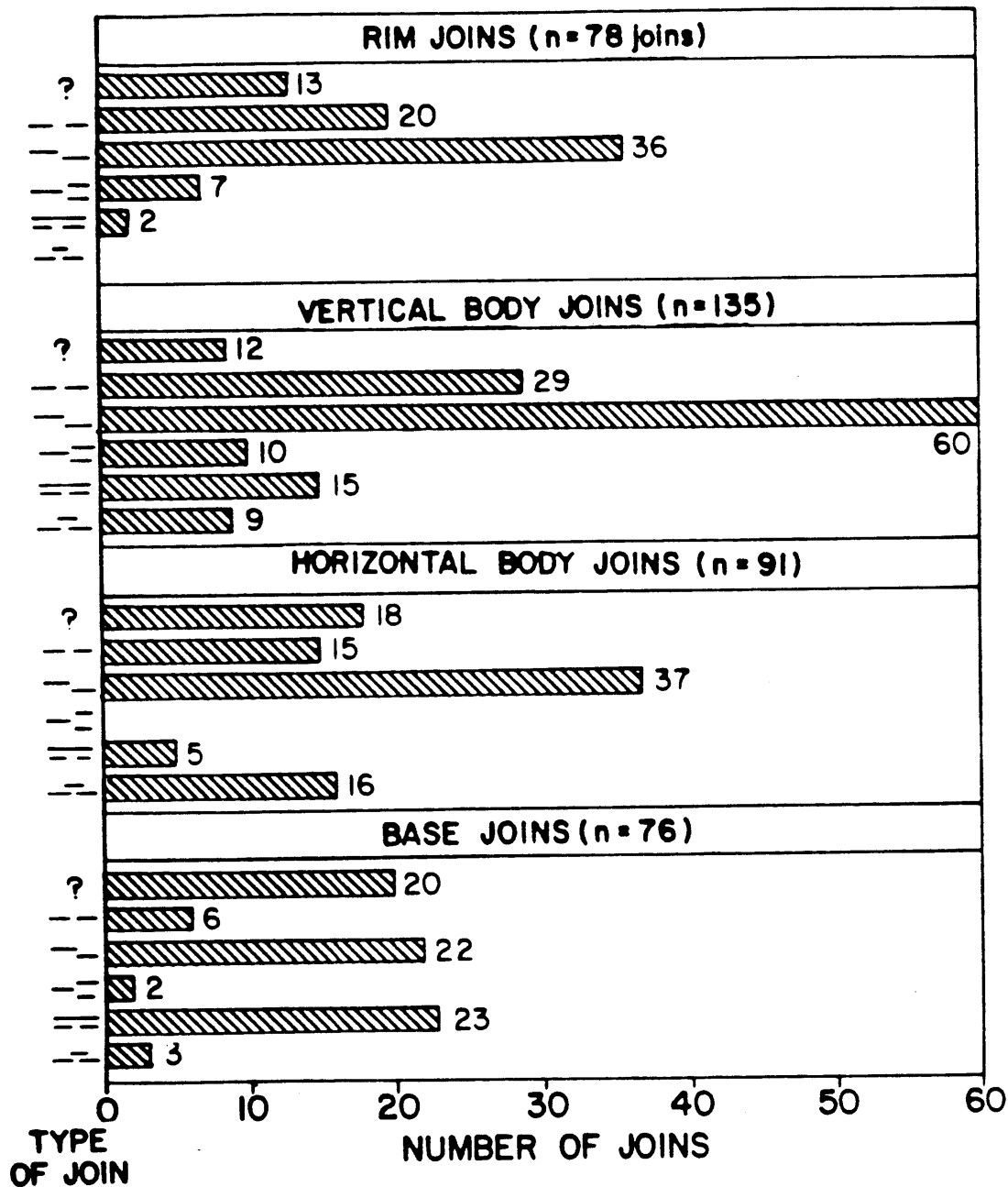


FIGURE 48. Frequency and Type of Joins from Mound C, Seh Gabi, Buff and Painted Coarseware, Shahnabad Period. Number of sherds represented is 250.

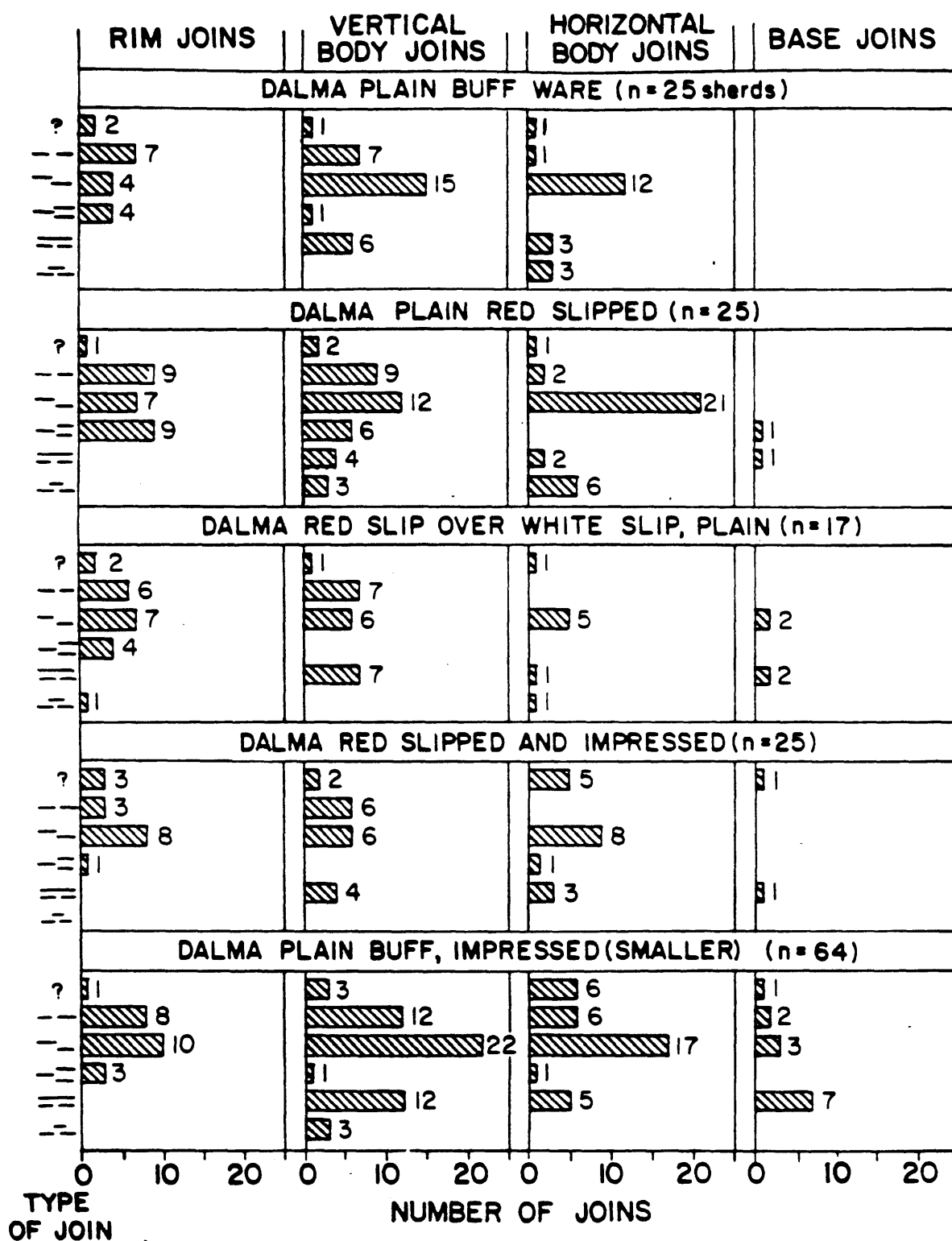


FIGURE 49. Frequency and Type of Joins from Seh Gabi Mound B, Dalma Period. The two graphs represent 305 sherds total, in which bevel joins predominate in the body in both horizontal and vertical sections, and there are similar numbers of butt and bevel joins at the rim.

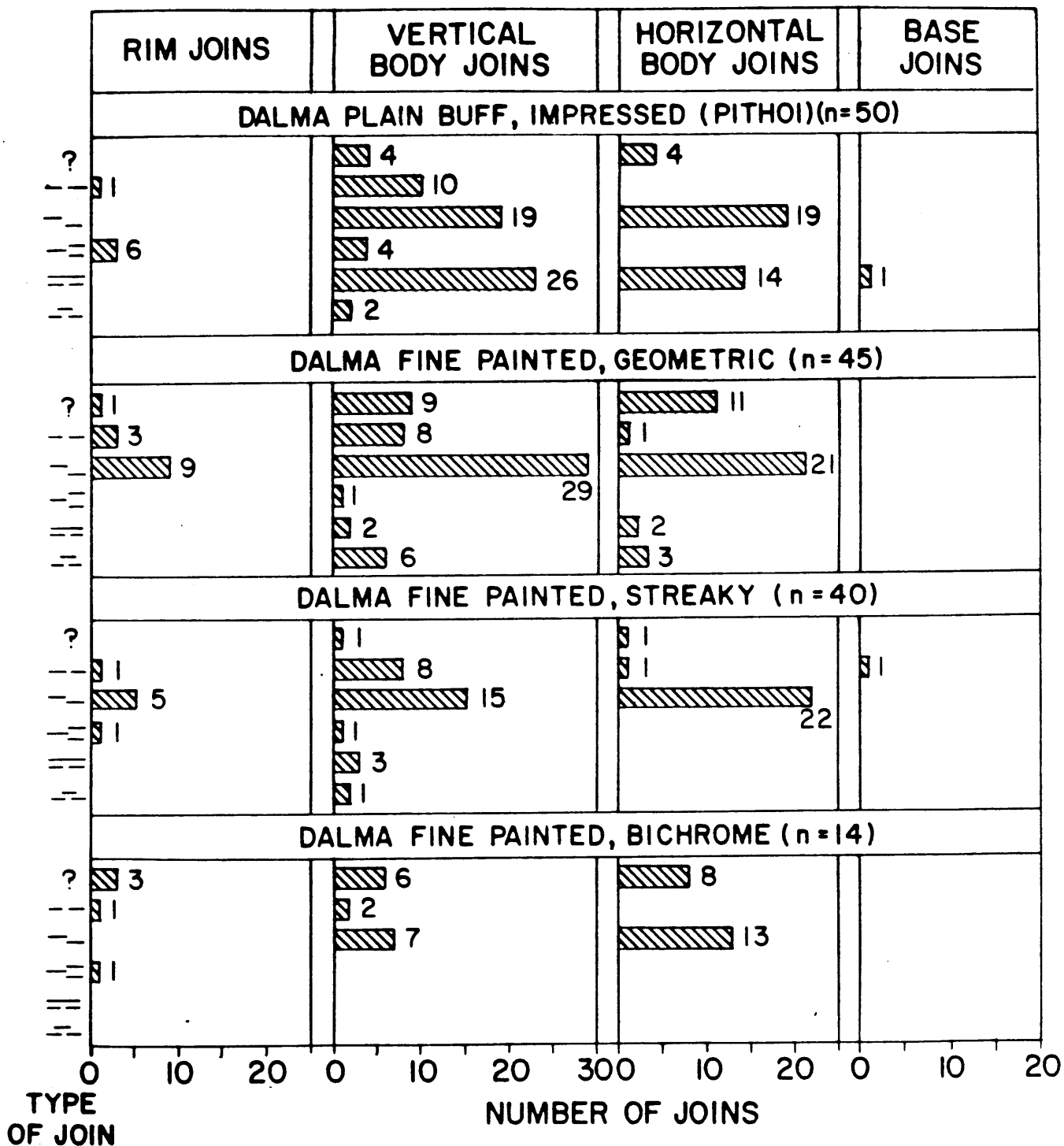


FIGURE 49. Frequency and Type of Joins from Seh Gabi Mound B, Dalma Period, Continued.

Table 17. Number and Percent of Each Join Type
from Mounds C and B at Sah Gabi

Type of Join	No. of Joins	% of Ea Type	No. of Joins	% of Ea Type	No. of Joins	% of Ea Type
	Mound C Coarse Ware		Mound B Dalma Plain Buff Coarse Wares		Mound B Dalma Red Slipped Coarse Wares	
?	63	16.6	4	6.0	4	4.2
Butt	70	18.4	15	22.4	20	20.8
Bevel	155	40.8	31	46.3	40	41.7
2 to 1	19	5.0	5	7.5	16	16.7
Double Wall	45	11.8	9	13.4	7	7.3
Reinforced	28	7.4	3	4.5	9	9.4
Total	380	100.0	67	100.0	96	99.9
	Mound B Dalma Red Over White Slip		Mound B Dalma Red Slipped and Impressed		Mound B Dalma Plain Buff Impressed Small	
?	4	7.5	11	21.2	11	8.9
Butt	13	24.5	9	17.3	28	22.8
Bevel	20	37.7	22	42.3	52	42.3
2 to 1	4	7.5	2	3.8	5	4.1
Double Wall	10	18.9	8	15.4	24	19.5
Reinforced	2	3.8	0	-	3	2.4
Total	53	99.9	52	100.0	123	100.0
	Mound B Dalma Plain Buff Impressed Large		Mound B Dalma Fine Painted Geometric		Mound B Dalma Fine Painted Streaky	
?	8	7.3	21	19.8	2	3.3
Butt	11	10.0	12	11.3	11	18.0
Bevel	38	34.5	59	55.7	42	68.9
2 to 1	10	9.1	1	0.9	2	3.3
Double Wall	41	37.3	4	3.8	3	4.9
Reinforced	2	1.8	9	8.5	1	1.6
Total	110	100.0	106	100.0	61	100.0
	Mound B Dalma Fine Painted Bichrome		Mound B Dalma Wares Totals			
?	17	41.5			82	11.6
Butt	3	7.3			122	17.2
Bevel	20	48.8			324	45.7
2 to 1	1	2.4			46	6.5
Double Wall	0	-			106	15.0
Reinforced	0	-			29	4.1
Total	41	100.0			709	100.0

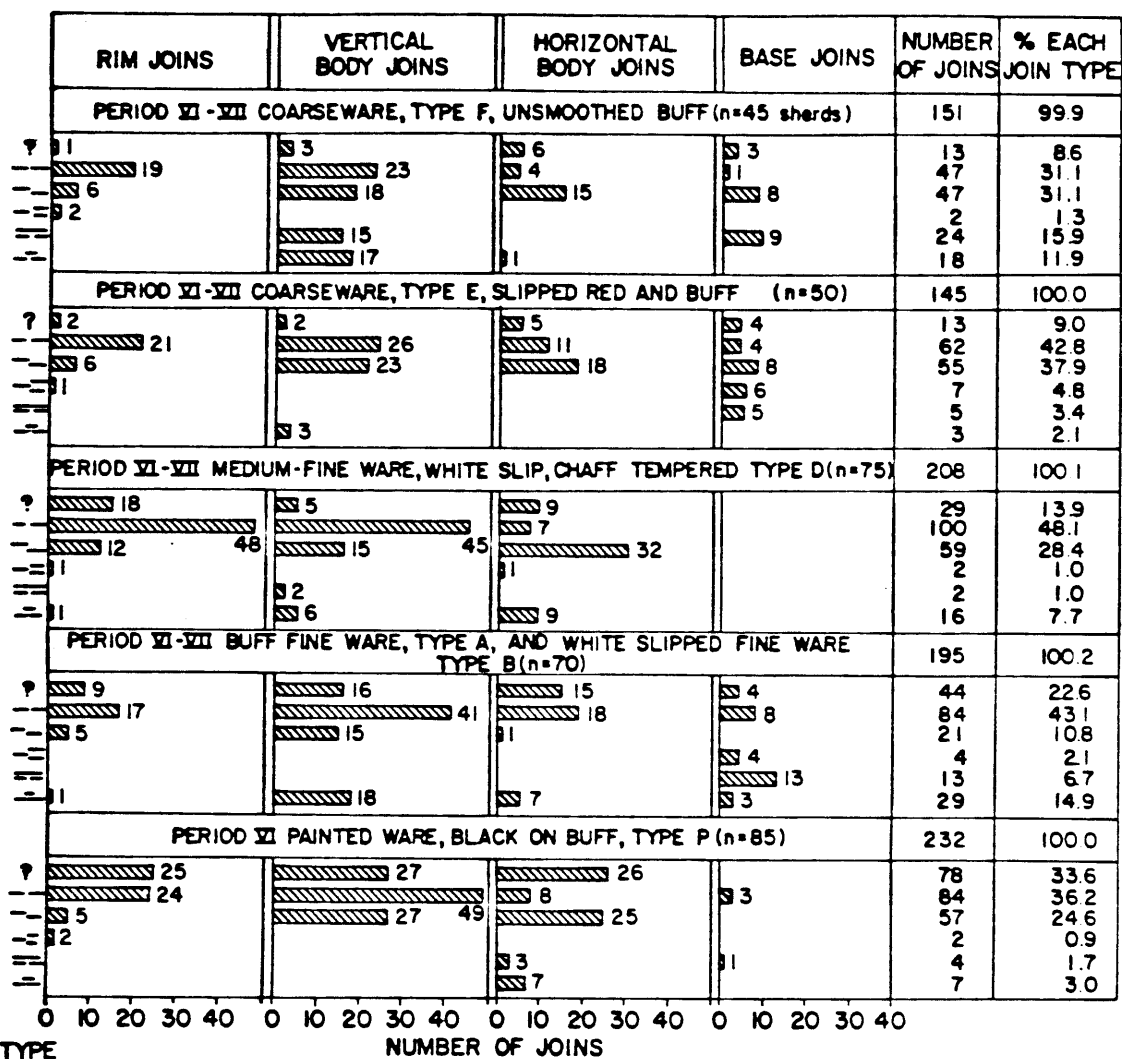


Figure 50. Frequency and Type of Joins from Mounds A and E, Godin Periods VI and VII.

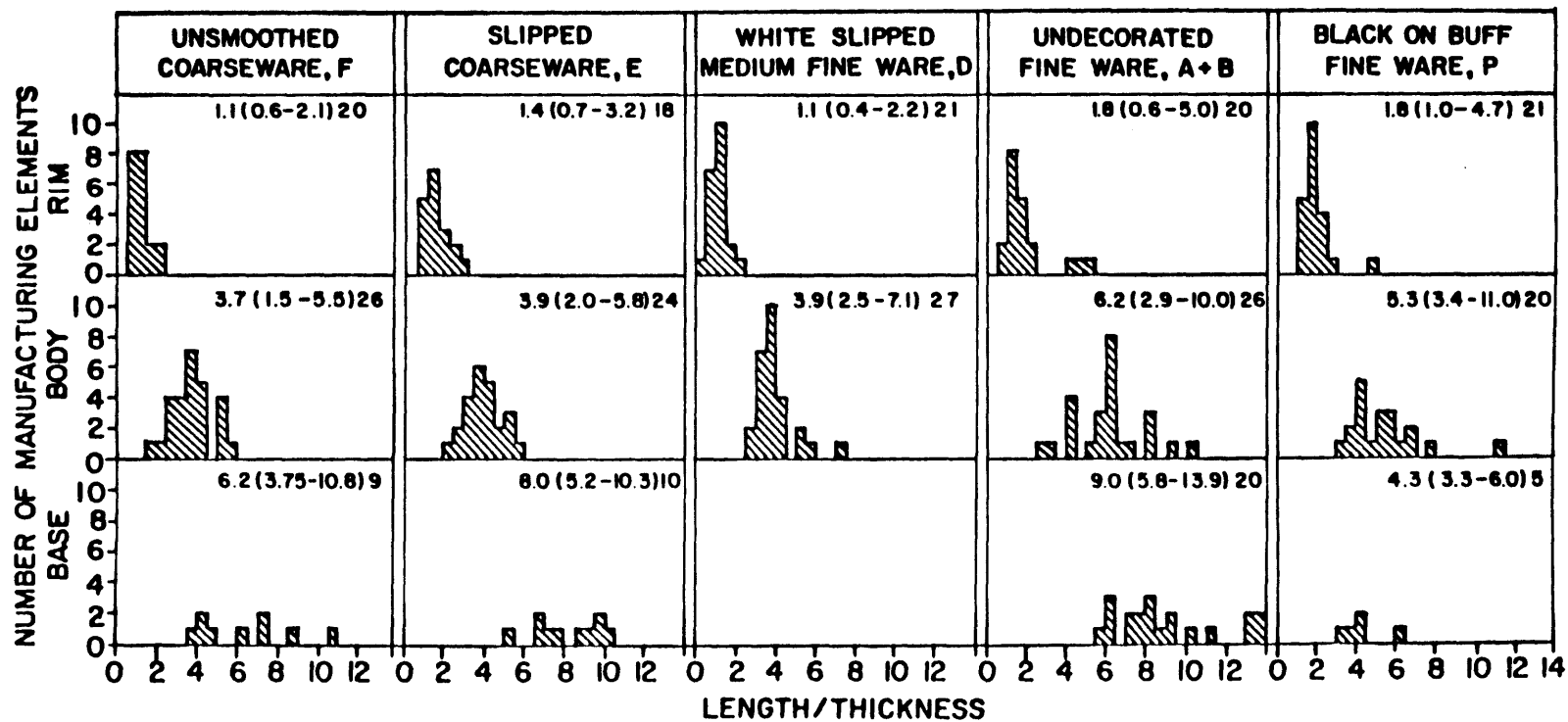


Figure 51. Relative Size of Manufacturing Elements from Mounds A and E, Periods VI and VII, Coarse and Fine Wares.

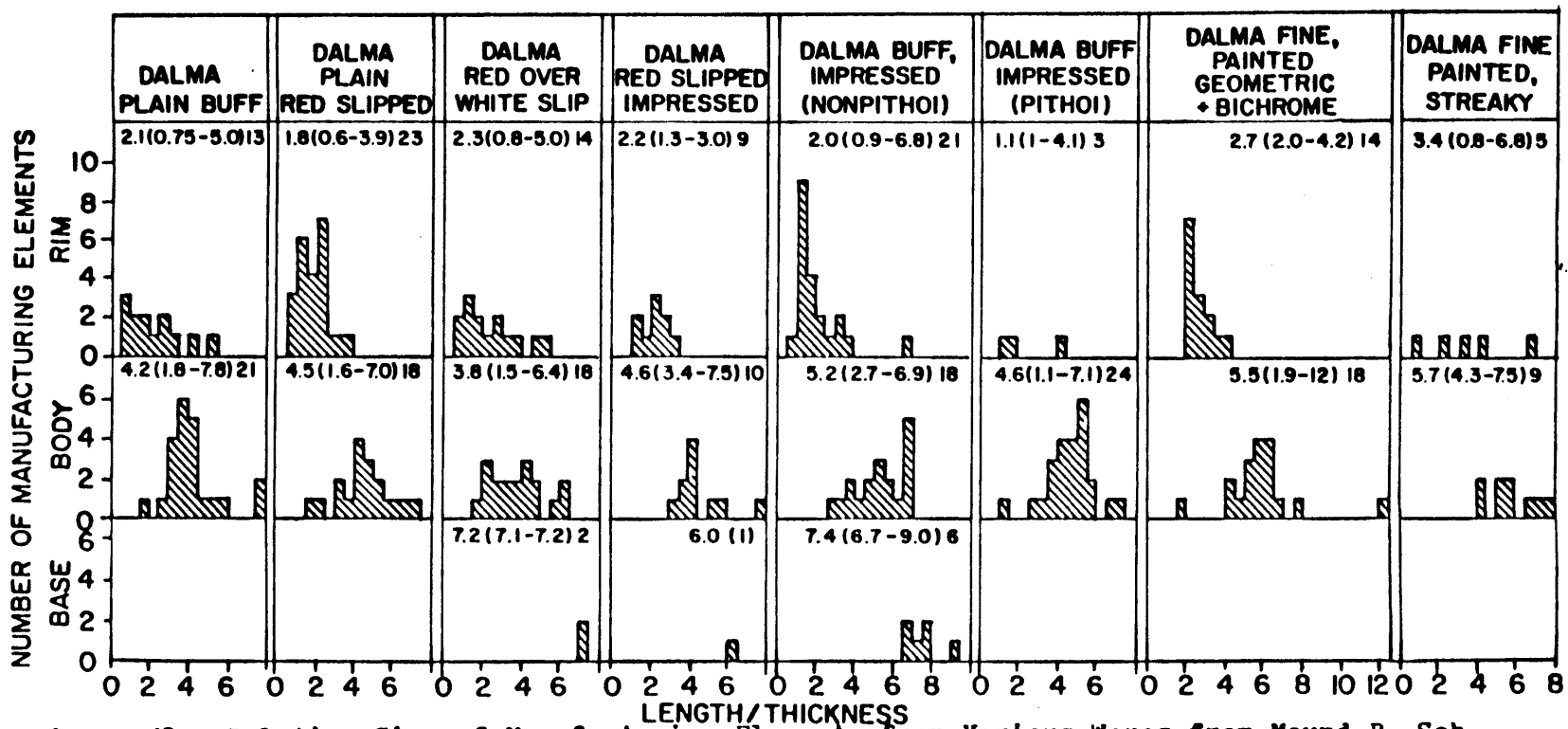


Figure 52. Relative Size of Manufacturing Elements from Various Wares from Mound B, Seh Gabi, Dalma Period.

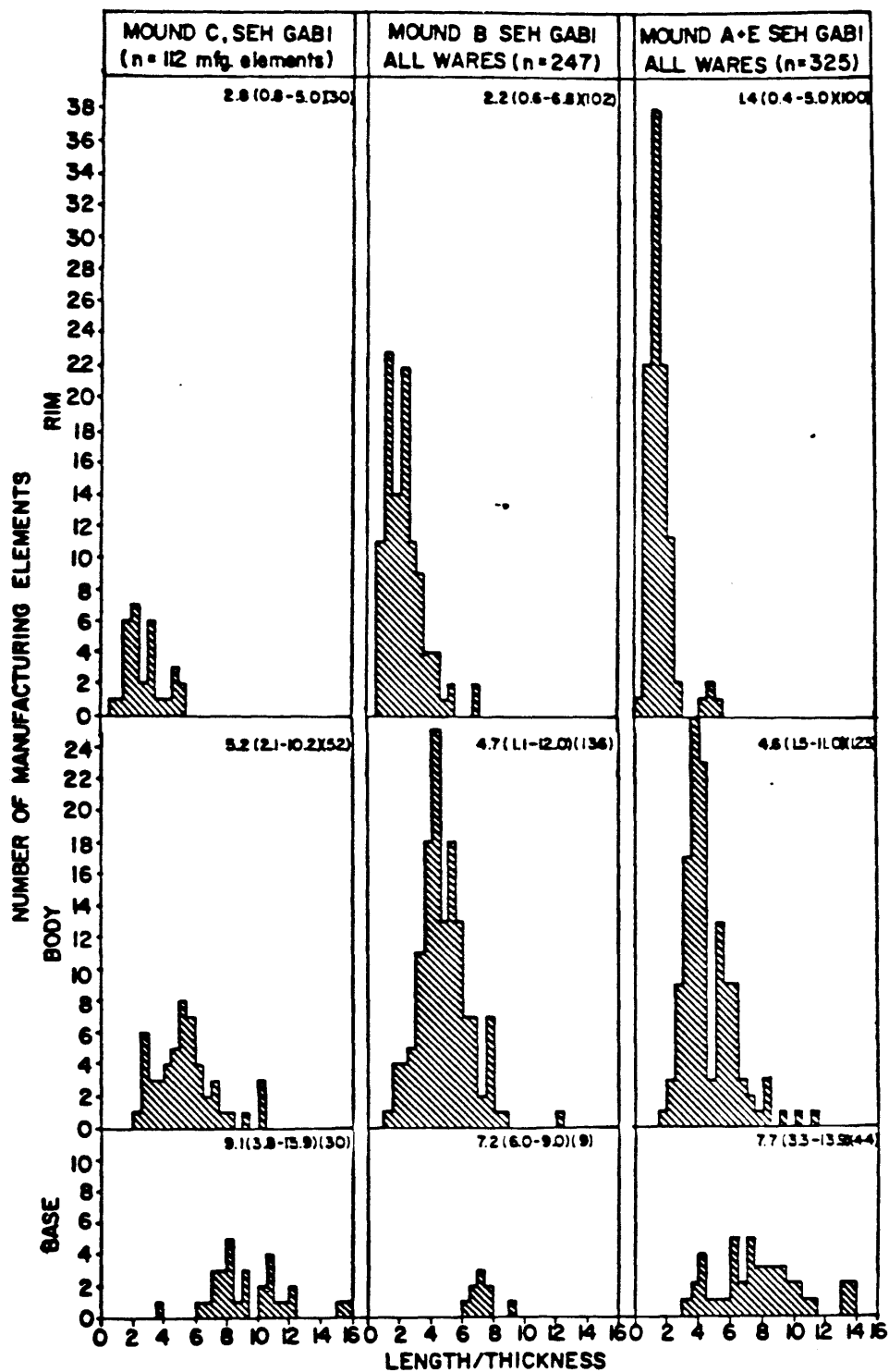
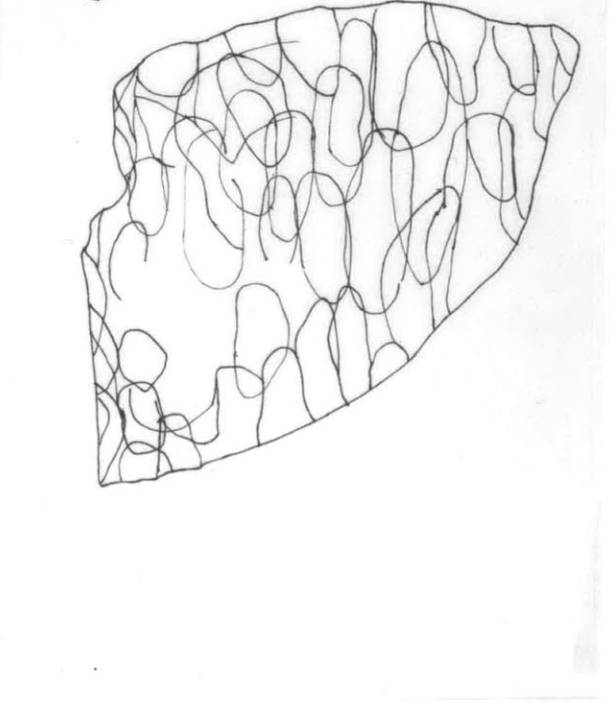
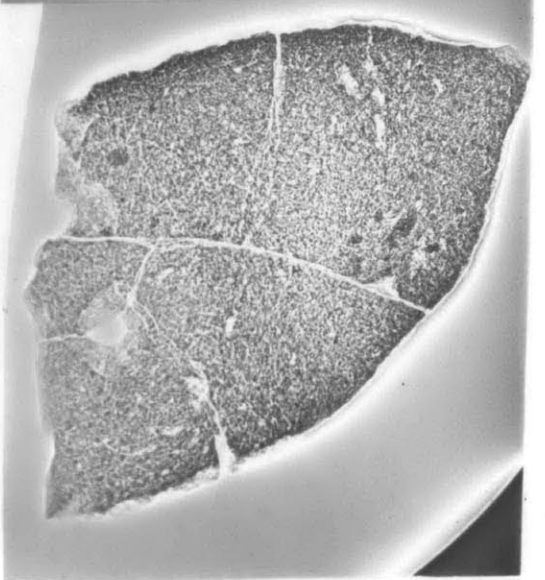
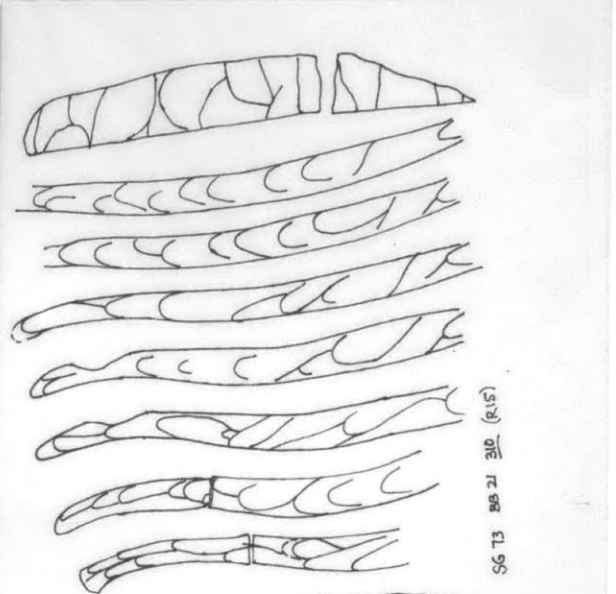
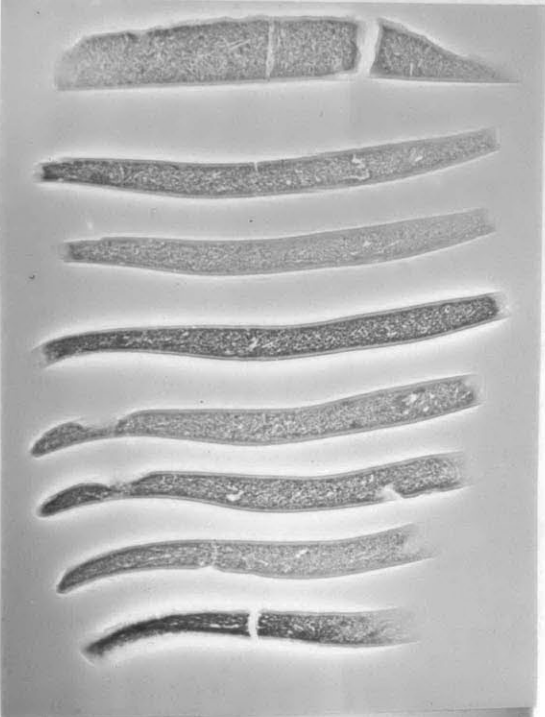
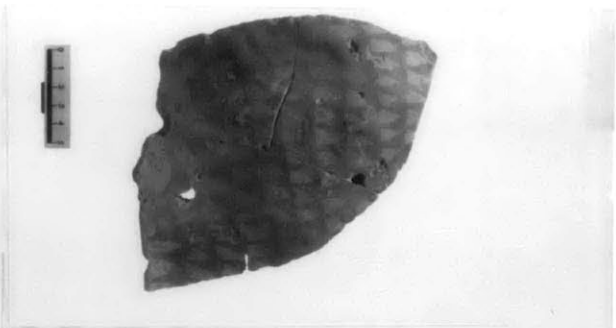
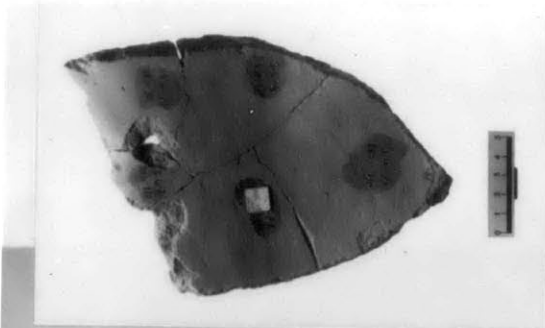
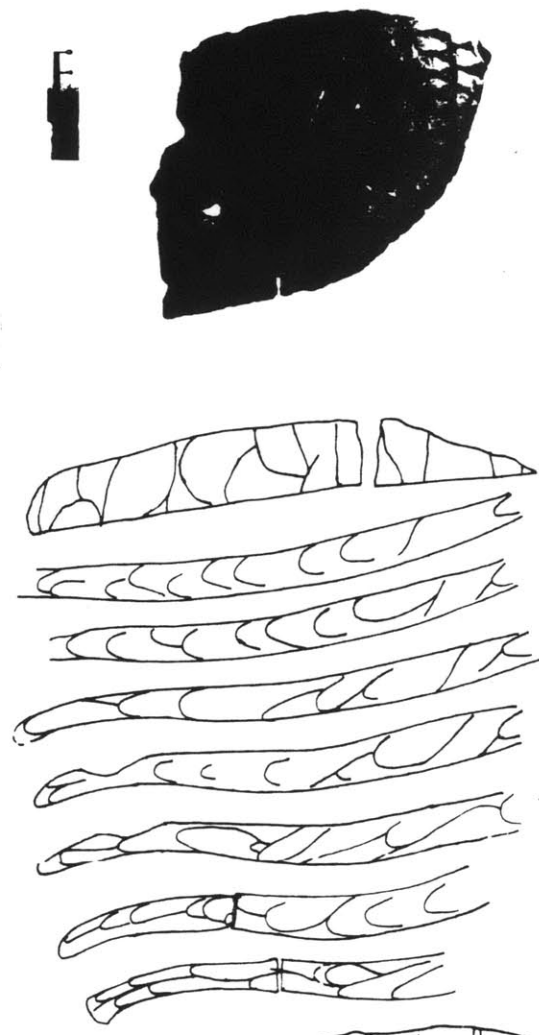
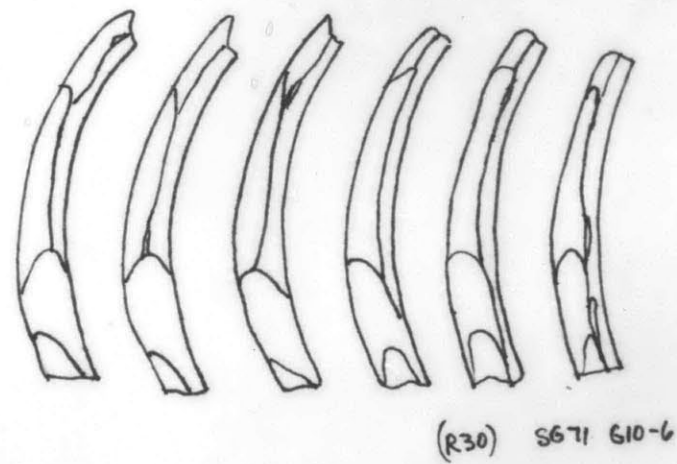
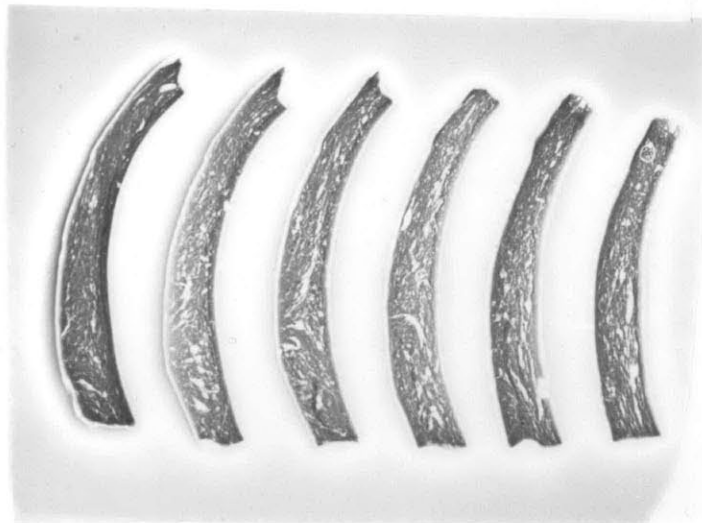
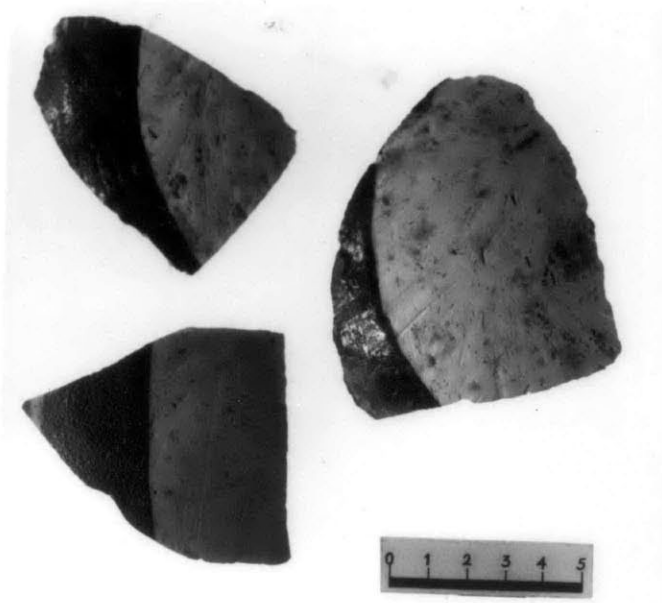


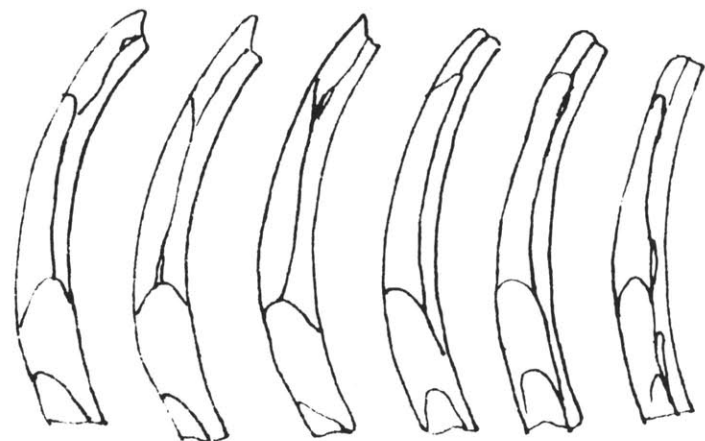
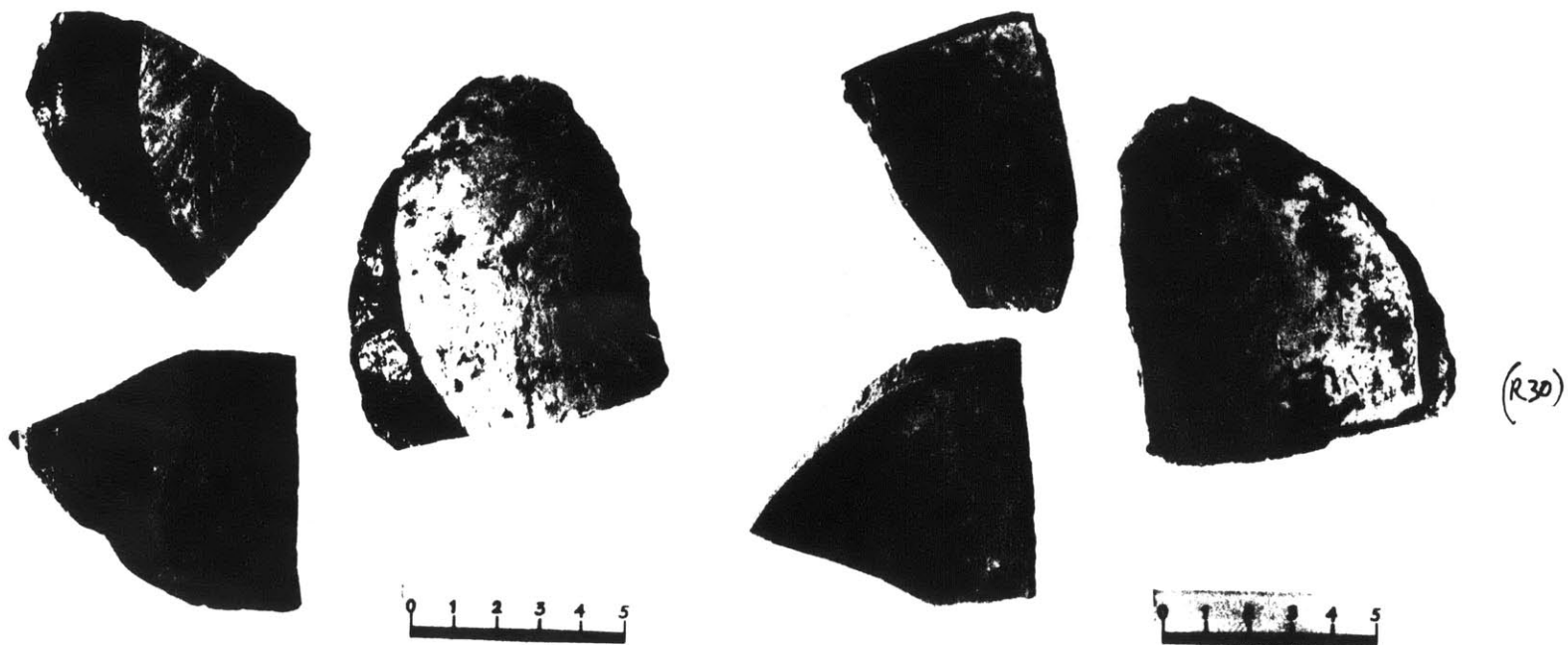
Figure 53. Relative Size of Manufacturing Elements Used in the Rim, Body and Bases of Wares from Seh Gabi in the Shahnabad (Mound C), Dalma and Seh Gabi (Mound B), and later periods VI and VII (Mounds A and E).





S6 73 89 21 310 (R15)
FIG. 54





(R30) 5671 610-6

6. Chagha Sefid: A Similar Pattern with Evidence for Molding

At Chagha Sefid, the same pattern of manufacture is found as for the pottery of Yahya, Hajji Firuz and Seh Gabi. Ware types, separated in the site publications by placement or occurrence of slip or paint were found to be the same in body fabric and method of construction as the plain ware. For instance, Jaffar painted and plain and Khazineh red are indistinguishable from the point of view of their construction, and similarly the 5 different quite fine slipped wares, the Sefid wares, seem primarily distinguished by variations in the oxidation state of the kiln during firing not by method of construction. The fine Susiana wares with no organic temper and the fine organic tempered Sialk black-on-red ware are constructed in a way similar to the coarse wares. The radiographs show quite well the variation in organic temper.

At Tepe Farukhabad about 3200 B.C. (Jemdet Nasr Period) there are small beakers or cups with string cut bases which have evidence of having been thrown, both in surface texture and edge fracture. Yahya has similar small beakers which were thrown at about the same time, 3000 B.C. The same gradual transition to a slow turning wheel is found in the Susiana black-on-buff wares as found at Tepe Yahya, Seh Gabi and Dalma-Pisdeli. The sequence from Chagha Sefid, Tepe Sabz and Tepe Farukhabad however is more complicated not only by the many ware types, but also by variations of such intangibles as quality of manufacture. For instance, the Tepe Farukhabad black-on-buff wares are poorly made and of low quality in terms of both designs and technical flaws compared with the high quality Mehneh wares, which have outstanding designs, and thin, even walls in comparison. This variation in quality bears further investigation and quantification. In addition many of the wares change from organic to grit temper as well as in

details of manufacture from one period to the next.

In examining the Sefid and Sabz pottery several vessels were found which had wide flaring walls just above the base and rounded bottoms and few with a double exterior carination, one at the base and another just above it, both of which may be taken as circumstantial evidence of molding. Both Halaf and Dalma Period pottery are characterized by rounded, convex bases and thin walls best formed in a mold. The Hajji Firuz basket impressed bases also were made using a template, but there are very few of them, and only one certain example of a wall fragment. Similarly, J.-F. Jarrige has examples of basket impressions, although how common are such impressions must be determined. There is no direct evidence such as basket impressions at Chagha Sefid, but a very few of the Jaffar wares meet criteria for molding of the base, namely the wide flair of the wall near the base. However, many of the Sefid wares have wide flaring walls near the base, as well as the thinner walls which use of a mold would entail. Thus, for the Jaffar wares, the use of molds was probably limited, but became more common for the Sefid wares. If we use David Pye's idea that craftsmen limit the risk of manufacture by using templates wherever possible, we should not be surprised to find molds being used frequently in each period. However, there seems to be a difference between less than 1-5% of an assemblage having basket impressions (as at Hajji Firuz), and the ubiquitous round bottom shapes of Dalma and Halaf pottery which suggest mold use. Thus we conclude that the fifth millennium pottery has strong circumstantial evidence for widespread mold use.

Evidence of the method of sequential slab construction was found in each of the samples of ware reported in Figures 55-60 and also in a sample of fine ware from Halaf and Chagar Bazar (Figures 61-62).

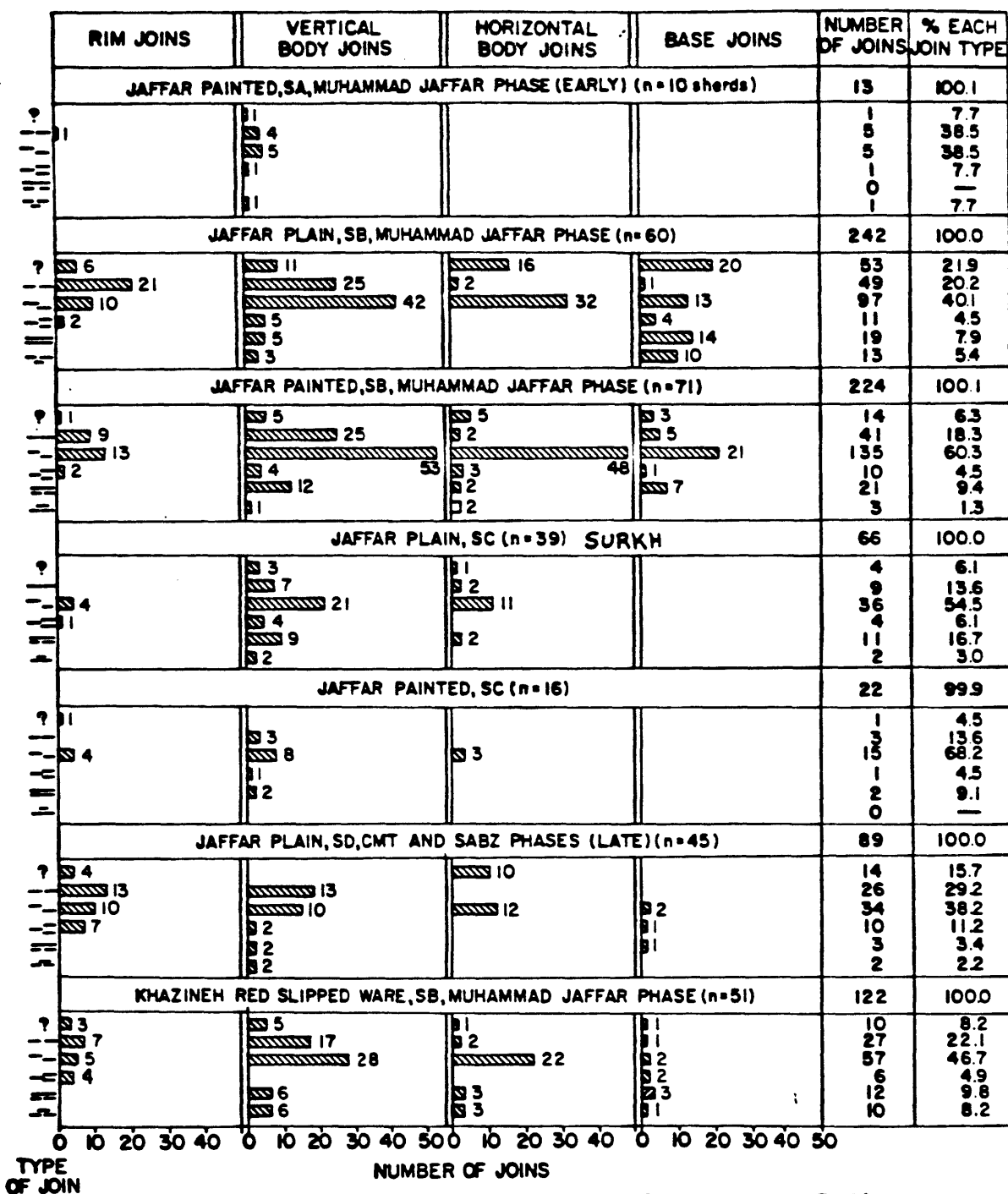


Figure 55. Frequency and Type of Joins from Chagha Sefid Coarse Wares, Jaffar through Sabz Phases.

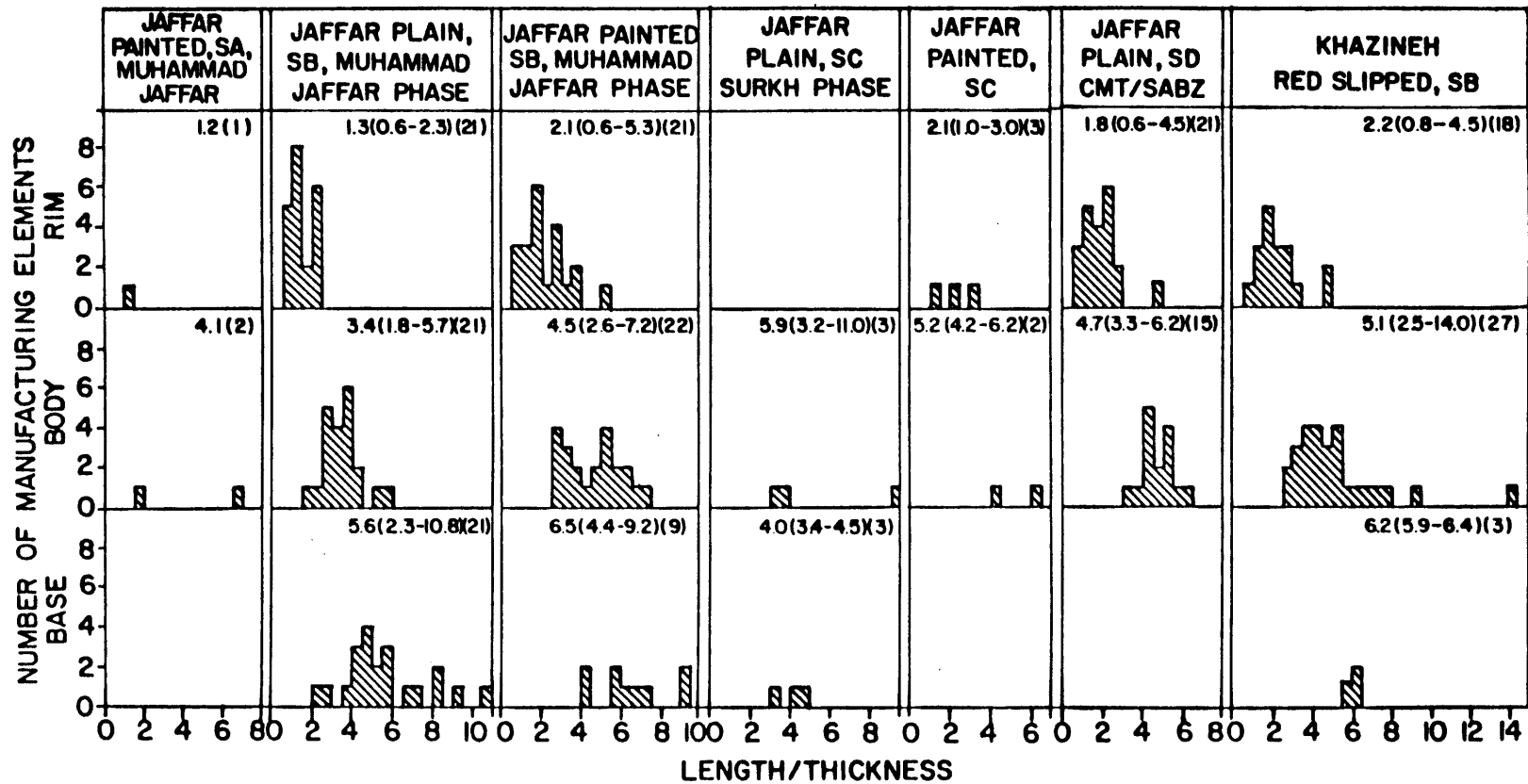


Figure 56. Relative Size of Manufacturing Elements from Early Period Coarse Wares at Chagha Sefid, Reported as Mean, Range of Values and Number of Manufacturing Elements Measured.

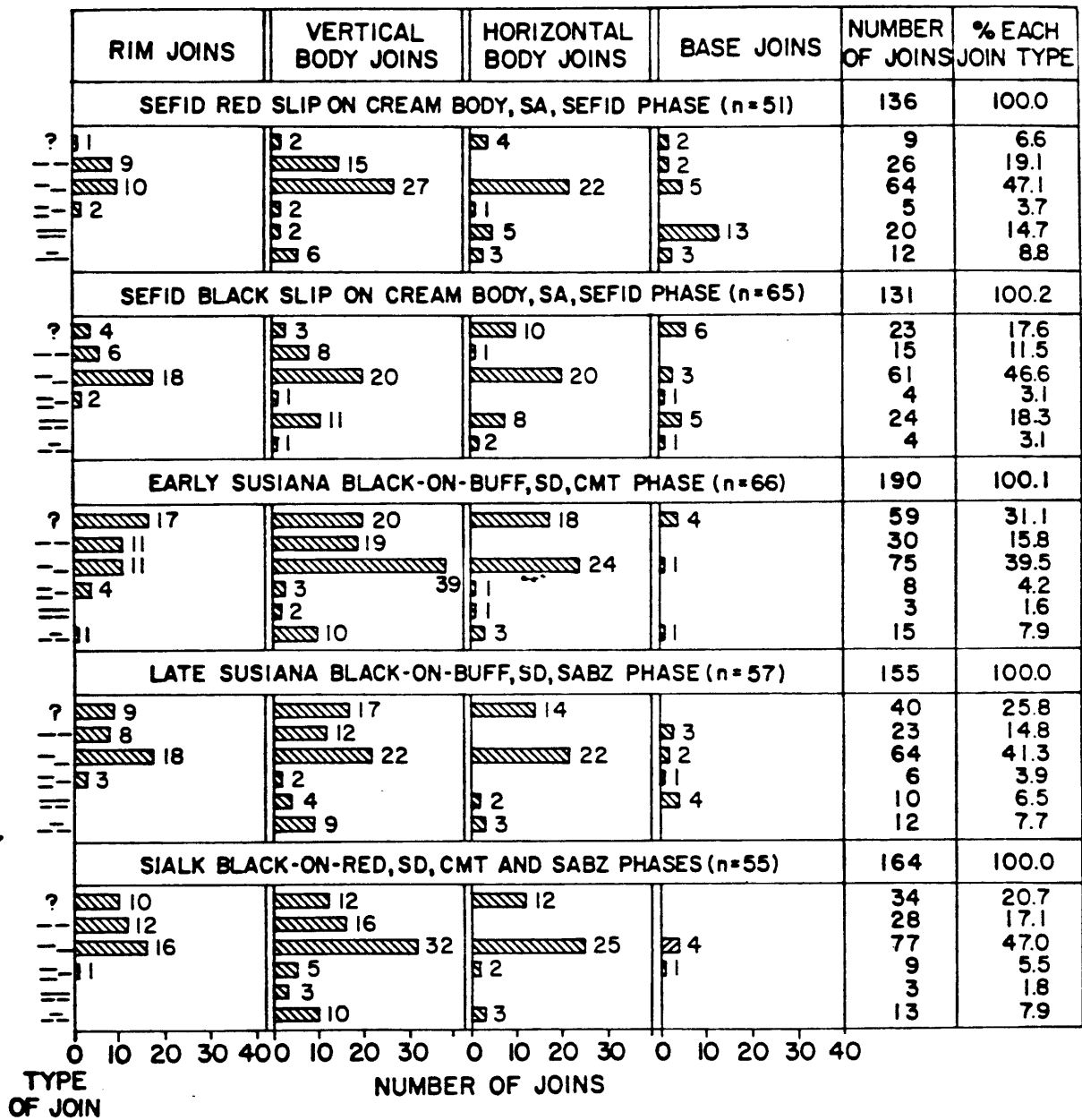


Figure 57. Type and Frequency of Joins in Fine Wares from Chagha Sefid, Sefid through Sabz Phases.

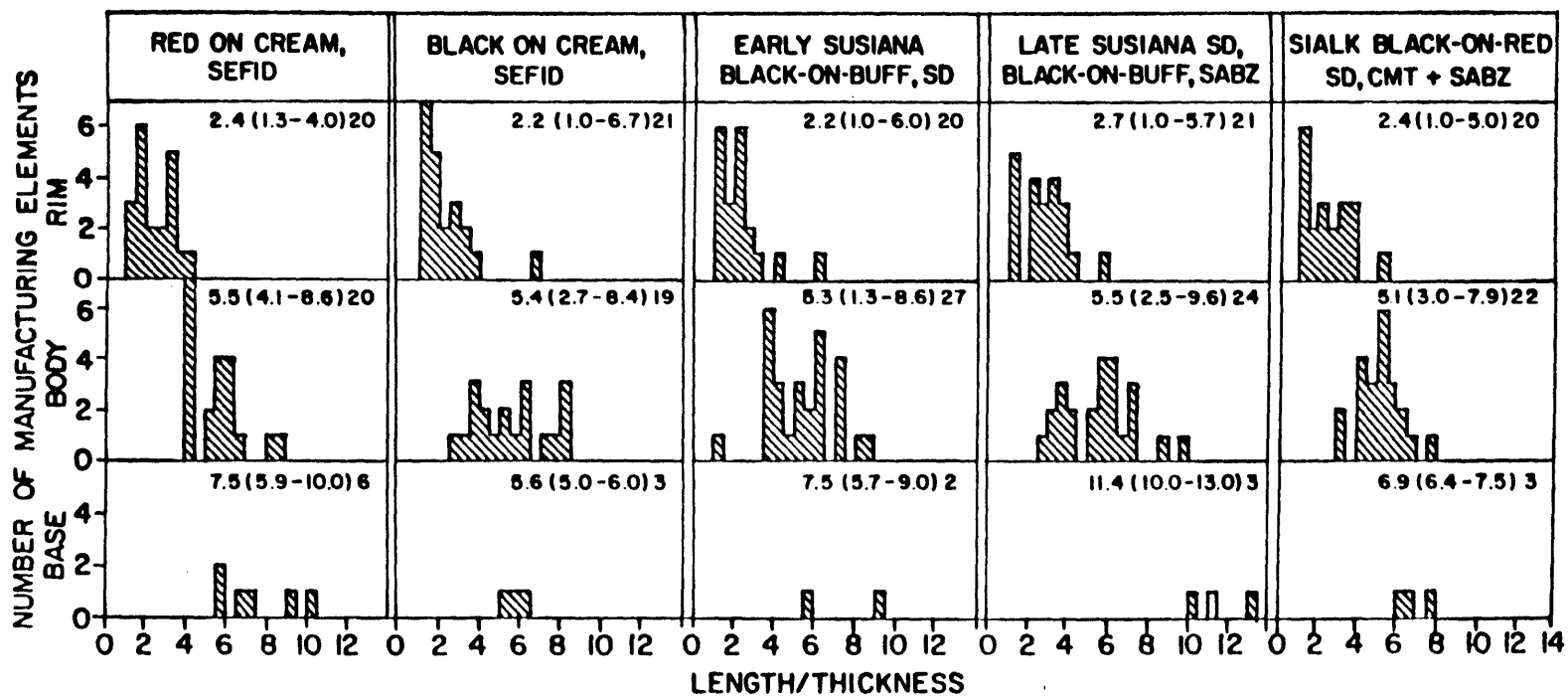


Figure 58. Relative Size of Manufacturing Elements from Chagha Sefid Fine Wares, Sefid through Sabz Phases.

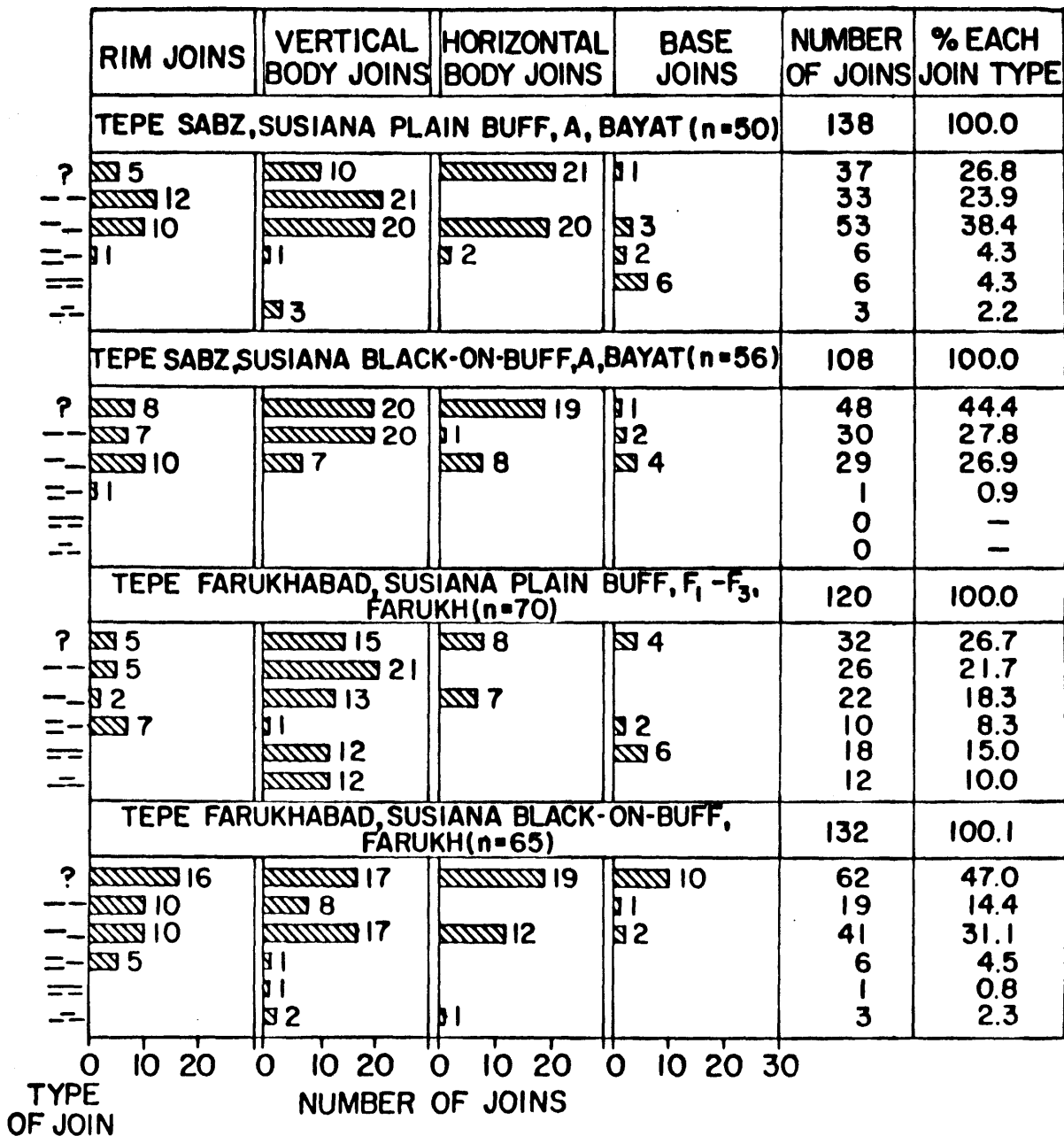


Figure 59. Type and Frequency of Joins in Wares from Tepe Sabz, Bayat Phase, and from Tepe Farukhabad, Farukh Phase.

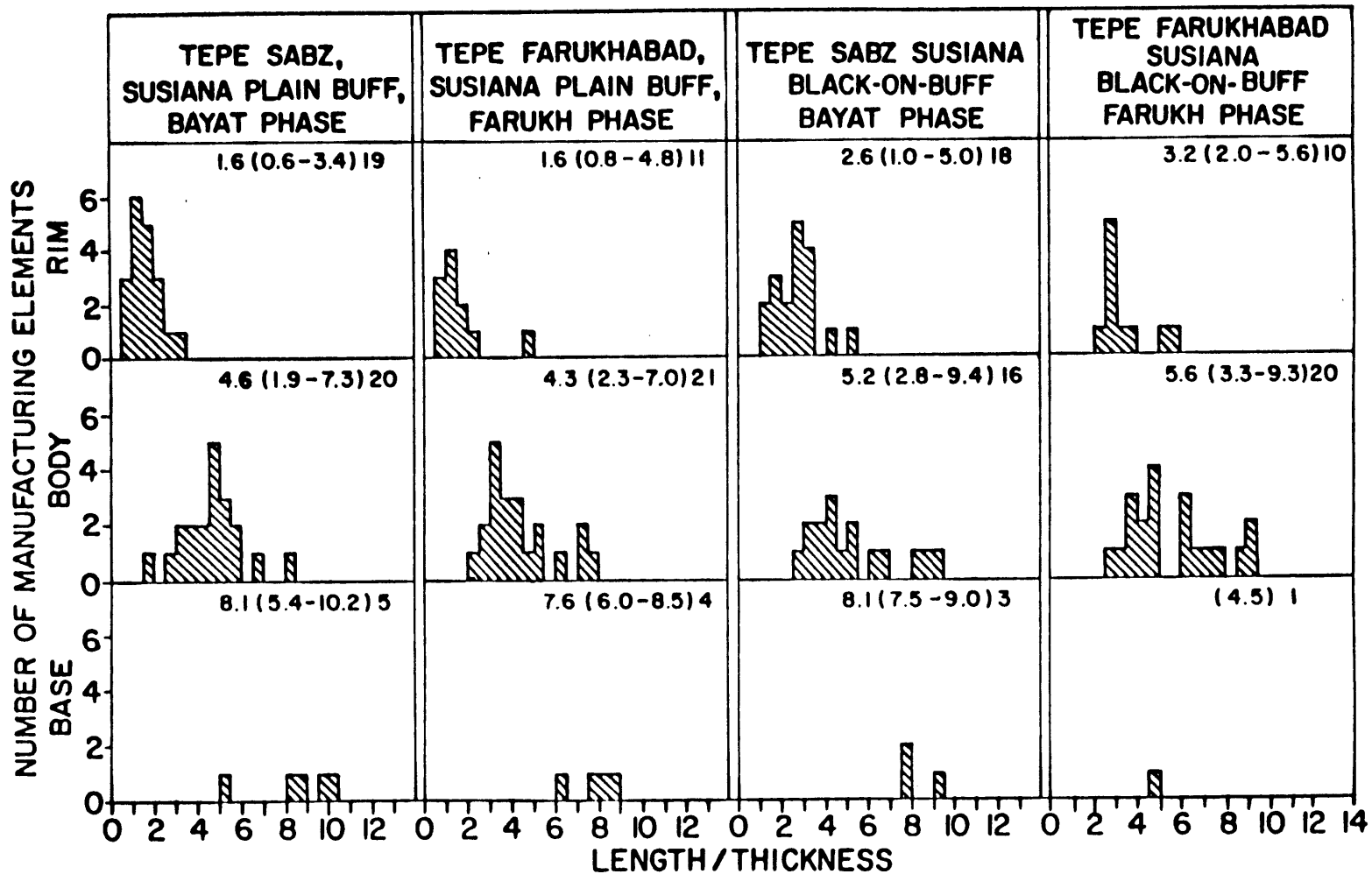


Figure 60. Relative Size of Manufacturing Elements from Tepe Sabz, Bayat Phase and Tepe Farukhabad, Farukh Phase, in Plain Buff Coarse Ware and Susiana Black-on-Buff Ware.

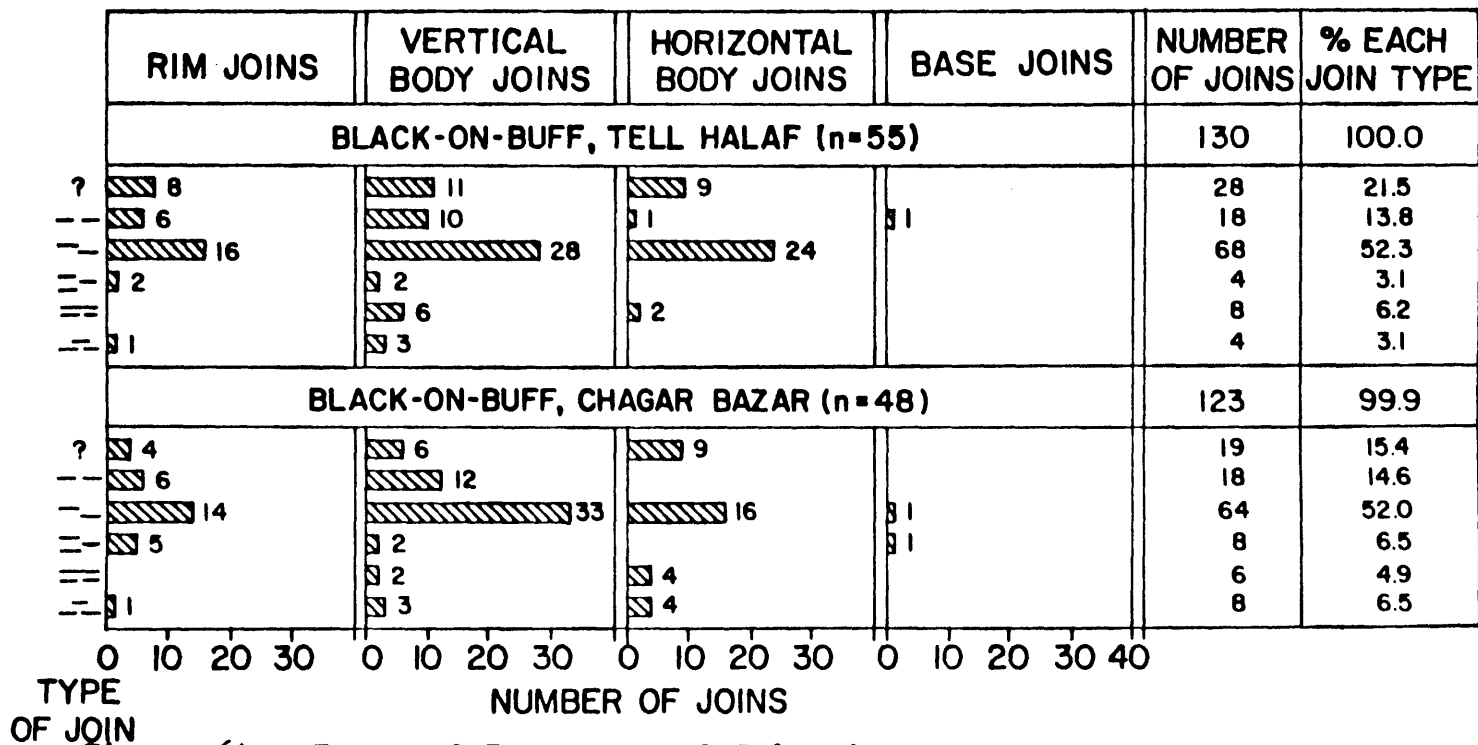


Figure 61. Type and Frequency of Joins in Black-on-Buff Halaf Ware from Halaf and Chagar Bazar.

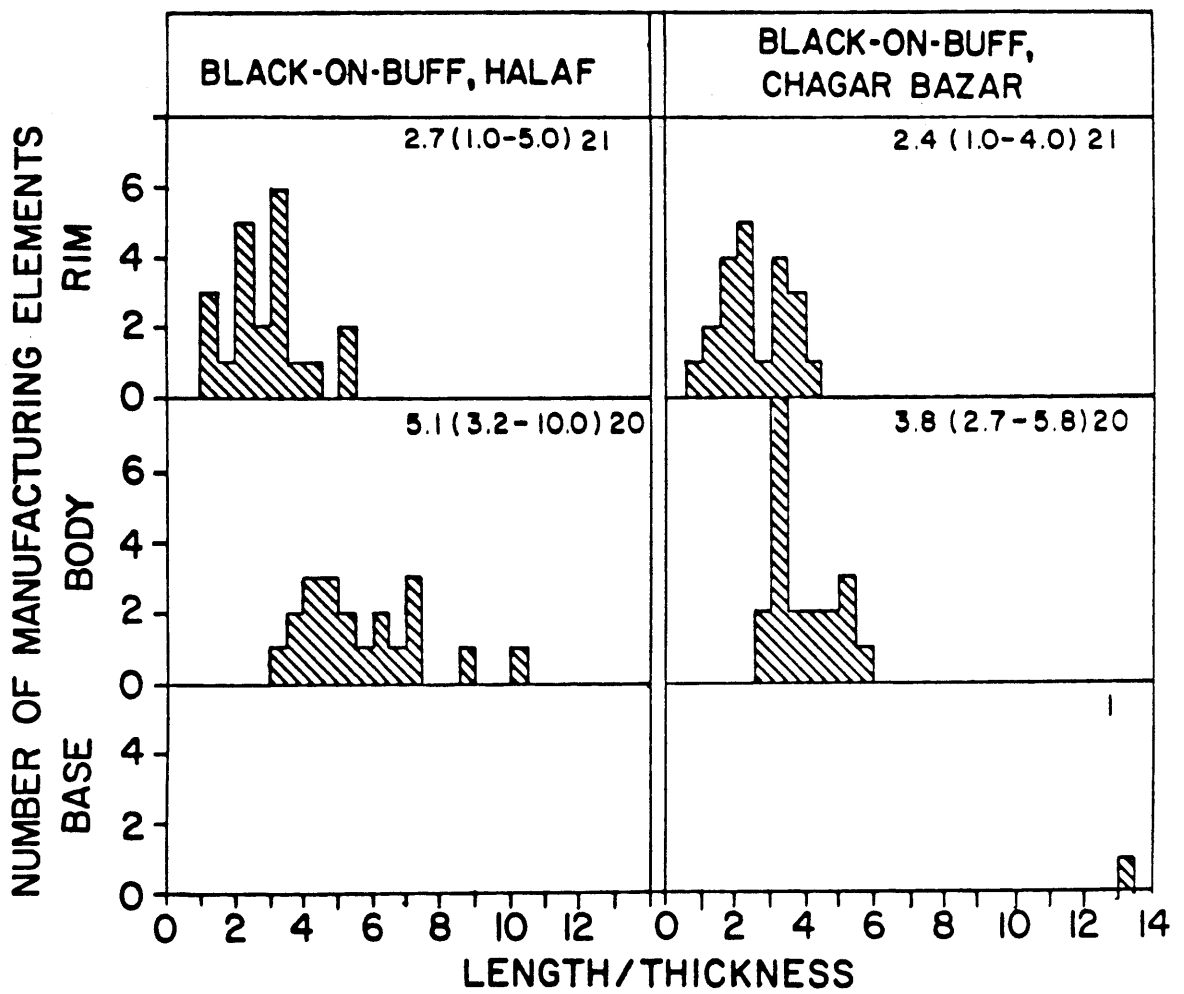
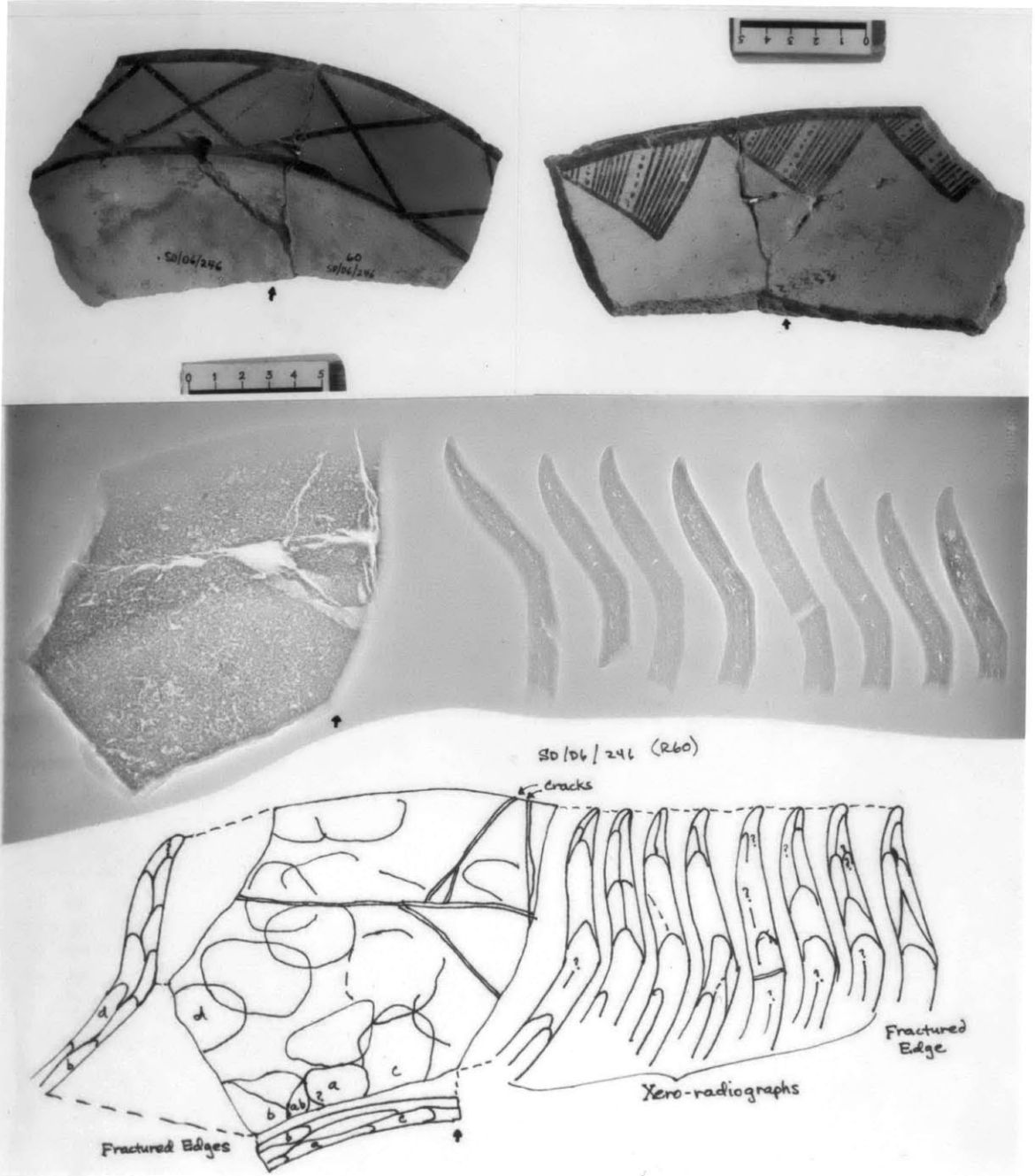
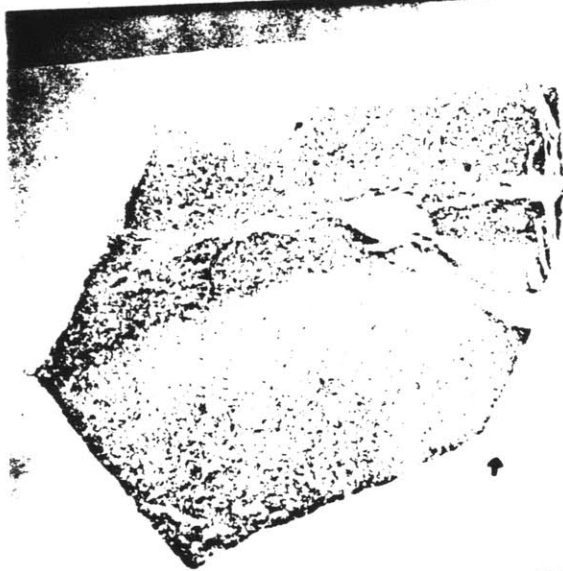
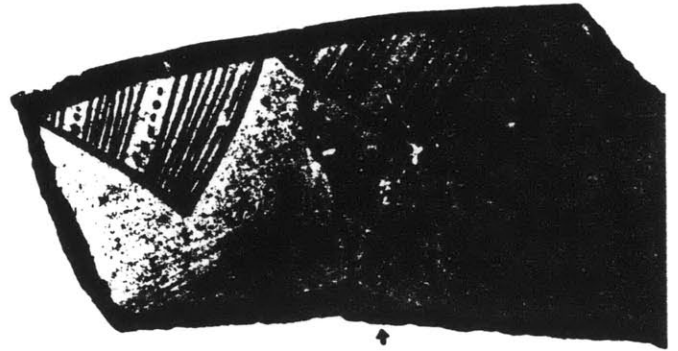
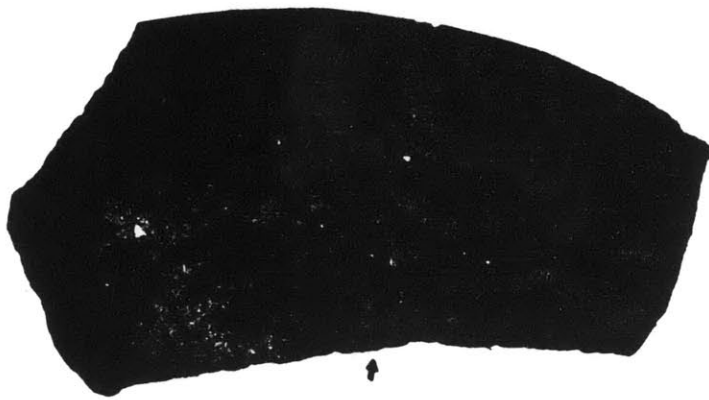
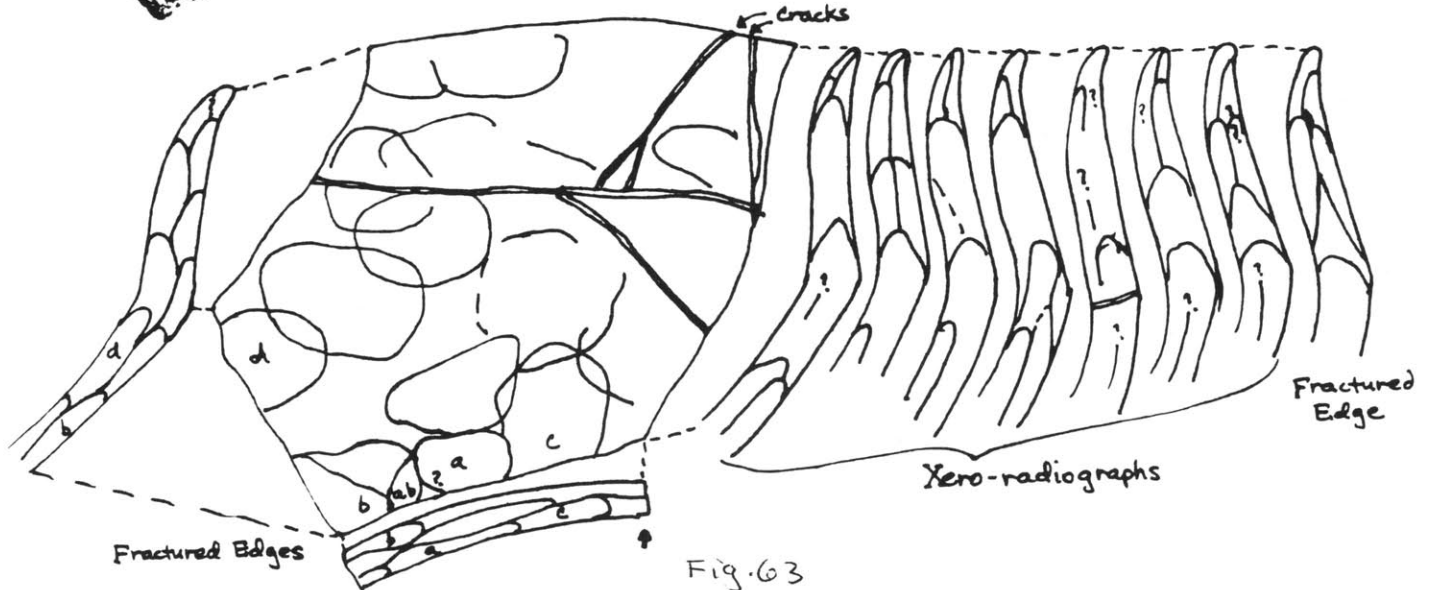


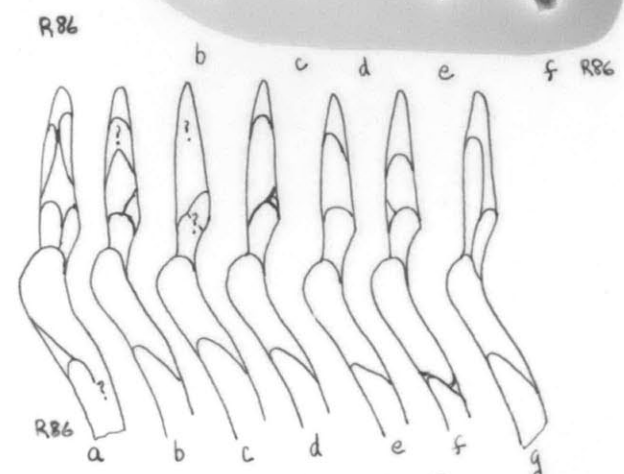
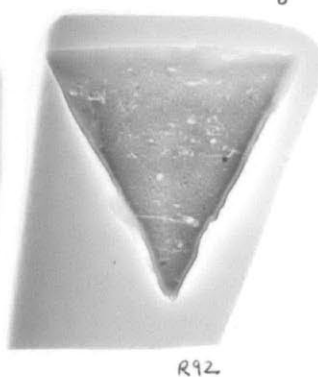
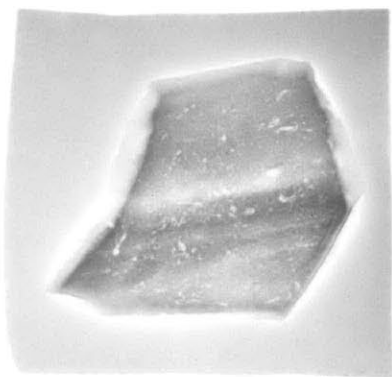
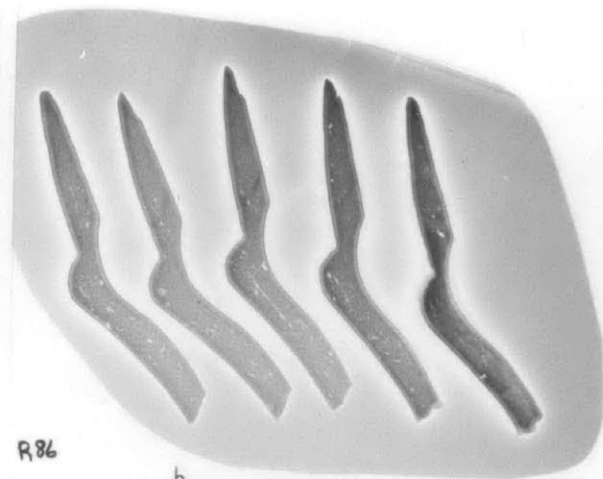
Figure 62. Relative Size of Manufacturing Elements from Halaf and Chagar Bazar.





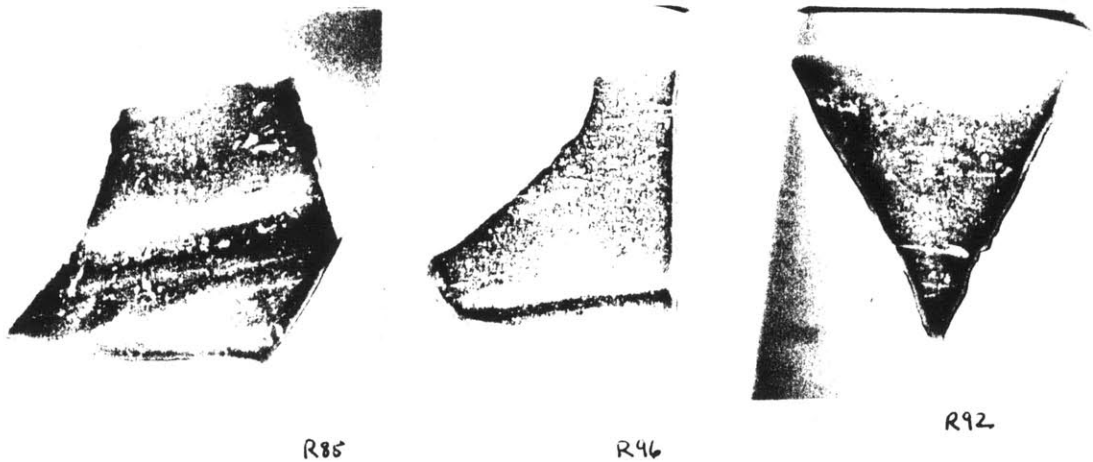
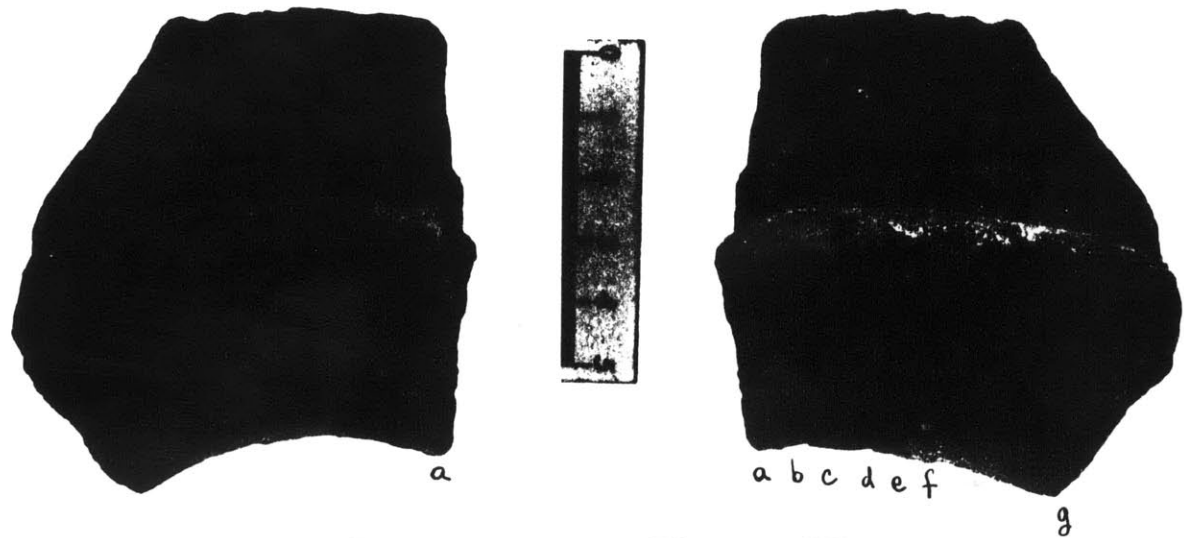
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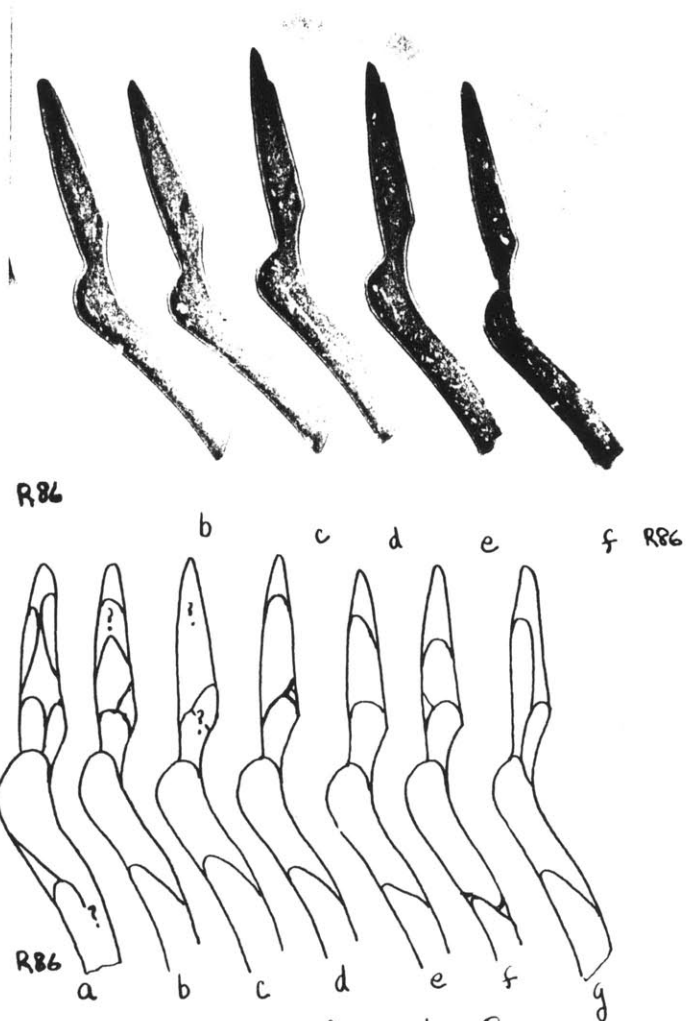
Xero-Radiographs of similar bowls, Tell Halaf

a and g are fractured edges. b to f are drawings of xero-radiographs.



Xero-Radiographs of similar bowls, Tell Halaf

Fig.63, cont.



a and g are fractured edges. b to f are drawings of xero-radiographs.

7. Pakistan and Egypt: The Probable Extent of S.S.C.

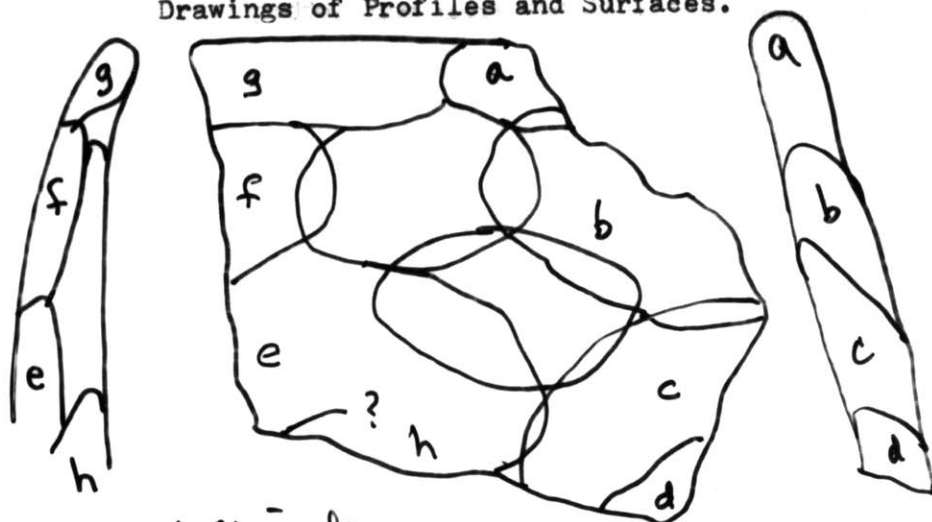
Instances of the same sequential slab construction of neolithic and chalcolithic pottery was found in Egypt at Merimde, a large delta site, and at Mostegedda, a cemetery near Badari, as well as at Mehrgarh in Pakistan. Visual examination of the surface textures of pottery in the British Museum and Boston Museum of Fine Arts from Mostegedda indicates that slabs were used in construction. In addition, radiographs of seven Merimde sherds and one Mostegedda jar were made along with drawings and measurements of the cross sections, as presented in Figure 64. This method of manufacture appears to continue through the Amratian and Gerzean periods, with some of the Gerzean vessels having a lip formed by throwing.

The early coarse ware pottery from Mehrgarh was only examined with a 10x loupe and then only very few examples which had been brought back to Paris. Visual examination of a large selection of over one-hundred coarse ware pottery sherds by R. Meadows during the 1984-85 field season revealed the common presence of butt and bevel joins in the walls and also of probable basket impressions concealed in the walls of many sherds. The size and regularity of these impressions will be measured during the next season in Mehrgarh. The findings may require the re-examination of pottery from Hajji Firuz.

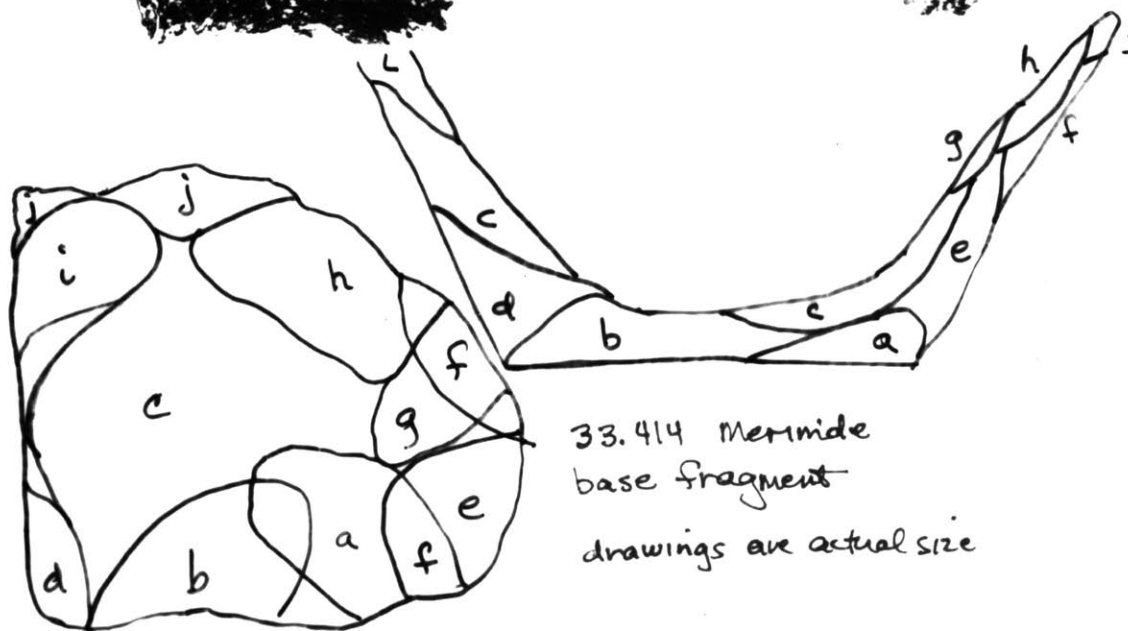
This attempt to study small samples from the far extremes in geographical extent of the Near Eastern culture area or sphere of influence was largely unsatisfactory. We had hoped to demonstrate the spatial extent of sequential slab construction. Although slab construction was found in both Egypt and Pakistan, not enough detail could be amassed with so few samples to show the differences as well as the nature and extent of the similarities. The result is a topic for further investigation rather than

unambiguous, fully reliable and interpretable data. The conclusion which can be drawn from this survey is that the vegetal tempered pottery of lower and upper Egypt as well as that from Pakistan bears considerable resemblance in fabric and method of manufacture to that from the Zagros region, but the nature and extent of this similarity bears further study.

Figure 65. Xero-radiographs of Merimde Coarse Ware and Drawings of Profiles and Surfaces.



33.416b Merimde
rim of bowl



33.414 Merimde
base fragment
drawings are actual size

B. IMPORTANT STEPS IN TECHNOLOGICAL DEVELOPMENT

To summarize and interpret the results discussed above, there are two features which stand out. One is that the technology is very conservative, having a wide spatial distribution and long time depth. The second is that the technology changes gradually. Aging of clay was a major rethinking of the way clay is made into pottery, but accounted for only a small amount of the pottery produced, and the pottery was constructed in the same sequential slab construction method even though any other method might have been used as the clay was fully plastic and no longer constraining on what could be made by being short and cracking during forming. Improvement in production by the use of a turn table for decorating, finishing and shaping was grafted onto the old technology with no basic change in the way the pottery was constructed. In addition, the complex technology of slips and paints required sufficient control that the technology was discontinuous, that is reinvented (or stored in another geographic region) compared with a simpler technological innovation like aging clay which was simple and could spread rapidly. Thus the main technological innovations are as follows:

1. Clay Preparation: A Major Technological Breakthrough to Fine Wares

We have documented a change in clay body preparation with the elimination of vegetal temper at four sites: Tepe Yahya, Period VC (ca. 4400 B.C.); Seh Gabi, Mound B, Dalma Period (ca. 4800 B.C.), Dalma (ca. 4800 B.C.), Chagha Sefid (ca 5600 B.C.) which spans about a thousand year period, being later at Yahya and earlier at Chagha Sefid. In order to form a montmorillonite clay body, without vegetal temper but containing grit temper, it is necessary to allow the clay to wet through. This type of clay has been well characterized in the ceramic literature (Singer and Singer 1963:63-67; R.W. Grimshaw 1971:506). It is known for very fine particle

size within the range of clay particle sizes, for a large shrinkage which leads to cracking during drying unless temper is used, and for the long storage time to achieve full plasticity. We hypothesize that finer, thinner wares were desired, that molds were used to form thin, rounded bottoms, that vegetal tempered bodies are difficult and tend to crack when formed in thin walls, and that another solution was found, which consisted of aging the clay to obtain maximum strength and plasticity during forming. (The thin walled bowls found at Sarab were made without molds in the vegetal tempered body and represent a refined ware, made with tour de force craftsmanship.)

Further, there is a relatively narrow bandwidth of time when this innovative change occurred. We hypothesize that this development was not an instance of independent discovery, but the result of technology transfer.

2. Improvements in Production Efficiency: The Turntable, Potter's Wheel and Spiral Coiling

Improvements in production efficiency occur in the mechanical means by which pottery is made. The turntable commences use between 5500 and 4500 B.C. for limited functions:

Table 18. Evidence of Limited Use of Turntable by Site

Function	Dalma	Seh Gabi (X)	Chagha Sefid	Tepe Yahya VI
// wet smoothing at rims	32%	25%	X	X
turning and shaping rims	Yes	?	?	Yes
banding of decoration	85%	30%	X	X

Later the turntable is used for more extensively for functions which determine shape:

Evidence for Use of Turntable for Shaping

	Pisdeli	Seh Gabi (IX)	Chagha Sefid	Tepe Yahya VB
// wet smoothing at rims	79%	80%	X	X
turning and shaping rims	Yes	?	?	Yes
banding of decoration	85%	89%	X	X
shaping walls*	X	X	X	X
trimming bases**	?	?	X	X

*Evidence in s.s.c. edge fractures combined with horizontally aligned pores and temper seen in radiographs.

**Evidence in vertical and horizontal scraping.

These developments occur later at Tepe Yahya and earlier at Chagha Sefid than at the other two sites. However, the same bandwidth of time and same general pattern is observed at all four sites.

Spiral coiling and the use of a wheel for the shaping of small vessels are later developments documented at Chagha Sefid, Seh Gabi and Tepe Yahya, between 3600-3200 B.C. These developments occur in a relatively narrow bandwidth of time and fit into the pattern of development seen at each site.

3: Slips, Paints and Washes: A Complex Chemical Technology Requiring Tight Processing Control Which Was Probably Reinvented

A general pattern of the development of slips, paints and washes emerges at each of the four sites: the northern region of Hajji Firuz, Seh Gabi, Sefid and Yahya, but in addition we see the refined stage in this recurring developmental sequence represented at the earlier site of Sarab. Either this technology disappeared and was reinvented or, one may argue, it was stored elsewhere and reintroduced. However, we know of no site intermediate in time with a technology comparable to Sarab.

The pattern of development at all four sites with a long sequence consists of the early use of red ochre (hematite, Fe_2O_3) as a fugitive red paint used to decorate a minor amount of the vegetal tempered coarseware pottery. Red ochre was found to be unstable as a fired paint or wash because it did not fuse. Subsequently it was mixed with clay to form a stable paint. This mixture was prepared separately from the clay body. Variations in the reduction-oxidation state of the firing are responsible for the color variation observed in the Dalma, Sefid and Lapui slipped wares, which range from red (comprising the majority of the ware) to buff,

grey and black with increasing reduction. There is also a variation in the durability and surface gloss of these slips which is independent of the degree of weathering and state of oxidation. We have not investigated whether this range of appearance is related to variation in composition in the best preserved of the red slips. We hypothesize that some form of potash flux may have been introduced in at least some of these wares to promote greater fusion and higher gloss, but this is a complex subject which requires separate study. A wide variety of black earths were used for the black painted wares, black-on-buff and black-on-red. They have been mixed with clay and with a potassia source, probably potash. These durable black paints represent a fully mature technology, which would be difficult to improve upon even today. This mature black paint technology is found in the Sarab three-colored ware without the developmental sequence, that is the combination of a pigment, clay and a flux. The data for these results is summarized below.

Table 19. Identification of Paint or Slip Composition by S.E.M. and E.D.S.

SITE/DESC.	RED	BLACK	WHITE	POTASSIA FLUX
Ganj Dareh	None	None	None	None
Sarab, SV	Fe+Clay	Mn+Minor Fe and Ti	Calcareous Clay	Yes, all 3
Hajji Firuz Fugitive Red Paint, HFV(3)Fl.1 (M. Voigt 1983:Pl. 8)	Fe	None	None	Not Used
Chagha Sefid Jaffar Painted, Fugitive Red, SB/A5/145(R16)	Fe	None	None	Not Used
Chagha Sefid Susiana Black-on-Buff, SD/B9-10/356(R41)	None on Ware	Fe+Minor Mn	None	?
Chagar Bazar Halaf Black-on-Buff (R75)	Not Analyzed	Fe+Minor Ti, Mn, Cr	None	Yes
Survey J-Ware, Md 75-095-61(R11)	Fe	Fe+Minor Mn and Ba	Calcareous Clay	Yes, all 3
Seh Gabi Mound B, Dull Black-on-Buff, Dalma Per., SG71 G10 6 (R30)	None on Ware	Fe+Minor Mn	None	Yes
Seh Gabi Mound B, Vitreous Black-on-Buff, S.G. Per., SG73 F22 308 (R49)	None on Ware	Fe	None	Yes
Tepe Yahya Soghun Ware, XCE 1(2)(R46)	Fe	None	None	?
Tepe Yahya Black-on-Red, XCE TT2(2)73	Fe+Clay	Fe+Mn	None	Yes, black only

Note: None is used to indicate none found in phase or level, not just none on sample.

One anomaly in this pattern is the black glasslike material decorating the Seh Gabi black-on-buff ware. This black paint has nearly the same composition as the Dalma Period black-on-buff paints, but they have been fired to a greater state of fusion than the earlier paints. The clay body of the two types of ware is similar in composition and has been fired to near the same temperature. We hypothesize that the paint pigment was prefired and ground before being applied as a paint to the unfired pottery, but this awaits further study by refiring and quantitative chemical analysis.

In summary, this preliminary investigation establishes that the paint, slip and wash technology was complex, and that different compositions and methods of preparation were used for the red and black colors, and that the paint technology was not a simple progression but was reinvented or reintroduced at various sites between 5500 and 4300 B.C. after its initial mature occurrence at Sarab about 6000 B.C. millennium.

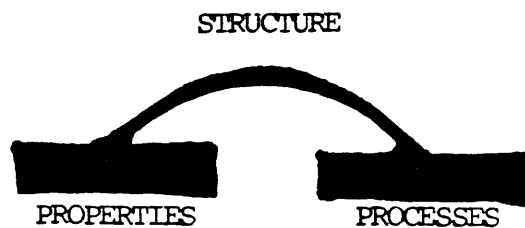
VII. THE NATURE OF TECHNOLOGICAL CHANGE AND MODELS FOR THE CULTURAL INTERPRETATION OF TECHNOLOGICAL INNOVATION AND CHANGE

A. Objective and Methodology

The objective of this thesis is to establish the nature of and changes in ceramic technology in the Near East by using macrostructure and microstructure to reconstruct pottery forming methods. This thesis has applied the methodology of materials science to reconstruct that technology by investigating structure as a means to understand the relation of material properties to processing, as schematized below. This method has proved more useful than the methods of archaeometry which apply analytical techniques of physics and chemistry to isolate differences and degrees of similarity in

groups of artifacts. Archaeometry has been useful for the establishment of trade patterns and for dating, but not for the reconstruction of technology.

Figure 65. Structure as a Bridge to Reconstruct Relations between Properties of Raw Materials and Finished Products and the Processes of Manufacture



This thesis has involved observation of the characteristics of processing: the structure of surface textures and edge fractures and measurement of the types of joins and sizes of preformed elements have established sequential slab construction as the method of manufacture used for a long time period and over a large area. The spatial distribution of preformed elements within ware has been determined by xero-radiography and polished sections for a large number of samples. In order to be sure that the pottery was really built in the way which observations and measurements detail, standards for materials and techniques were established. We have carried out replications of the deduced pottery forming methods, and have replicated both surface and fractured edge patterns. We have confirmed that the pottery we have made, as well as that of a Kurdish woman from Çimçime, Turkey, was made in the same way as ancient pottery from six Near Eastern sites in the Zagros region and that there are instances of this technology from two other sites which represent the limits of the Near Eastern culture

area. We have also confirmed that this method of manufacture was an effective one given the constraints of raw materials, and have specified the conditions under which slab building works better than coil building. The possibilities offered by composite materials have been assessed, such as fiber-reinforced clay, aged grit-tempered clay and paints containing clay, pigment and a flux.

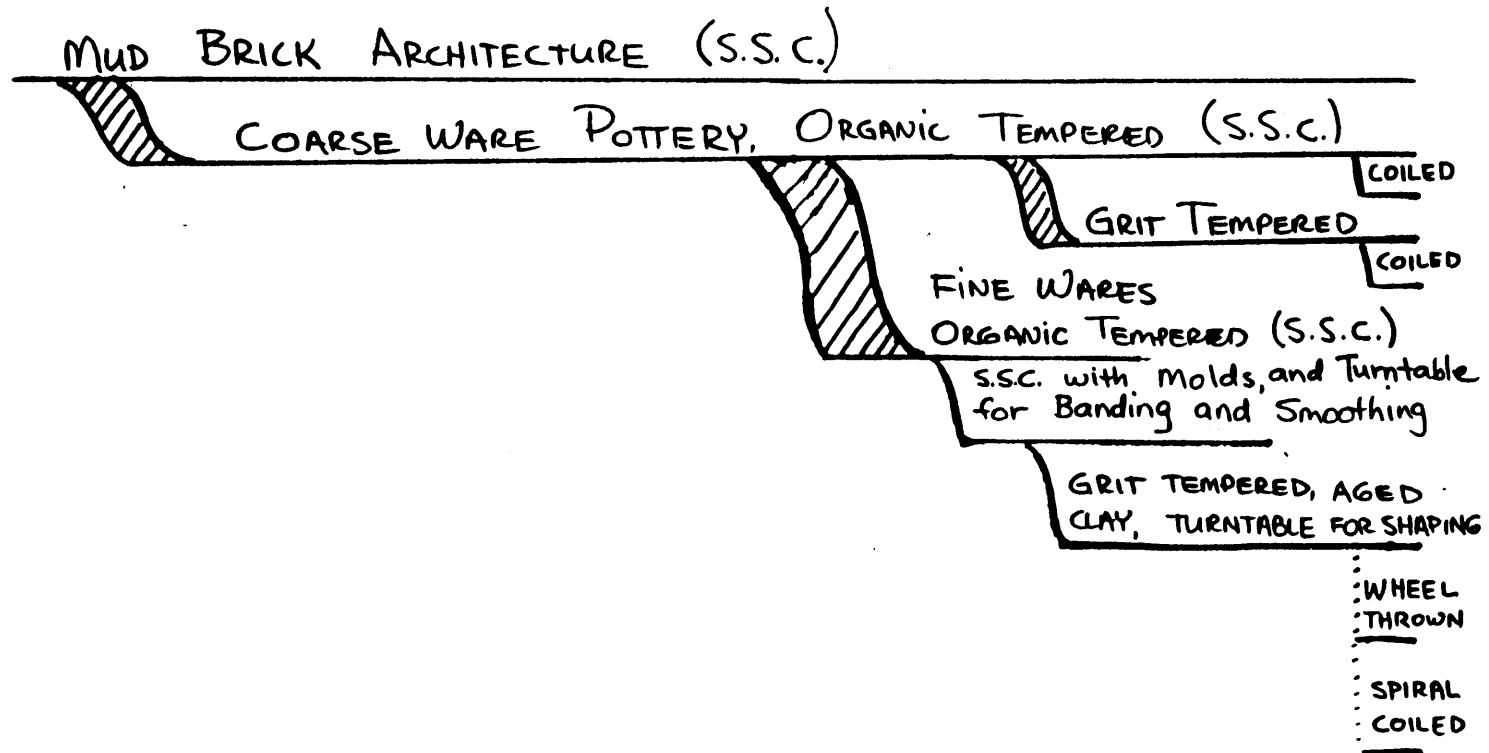
B. Narrative Description of the Pottery Production Technology

We have deduced from the results of this study a narrative description of the pottery production technology. Pottery was produced without exception by sequential slab construction, in which slabs, strips and lumps are preformed by flattening, but not in standardized sizes, and used to handbuild pottery by stacking one edgewise on top of another circumferentially around the pottery and by working the clay elements together in butt and bevel joins and by using these same joins in walls made of multiple layers of clay slabs. Often more than one layer of clay was used to construct a wall; two, three or more layers were used, particularly in bases. The slabs used in the bases are larger (having an average ratio of about 1:10 in thickness to length) than those used in the body (having an average ratio of about 1:5); both are greater than the bits and strips used in the rims (which have an average ratio of about 1:2). These ratios hold independent of the size of the vessels, which supports the idea that the pottery was made according to a mental set or template of how a pot ought to be made. In addition to having larger slabs, the bases of this pottery are constructed to be more robust, thicker in profile than the upper walls, unless a subsequent process like trimming or molding has been used. The pottery tends to be constructed in several work periods, in successive sections each composed of several layers of strips of slabs. The sections

are each as tall as allowed without deformation, cracking or buckling of the wall. This technology is fully established at each of the late Neolithic and early Chalcolithic period sites: Sarab, Hajji Firuz, Mound C at Seh Gabi, Chagha Sefid, and Tepe Yahya.

This technology is very different from the neolithic Chinese methods of constructing pottery catalogued by G. Wu (1936) and shown in the xeroradiograph in Figure 7. Chinese neolithic pottery is built in coils. In the example in Figure 7, cross sections of linear elements have a ratio of length to width which varies from 1:1 to 1:2. The size of the coils is the same at the bottom of the pot as at the top. Once the pot is constructed, it is thinned and densified by a paddle and anvil technique.

A representation of this narrative description of the development of Near Eastern pottery forming is shown in Figure ~~66a~~. The beginnings of this technology are found at Ganj Dareh. Pottery is built in multiple layers of slabs, both for large storage vessels and the smallest cup. The ratio of slab length to thickness is the same for the base, wall and rim. A vegetal-tempered clay body is used for the large pottery; the small pottery is made without organic temper by grinding clay into small pellets and adding water, so that the proper plasticity is achieved and shrinkage is minimized. Some very small pottery is made from a fine levigated clay similar to that used for geometrics and figurines. Thus there is already a considerable variation in preparation of clay body at a time presently considered to be the beginnings of pottery production, when a more simple technology might be expected. In the investigation of raw clay samples, we have established that selecting clay takes a specialized knowledge based on trial and error experience in processing the clay from forming and drying to firing. That specialized knowledge is found in the processing of clay at



THE DEVELOPMENT OF SEQUENTIAL SLAB CONSTRUCTION TECHNOLOGY

8000 B.C. 7000 6000 5000 4000 3000

Figure 66a. Overall Pattern of Technological Development.

Ganj Dareh. The larger pottery storage vessels are built into the walls in level D at Ganj Dareh, and made from the same raw materials as the sun dried brick, that is clay and chaff. As discussed in the results section, this fiber reinforced, composite body optimizes both strength and plasticity while minimizing drying shrinkage. The raw materials, preparation of raw materials and working properties of bricks production are the same as for the clay body used to construct the pottery. We conjecture that the early pottery developed from the architectural tradition, and will discuss this thesis in more detail below.

The sequential slab construction process preserved for more than 3000 years without change in the essential forming method, continuing through the development of fine wares. The technology was incrementally changed to include the use of molding to make thinner wares, the turntable for banding, wet smoothing and forming of rims, and eventually to shape a wall build with sequential slab construction. At the end of the period under study new methods were added, that is wheel throwing and spiral coiling. This is different from the traditional view of development of pottery as evidence of the neolithic and thrown pottery as a technological revolution which occurs with urbanization. Instead, the pottery production technology is seen as a slowly developing, conservative technology which is in accord with the view of technological change in historical times. The process of development is shown in Figures 66 through 69 for the sites of Tepe Yahya, Ganj Dareh and Sarab, Chagha Sefid and the Hajji Firuz, Dalma and Pisdeli complex.

C. The Nature of Technological Change

Technology is conservative, consisting of reliable and proven ways of doing things, as shown by the time span and geographical extent of sequential slab construction. Changes are gradual and incremental, not

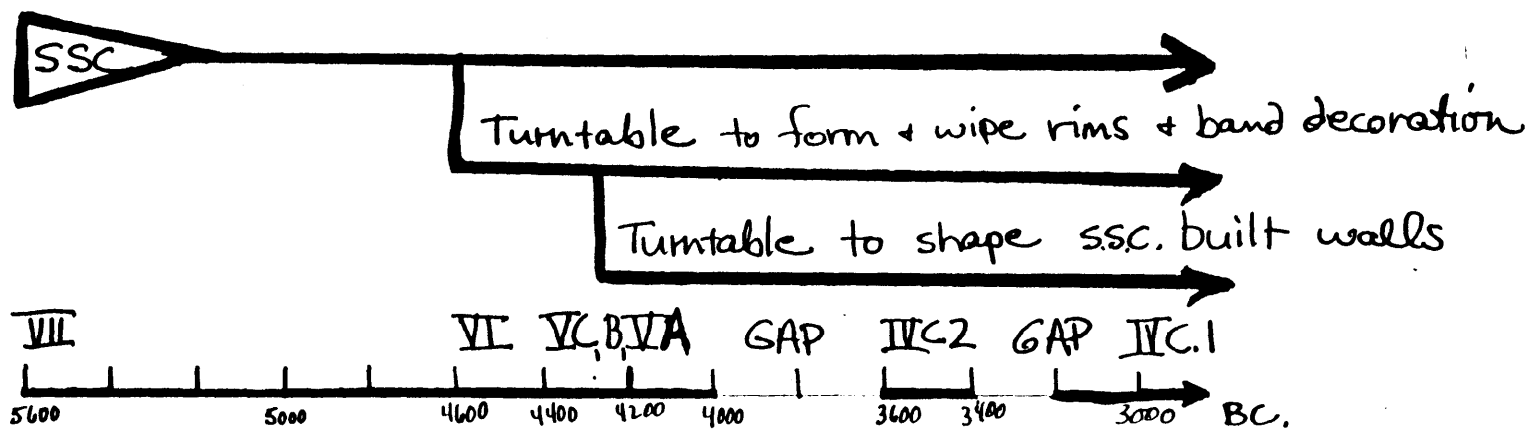
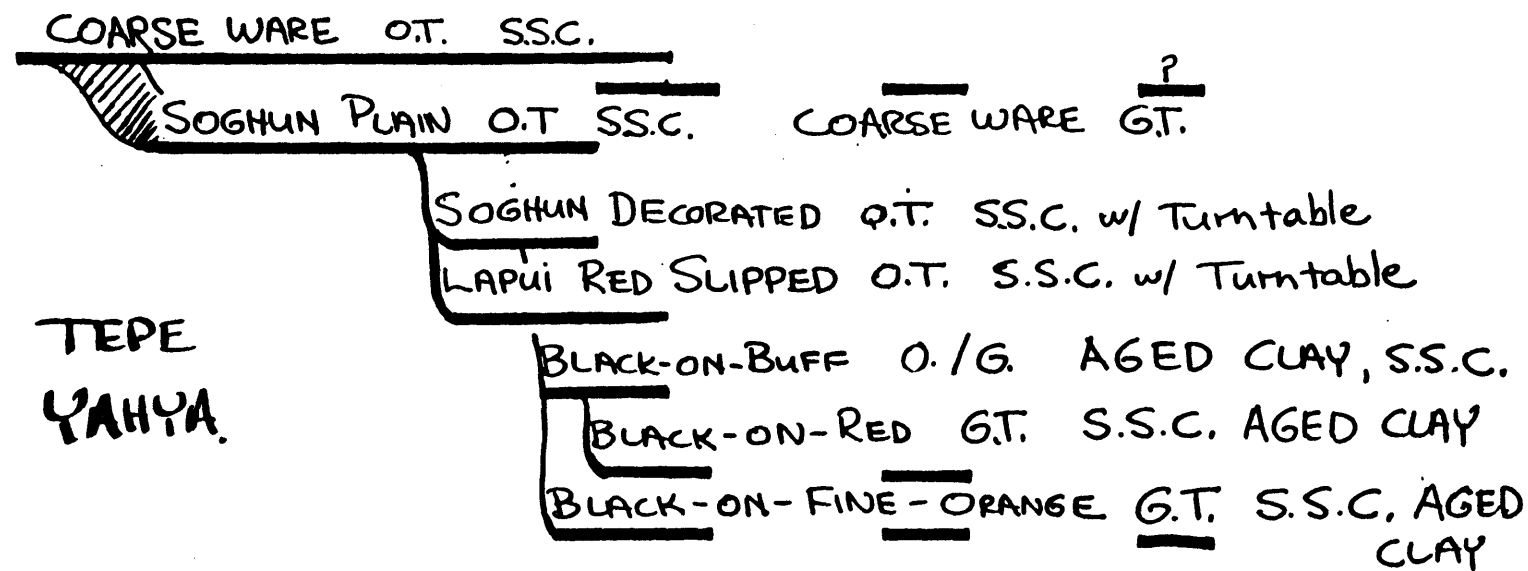


Figure 66b. Pattern of Development at Tepe Yahya.

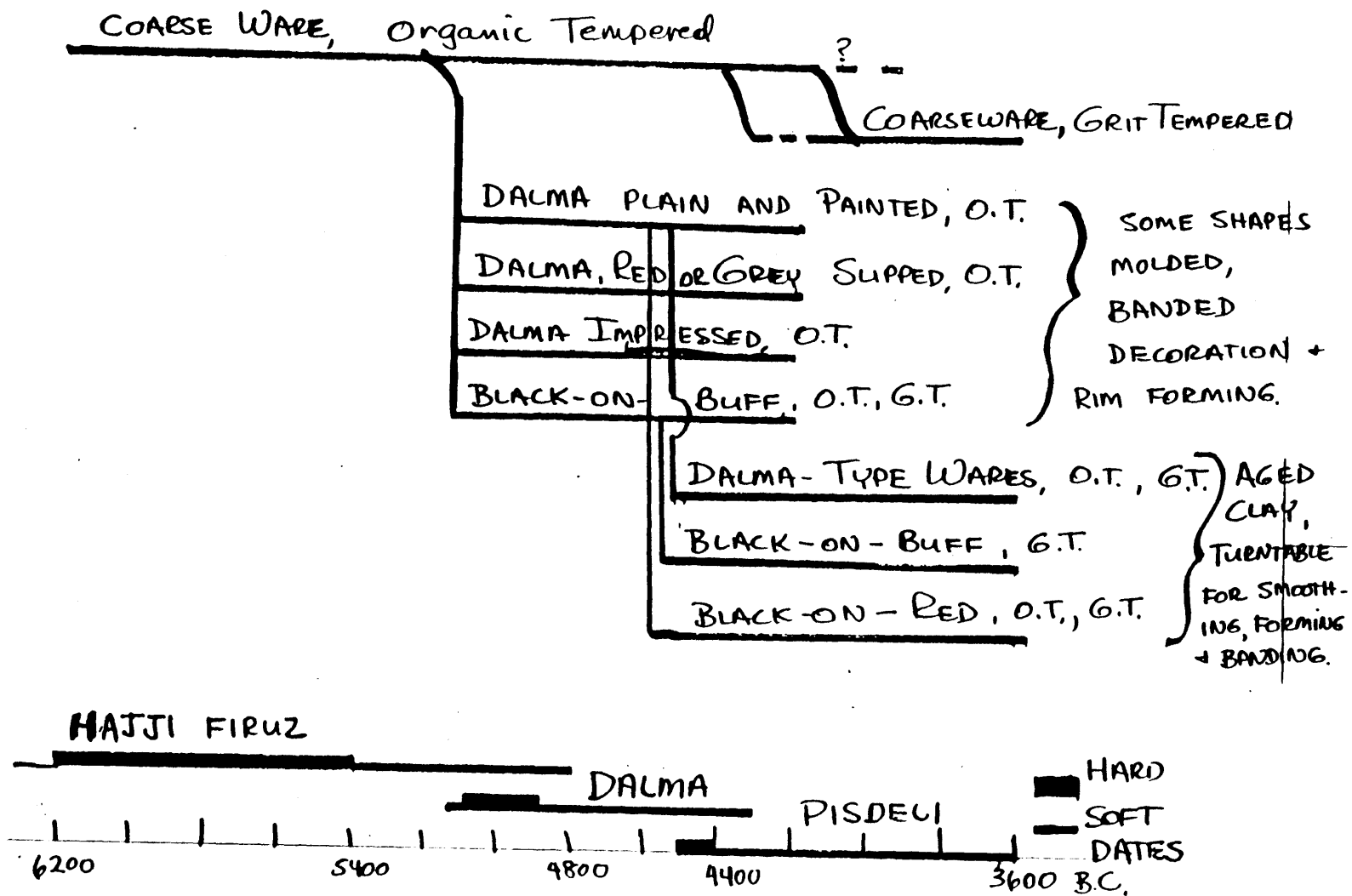


Figure 67. Pattern of Development Hajji Firuz, Dalma and Pisdeli.

COARSE WARES, ORGANIC TEMPERED
COARSE GROUND & WETTED FOR FINE WARES
(SELECTED PLASTIC CLAYS MODELED, NOT S.S.C.)

BUFF & RED SLIPPED COARSE AND FINE WARES, O.T.

3-COLOR FINE WARES, O.T.

SEQUENTIAL SLAB CONSTRUCTION →

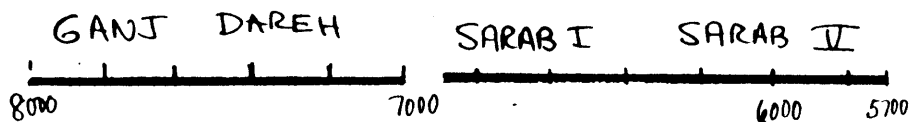


Figure 68. Pattern of Development at Ganj Dareh and Sarab

Jaffar Plain : Painted, Organic Tempered.

KHAZINEH RED, O.T.

SEFID PAINTED, O.T.

SEFID RED-ON-CREAM, O.T.

SEFID-BLACK-ON-CREAM, O.T.

SEFID BURNISHED, O.T.

SEFID BLACK-ON-RED, O.T.

Susiana Black-ON-Buff, G.T. →

Susiana Plain, G.T. →

Sialk Black-ON-RED, O.T.

WHEEL THROWN
— Black-on-Buff.

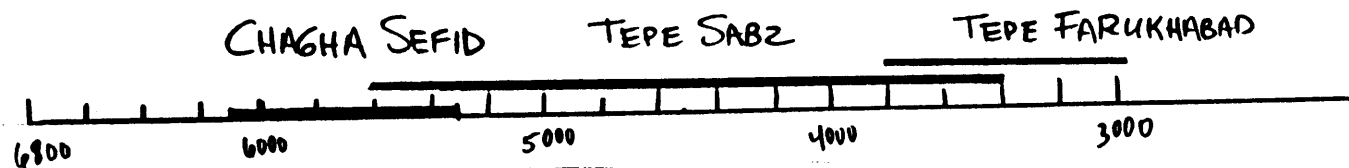
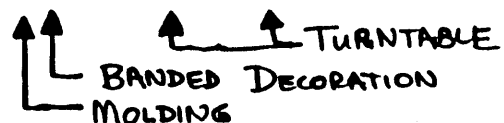


Figure 69. Pattern of Development at Chagha Sefid.

revolutionary. Changes in science, according to the Kuhnian model (T. Kuhn 1962), occur by paradigmatic innovation in which a conceptual innovation or discovery leads to a different understanding and practice. Technological change requires firsthand, specialized knowledge of particular processes and raw materials. For instance, specialized skills in the selection of clays, preparation of clay bodies, or use of sequential slab construction. This technology changes to meet a recognized social need, as for instance in the case of pottery production for fine wares, for serving vessels, for decorated luxury wares. Once there is an established need for that technology, how rapidly the technology diffuses is a measure of the degree of cultural integration and interaction. For instance, the spread of the potter's wheel and spiral coiling occur within a relatively brief span, which can be documented to within two hundred years; whereas the earlier turntable technology takes about one thousand years to spread through the Zagros region. The new technology grows out of the technology which preceded it, but without losing the framework of the old technology, because it is safe, reliable and proven. Technological innovation takes place by analogical reasoning, by modification of what is being done to serve a new purpose, as for instance with the gradual introduction of wheel technology, or the development of fine wares first by molding and then by the replacement of vegetal with grit temper, and perhaps as the pottery technology developed out of an architectural precursor. Because specialized skills are required, technology must be transferred by knowledgeable, capable people bringing new methods into a receptive culture which can change that technology to meet its own social needs. Technology cannot be transferred by artifacts or equipment, nor by written descriptions, nor by ideas as the vehicle of transfer. Even in literate cultures where

technology might have been transferred by other means, people, not ideas, objects or documents, have been the vehicle of transfer. The degree of cultural integration and interaction is shown by how rapidly technology diffuses once there is an established need for that technology.

Recent models for innovation processes in technology emphasize this conservatism and the gradual, incremental nature of change, thus agreeing with the model of technological innovation and transfer adduced above. Devendra Sahal in Patterns of Technological Innovation (1981:42,200,202) states:

Rather the origin of technical discoveries lies in complex interactions between a multitude of factors. If there is any aspect of innovative activity that stands out above all others, it is the extreme diversity of the context within which it takes place. In consequence, the individual innovation often seems to be a sport of chance.

Second, it is evident that the origin of new techniques depends to a large extent on the sheer passage of time, or more accurately, on the accumulation of relevant know-how. There are very few instances of technological change without a history of unsuccessful efforts.

Innovations depend on gradual modifications of a technique. Technical advances do not materialize at once; rather, they take place in stages.

Learning in innovation processes occurs in many different patches rather than in the form of a seamless whole. It is generally based on the acquisition of firsthand experience in the production activity.

D.H. Stapleton in his doctoral dissertation, The Transfer of Technology to the United States in the Nineteenth Century (1975) found that the transfer of technology was not carried out by the transfer of artifacts or equipment, nor by written descriptions but that ideas are transferred by knowledgeable, capable people bring a new technology into an active and receptive culture. In three case studies, Stapleton found that they each "...confirm a humanistic appraisal of technology because they emphasize that technology is contained within men, and not in the materials they use or the objects which their skills create" (p. 317), and that the technology which transfers is both selected and modified by the receiving culture.

In the Savage Mind (1966), Claude Levi-Strauss discusses the nature of

reasoning in "primitive" people as "the science of the concrete" which is not trial and error learning, but associative or analogical reasoning, in other words, problem solving. This low level theorizing is in effect a description of technological innovation. Prof. Maybury-Lewis (personal communication, Nov. 1984) cites the following example: tapioca is prepared from bitter manioc by separation from a poisonous liquid; the preparation of tapioca is complex and of necessity conservative, and was developed by firsthand experience through problem solving.

Proceeding further back in time, the same description is found for technological innovation in primates, which has been shown to depend on chance occurrence usually during play and by juveniles in which the occurrence was then applied to a problem solving task (A. Jolly 1972:350-351). Often older members of a troop never did pick up the innovation. B. Beck (1980:147-148) relates studies of tool use in animals to three factors "...sensorimotor maturation, associative experience with environmental objects in play or problem settings, and early experiences that involve response-contingent stimulation". Thus, tool use is a gradual, incremental behavior which requires firsthand experience and problem solving skills. This is consistent with the findings of Stapleton and Sahal on the nature of technological development, and of Levi-Strauss on problem solving.

This same view of technology as conservative and unchanging unless there is a recognized need still drives technological innovation in the late twentieth century. Prof. H.K. Bowen, Director of the Ceramics Processing Laboratory and Head of the Center for Manufacturing Productivity, has stated that even in the development of modern materials and processes for high tech ceramics an additive once found useful is almost never taken out of a formulation even when its function is taken over by another additive or that

a way once found effective in producing a particular property or desired microstructure is almost never abandoned, sometimes even if another method can be scientifically proven more effective (personal communication: spring, 1984). People do not like to change the way they do things unless they have to, even when it can be shown that another way is more efficient, more correct or better by some other criteria. This is particularly true with a complex way of doing things which is not well understood, and particularly so, when each contributing factor cannot be separately evaluated. Until recently the science underlying ceramic technology has not been understood, so there was good reason for the conservatism. In another example, L. Franchet observed that nineteenth century French potteries would not allow menstruating women on the premises while kilns were being fired (1911b:"Avant-propos"). So-called primitive or ancient people are not the only ones to be conservative in doing things in an established, traditional way.

Complex and established ways of doing things arise out of an historical pattern. For instance, C.S. Smith (1981:97) has investigated the techniques of Iuristan smiths who first made swords, horse trappings and other implements of iron using the same construction techniques which had been used to fabricate bronze implements. In other words, the technology was conceived in terms of the old material; the smiths did not use the property of iron to be hammer welded as any blacksmith would do, but fitted, constructed, banded and riveted the individual pieces of iron together. Early examples of Egyptian faience (P. Vandiver 1982:167-180) grew out of a pre-existing stone-working technology, and early examples are ground using stone-working techniques. The body was formulated to produce a particular visual effect in imitation of semi-precious stones like lapis and turquoise.

The pre-existing pottery technology was inadequate to provide a possible technological solution to the problem of producing a bright blue colored imitation stone. Out of an early period of diverse ways of making imitation blue and green stone, a single method was found which persevered for more than a thousand years. Likewise, the pottery technology found in the Near East develops incrementally out of that which preceded it. It is not just part of a conservative, inner mental or cultural set, but arises out of that which preceded it in a particular way which is determined in part by that initial pattern, in part changed by need, innovation and imagination, but also constrained by the uncertainty of changing something while not knowing what will happen if changes are improper or not in the natural order of things. Thus, the conservatism is not just part of a subconscious mental set within a culture but exists for good reason.

D. Technological Precursors to S.S.C.

If we try to answer the question: "Why was pottery built using sequential slab construction over such an expanse of time and space?", there are many answers. The constraints of raw materials have a strong influence on the choices which can be made in the manufacture of pottery. Clays from each site in this study have been identified as montmorillonite. A lot is known about this type of clay. It consists of fine particles which give excellent plasticity during forming along with the disadvantage of high shrinkage on drying. The addition of chaff to these clays yields a composite material with considerable plasticity, but reinforced with linear elements which when aligned in forming stiffen and strengthen a lump of clay and act to limit the shrinkage during drying. Adding chaff to the clay requires dry mixing in order to obtain homogeneity. Unless this clay body is allowed to age, optimal plasticity does not develop as there is only

incomplete wetting of the fine clay particles. The addition of organic temper provides a sound engineering solution to working with montmorillonite clay because it lessens drying shrinkage and coheres the short, difficult to form, easily cracked clay.

Such a technology cannot arise out of nothing, but must have developed out of known ways of doing things, in response to a perceived need. What technologies prefigure the software horizon pottery? What are the possible paleolithic and early neolithic precursors? Some of the possibilities are pigments, figurines, baked bread, dung-cake fuel, use of fire, storage pits, architectural mud, and sun-dried brick architecture.

Pigments are specially selected for their color, often ground or mixed. Their composition often contains clay and for some pigments the water content is controlled during application, as shown by P. Vandiver and W.D. Kingery (1985) in a study of paleolithic pigments at Lascaux. There are many general structural elements in common between clay and pigment technology, such as selection, grinding and mixing, but there is not the use of composite materials to produce desired properties which is fundamental to the pottery making. Figurines use the same raw material, but the clay for figurines is usually very fine and homogeneous and the objects are small, thus fine wet clay from a riverbank would provide a reasonable source. If this same clay were used to build larger sections, it will not hold its shape but deforms under its own weight, and shrinkage cracks would result during drying. An examination of figurines and geometrics from Ganj Dareh showed that close control of water content was necessary from the number which had a slightly dry, almost crumbly appearance, but the two technologies are so different that one cannot visualize how knowledge of one would lead to the other.

Many of the elements of bread manufacture, such as selection, grinding, mixing, forming and firing are similar to pottery production, as R. Amiran (1965) has pointed out. Pottery and bread could both be fired in open pits or small enclosures. Even though there is a general structural isomorphism, there is lacking the detailed fabric of technique which could transfer from one technology to another. For instance, bread is not a two phase composite material as there is no fibrous addition. In the Zagros region there is an emphasis on herding, cultivation of grain might have been introduced from the West, and we cannot establish that bread is made before pottery. The assumption is that foods like gruel, stew or soup preceded bread.

Another possibility about which there is no evidence is the use of grass or dung-based fuels. If wood was scarce, then it is probable that grass may have served as a fuel. In order to have such fuel last a substantial length of time, it is likely that clay or ash was mixed with the grass to slow the rate of burning. Microscopic examination of ash lenses, which do not contain obvious wood remnants, support this idea. Construction of fire and storage pits as containers is structurally similar to building pottery containers. Both storage pits and pottery used for storage must be rodent-proof. Storage pits are often lined with many layers of packed clay, or clay and plaster layers interspersed, often after the pit has been smoked or burned or lightly sintered to prevent rodent encroachment. These may well have been built with lumps of material, pressed and smoothed into place, a similar construction technique to pottery making. Other sorts of containers which might prefigure pottery are baskets and skin or cloth containers, although the materials and methods of manufacture are very different.

The technology which most likely led to the manufacture of pottery is

wet-mud brick and sun-dried brick architecture (Wulff 1966:108-117, Nissen 1968, Braidwood and Howe 1960:40). The raw material is the same, montmorillonite clay mixed with vegetal temper. In the chineh or wet mud brick construction method, as in the manufacture of sun-dried bricks, there is a similarity of working properties of the clay body. For instance compare the making of chineh in Figure 70 (photos courtesy of Dr. S. Henrickson) with that of the Çumçume pot made by Mrs. Boztepe, as shown in Figure 20. Straw is gathered and cut into short lengths with a scythe. Clay and straw are mixed, in a pit with a shovel or mixed with water by hand and kneaded in a depression as shown in Figures 70a,b,c. The wall can be constructed only so high and then it will support no more weight without deforming, so that a period must be left for partial drying before construction begins again on a new section. The clay is easily rewetted so that more material can be joined. The base is constructed of larger lumps or slabs, with more lumps and slabs being added. At Ganj Dareh, in level D with unusual preservation of upper walls, the upper walls were constructed to be lighter than the lower bricks. In ethnographic examples the uppermost part of the wall is worked using smaller elements, as for instance in the construction of the upper wall and roof from a part of the dig house at Godin, shown in Figure 70d. In the final surface texture of the chineh wall there develop cracks and more rapid weathering where joins of one session's work or one day's work has been joined with another, even though the surface of the wall is plastered over with a layer or facing coat of mud plaster. The surfaces of both walls and pots are plastered over with a skim coat or surface layer or slip coating. Sometimes, the surface is decorated with painting.

Thus, the raw materials are the same, the working properties of the

material are the same, and the general methods by which they are constructed and decorated are the same.

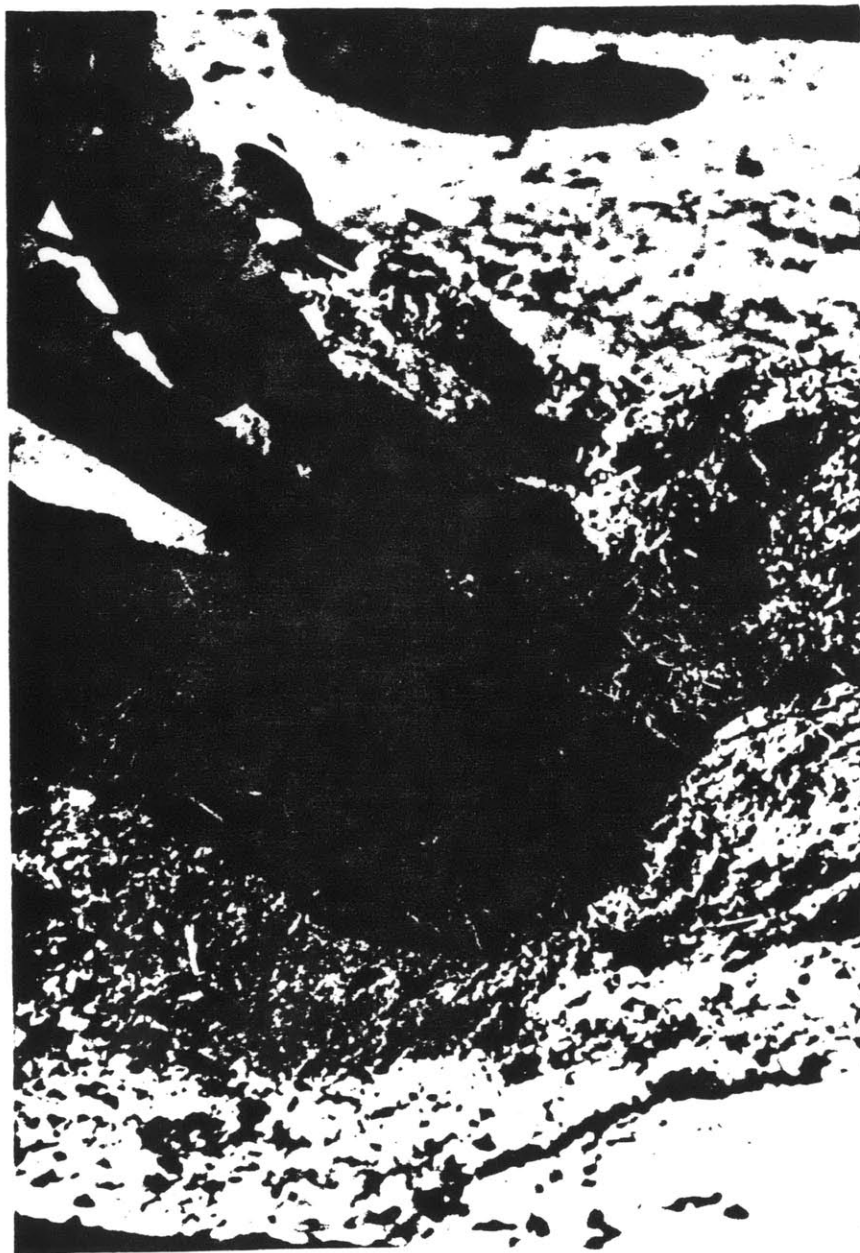


Figure 70a. Similarities of Coarse Ware Pottery Production to Architectural Construction; Wedging of a lump of clayey mud, straw and water of the same consistence as used in pottery. This lump will be used as a manufacturing element in a wall made of wet mud bricks, or chineh. (Photographs courtesy of Seana Henrickson.)

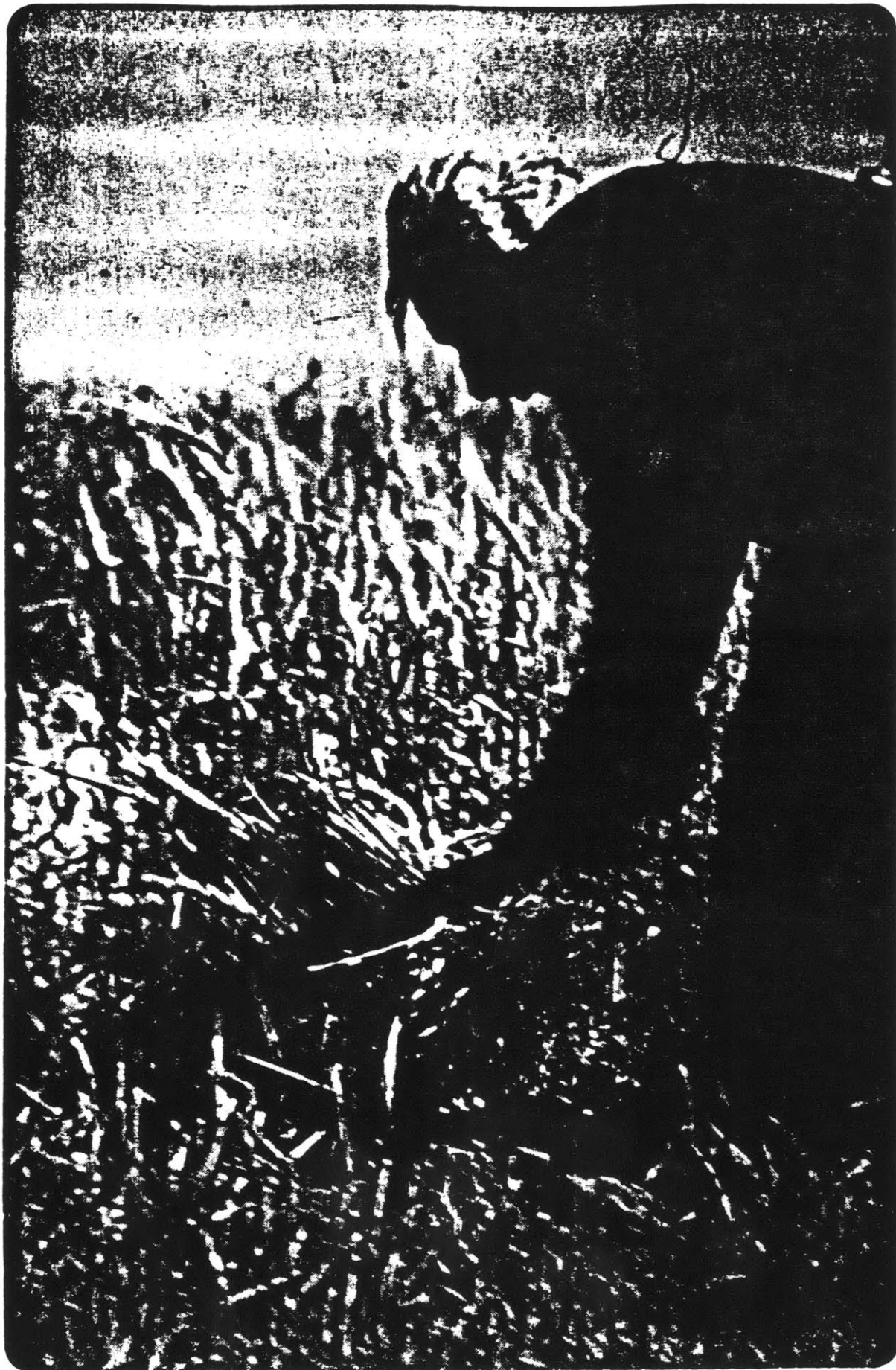


Figure 70b. Harvesting of wheat near Keshkul (Hamrin), Iran.

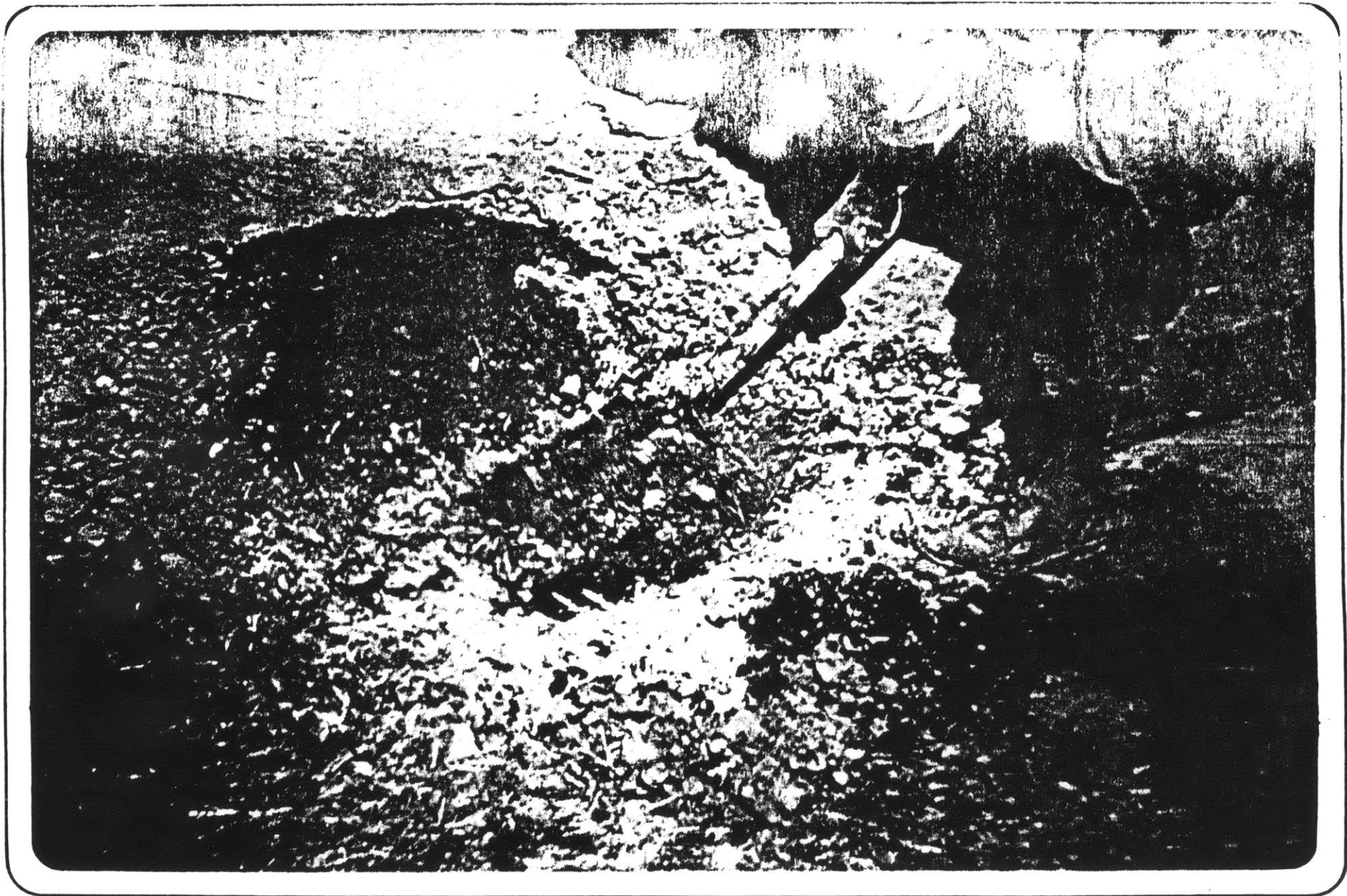


Figure70c. Mixing Mud and Straw for Chineh.



Figure 70d. Water is added to the dry mixture of earth and chaff, and the composite material is kneaded or wedged to the proper consistency and degree of homogeneity.

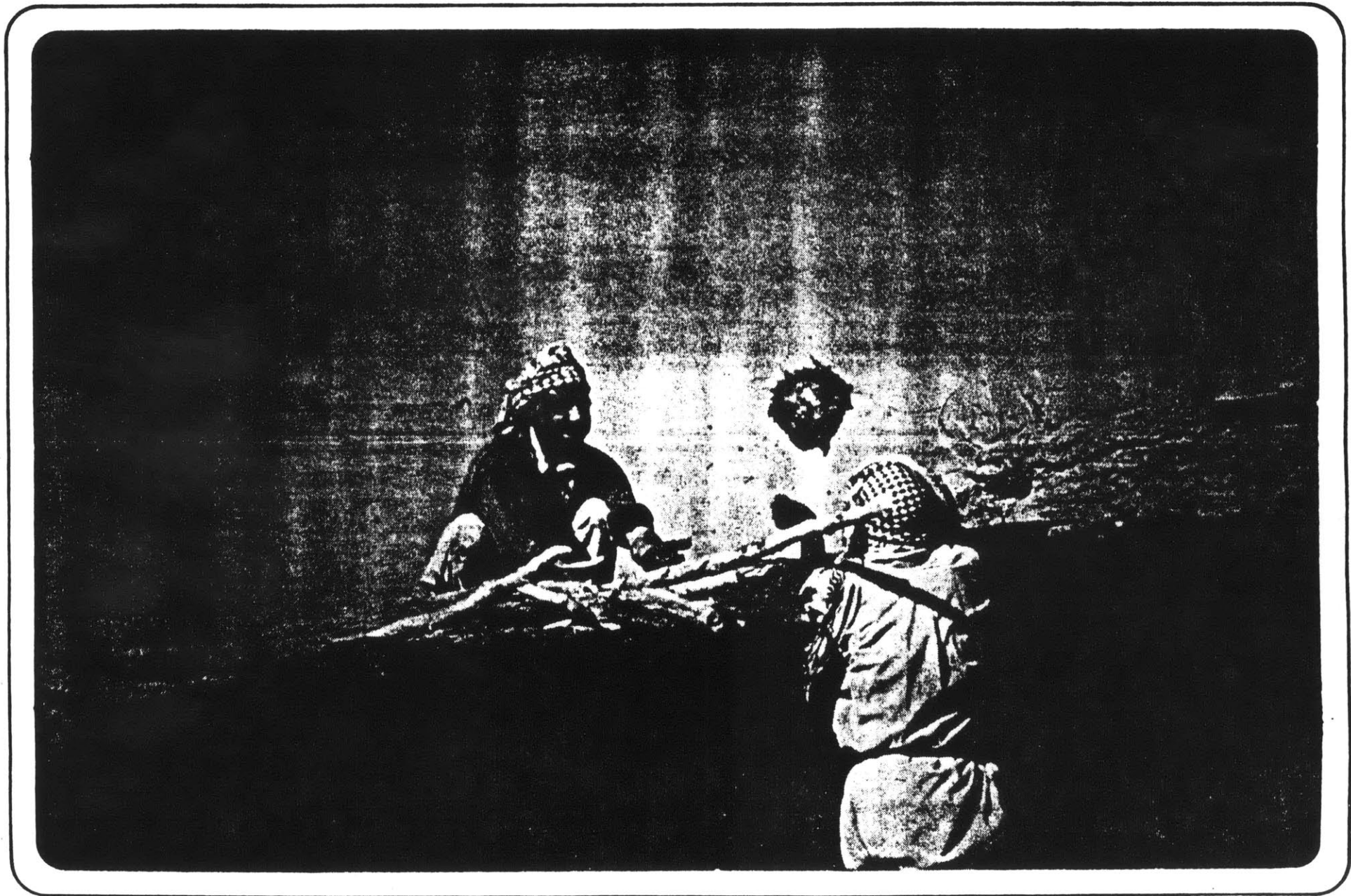


Figure 70e. The lump is thrown to the builder whi sets it in place on the roof.

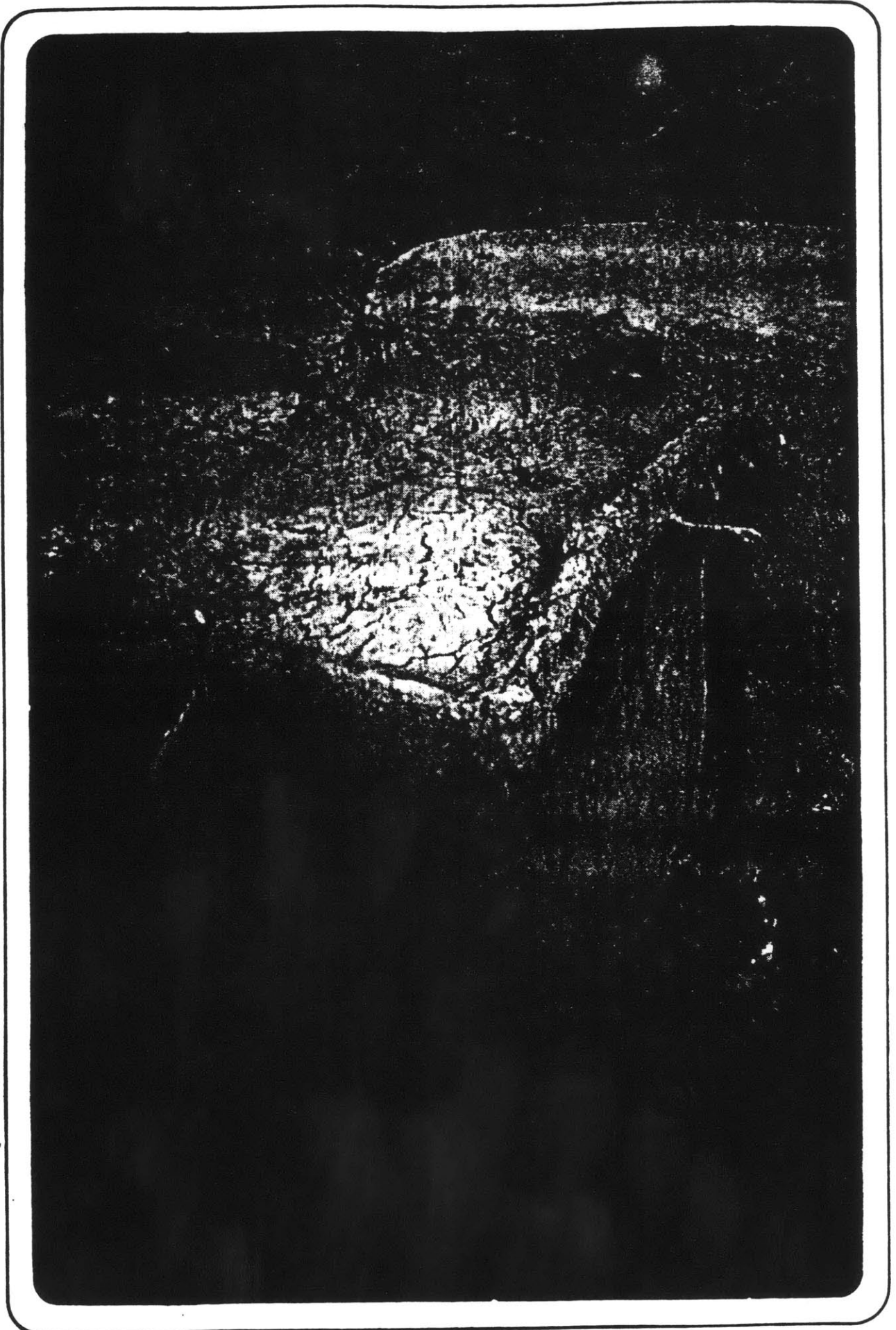


Figure 70f. Completed building has been allowed to dry. A skim coat was added over the chineh which has cracked.

Our conclusion is that, when the question is asked, "Why was sequential slab construction used to manufacture pottery?", the answer is that it grew naturally out of a pre-existing technology. The method is an efficient way of building containers for both people and their possessions. In addition, the early pottery from Ganj Dareh is built into the architecture. Slab construction is an efficient way of building large pots, according to Owen Rye (1981) and others describing pottery technology. Sequential slab construction is an appropriate way to use a difficult material, montmorillonite clay, as a composite with straw or grass or chaff such that the disadvantages of the material, large drying shrinkage and low wet strength, are minimized. In addition, slab construction is still a viable technique, as shown in the modern porcelain vessel by Rudolf Staffel (Figure 13, about p. 107).

In assembling details of architectural construction which show the same sort of construction found in pottery made by sequential slab construction, the work of Tom Beale (1971) shows detailed brick by brick by construction, examples of which are shown in Figure 71. These drawings show construction with sundried bricks from a fairly early time, Tepe Yahya Period VIA and one example from VC, about 4500 B.C. These drawings demonstrate a similar kind of organic construction to the drawings of slabs in the walls of pottery shown in the results section. These structural similarities consist of the following elements. First, there are no standardized sizes in the bricks just as in the pottery. In particular, the length

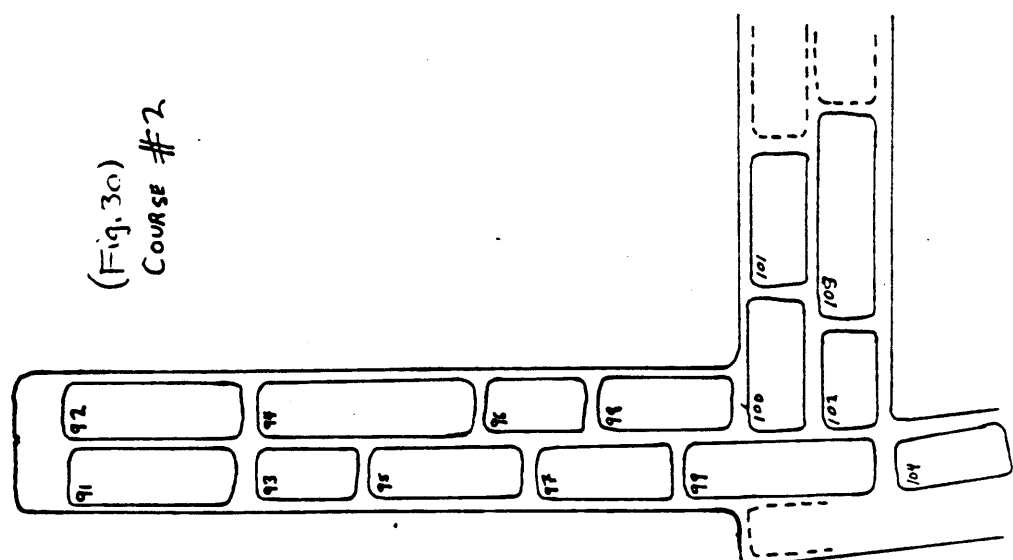
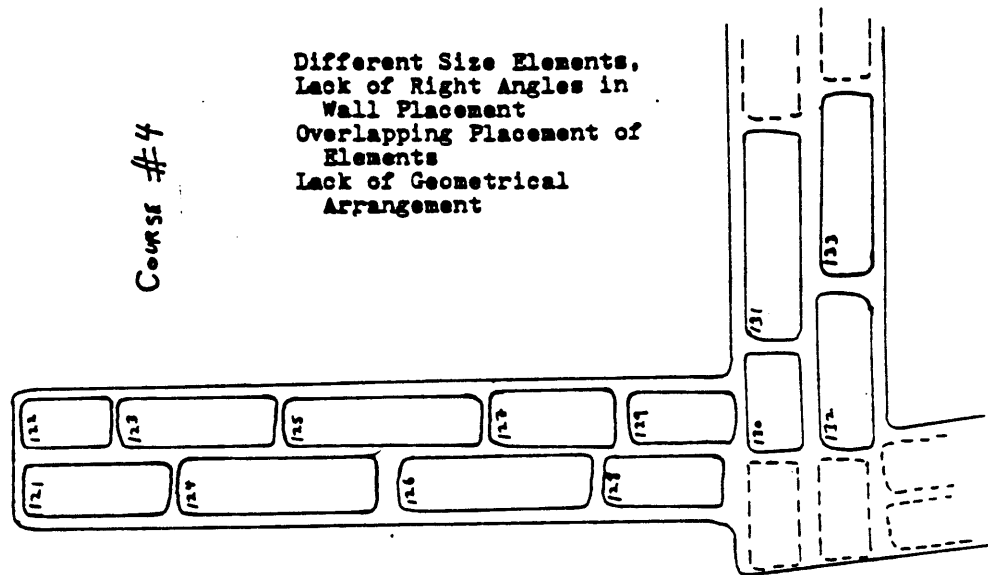


Figure 7). Architectural Reconstruction at Tepe Yahya.

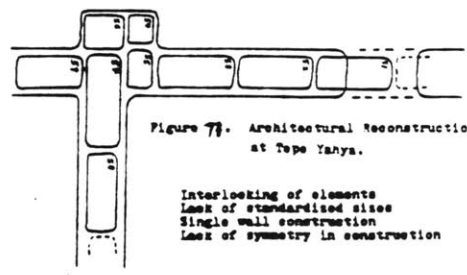
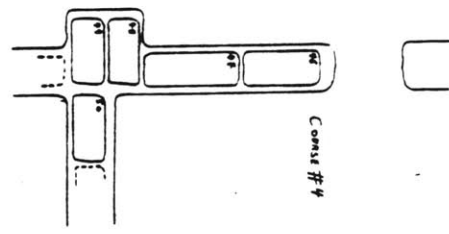
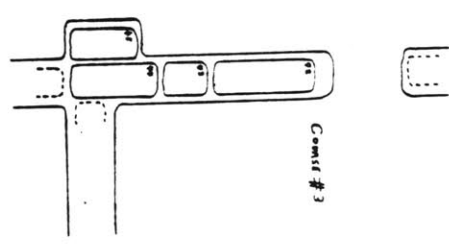
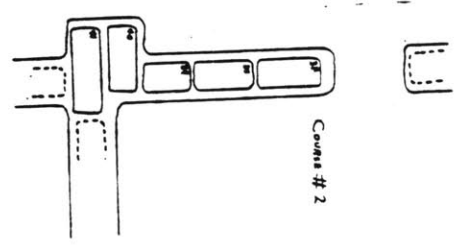
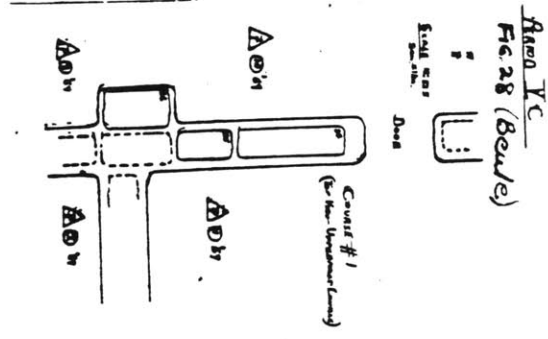


Figure 77. Architectural Reconstruction at Tepe Yahya.

Interlocking of elements
 Lack of standardized sizes
 Single wall construction
 Lack of symmetry in construction

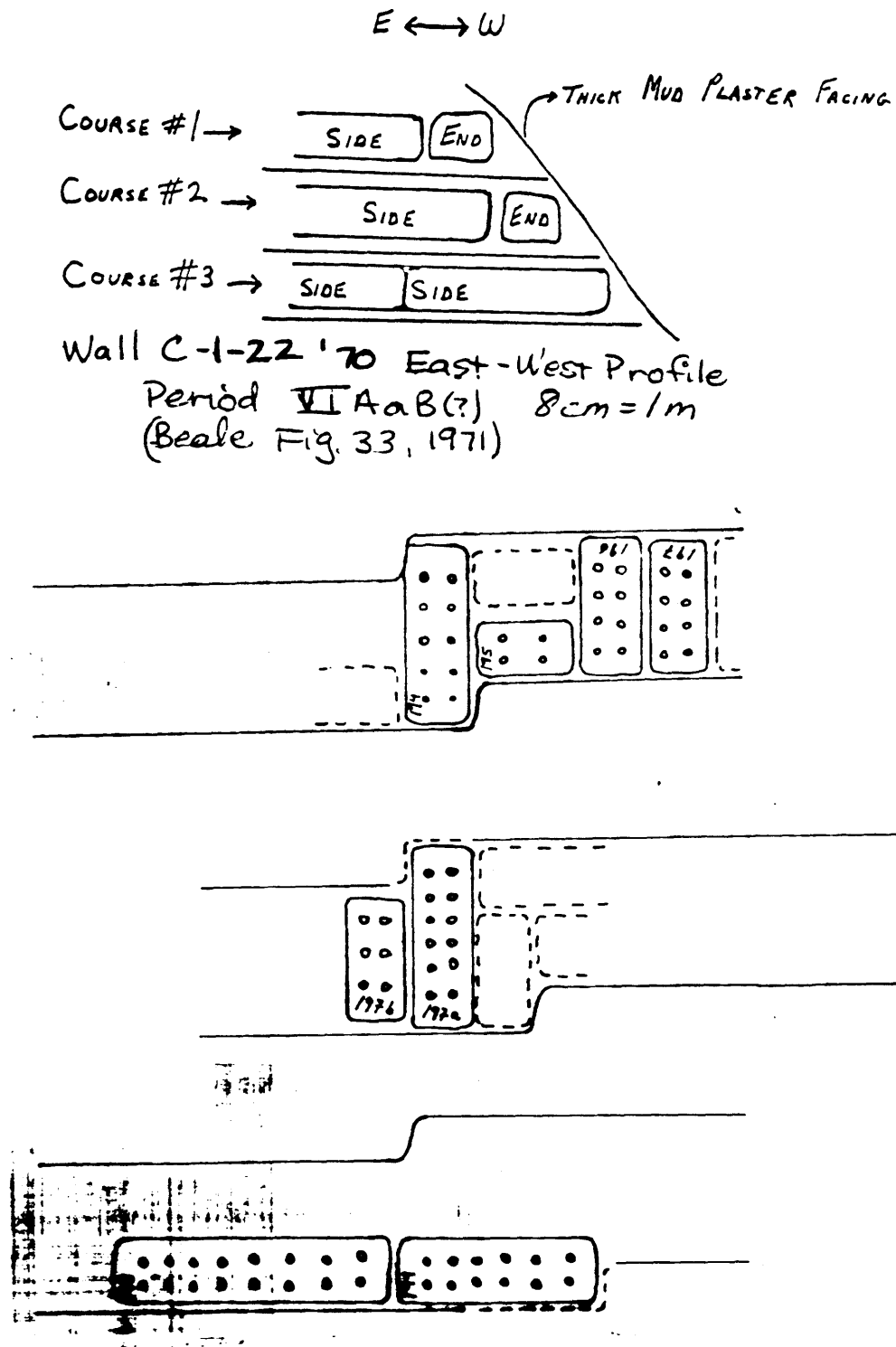
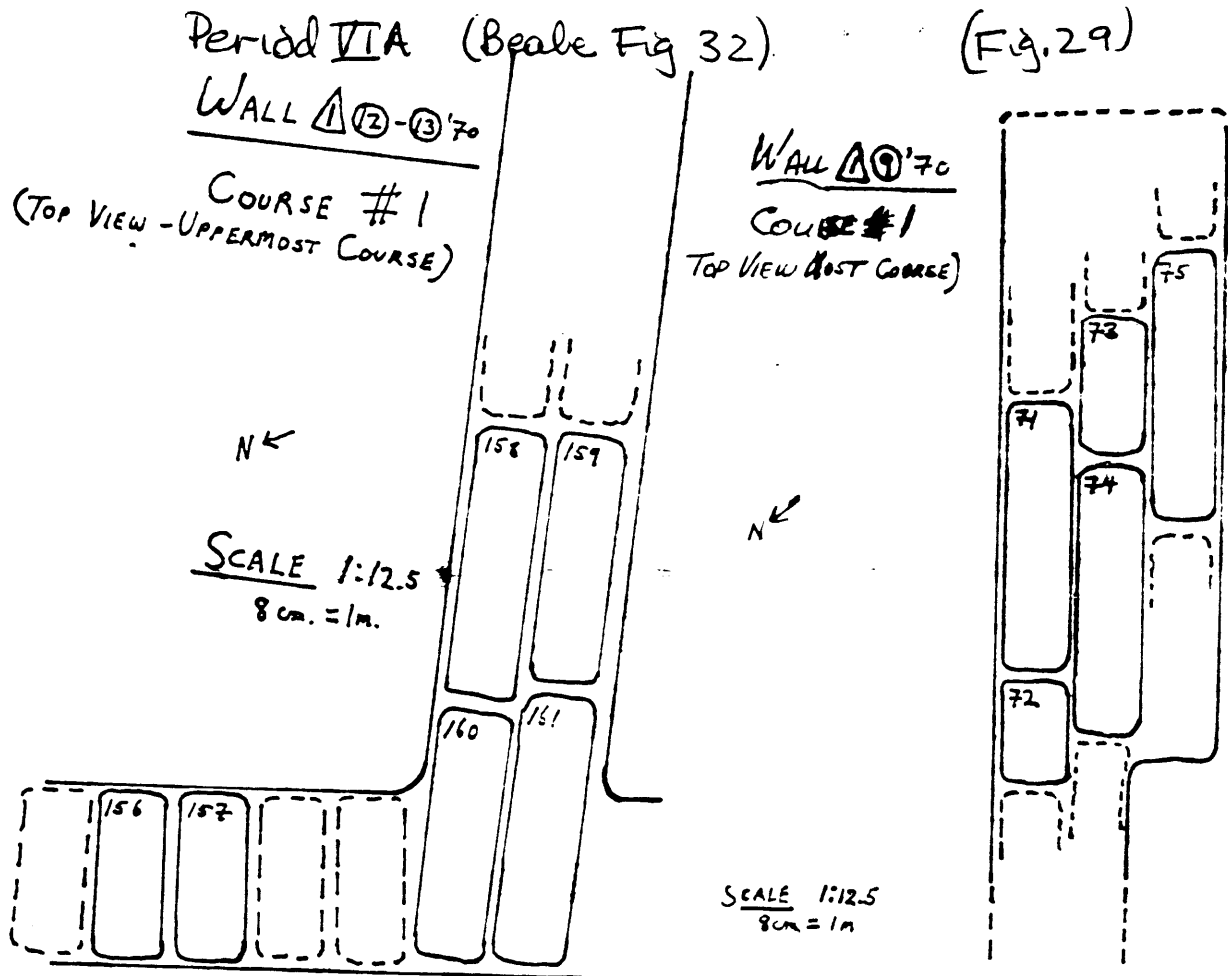


Figure 71. Architectural Reconstruction at Tepe Yahya
 (Drawings courtesy of Dr. T. Beale).



Double and Triple Layer Wall Construction

Figure 71. Architectural Reconstruction at Tepe Yahya.

of the bricks varies by a factor of 3.5, to 4.5 in a few examples, as the length of the thumb impressed bricks varies from 20-70 cm, with a few examples at 15 cm. Second, there are many instances of double and triple wall construction, just as there are of single element wall construction, and some of the bases of the walls tend to be more robust than the upper walls. Third, in the placement of bricks, one finds an overlap of one layer on top of another to stagger the joints between the bricks, although sometimes there is vertical alignment of the joints in two courses, as would not be found in a geometric construction. This is similar to the interworking of slabs in pottery, where most are staggered but some align. Fourth, where two walls meet or are buttressed, there is a lack of symmetry in construction as one's eye rises in a vertical column from course to course, in the size and placement of bricks, in the occasional lack of squared corners and in the fitting together of the individual preformed elements. A similar lack of symmetry is found in the pottery. A comparison of construction with chineh elements would be most profitable, but none could be found.

In summary, there are four points of similarity between the architectural and pottery technologies which make architecture, the most likely precursor to pottery. These are the similarity of raw materials, the similarity in preparation of those raw materials, and the same working properties which are found in the making of bricks, construction of pottery or in the making of a chineh wall using wet unstandardized,

preformed elements. Last, the same organic principles of construction are used, in addition to the emphasis on surface coats or slips which hide the preformed manufacturing elements beneath.

This argument may be taken one step further by comparing the pottery and architectural construction in the Near East with that found in China (K.C. Chang: personal communication, March 1985), and by inquiring into the cultural meaning of such differences. The neolithic pottery of northern China in the Yangshao culture beginning about 5000 B.C. is grit-tempered coarse ware which has been made by coiling, and then cord marked and rocker stamped, and the architecture is wattle and daub in semi-subterranean structures built of timber. In the Pei-li-gang which dates to 7000-7500 B.C. the pottery is cord marked, rocker stamped and, as far as known, grit-tempered. The housing is semi-subterranean, shallow pits with post holes, and wattle and daub walls. Millet and pigs have been identified. In the southern Homudu, the architecture is timber frame and wall with raised timber flooring. The walls were packed with mud and rice straw. The pottery was made by coiling and organic tempered with rice chaff. In the late third millennium in the Lungshan culture, rammed earth walls were made which had been hammared in place in layers with river stones and later weighted pounding sticks. This technology is still seen today. Fired clay was first used for roofing about 1200 B.C., large bricks were first used for tomb construction about 400-500 B.C., and not for houses until Han times. The

use of linear elements, such as coils and stick or timber frames, and surface treatments based on impressing and stamping represent a very different, and just as conservative technology, from that found in the Near East. The similarities in the construction of pottery and architecture in China make the connection between the two even more likely in the Near East.

E. Technological Transfer and Cultural Diffusion

When the same technology is found in two different places, it is more likely that the technology has been transferred than that it has arisen independently. Wu has observed that in China the earliest pottery technology is based on coiling and thinning with paddle and anvil techniques in addition to the use of molds. There is no slab construction as found at Near East sites. Where there is a reasonable chance of exchange as within the Near East or within China, the same technology of pottery manufacture is found. Where there is little chance of such exchange of people and technology, different methods of pottery manufacture are found. In other words, knowledgeable people doing or making something is essential to technology transfer. To emulate the idea of an imported object, the new technology developed which is derivative of the technology found in the culture into which the object or idea is imported. A corollary of this is that a perceived need must facilitate sufficient interest in the new technology that the risk of changing an established norm is undertaken. One has only to cite the instance of the computer developed in the nineteenth

century by Charles Babbage. Without a perceived social need for this invention, it did not become a technology until the mid-twentieth century when developments in the complexity of modern communications, systems control and analysis, and the amounts of information to be processed overwhelmed manual methods (A. Hyman 1982).

We can then consider whether software pottery was independently invented or diffused from one or several central or source areas. Can we say that sequential slab construction is a complex technology requiring specialized skills, and that such specialized skills require transmission of complex, learned behavior? Manufacturing pottery requires that one has learned that clay will harden by firing, as clayey earth beneath a campfire becomes hard. Pottery manufacture also requires a need for containers which cannot be met by underground storage pits, and an environment in which clay and fuel are available. These conditions are met in much of the Near East. Is there anything in the ecological conditions of the Near East which would make independent invention probable? The arid environment with clay and clay-lime mixtures commonly found beneath campsites means that the hardening of particular earths by firing would have been observed during the paleolithic, with some sorts of earth hardening more readily (clay) and others powdering more readily (lime). In general, there was insufficient wood to rely on it as a sole source of fuel. Presumably wild grasses and brush were also burned as fuel. In marginal circumstances, in order to eliminate smoking

and prolong fires for warmth and cooking, various sorts of earth may have been mixed with the grass, as is done in villages today where not only dung cakes are used as fuel but mixtures of straw and clay and dung are made (Carol Snow and M. Voigt winter, 1984: personal communication). Such a practice is common in China and Korea where clay is mixed with coal to extend precious resources. Thus, there was an opportunity for observation and use of the raw materials for pottery throughout wide expanses of the Near East. The widespread availability and common use of such materials is an argument for the independent invention of software pottery.

We must then ask, "What are the characteristics of the technology which required specialized skills such that transmission may have been necessary?". First, clay selection is a specialized skill requiring knowledge of the lime content of the earth selected. A common perception is that clay is ubiquitous in the Near East. However, when examples of possible potter's clay collected from the sites in this study were evaluated, several examples would not fire to rock hardness. Some contained fine particled, well sedimented lime, and others would not form well because they were either too coarse or too fine. In addition, the ancient objects such as tokens, jar sealings and bricks, that is objects which did not require hardening by fire, all had higher amounts of lime present than the coarse ware pottery. Some examples of the specialized skill have been documented by archaeologists. Mary Voigt found that clay was brought to Hajji Firuz from the far

end of the valley. Frank Hole has described a platform with ashy clay within and fine clay on top, and another example where the color of plastered surface layers on walls was different in color and texture from what was below. Thus, there was knowledge of the properties of various clayey earths, and clay selection required specialized knowledge of and practice in using local raw materials.

Second, clay preparation required specialized knowledge. It is almost impossible to add chaff or short lengths of grass to wet clay and obtain a homogeneous distribution of vegetal temper. It is not efficient to transport wet clay in which about 20% of the volume is water. By adding dung to the clay, it is difficult to get an even wet mix; and the two have different consistencies and working properties. In addition, sheep and goat dung is produced in small pellets, and the shape and size does not match that seen in the pores left by organic burnout, although cow and donkey dung is produced in larger, easier to collect amounts and is closer in appearance. The path of least effort is mixing the organic material with powdered dry clay, unlike clay preparation for figurines or geometrics where very fine silty clay is used. The small amounts required could be collected and used wet, or ground and mixed with water. Thus, there is variability in the preparation of clay bodies for different sorts of artifacts. At Ganj Dareh there is circumstantial evidence for a third method, the coarse grinding of clay into pellets about 3-5 mm and their subsequent mixing with water to produce a body with

strength and without excessive plasticity. The coarse ware pottery required the formulating of a composite material in the modern engineering sense of the term. There is no clay deposit in nature which resembles the clay body formulated by man.

Third, the forming by construction methods using two-dimensional elements which are stacked, overlapped and joined gives good strength. The working of the surface to insure that there are no crevices at joins from which cracks might open during drying increases this strength. That these pots were constructed according to a prescribed mental set is shown by widespread presence of the sequential slab construction method. Examples of the importance of construction is shown by many instances of rims reinforced with two or three extra strips of clay, extra clay added around handles and at carinations, and the addition of foot rings at the base once the base has been formed. Another example is the construction of footed pots at both Pisdeli and Seh Gabi in which a peg of clay is placed into a hole in the base of the pot and sealed to the interior, and then a cap of clay is placed over the clay peg on the exterior surface which braces against the outer wall of the pot and the peg for added strength. This complex join decreases the possibility of failure from cracking at a simple join and provides a spreading of the stresses which are produced during drying shrinkage, and is another instance of sound construction principles.

The firing is also a specialized skill. If the pottery is too wet or fired too fast, the pot explodes as steam is formed within, and there are many examples of pots with a chunk of clay which has blown off the base or side of the vessel. However, there is clearly a high success rate or there would be report of broken wasters and small bits and lumps of fired clay with one surface looking like it has been worked and the other rough and split, from middens, courtyards and perhaps near fire pits. In addition, pottery with low permeability, that is which will hold liquid contents for a couple of hours for cooking or serving, was produced in the software horizon which is not worse than that of the later fine wares, in which one would expect an improved capability.

We conclude that pottery was a complex technology, requiring many specialized skills including raw material selection, body preparation, forming and firing. That pottery manufacture was a conservative skill for so long, in addition to being a well developed or optimized skill, supports the argument that it did require specialized, learned skills. From the complexity of specialized skills and conservatism of the technological tradition, we can conclude that the manufacture of software pottery required transmission of complex learned behavior, and thus it is more likely to have diffused than to have been independently invented.

The mechanism of transfer of technology might have included a wide variety of vehicles. For instance, intermarriage, particularly exogamous marriage, of women who brought with them pottery making skills would diffuse a technology. The migration of settlers from a different region, the colonization of a region by people bringing with them another style of pottery which might be accepted by local inhabitants, or the movement of potters from village to village bringing with them a particular expertise

would all serve as mechanisms of technology transfer. Other instances where technology might be transferred would be at tribal gatherings or particular celebrations or at markets where goods are exchanged; that is, when large groups were together for a period of time. Improvements in paints, clay preparation or ways of firing might be discussed or exchanged, but for the introduction of complex innovations some person must have moved from one village to another. We cannot be certain whether only women made pottery as is often assumed, and the evidence for craft specialization is also speculative. We could state which of these mechanisms we might expect in a modern situation if the level of cultural complexity, degree of integration and social structure were known. To do more than speculate is not possible here.

We can state that, although pottery has a long time depth dating to 8000 B.C. at Ganj Dareh, there does seem to be a period in which pottery becomes widespread and sites which are aceramic in the lower levels later contain pottery, such as at Ali Kosh. This seems to occur in a limited range of time, as P.J. Watson has noted from 6400 to about 6000 B.C., in which pottery appears at a number of sites. This feature seems to argue for the diffusion of pottery practices. Careful comparison of the technology at group of these sites would indicate how strongly this argument could be made and in which direction the technology was transferred.

The fine ware tradition seems to become widespread within a limited period of time. In Table 1 (p. 20), I have inserted the symbol FW for the occurrence of fine wares to indicate that there is a range of time from about 5700-4800 B.C., the early chalcolithic, in which fine wares occur. By fine wares we probably should be designating pottery which does not contain organic temper, and which has a fine montmorillonite clay body which would

have required aging prior to use, but these symbols indicate the definition given by archeologists of refined wares. Further study of the context of these early fine ware finds should determine whether this range of dates can be narrowed, as significant information about the spread of technology could be gained. A thousand years is too long a time in which to discuss diffusion of technology.

We can also specify the history of this conservative technological tradition. At Ganj Dareh, where one would expect the simplest technology, instead the greatest variety is found, in both clay preparation and forming methods. From the fact that this same diversity is not found at later sites, we can conclude that the people making pottery settled on one way and that this way was preserved through minor technical innovations over at least 1400 kilometers and 5000 years from Hajji Firuz to Tepe Yahya, and that preliminary investigation shows that instances of this technology may have occurred over 4000 km from Mehrgarh to Mostegedda, which is a very long way to discuss diffusion without detailed consideration of a host of specific, quantifiable traits. The pottery production is a really conservative technology.

Although changes in shape and decoration can be used to make fine distinctions in the pottery, the technology is unusually uniform. Once a successful way of doing something was found, there was no reason to change. In other studies the uniformity of raw materials has been taken as a criterion of craft specialization (S. De Atley 1982), but there is no evidence of this uniformity varying with any particular period or ware type. Neutron activation studies of trace elements at Seh Gabi and Godin (R. Hancock, winter 1984: personal communication) and at Ganj Dareh (A. Yelon, winter 1984: personal communication) have failed to show differences in the

clays used for pottery, with the exception of some variability in CaO (lime) content. We have failed to find indications of covarying differences in the concentration of major elements in the pottery using energy dispersive x-ray analysis. Thus, the starting materials are quite uniform, even though the host of raw materials available to ancient potters was highly variable. In the manufacture of software pottery the uniformity of raw materials cannot be taken as a measure of craft specialization. These early village sites occur at a time before it is possible argue for the presence of craft specialists.

Another criterion of craft specialization has been the uniformity of decorative motifs and of forming methods (P. Rice, 1982, 1984, 1985; Rita Wright 1984). In the early periods at Tepe Yahya, Chagha Sefid, Seh Gabi, and Sarab, there are only a limited number of motifs used and the forming technology is the same. In early villages where craft specialization is unlikely, we find traits which have been considered as characteristics of craft specialization, but which occur at a time before there is a possibility of complex social organization, or stratification in which craft specialists would be expected. Thus, we need to review the criteria for craft specialization. M. Tosi (1983) has suggested that some fraction of a site must be dedicated to a particular task or set of tasks as an indication of craft specialization. Thus to establish craft specialization may require the examination and measurement of a particular workshop's production (R. Henrickson: 1984) or similar vessels not known to be from a single workshop might be modeled and analyzed using a cluster model for multiple variables: design motif, placement on the vessels and spatial organization according to symmetry relations such that the computer can generate the pattern (F. Hole 1984). Another way of establishing craft specialization is to plot the

temporal and geographic distribution of pottery and to hypothesize what kind of an economy would support such a distribution (S. Henrickson 1983). In the software pottery we find a general uniformity of technology, but which is still amenable to personal choice, for instance whether the side wall slab is placed on top of or beside the bottom slab. Therefore, once the metrics are meticulously carried out, we expect range of variability which would exceed that of a workshop but we are still far from understanding the degree of variability present within a workshop. Until such baseline studies are carried out we need to examine other variables to understand the uniform, conservative tradition found in the software horizon.

The variables which must be examined are the nature of technological change and technology transfer. Although models for social and scientific change have been postulated which state that conjunctions or revolutions occur (T. Kuhn 1962,1970; F. Braudel 1979), the model for technological change is very different. Technological change is gradual and slow. Small changes occur which are based on firsthand knowledge of particular processes and raw materials. They are not based on ideas which can be implemented through organizational structures and communication mechanisms. They need to be demonstrated and practiced, for instance in an apprentice situation, to be usable. Ware type, form class and designs change rapidly and have been used as the prime means of setting up phases and comparing sites. Archaeologists have been splitters in order to make distinctions. In this study many of the variations of color (for instance, black, brown or red slipped wares) or whether paint is used (for instance, Jaffar plain and painted) are shown not to be useful technological distinctions. The different slip colors are the result of variations in firing, and the application of paint to some pottery is a matter of personal choice when the

pottery is chemically and physically the same and the forming and shapes are the same.

The technological changes which are grafted onto this conservative tradition are only minor modifications, rather than revolutionary changes. These consist of changes in clay preparation. The practice of aging clay gives a fully plastic body consisting of montmorillonite clay and either naturally occurring or added sand and grit temper. Thus, the technology comes fully of age independent of the architectural technology, but the same old ways of forming clay continue as a construction process analogous to the way chineh (or wet brick) and sun-dried brick architecture is constructed. Any method of manufacturing clay could have been adopted at this point but it was not, because of the conservative nature of technological change. With the fine wares the body once constructed could be manipulated as a formable shape, thus a turntable adapted to facilitate construction of the walls without the potter having to walk around the pot was employed for banded decoration and for smoothing and shaping of the rim, and eventually for shaping, that is enlarging the diameter of, an already constructed vessel, and thus aligning the temper and pores in a horizontal fashion. The molds used to produce particularly desired round bottom shapes, common in the Dalma red slipped and Halaf wares as bowls and jars, may have been adapted as a turntable. There seems to have been a change associated with the manufacture of fine wares which involved molding of round bottom shapes, both the Halaf and J-ware imports, which affected the production of coarse ware pottery such as the Dalma vessels but did not cause a change in the underlying clay body technology of organic temper added to montmorillonite clays. The Dalma red slipped wares and the Sefid red-on-cream, the Yahya Lapui red slipped wares are all coarse wares but they are elegant shapes,

thin walled, and represent tour de force craftsmanship with a very difficult to form material. During the transition from Dalma to Pisdeli or from Godin X to Godin IX, there are changes in the decorating and forming of the rim which suggest that turntables were made useful as more rapid turning devices. The nature of the mechanical changes involved is unknown.

The nature and extent of the centrifical force exerted by such a wheel is unknown, but it is not unlikely that raising a vessel wall as well as shaping it occurred but is not be found except in a few instances. Colin Hope (1981:127-133; 1982:13-14) has investigated examples of potter's wheels from much later periods and found them to be unable to produce sufficient speed to easily form pottery. We suggest that onto this gradual development is the appearance of the potter's wheel at first in a tentative way. The first products which can be definitely described as thrown on a wheel are the small cups, which some have described as quite crude, with string cut bases from Tepe Yahya IVC and from Tepe Farukhabad, Jemdet Nasr phase, and which are common from many other sites, and which date to about 3200-3000 B.C.

Thus, from an intensive investigation of particular examples of pottery and ware types, and by the interpretation of our model for technological change, the technology of early Near Eastern pottery production begins to unfold. The importance of determining the external and internal macro- and microstructure cannot be emphasized enough, nor can combining all of these aspects with an understanding of the properties of the clays and clay bodies, both fired and unfired.

VIII. CONCLUSIONS

A. Conclusions about the Near Eastern Ceramic Production:

1. The sequential slab construction technology in coarse and fine ware pottery manufacture is conservative. The features of this technological tradition have been isolated, in which the method of sequential slab construction is used to manufacture beakers, bowls, trays, cookpots, storage vessels and other containers used in the neolithic and chalcolithic periods, continuing over a period of about 5000 years, from ca. 8000 B.C. at Ganj Dareh and ca. 6500 at Sarab to 3000 B.C. at Tepe Yahya, Chagha Sefid, Tepe Sabz, Tepe Farukhabad, Seh Gabi, and Hajji Firuz, Dalma and Pisdeli.

2. The geographical extent over which the sequential slab construction technology is found has been shown to consist of the central Zagros region and as far east as the Iranian Plateau. This conclusion is based on a large sampling of wares types and form classes from well excavated sites having large quantities of pottery with good context and dating as well as long sequences.

3. From a survey of small amounts of pottery, we conclude that there are instances of sequential slab construction as far east as Mehrgarh in Pakistan and as far west as the Badarian/Tasian pottery of Egypt, a distance spanning some 4000 km.

4. The same method of sequential slab construction used for coarse wares continued to be used for the production of early fine wares. Other studies have differentiated these ware types by variations in form, color and decoration, without recognizing the commonality of forming technology. The major technological breakthrough which produced the fine wares was aging of the clay, not a change in the selection of another clay type or use of

other tempering additives. In the grit-tempered fine wares the clay is fully plastic and is no longer constrained to the s.s.c. method of manufacture as an optimal forming method. A measure of the technological conservatism is the persistence of sequential slab construction.

5. A developmental sequence of pottery forming methods has been established for four sites: Tepe Yahya, Seh Gabi, Hajji Firuz-Dalma-Pisdeli, and Chagha Sefid-Sabz-Farukhabad, and shown to be the same. This process of development includes four variables: molds, aging of clay, temper and turning. A narrative description of the technological change includes the use of molds to form thinner, more refined ware, the aging of clay and change in the type of temper to make the fine wares and finally a turntable or other rotatable device is introduced to wet smooth and form rims and to apply banded, horizontal lines of decoration, all without shaping walls which had been formed by sequential slab construction. By 3000 B.C. walls of small vessels are shaped and thinned by rotation of the vessel on a potter's wheel. The use of a turntable to shape already constructed pottery precedes the use of a potter's wheel in which the wall is raised using the centrifugal force of the rotating wheel. We have fixed a date for the introduction of the potter's wheel as Jemdet Nasr at Tepe Farukhabad and IVC at Tepe Yahya, and after Godin VII-VIII at Seh Gabi.

6. There are differences in the details of the sequence of development and time at which the changes occurred at different sites, some of which has been isolated here but the should also be the subject of a future study. However, these conclusions indicate that there is an increase in the degree of cultural integration and interaction in the Zagros region during the fifth and fourth millennia, as shown by the spread of pottery technology. From the dating given in Table 1, the spread of turntables and the aging of

clay each took about 1000 years; whereas, the later development of the potter's wheel took only 200 years (3200-3000 B.C.).

B. Conclusions about Pottery Forming Methods:

1. The method of sequential slab construction has been described and replicated using Near Eastern montmorillonite clays. In addition, an ethnographic example of this method has been recorded and an example of this potter's work analyzed. This method of construction has been set within a framework of the constraints of raw materials and the optimization of those materials offered by this method.

2. Criteria have been established for each of the pottery methods considered in this study using observations of the macrostructure and microstructure: slab construction, coiling, throwing and molding.

3. Because of the extensive finishing of the bases of early fine and coarseware pottery by wet smoothing, adding slip coatings, scraping away or adding a layer or coiled foot ring, there is little visible evidence on the surface of molding of the bases. No evidence of such molding was found in cross sections by xero-radiography or optical microscopy. By using direct evidence of the mold impression, the presence of molding can be found in a limited number of Hajji Firuz examples, one from Ganj Dareh and another from Tepe Yahya. By using indirect evidence, there seems to be an increased use of molding in the Dalma or fourth millennium wares and in the fifth millennium wares from Chagha Sefid as well as the Halaf wares in which rounded bases and cantilevered lower walls are found. There are a few sherds from Hajji Firuz for which the method of using a coiled or plaited basket as a mold has been determined, and a higher proportion is found at Mehrgarh in which the same method is highly likely. From replication

studies and inquiries of pueblo potters and observation of their practices, there are certain flaring base shapes which are difficult to make without molds. Thus there is a small group of pottery for which the technique of molding can be detailed, and a group of shapes for which we can state molding is probable.

4. There is no evidence for use of coiling as a widespread means of constructing pottery vessels in the Near East between 8000-3000 B.C. Coils were used in specialized locations at the lip rim and base ring, where it was necessary to finish an edge, and for the practice of spiral coiling for which a limited number of instances can be found dating from ca. 3200 B.C.

5. There is no evidence for the use of paddle and anvil techniques.

C. Conclusions about the Technology of Pottery Production:

1. The method of sequential slab construction was a conservative technology which persisted through the development of various types of fine wares and stylistic changes in vessel form and decoration. We conclude that compared with these other attributes, the rate of change of production technology was slow, but incremental with a substantial part of the old technology surviving in the incremental change in order to meet social needs first for pottery containers and then for fine wares.

2. The pottery technology developed out of the architectural technology. The composition, raw material preparation, and working properties of wet mud brick (chineh) and coarse ware pottery are the same. The construction techniques using preformed elements without standard sizes to stack on top of one another and the application and smoothing of a surface coating. The elements of the technology are structurally isomorphous, more so than the comparison of pottery to any other technology.

In addition, the early pottery is built into walls in level D at Ganj Dareh. We conclude that pottery grew out of the mud brick architecture and shared a common tradition. The coarse ware pottery was a technological innovation developed in the eighth millennium by analogical reasoning, that is by recognizing known techniques and materials could be modified to better suit a purpose deemed socially important, that is storage of grain.

IX. THE CERAMIC COMPLEX

The ceramic complex is the whole of those activities, traits, values and objects related to the making of pottery and other clay artifacts; such as the (1) formal conventions of vessel shape and function (S. Henrickson and M.M.A. MacDonald, 1983), design elements and surface treatment and manufacturing methods, (2) the material repertoire, including clay type and properties, temper, decorative materials and the conventions of preparation and application, (3) the level of chemical technology and (4) firing technology, (5) as well as the conventions which govern quality, use, reuse and value. From a technological point of view, this ceramic complex includes clay preparation, forming and decorating technologies, chemical and firing technologies. To determine the nature of this ceramic complex at any time and place requires developing a technological typology with proper reference standards. We have done this for pottery production methods and for clay preparation for the Zagros region of the Near East; however, technological typologies have yet to be established for the chemical technology involved in pigment and slip decoration. Nevertheless, we can already make a few observations and speculations which suggest that:

a. The rate of development of pigment technology is independent of forming technology, and because of its level of complexity, proceeds independently at different rates in different sites unless there is a sharing of the technology.

b. Clay preparation varied for different types of clay products, an example of which is Ganj Dareh pottery and figures, but it is not possible to separate clays levigated by man from naturally sedimented clays in these ceramic wares.

c. A sophisticated technology found in one place at one time does not necessarily indicate a general level of technology has been reached, an example of which is found in the Sarab paint slips.

X. FURTHER WORK

1. Little is known of the uses of clay in the Upper Paleolithic and Mesolithic in the archaeological record of the Near East (D. Schmandt-Besserat 1974,1977). We would like to suggest that the origins of clay technology are not to be found in clay-based pigments or the manufacture of figurines, but rather in type of fuel used in grasslands and upland meadows where wood is not readily available. I think we should be investigating ash lenses to find out if the pottery and architectural tradition cannot be related to the materials out of which fuel was made, to shapes in which fuel was made prior to use. In other words, we need to establish the evidence for alternate sources of fuel, such as the presence of straw, clay, ash and perhaps dung by microscopic excavation of charcoal lenses.

2. Based on a limited survey of wheel thrown pottery, we conjecture that wheel throwing was introduced for small vessels; whereas, large vessels continued to be produced by the sequential slab process. Coiling seems to have largely replaced s.s.c. after the introduction of wheel throwing in order to solve the problem of constructing large vessels more rapidly and with less manual labor. Further investigation is needed.

3. Other sites with long sequences must be investigated to fill in the picture of pottery forming in other geographic areas. For instance, are there variations as one proceeds west of the area of this study. We intend and have received permission to study material from Hassuna, Jarmo, Choga Mami, Shimshara, Guran, Susa and Mehrgarh.

REFERENCES

- M.J. Adams
 1977 "Style in Southeast Asian Material Processing: Some Implications for Ritual and Art", in H. Lechtman and R.S. Merrill, editors, **Material Culture: Styles, Organization, and Dynamics of Technology**, West Publishing, St. Paul, pp. 21-52.
 1973 "Structural Aspects of a Village Art", **American Anthropologist**, Vol. 75, pp. 265-279.
- R.McC. Adams
 1983 "The Jarmo Stone and Pottery Vessel Industry", in R.J. Braidwood, **Prehistoric Archaeology Along the Zagros Flanks**, Oriental Institute Press, Chicago, pp. 209-233.
- W.Y. Adams
 1979 "On the Argument from Ceramics to History: A Challenge Based on Evidence from Medieval Nubia", **Current Anthropology**, Vol. 20, No. 4 (Dec.), pp. 727-744.
- R.E. Alexander and R.H. Johnston
 1982 "Xeroradiographs of Ancient Objects: A New Imaging Modality", in J.S. Olin and A.D. Franklin, **Archaeological Ceramics**, Smithsonian Institution Press, Washington, pp. 145-154.
- R. Amiran
 1965 "The Beginnings of Pottery-Making in the Near East", in F. Matson, editor, **Ceramics and Man**, Aldine Pub. Co., New York, pp. 240-247.
- R. Amiran and D. Shenhav
 1984 "Experiments with an Ancient Potter's Wheel", in P.M. Rice, **Pots and Potters: Current Approaches in Ceramic Archaeology**, Institute of Archaeology Monograph 24, University of California, Los Angeles, pp. 107-112.
- A.J. Ammerman and L.L. Cavalli-Sforza
 1984 **The Neolithic Transition and the Genetics of Populations in Europe**, Princeton University Press, Princeton.
- J.R. Arnold, J.P. Testa, P.J. Friedman and G.X. Kambic
 1983 "Computed Tomographic Analysis of Meteorite Inclusions", **Science**, Vol. 219 (3 Jan.), pp. 283-284.
- E.J. Baumgartel
 1970 "Predynastic Egypt", in I.E.S. Edwards, et.al., **The Cambridge Ancient History**, Vol. 1, Part 1, Cambridge University Press, Cambridge, pp. 483-484.
- T.W. Beale
 1983 "On the Track of the Yahya Large Kus: Evidence for

- Architectural Planning in the Period IVC Complex at Tepe Yahya", **Paleorient**, Vol. 9, No. 1, pp. 81-88.
- 1978 **Tepe Yahya: The Early Periods**, Ph.D. Thesis, Harvard University.
- 1971 **The Fifth and Fourth Millennia B.C. at Tepe Yahya: A Study of Prehistoric Trade and Cultural Contact in Southern Iran**, B.A. Honors Thesis, Harvard University.
- Benjamin Beck
- 1980 **Animal Tool Behavior**, Garland Press, New York, pp. 139-248.
- L.R. Binford
- 1982 "Objectivity-Explanation-Archaeology 1981", in C. Renfrew, et.al., editors, **Theory and Explanation in Archaeology: The Southampton Conference**, Academic Press, New York, pp. 125-138.
- 1981 **Bones: Ancient Men and Modern Myths**, Academic Press, New York.
- 1969 "Conceptual Problems in Dealing with Units and Rates of Cultural Evolution", **Anthropology U.C.L.A.**, Vol. 1, No. 1 (Jan.).
- L.R. Binford and J.A. Sabloff
- 1982 "Paradigms, Systematics and Archaeology", **Jour. of Anthropological Research**, Vol. 38, No. 2 (Summer), pp. 137-153.
- M. Bloch
- 1953 **The Historian's Craft**, Vintage Books, New York.
- P. Bohannon and M. Glazer
- 1973 **High Points in Anthropology**, A.A. Knopf, New York.
- J. Bourriau
- , 1981 **Umm El-Ga'ab: Pottery from the Nile Valley before the Arab Conquest**, Fitzwilliam Museum, Cambridge University Press, Cambridge.
- R.J. Braidwood, L. Braidwood, J.G. Smith and C. Leslie
- 1952 "Matarrah: A Southern Variant of the Hassunan Assemblage, Excavated in 1948", **Jour. of Near Eastern Studies**, Vol. 11, No. 1, pp. 1-75.
- R.J. Braidwood and B. Howe
- 1960 **Prehistoric Investigations in Iraqi Kurdistan**, The Oriental Institute Studies in Ancient Oriental Civilization No. 31, University of Chicago Press, Chicago, esp. p. 40.
- F. Braudel
- 1982 **Civilization and Capitalism: 15th-18th Century, Vol. II, The Wheels of Commerce**, Harper and Row, New York.

- G.W. Brindley and G. Brown
1980 **Crystal Structures of Clay Minerals and Their X-Ray Identification**, Mineralogical Society, London.
- G. Brunton
1937 **Mostegedda and the Tasian Culture**, Quaritch, London.
- J.R. Caldwell
1967 **Investigations at Tal-i-Iblis**, Illinois State Museum, Preliminary Report No. 9, Springfield.
- J.R. Caldwell and S.M. Shahmirzadi
1966 **Tal-i-Iblis: The Kerman Range and the Beginnings of Smelting**, Illinois State Preliminary Report No. 7, Springfield.
- L.L. Cavalli-Sforza and M.W. Feldman
1981 **Cultural Transmission and Evolution: A Quantitative Approach**, Princeton University Press, Princeton.
- M. Centlivres-Demont
1971 **Un Communauté de Potiers en Iran: Le Centre de Meybod (Yazd)**, Ludwig Reichert Verlag, Wiesbaden.
- K.C. Chang
1980 "Theoretical Models" in "Five Doors to Shang", **Shang Civilization**, Yale University Press, New Haven, pp. 60-65.
1977 **The Archaeology of Ancient China**, Yale University Press, New Haven, pp. 85-126.
1968 "Toward a Science of Prehistoric Society", K.C. Chang, editor, **Settlement Archaeology**, National Press Books, Palo Alto.
- V.Gordon Childe
1951 **Man Makes Himself**, Mentor reprint, New American Library, New York, pp. 76-79.
- S. Crandall and A. Dahl
1972 **Introduction to the Mechanics of Solids**, McGraw-Hill, New York, 2nd edition.
- T. Davidson and H. McKerrell
1980 "The Neutron Activation Analysis of Halaf and 'Ubaid Pottery from Tell Arpachiyah and Tepe Gawra", **Iraq**, Vol. 42, pp. 155-167.
1976 "Pottery Analysis and Halaf Period Trade in the Khabur Headwaters Region", **Iraq**, Vol. 38, pp. 45-56.
- P. Delougaz
1952 **Pottery from the Diyala Region**, Oriental

Institute Publications Vol. 63, University of Chicago Press, Chicago.

G. Dollfus

1983 "Tepe Bendebal, Traveau 1977, 1978", **Cahiers de la Delegation Archaeologique Francais en Iran**, Vol. 13, pp. 133-276, esp. 167-168.

1978 "Djaffarabad, Djowi, Benezal: Contribution a l'etude de la Susiane au Ve millenaire et au debut du IVe millenaire", **Paleorient**, Vol. 4, pp. 141-167.

1975 "Les fouilles a Djaffarabad de 1972 a 1974, Djaffarabad, Periodes I and II", **Cahiers de la Delegation Archaeologique Francais en Iran**, Vol. 5, pp. 11-222.

G. Dollfus and A. Hesse

1977 "Les Structures de Combustion du Tepe Djaffarabad, Periodes I a III", **D.A.F.I., Cahiers**, Vol. 7, pp. 11-47.

R.J. Dyson, Jr.

1965 "Problems in the Relative Chronology of Iran, 6000-2000 B.C.", in R.W. Ehrich, **Chronologies in Old World Archaeology**, University of Chicago Press, pp. 215-256, esp. 217.

W.I. Edwards and E.R. Segnit

1984 "Pottery Technology at the Chalcolithic Site of Teleilat Ghassul (Jordan)", **Archaeometry**, Vol. 26, Pt. 1, pp. 69-77.

N. Egami and S. Masuda

1962 **Marv Dasht I: The Excavations at Tal-i-Bakun**, Institute for Oriental Culture, University of Tokyo.

J.N. Enault and J.-F. Jarrige

1973 "Chalcolithic Pottery from Four Sites in the Bolan Area of Baluchistan, West Pakistan", in N. Hammond, editor, **South Asian Archaeology**, Noyes Press, Park Ridge, New Jersey.

G.V. Foster

1983 "Kourion Figures: A Study Using Xeroradiography", **MASCA Journal**, Vol. 2, No. 6 (Dec.), pp. 179-181.

L. Franchet

1911^a **Ceramique Primitive: Introduction a l'Etude de la Technologie**, Paris.

1911^b **La Fabrication Industrielle des Emaux et Couleurs Ceramique**, Paris.

H.J. Franken

1974 **In Search of Jericho Potters**, Elsevier Pub. Co., New York.

H.J. Franken and J. Kalsbeek

1975 **Potters of a Medieval Village in the Jordan Valley: Excavations at Tell deir cAlla: a Medieval Tell, Tell Abu Gourdan, Jordan**, Elsevier Pub. Co., New York, p. 29ff.

U.M. Franklin

1983 "On Bronze and Other Metals in Early China", in D.N. Keightley, editor, **The Origins of Chinese Civilization**, University of California Press, Berkeley, pp. 279-296.

Hetty Goldman

1952-63 **The Excavations at Gozlu Kule, Tarsus, Vol. 2, The Neolithic to Bronze Age**, Princeton University Press, Princeton.

S.C. Gilfillan

1935 **The Sociology of Invention**, Follett Pub. Co., Chicago.

W. Glanzman

1983 "Xeroradiographic Examination of Pottery Manufacturing Techniques: A Test Case from the Baq'ah Valley, Jordan, **MASCA Journal**, Vol. 2, No. 6 (Dec.), pp. 163-169.

W.H. Gourdin and W.D. Kingery

1975 "The Beginnings of Pyrotechnology: Neolithic and Egyptian Lime Plaster", **Jour. of Field Archaeology**, Vol. 2, pp. 133-150.

E.F.F. (of S.) Henrickson

1985 "An Undated Chronology of the Early and Middle Chalcolithic of the Central Zagros Highlands, Western Iran", **Iran**, Vol. XXIII (in press).

1983 **Ceramic Styles and Cultural Interaction in the Early and Middle Chalcolithic of the Central Zagros, Iran**, Ph.D. Thesis, University of Toronto.

E.F.F. Henrickson and M.M.A. MacDonald

1983 "Ceramic Form and Function: An Ethnographic Search and An Archaeological Application", **American Anthropologist**, Vol. 85, No. 2, pp. 630-643.

D. Heskell

1981 **The Development of Pyrotechnology in Iran during the Fourth and Third Millennium B.C.**, Ph.D. Thesis, Harvard University.

B. Hindle

1981 **Emulation and Invention**, New York University Press, N.Y.

F. Hole

1980 "The Desert Culture in Southwest Asia", **Rice**

University Studies, Vol. 66, No. 1 (Winter), pp. 153-166.

1979 "Rediscovering the Past in the Present: Ethnoarchaeology in Luristan, Iran", in C.H. Kramer, editor, **Ethnoarchaeology: Implications of Ethnography for Archaeology**, Columbia University Press, New York, pp. 192-218.

1978 "Pastoral Nomadism in Western Iran" in R.A. Gould, **Explorations in Ethnoarchaeology**, School of American Research, University of New Mexico Press, Albuquerque, pp. 127-167.

1977 **Studies in the Archaeological History of the Deh Luran Plain: The Excavations of Chagha Sefid**, Memoirs of the University of Michigan, Ann Arbor, No. 9, esp. pp. 95-96ff.

1973 "Questions of Theory in the Explanation of Culture Change in Prehistory", C. Renfrew, editor, **The Explanation of Culture Change**, Duckworth, Gloucester Crescent.

1966 "Investigating the Origins of Mesopotamian Civilization", **Science**, Vol. 153, No. 3736 (Aug.), pp. 605-611.

1962 "Excavations at Ali Kosh, Iran, 1961", **Iranica Antiqua**, Vol. 2, pp. 97-147.

F. Hole, K. Flannery and J. Nealy

1969 **Prehistory and Human Ecology of the Deh Luran Plain**, Memoir No. 1, Museum of Anthropology, University of Michigan, Ann Arbor, esp. p. 112.

C. A. Hope

1982 "Concerning Egyptian Potters' Wheels", **The Jour. of the Soc. for the Study of Egyptian Antiquities**, Vol. 12, No. 1 (Jan.), pp. 13-14.

1981 "Two Ancient Egyptian Potters' Wheels", **The Jour. of the Soc. for the Study of Egyptian Antiquities**, Vol. 11, No. 3 (May), pp. 127-133.

A. Hyman

1982 **Charles Babbage: Pioneer of the Computer**, Princeton University Press, Princeton, N.J.

F. Ikawa-Smith

1980 "Current Issues in Japanese Archaeology", **American Scientist**, Vol. 68, No. 2, pp. 134-145.

J.-F. Jarrige

1985 "The Beginning of Pottery in Baluchistan", Beatrice di Cardi felicitation volume, Centre Nationale de Recherche Scientifique (in press).

J.-F. Jarrige and R. Meadows

1980 "The Antecedents of Civilization in the Indus Valley", **Scientific American**, Vol. 243, No. 2, pp. 122-133.

D.J. Jeremy

1981 **Transatlantic Industrial Revolution: The Diffusion of Textile Technologies between Britain and America, 1790-1830s**, M.I.T. Press, Cambridge.

J. Jewkes, D. Sawers and R. Stillerman
1969 **The Sources of Invention**, Norton, New York.

A. Jolly
1972 **The Evolution of Primate Behavior**, MacMillan, New York.

H. Junker
1929-1940 **Anzeiger der Osterreichischen Akademie der Wissen schaften (Phil.-Hist. Klasse) wien**, Vienna Academy of Natural Sciences , 6 reports span this time period.

D. Kamilli and C.C. Lamberg-Karlovsky
1978 "Physico-Chemical Analyses of Selected Ceramics from Tepe Yahya, Iran", **Archaeometry**, Vol. 20.

H.J. Kantor
1984 "Chogha Mish", **1983/84 Annual Report**, The Oriental Institute, Chicago, pp. 25-27.
1965 "The Relative Chronology of Egypt and Its Foreign Correlations Before the Late Bronze Age", in R.W. Ehrich, **Chronologies in Old World Archaeology**, University of Chicago Press, Chicago, pp. 1-46.

K.M. Kenyon and T. Holland
1982 **Jericho, Vol. IV: The Neolithic Pottery**, Institute of Archaeology, London.

W.D. Kingery
1984 "Interactions of Ceramic Technology with Society", in P.R. Rice, **Pots and Potters**, Institute of Archaeology Monograph 24, University of California, Los Angeles, pp. 171-178.
1982 "Plausible Inferences from Ceramic Artifacts", in J.S. Olin and A.D. Franklin, **Archaeological Ceramics**, Smithsonian Institution Press, Washington, pp. 37-45.
1974 "A Technological Characterization of Two Cypriot Ceramics", in A. Bishay, **Recent Advances in the Science and Technology of Materials**, Vol. 3, Plenum Pub. Corp., New York, pp. 169-186.
1966 "On the Interaction Between Basic Science and Technological Development in Ceramics", **Xth International Ceramic Congress in Stockholm, Sweden, June 12-18**.

W.D. Kingery, A.J. Brook, R.L. Anderson, S. Prochazka, B.J. Wuensch, R. Shaw and others
1973 "Progress Report on a cursory Technical Examination of Some Near Eastern Ceramic Sherds", unpub. ms.

D. Kirkebride

"Umm Dabaghiyah 1971: A Preliminary Report", *Iraq*,
Vol. 34m pp. 3-72, esp. p. 8.

P. Kohl

1975 **Seeds of Upheaval: The Production of Chlorite at Tepe Yahya and an Analysis of Commodity Production and Trade in Southwest Asia in the Third Millennium**, Ph.D. Thesis, Harvard University.

P. Kohl and R. Wright

1977 "Stateless Cities: The Differentiation of Societies in the Near Eastern Neolithic", **Dialectical Anthropology**, Vol. 2, No. 4 (Nov.), pp. 271-283.

C. Kramer (a.k.a. C. Hamlin)

1982 **Village Ethnoarchaeology: Rural Iran in Archaeological Perspective**, Academic Press, New York.

1979 "An Archaeological View of a Contemporary Kurdish Village: Domestic Architecture, Household Size and Wealth" in C. Kramer, **Ethnoarchaeology: Implications of Ethnography for Archaeology**, Columbia University Press, New York, pp. 139-163.

1975 "Dalma Tepe", *Iran*, Vol. 13, pp. 111-127.

L. Krzyzaniak

1983 **Early Farming Cultures in the Lower Nile**, Varsovie, Poland, esp. pp. 92-96.

T.S. Kuhn

1962 **The Structure of Scientific Revolutions**, University of Chicago Press, Chicago.

C.C. Lamberg-Karlovsky

1985 **Tepe Yahya: The Early Periods** (in press).

1974 "Historical Continuity, Stage and Process: The Development of a Metallurgical Technology", A. Ghosh, editor, **Perspectives in Paleoanthropology**, Mukhopadhyay, Calcutta, pp. 331-344.

1973 "Urban Interaction on the Iranian Plateau", Reckitt Lecture, **Proc. of the British Academy**.

1972 "Trade Mechanisms in Indus-Mesopotamian Interrelations", *Jour. American Oriental Society*, Vol. 92, No. 2, pp. 222-230.

1970 **Excavations at Tepe Yahya, Iran, 1967-1969**. American School of Prehistoric Research Bulletin 27, Peabody Museum, Harvard University.

1969-1972 Site reports on Tepe Yahya in *Iran*, vol. 7, pp. 184-186; vol. 8, pp. 197-199; vol. 9, pp. 87-96; and vol. 10, pp. 89-100.

H.N. Lechtman

1984 "Andean Value Systems and the Development of Prehistoric Metallurgy", **Technology and Culture**, Vol. 25, No. 1, pp. 1-36.

H.N. Lechtman and R.S. Merrill

1977 **Material Culture: Styles, Organization, and Dynamics of Technology**, West Publ Co., St. Paul.

H.N. Lechtman and A. Steinberg

1979 "The History of Technology: An Anthropological Point of View", in G. Bugliarello and D.B. Donner, **The History and Philosophy of Technology**, symposium held in 1973, University of Illinois Press, Urbana, pp. 135-160.

C. Leslie

"Style, Tradition and Change: An Analysis of the Earliest Painted Pottery from North Iran", in R.J. Braidwood et. al., "Matarrah: A Southern Variant of the Hassunan Assemblage, Excavated in 1948", **Jour. Near Eastern Studies**, Vol. 11, pp. 56-60.

C. Levi-Strauss

1969 **The Raw and the Cooked**, Harper, New York.

1966 **The Savage Mind**, University of Chicago Press, Chicago.

L.D. Levine and M.M.A. MacDonald

1977 "The Neolithic and Chalcolithic Periods in the Mahidasht", **Iran**, Vol 15, pp. 39-50.

S. Lloyd and F. Safar

1945 "Tell Hassuna", **Jour. of Near Eastern Studies**, Vol. 4, pp. 255-289.

M.M.A. MacDonald

1979 **An Examination of Mid-Holocene Settlement Patterns in the Central Zagros Region of Western Iran**, Ph.D. Dissertation, University of Toronto.

R.C. MacKenzie

1970 **Differential Thermal Analysis**, Vol. 1, Fundamental Aspects, Academic Press, London.

C.K. Maisels

1984 **The Origins of Settlement Agriculture and the City State in Mesopotamia**, Ph.D. Thesis, University of Edinburgh.

Y. Mahidzadeh

1975-1977 "The Development of the Pottery Kiln in Iran from Prehistoric to Historical Periods", **Paleorient**, Vol. 3, pp. 207-221.

Y. Maniatis and M.S. Tite

1981 "Technological Examination of Neolithic and Bronze Age Pottery from Central and South-east Europe and from the Near East", **Jour. Archaeological Science**, Vol. 8, pp.

59-76.

F.R. Matson

1971 "A Study of Temperatures Used in Firing Ancient Mesopotamian Pottery", in R.H. Brill, **Science and Archaeology**, M.I.T. Press, Cambridge, pp. 56-79.

1965 **Ceramics and Man**, Aldine Pub. Co., New York.

1960 "Specialized Ceramic Studies and Radioactive Carbon Techniques", in R.J. Braidwood and B. Howe, **Prehistoric Investigations in Iraqi Kurdistan**, Studies in Ancient Oriental Civilizations, No. 31, Oriental Institute of the University of Chicago, Chicago, pp. 63-69.

C.G. Meade, P.E.L. Smith and T. Cuyler Young

1968 "Survey of Excavations in Iran during 1966-67: Baba Jan, Ganj Dareh and Godin Tepe", **Iran**, Vol. 6, pp. 157-161.

J. Mellaart

1970 "The Earliest Settlements in Western Asia from the Ninth to the End of the Fifth Millennium B.C." in I.E.S. Edwards, et.al., editors, **The Cambridge Ancient History**, Cambridge University Press, pp. 248-326.

C. Mitcham

1979 "Philosophy and the History of Technology", in G. Bugliarello and D.B. Donner, **The History and Philosophy of Technology**, University of Illinois Press, Urbana, pp. 163-201.

A.M.T. Moore

1975 "The Excavation of Tell Abu Hureyra in Syria: A Preliminary Report", **Proc. of the Prehistoric Society**, Vol. 41, pp. 50-77.

P. Mortensen

"Early Village Farming Occupation" in J. Meldgaard, P. Mortensen and H. Thrane, "Excavations at Tepe Guran, Luristan", **Acta Archaeologica**, Vol. 34, pp. 110-121.

"Tell Shimshara: The Hassuna Period", **Kongelige Danske Videnskabernes Selskab Historisk-Filosofiske Skrifter**, Bd. 5, No. 2, Copenhagen, Munksgaard.

H.J. Nissen

1968 "Survey of an Abandoned Modern Village in Southern Iraq", **Sumer**, Vol. 24, pp. 107-114 esp. p. 108-9.

J.V. Noble

1965 **The Techniques of Attic Painted Pottery**, Faber and Faber, London.

W. Noll

1976 "Mineralogie und Technik der fruhen Keramiken Grosmesopotamiens", **N. Jb. Miner. Abh.**, Vol. 127, No. 3, pp. 261-288.

1978 "Mineralogie und Technik der bemalten Keramiken Altagyptens", **N. Jb. Miner. Abh.**, Vol. 133, No. 3, pp. 227-290.

1979 "Anorganische Pigmente in Vorgeschichte und Antike", **Fortschr. Miner.**, Vol. 57, No. 2, pp. 203-263.

W. Noll, R. Holm and L. Born

1972 "Manganoxyd-Phasen als Pigmente antiker Vasenmalerei", **Naturwissenschaften**, Vol. 59, pp. 511-512.

1975 "Painting of Ancient Ceramics", **Angewandte Chemie**, Vol. 14, No. 9, p. 602-613.

J. Oates

1969 "Choga Mami, 1967-1968: A Preliminary Report", **Iraq**, Vol. 31, pp. 115-152.

D.P.S. Peacock

1977 **Pottery and Early Commerce**, Academic Press, London, esp. pp. 29 and 31.

D.G. Peters, J.M. Hayes, and G.M. Heiftje

1974 **Chemical Separations and Measurements**, Saunders, Philadelphia.

M. Piperno

1973 "The Lithic Industry of Tepe Yahya: A Preliminary Typological Analysis", **East and West**, Vol. 23, No. 1-2, pp. 59-74.

G. Polya

1957 **How to Solve It**, Doubleday Anchor Books, New York.

D. Potts

1981 "The Potter's Marks of Tepe Yahya", **Paleorient**, Vol. 7, No. 1, pp. 107-122.

1980 **Tradition and Transformation: Tepe Yahya and the Iranian Plateau during the Third Millennium B.C.**, Ph.D. Thesis, Harvard University.

M.E. Prickett

1985 **Man, Land and Water: Settlement Distribution and the Development of Irrigation Agriculture in the Upper Rud-i Gushk**, Ph.D. Thesis, Harvard University.

D. Pye

1968 **The Nature and Art of Workmanship**, Cambridge University Press, Cambridge.

C.L. Redman

1973 "Early Village Technology: A View Through the Microscope", **Paleorient**, Vol. 1, No. 2, pp. 249-261.

C. Renfrew

"Trade as Action at a Distance: Questions of Integration and Communication", in J.A. Sabloff and C.C. Lamberg-Karlovsky, **Ancient Civilization and Trade**, School of American Research, University of New Mexico Press, Albuquerque, pp. 3-59.

C. Renfrew, M.J. Rowlands and B.A. Segraves
1982 **Theory and Explanation in Archaeology**, Academic Press, New York.

P.M. Rice
1985 "The Archaeological Study of Specialized Pottery Production: Some Aspects of Method and Theory", in P.M. Rice, editor, **Pots and Potters: Current Approaches in Ceramic Archeology**, Institute of Archaeology Monograph 24, U.C.L.A., pp. 45-54.

1982 "Pottery Production, Pottery Classification, and the Role of Physicochemical Analyses", in J.S. Olin and A.D. Franklin, **Archaeological Ceramics**, Smithsonian Institution Press, Washington.

1981 "Evolution of Specialized Pottery Production: A Trial Model", **Current Anthropology**, Vol. 22, No. 3, pp. 219-240.

G. Richter
1923 **The Craft of Athenian Pottery**, Yale University Press, New Haven.

O.S. Rye
1981 **Pottery Technology: Principles and Reconstruction**, Taraxacum, Washington, esp. pp. 134-137.

O.S. Rye and C. Evans
1976 **Traditional Pottery Techniques of Pakistan: Field and Laboratory Studies**, Smithsonian Contributions to Anthropology, No. 21, Smithsonian Institution Press.

D. Sahal
1981 **Patterns of Technological Innovation**, Addison-Wesley Publ Co., Reading, Mass.

D. Schmandt-Besserat
1978 "The Earliest Presursor of Writing", **Scientific American**, Vol. 238, No. 6, pp. 50-59.
1977 "An Archaic Recording System and the Origin of Writing", **Syro-Mesopotamian Studies**, Vol 1., Undena Pub. Co., Malibu.
1977 "Earliest Uses of Clay in Syria", **Expedition**, Vol. 19, No. 3, pp. 28-42.
1977 "The Beginnings of the Use of Clay in Turkey", **Anatolian Studies**, Vol. 27, pp. 133-150.
1974 "The Use of Clay before Pottery in the Zagros", **Expedition**, Vol. 16, No. 2, pp. 11-17.

L. Scott

1967 "Chapter 15, Pottery", in C. Singer, E.J. Holmyard and A.R. Hall, **A History of Technology**, Vol. I, Clarendon Press, Oxford, esp. pp. 384-385.

S.A. Semenov

1964 **Prehistoric Technology**, tr. by M.V. Thompson, Cory, Adams and McKay, London.

A.O. Shepard

1954 **Ceramics for the Archaeologist**, Carnegie Institute, Washington, esp. pp. 140-141 and 181-193.

C.S. Smith

1981 **A Search for Structure: Selected Essays on Science, Art and History**, M.I.T. Press, Cambridge.

1973 "Remarks on the Discovery of Techniques and on Sources for the Study of Their History", in G. Bugliarello and D.B. Donner, **The History and Philosophy of Technology**, University of Illinois Press, Urbana.

P.E.L. Smith

1983 "Ganj Dareh: An Early Neolithic Site in Iran", **Archiv fur Orientforschung**, Vol. 29, pp. 300-302.

1978 "An Interim Report on Ganj Dareh Tepe, Iran", **American Jour. Archaeology**, Vol. 82, No. 4, pp. 538-540.

1974 "Ganj Dareh Tepe", **Paleorient**, Vol. 2, pp. 207-209.

P.E.L. Smith and R. Crepeau

1983 "Fabrication Experimentale de Repliques d'un Vase Neolithique du Site de Ganj Dareh, Iran: Recherche Technologique", **Paleorient**, Vol. 9, No. 2, pp. 55-62.

P.E.L. Smith and P. Mortensen

1980 "Three Early Neolithic Sites in Western Iran", **Current Anthropology**, Vol. 21, No. 4, pp. 511-512.

P.E.L. Smith and T. Cuyler Young

1966 "Research in the Prehistory of Central Iran: Recent Preliminary Excavations Promise to Document 40,000 Years of Prehistory in the Zagros Mountains", **Science**, Vol. 153, No. 3734, pp. 386-391.

D.H. Stapleton

1975 **The Transfer of Technology to the United States in the Nineteenth Century**, Ph.D. Dissertation, University of Delaware, see especially "A Survey of Concepts of the Transfer of Technology", pp. 1-59 and conclusions.

M.S. Tite, I.C. Freestone, N.D. Meeks and M. Bimson

1982 "The Use of Scanning Electron Microscopy in the Technological Examination of Ancient Ceramics", in J.S. Olin and A.D. Franklin, editors, **Archaeological Ceramics**,

Smithsonian Institution Press, Washington, pp. 109-120.

M.S. Tite and Y. Maniatis

1975 "Examination of Ancient Pottery Using the Scanning Electron Microscope", *Nature*, Vol. 257, pp. 122-123.

M. Tosi

1983 "The Notion of Craft Specialization and Its Representation in the Archaeological Record of Early States in the Turanian Based", in M. Spriggs, editor, **Marxist Approaches in Archaeology**, Academic Press, New York.

P.B. Vandiver

1985 **Paleolithic Pigment Processing**, Prehistory and Ecology Series, University of Chicago Press, Chicago (in preparation).

Nov. 1983 "Preliminary Study of the Production Technology of Tepe Yahya Earthenware Ceramics, ca. 5600-3000 B.C.", unpublished manuscript.

1983 "The Manufacture of Egyptian Faience", in A. Kaczmarczyk and R.E.M. Hedges, **Ancient Egyptian Faience**, Aris and Phillips, Warminster, pp. A1-A144.

1982 "Technological Change in Egyptian Faience", in J.S. Olin and A.D. Franklin, **Archaeological Ceramics**, Smithsonian Institution Press, Washington, pp. 167-180.

1982 "Soda-Lime Silicate Technology at the Second Millennium B.C. Site of Nuzi (Iraq)", in T. and S. Wertime, **Early Pyrotechnology: The Evolution of the First Fire-Using Industries**, Smithsonian Institution Press, Washington, pp. 73-92.

P.B. Vandiver and W.D. Kingery

1985 "Paleolithic Pigment Processing" (in preparation for submission to the **Jour. of Field Archaeology**).

M.M. Voigt

1983 **Hajji Firuz Tepe, Iran: The Neolithic Settlement**, Hasanlu Excavation Reports, Vol. I, University Museum, University of Pennsylvania, Philadelphia.

1976 **Hajji Firuz Tepe: An Economic Reconstruction of a Sixth Millennium Community in Western Iran**, Ph.D. Dissertation, University of Pennsylvania.

M.M. Voigt and R.H. Dyson, Jr.

submitted March, 1984 "Hasanlu Excavation Reports II: The Early Periods (6000-4000 B.C.)", N.S.F. proposal, unpublished manuscript.

P.J. Watson

1965 "The Chronology of North Syria and North Mesopotamia from 10,000 to 2000 B.C.", in R.W. Ehrich, **Chronologies in Old World Archaeology**, University of Chicago Press, Chicago, pp. 61-100.

L. White, Jr.

1962 **Medieval Technology and Social Change**, Oxford University Press, London.

1962 "The Act of Invention: Causes, Contexts, Continuities and Consequences", **Technology and Culture**, Vol. 3 (fall), pp. 486-500.

R. and D. Whitehouse

1975 **Archaeological Atlas of the World**, W.H. Freeman, San Francisco, pp. 56-57.

H. Wright

1981 **An Early Town on the Deh Luran Plain: Excavations at Tepe Farukhabad**, Memoirs of the Museum of Anthropology No. 13, University of Michigan, Ann Arbor.

R. Wright

1984 **Technology, Style and Craft Specialization: Spheres of Interaction and Exchange in the Indo-Iranian Borderlands, Third Millennium B.C.**, Ph.D. Thesis, Harvard University.

G.D. Wu

1938 **Prehistoric Pottery in China**, Kegan Paul, Trench, Trubner Co., London, especially Introduction, pp. 132-136 and "Method of Making" by site.

H.E. Wulff

1966 **The Traditional Crafts of Persia: Their Development, Technology and Influence on Eastern and Western Civilizations**, M.I.T. Press, Cambridge, pp. 102-171.

T. Cuyler Young, Jr., and L.D. Levine

1974 **Excavations of the Godin Project: Second Progress Report**, Art and Archaeology Occasional Paper 26, Royal Ontario Museum, Toronto.

"Dalma Painted Ware", **Expedition**, Vol. 5, No. 2, pp. 38-39.

Additions:

R.W. Grimshaw

1971 **The Chemistry and Physics of Clays**, J. Wiley, New York.

F and S.S. Singer

1963 **Industrial Ceramics**, Chapman and Hall, London.

M.R. Smith

1977 **The Harper's Ferry Armory and the New Technology**, Cornell University Press, Ithaca.