II. CAN POTTERY RESIDUES BE USED AS AN INDEX TO POPULATION?

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This paper attempts to explore a field which is vast in scope, but which has been entered only casually and with few concrete, satisfying results. It attacks the problem of how archaeology may contribute to knowledge of demography among populations for which there exist no head counts and no written records. The procedure must be indirect and must establish associations between the physical aspects of departed cultures on the one hand, and, on the other hand, the number of human beings who constituted those cultures. Thus we must seek to utilize material residues as a clue to the magnitude and nature of the population which produced them. It is recognized that no simple formula exists for solving this problem, and that first results may be dubious, incomplete, and disappointing. It is worthwhile, however, to discover where information is lacking, and what blank spaces must be filled in before the analysis can be fully accomplished.

Of all the material substances deposited by former human populations, the most conspicuous, ubiquitous, and prolific are those derived from ceramics. Pottery, the product of fire clay, is virtually indestructible, and can be recovered in immense quantity from habitation areas over much of the surface of the earth. It is therefore widely available as material to examine the possibility of whether it may not be utilized for evaluating population sizes, and, to a limited extent, interrelations between population and environment.

If we are to establish a numerical relationship between an accumulation of ceramics, usually in the form of broken fragments called potsherds, and the population which produced it, methods must be developed which will be broadly applicable to archaeological sites. At the same time these methods will vary widely in detail from one area to another, first, because no two inhabited localities will have passed through exactly the same series of experiences, and, second, because excavators and students have differed enormously in their competence and in the categories of data which they wished, or were able to obtain. For these reasons only a few rules of a general nature can be formulated. Beyond them, an analysis of each individual site must be undertaken.

In view of these considerations we present a discussion which employs the device of the case history. From the almost unlimited range of choice provided by archaeology, we select, almost at random, a few examples for detailed examination, and devote especial attention, as they arise, to certain subsidiary problems which we encounter. The broad area to be considered is the American Southwest. This area has been selected because it has been exhaustively studied, and is characterized by relatively well-dated sequences. Moreover, it manifests a prolific display of pottery. We are concerned primarily with four representative sites.

The first test site will be the Pueblo of Peco, and the discussion is based upon the work of A. V. Kidder, as published in Southwestern Archaeology (1924) and Pottery of the Pecos, volumes I and II (1931 and 1936). We have here an important site which illustrates an advanced culture and which persisted into historic times.

A second extensive archaeological investigation, one which merits attention principally because of the methodological questions it raises, is the study made by Newell and Krieger (1949) of the George C. Davis site, Cherokee County, Texas. This site consists of a ceremonial mound built upon a former, or contemporary village.

The third archaeological situation to be explored is the Snaketown site on the north bank of the Gila River, thirty miles southeast of Phoenix, Arizona. Its initial excavation has been described exhaustively by Gladwin, Haury, Sayles and Gladwin (1937). Here will be found a habitation surface on the desert floor, covering roughly one square kilometer, numerous small, intrusive pits, the remains of various ceremonial structures, and about sixty refuse mounds.

The fourth sample is the S-U site, a Mogollon village near Pine Lawn on the headwaters of the Gila River, southwestern New Mexico. It was excavated in 1939, 1941, and 1946 by P. S. Martin, J. B. Rinaldo and their collaborators, who published their findings in the Anthropological Series of the Field Museum of Natural History, Vol. 32, Nos. 1,2, and 3, 19 -19 .

The initial problem which confronts the investigator who attempts to study pottery usage in these four sites, or indeed in any site whatever, is to determine the quantity of fragments, or sherds, which are contained in the habitation area. We confine ourselves at the present stage to the number of fragments, for counting is the easiest field or laboratory procedure, and most excavators have reported their results in number rather than weight. We first examine the record for the Pueblo of Pecos.

The first step is to calculate the volume of the pottery-bearing material. This is derived from two sources: rubbish heaps, and the surface of the mesa where the pueblo was constructed. On the north and east sides of the pueblo, according to the plan shown by Kidder (Plate 7, Southwestern Archaeology) the rubbish heaps extend for a distance of 1,333 feet, or 406 meters. The maximum depth, near the wall of the mesa, is 20 feet. However Kidder in his diagram of the profile of the heap (page 19, Southwestern Archaeology) does not include a scale of linear measure. It is therefore necessary to set the maximum depth as shown at 20 feet and project the figure onto coordinate paper, whereby the area of the cross section may be computed by graphic interpolation. It may be argued with reason that the cross-sectional area of the rubbish heap is not likely to be uniform throughout its length and therefore desirable accuracy would require at least sample measurements at intervals. In the total absence of such information, however, it is necessary to depend upon the one datum provided by Kidder. The value obtained is 450 square feet, or 41.8 square meters.

Another diagram of the deposits is given on page 22 (Southwestern Archaeology). This diagram, although incomplete as published, may be interpolated and used as a profile. The value secured here is 564 square feet, or 52.4 square meters. The mean of the two estimates is 47.6 square meters. The volume of the rubbish heaps is then 406 x 47.6, or 19,320 cubic meters.

The surface of the mesa is demonstrated by Kidder's data (Pottery of Pecos, Vol. 1, page 41) to contain pottery to a depth of ten feet. The area of the mesa top may be estimated from the diagram given on page 20 of Southwestern Archaeology as 400,000 square feet. Therefore the volume of pottery-bearing material is 4,000,000 cubic feet, or 112,000 cubic meters. The aggregate from the two sources, rubbish heaps and mesa top, amounts to 131,320 cubic meters.

The second step must be to estimate the total number of fragments. Normally a large series of samples would be taken from well distributed points in the site in order to test the variability in potsherd density. However Kidder opened only three pits, or trenches, making the sample number one or three depending upon whether the three openings are regarded individually or collectively. The test therefore rests upon a very insecure statistical basis.

Kidder is also ambiguous with reference to the volume of dirt removed as well as to the number of fragments found. In Pottery of Pecos Vol. I, page 41, he states that a total of 4,219 fragments were removed from the stratigraphic pits on the mesa top and that the volume of earth taken out was 693 cubic feet, or 19.4 cubic meters. According to these figures the potsherd density was 217 pieces per cubic meter.

The three trenches are described in detail on pages 37 and 41. In the text on page 41, Kidder says: "The three tests consolidated comprise a single test of considerable proportions; one which involves.....a surface area of 208 square feet and a volume of 77 cubic yards." On the other hand, in his descriptions of the individual tests he states that trench XIX has a "surface area about 3 by 4 feet", trench XX a "surface area about 5 by 6 feet", and trench XXI a "surface area about 5 by 6 feet". In other words, by this reckoning the total surface area was 72, not 208 square feet.

In Kidder's table XII (Pottery of Pecos, Vol. I) the combined results of the three trenches are given by cuts from no. 4 to no. 11, inclusive. Since it is stipulated that each cut measured slightly under one foot in depth, the total of eight cuts may be considered as 7 feet. The volume will equal 72 x 7, or 504 cubic feet, i.e., 14.11 cubic meters. The fragment number, as totalled from individual counts, equals 3,933, and the density is 278 per cubic meter. This figure is probably closer to the truth than Kidder's estimate of 217 pieces per cubic meter, and is here provisionally accepted. The entire number of fragments in the site is now seen to be 278 x 131,320, which amounts to 36,506,960.

The George C. Davis site originally consisted of an inhabited village built upon a terrace above the Neches River. Many of its housepits were uncovered by Newell and Krieger. The occupancy of the village as such comprises phase 1 in the history of the area. Then the people contructed a ceremonial mound on the village site itself and followed it later by another, secondary mound placed upon the first. This work occurred during phases 2 and 3. However, Newell and Krieger are of the opinion that all three phases followed one another without any significant interruption, and that there were no profound cultural changes from beginning to end. The entire sequence constituted the Alto focus.

The site contained large numbers of potsherds scattered throughout the mound, under the house floors, and over adjacent fields. That portion of the <u>village</u> area shown on Map 4, page 16 of Newell and Krieger's monograph embraced a rectangular area 300 x 350 feet, or 105,000 square feet. Of this space, 588 sections 10 feet square, or 58,800 square feet were excavated, so as to uncover the full depth of the deposit. This is 56 percent of the area shown.

Approximately one half the surface area of the <u>mound</u> was uncovered. However, as is explained on page 17, not all the content was removed. The excavation proceeded from the level of the base, or below it, into the mound by a series of steps, each 5 feet high and 10 feet wide. Since we do not know from the published record the exact amount of dirt removed, we can only make a fair estimate that perhaps one quarter of the total quantity was obtained.

Newell and Krieger found 70,533 archaeological specimens in the village area, and 27,292 in the mound. Of the total, 96,000 were sherds. If we consider the factors mentioned, and if we project these figures to the entire site, we get close to 126,000 in the village deposit and 109,000 in the mound, or for both portions 235,000 specimens. However, sherds were found for a considerable distance scattered over the terrace upon which the village and the mound were built. In order to account for this additional source, we may add 25 percent, or almost 59,000 pieces, making a total of 294,000. The text states that of these artifacts, 98 percent were potsherds, or approximately 288,000.

A careful reading of the monograph and examination of technical descriptions can lead to no conclusion other than that stated above; the excavated area shown in figure 4 of the text constitutes virtually one quarter of the mound and one half of the inhabited village. Furthermore, it appears that the excavated sample was exhaustively searched, and that the 96,000 sherds reported by the authors represent substantially all those contained in the dirt which was moved. Nevertheless, on page 78, the statement occurs, with reference to the 96,000 potsherds: "This, of course, does not represent, and perhaps does not even approach, the total made at the site as a whole, for only a small fraction of the terrace was explored." Adjustment has been made for those portions of the mound and the village site which were not excavated, and the total has been increased by 25 percent in order to account for unexplored parts of the terrace. In view of the statement cited above, the possibility remains that our estimate is too low.

We may now turn to Gladwin's account of Snaketown, written in 1937. His discussion on pages 7, 8, and 9 leads to the inference that the habitation area coincides more or less with the grid measured off by the excavators, a grid which consisted of test blocks, each 60 meters square. With 16 of these north to south and 16 east to west, the total would be 256 blocks and 921,000 square meters. However, Gladwin says, on page 9, that he tested "each one of the one hundred and fifty blocks which covered the site". The total area then becomes 540,000 square meters. The potsherds were found in three types of situation; in the 60 refuse mounds, in numerous small excavated pits, and in a surface sheet covering the area in general.

Of the refuse mounds, one, no. 29, was selected for intensive study, and three stratigraphic trenches were dug therein. On page 25 of the 1937 account, footnote 3 contains the sentence: "The analysis of the 230 odd sections in the three trenches of Mound 29, resulted in the handling of over 170,000 sherds." In addition to the total number, we must also know the density of the sherds in the excavated trenches. Although the authors state, on page 25, that the number of sherds per section of 0.5 cubic meter averaged approximately 800, and in some instances ran as high as 4,000, nevertheless it is reasonable to make an independent calculation.

There were 230 sections of dirt moved in Mound 29, each having the dimensions 2 x 0.5 x 0.5 meters, or a volume of 0.5 cubic meter. The ground was sloping, and from the diagrams shown on figures 5, 6, and 7, it may be estimated that 48 sections of trench 1 and 20 sections of trench 2 contained only one half the standard mass of soil. We may use, therefore, 230 - 34, or 196 full sections, with a volume of 98 cubic meters. The density, then, is 868 sherds per section, and Gladwin's statement is confirmed. Otherwise expressed, the density is 1,736 sherds per cubic meter. Now we need to know the volume of Mound 29 as a whole. According to the profile shown in Figure 5, and the contour surface map in Figure 4, the mound is a segment of a prolate spheroid, since the base of the mound is bounded by an ellipse. However, the axes of this ellipse are sufficiently close to warrant averaging them and treatin the mound as the segment of a sphere rather than of a spheroid. From the figure an approximation of the dimensions shows an average radius of the base (a) of 34 meters and a height (h) of 3.5 meters. Then we may apply the formula:

$$\text{volume} = \frac{h(h^2 + 3a^2)}{6}$$

This yields 6,380 cubic meters. Then, if, from the trenches, the sherd density is 1,736 pieces of pottery per cubic meter, the total in the mound is close to 11,080,000.

The sherd count for Mound 29, however, is of relatively little value since the relation of the mound by itself to the population of the entire settlement is unknown. What is really needed is the sherd count of the complete site.

With reference to mounds, we have already outlined the method for attacking the problem. When not merely Mound 29 as an individual is considered, but many such mounds collectively, it is unavoidable that they be treated as segments of spheres, and that a uniform sherd density be ascribed to all of them. To do otherwise would require extensive field examination.

From page 21 we learn that there are 60 mounds varying from 1 to 3 meters high and from 10 to 60 meters in diameter. Using the approximate mean values, we may call h equal to 2 meters and a equal to 15 meters. If the formula is applied as above, the total volume becomes 42,700 cubic meters. At 1,736 sherds per cubic meter, the total sherd number if 74,000,000.

For pits there is no definite information. Merely as an estimate, it may be held that the aggregate content of the pits is one percent of the mound content, but that the sherd density is twice as great. Then the pits would hold 1,500,000 sherds.

The sheet deposit extends over about 540,000 square meters, according to the statements previously cited, but from this value must be deducted the area covered by the mounds. If the average diameter of the latter is 30 meters, the total area is 706.86 x 60, or 42,500 square meters, leaving, in round numbers, 500,000 square meters for sheet deposits.

If we continue to base estimates upon density, that is, number of sherds per unit volume, we may note that the average depth of the surface layer is of the order of 0.5 meter, for, as is stated on page 9, "As a general rule caliche was found at about half a meter." Then the volume is 500,000 x 0.5, or 250,000 cubic meters. We took the average sherd density in the mounds as 1,736 sherds per cubic meter, but this is an extremely high value for a surface deposit. Moreover, the sherds tend to be accumulated at the surface of the ground and immediately below it. Hence an even distribution to a depth of 50 centimeters can not be assumed. If, as a compromise, we estimate the maximum depth of significant occurrence to be 5 centimeters, the volume becomes 25,000 cubic meters. Were the density equal to that in the mounds, 1,736 sherds per cubic meter, the sheet deposit would contain 43,400,000 sherds. The value for the entire site would then be 118,900,000 sherds.

An alternative method is to disregard depth and to consider that the potsherds lying on the surface, together with those directly below it, constitute essentially the entire deposit, and that their number is a function of the surface alone. Since the excavators made no counts according to area, it is necessary to make a reasonable guess. We take 100 sherds per square meter as representing a fair average for the complete site. This means one sherd on every 10-centimeter square. If this number is too low for heavily occupied spots, in the center of the settlement, it is too high for the periphery, since habitations gradually taper off into desert. On 500,000 square meters there would then be 50,000,000 sherds, as the value for the site as a whole would be 125,500,000 sherds.

At the S-U site in New Mexico, excavation was carried out during three seasons, 1939, 1941, and 1946. Concerning each of these a separate monograph was later published, with paging continuous from the beginning of the first to the end of the third. In the second and third seasons the work extended and amplified what had been done in the first season, so that the data from all three must be considered as a unit.

The site lies on a flat ridge at about 1,950 meters elevation. In its almost level surface were found nearly thirty housepits, all of which were excavated at one time or another. Map No. 2, in the monograph covering 1939 shows 8 houses lying within a rectangular space 50 x 100 meters. Map No. 13, in the monograph on the 1941 work, extends and relocates the area to include the 10 houses studied in 1941. All 18 are placed within a rectangle of approximately 100 x 200 meters in dimensions. These two maps show also 1-meter contour lines, roads, and stream courses. Map No. 25, in the monograph on the 1946 season, adds the 9 houses dug in that year, and placed within a rectangle of 75 x 200 meters which is indicated as being subjoined to the preceeding area at the northwestern end of the latter. There are, however, no contour lines or other topographic features on this map.

If these fractions are pieced together, they produce a roughly rectangular area 100 x 400 meters. How far the site extends peripherally can not be determined from the descriptions. However, the fact that the ridge falls away steeply on all but the northwest side, implies that the habitation space was confined to the level top, covered by Martin's rectangles. We therefore take the latter as defining the site and assign an area of 40,000 square meters.

During the three seasons, more than 45,000 sherds were gathered. These were found in two types of locality, in and associated with the houses, and scattered at large over the surface of the site. The recovery for the houses, as computed from the tables on pages 84, 247-248, and 372-374, was 41,487. There were 26 houses, with a total of approximately 885 square meters floor space; hence there was an average of 45 sherds found per square meter of interior area.

The site surface, apart from the houses, was tested by a series of trenches, of which 13 are shown on maps 2 and 13, with corresponding sherd counts in the tables. Also the soil down to the sterile sub-site was tested by stripping in a reported 6 places. The depth was not more than half a meter if one may judge by the illustration in Figure 47, on page 147. Therefore the total sherds may be estimated with reference to surface rather than to volume. Dimensions of trenches and stripping are not given, but it is possible to get a close approximation from the maps, which are drawn to scale. In this manner it is found that the aggregate surface area of the 13 trenches and 6 strippings described in the first two monographs, was 603 square meters. The sherds removed were 4,221, or very close to 7 sherds per square meter.

From the 40,000 square meters estimated for the site may be deducted 885 for the houses, leaving 39,115. At 7 sherds per square meter, there would have been 273,805, or, let us say, 274,000 scattered over the surface and in the top soil. When we add 41,000 for the house interiors, the total becomes 315,000.

At the outset of this discussion, it was decided to express sherd quantity in terms of number. However, for many purposes, including the estimate of populations, it is preferable to work with weight of material rather than with number of pieces. But first it must be decided whether a stable relationship exists between these two parameters.

A simple method for comparing results by number and by weight is to determine the correlation coefficient, $\underline{r}$, for a series of samples. Any value that did not reach the one percent level of probability for the number of samples employed, would be subject to suspicion. In this manner have been tested the series of Gifford (1951) as recast by Solehim(1960, table 4), and those of Solheim (1960, tables 1 and 2). To these we have added the data of King (1949), as presented by Baumhoff and Heizer (1959, table 2). The latter table shows the potsherds arranged according to three criteria: firing technique, kind of ware, and type of design. The results may be given in brief as follows.

Source	Number of samples	Value of r, calculated	Value of r, at the one percent level
Gifford	9	+0.984	0.765
Solheim, table 1	13	+0.974	0.661
Solheim, table 2	51	+0.973	0.354
King, by firing technique	8	+0.938	0.798
King, by kind of ware	8	+0.927	0.798
King, by type of design	22	+0.944	0.526

The very high values of r, with all these series, well beyond the one percent level of probability, indicate a close correspondence between weight and number as a means of expressing quantity of potsherds, when field collections, or other large aggregates are involved.

The question now becomes that of estimating the average weight of a potsherd, when it is encountered among masses which include many types, and which are derived from the most diverse times and places.

It is certainly obvious that a potsherd has no fixed weight. The density of the pottery itself will depend upon the nature and processing of the materials used. Furthermore, the average size of the pieces into which a vessel will break will be a function of the shape of the vessel, its strength, and the stresses to which it is subjected. These facts are demonstrated by all authors who have published pertinent data, such as those already cited. In addition, there are several calculations on record according to which average weights have been quite accurately determined.

Kroeber (1925) at San Angel, Mexico found a mean weight of 8.27 grams for 4,050 sherds. Gamio (1922) at Teotihuacán with more than 100,000 fragments obtained a mean weight of 18.8 grams. The data from Bc 50-51, as set forth by Kluckhohn and Reiter in the table on page 41 of the University of New Mexico Bulletin No. 345 (1939) may be rearranged as follows.

Pottery Type	Number of sherds	Total weight in ounces	Mean weight per sherd in grams
Exuberant	834	359	12.18
Escovada	595	200	9.51
Lino	435	131	8.52
Red Mesa	276	90	9.23
Gallup	194	92	13.42
McElmo	75	32	12.07

The range for all types is 8.52 - 13.42, and the mean for the total number is 10.62 grams per sherd (1 ounce equals 28.35 grams).

King (1949) reports that 5,881 pieces weighed 2,856 ounces. This is

0.486 ounce each, or 13.75 grams. Smith (1952) weighed 10,817 sherds and found the average to be 0.482 ounce, or 13.64 grams per sherd. Gifford's values (1951) were much lower. For 9,783 sherds the mean was 4.14 grams.

Solheim expressed his results as number of sherds per ounce, thus using the reciprocal of the more common unit weight per sherd. According to his table 1, the mean of thirteen types of classified sherds was 2.14 pieces per ounce, or 13.25 grams per piece. When the total number of sherds was used, 5,317, the values were 2.4 pieces per ounce, or 11.81 grams per piece. The difference was due to a preponderance in the entire sample of a very light type of pottery. A similar calculation based upon table 2, with thirteen types and four depth levels (52 items) gives a mean of 12.89 grams per piece. The Standard Error of this mean is $\pm$0.1 gram per piece, a very small value indeed, when compared with other sources of variation.

The present writer weighed 9,097 pottery fragments from the Isabel Kelly collection in the Museum of Anthropology at Berkeley, California. This collection is from western Jalisco, Mexico. The mean values for the different pottery styles varied from 8.69 grams for "Tuscacuesco incised red" to 109.30 grams for "Tuscacuesco polished utility". The overall mean was 25.95 grams. However, the latter value was no doubt spuriously high since the material was not a true sample of a site but represented a selection made for study and museum type collection purposes.

A recent discussion of the problem has been contributed by Johnson(1964) who examined potsherds from two Arizona sites only a few miles from Snaketown. In order to expedite the work he consistently weighed the sherds instead of counting. His criterion he explains on page 153: "In order to make the weights comparable to the counts published in the past, the average number of sherds per pound was calculated for Gila Plain and for Hohokam buff ware." There were 35 buff ware and 22 Gila Plain sherds to the pound. Johnson appears to have used the average of the two types, for, thereafter, he calculated that the 1,795 pounds which he collected at site Arizona U:13:9 represented 52,500 sherds. This amounts to 29.2 sherds per pound, and (35/22)/2 equals 28.5. Throughout the paper approximately the same factor, 29.2 is employed. The corresponding average sherd weight is 15.4 grams.

Johnson's procedure, although reasonable, is subject to question on the ground of sampling method. On page 146, he states that "Material from two of the stratigraphic tests was screened through a half-inch screen, but the soil from the other tests was simply spread out on the ground and the larger sherds collected."

Passage through a half-inch screen eliminates many of the smaller sherds, which would be counted if the material were picked over carefully by hand. Hence a bias is created in favor of large size. This bias is vastly accentuated by a deliberate selection of only the larger pieces in the unscreened soil. The final value of 15.4 grams per sherd is therefore too high. No correction is possible because there is no unbiased sample for comparison. It is noteworthy, however, that the average weight, 15.4 grams per sherd, is close to the range which is usually observed.

If we omit the last two examples on account of their obvious statistical bias, the mean of six means is 11.41 grams. For the analysis of the sites here described, this figure may be rounded off to an even 11 grams, with the full realization that this is a pure estimate, adopted for working objectives only.

The next, and perhaps the most difficult step in the development of the study must be the consideration of the mean annual production, or acquisition of pottery. The most serious attempt to measure the life of domestic pottery and estimate its durability is that of Foster (1960), who worked at Tzintzuntzan, Michoacan, Mexico. Foster reports an approximate count of the vessels found in four households, together with an appraisal of the factors which determine their longevity.

The vessels, of which there were 50 to 75 in each kitchen, may be segregated roughly according to size and to function.

1. <u>Cooking and eating vessels in daily use</u>. From Foster's description the inference is reasonable that perhaps two fifths of the vessels in each house were constantly employed. There was general agreement that the average lifetime of such an article was about one year.

2. <u>Cooking and eating vessels in occasional use</u>. These were of various sorts, from tea cups to large casseroles, and may have constituted another two fifths. They were kept protected most of the time and were taken out relatively rarely, so that they lasted for several years. The values quoted range from 2 or 3 to 10 or 12 years. We may say 8 years as an approximation.

3. <u>Storage and semi-ceremonial vessels</u>. These can not have amounted to more than one fifth of the total. They were uniformly large. The maximum capacity mentioned by Foster was 45 liters. Due to their size and strength their lifetime extended for many years. Let us say 20 years as an average.

Foster made no attempt to determine weights. For the purpose of making a rather crude estimate, the writer weighed a series of five unglazed flower pots, ranging in outside diameter from 10 to 20 centimeters, and in height from 9 to 19 centimeters. The capacities approximated 0.5 to 5 liters, the range of most table and culinary pottery. The weights averaged 940 grams, or not far from one kilogram. Thus there may be ascribed a mean weight of one kilo to the vessels of Tzintzuntzan which fell in types 1 and 2. The vessels of type 3 were much larger. Some may have reached 15 or 20 kilograms, but these were very few in number. The order of magnitude can not have deviated very widely from 5 kilograms, and this value will be assumed.

If we consider 50 vessels to be the domestic stock, we get for the three types respectively 20, 20, and 10. By weight this amounts to 20, 20, and 50 kilograms. At the turnover rates sugested previously, the outcome is a destruction and replacement rate of 20 + 2.5 + 2.5, or 25 kilograms a year. This seems to be a very high value. It is properly subject to further examination before it is accepted as applicable to archaeological habitation sites.

Tzintzuntzan is a town of close to 2,000 inhabitants, the head of a municipality of 7,820 persons. It lies in the rich lowland along the shore of Lake Patzcuaro, and has easy commercial outlet to the State Capital, Morelia. Furthermore, it is the center of a substantial pottery making industry. This feature is emphasized by the fact that the heads of two out of four of Foster's reported households were themselves potters. As such, they were no doubt living in comparatively comfortable economic circumstances. These factors are all conducive to a very substantial home store of earthenware vessels. Indeed, one would be justified in regarding the approximate 50 vessels found by Foster as the maximum likely to be seen in modern Mexico outside of the relatively affluent urban residences.

If one explores the thoroughly Indian areas, mamy of which are still to be encountered in rural Mexico, a somewhat different condition is observed. According to my observations many of the homes of the Mixteca Alta in northern Oaxaca, and of the Otomi region in central Hidalgo, the inhabitants are desperately poor, and their possessions represent the minimum with which it is possible to subsist. Seldom, if ever, do such households maintain a supply of more than ten or a dozen pottery vessels, and frequently they get along with fewer. Moreover, the proportion of vessels in continuous use is much higher than at Tzintzuntzan. Relatively few are reserved for ceremonial occasions, and no more than one or two function for long-term storage. We might, therefore, allow 7 vessels of one kilogram each for everyday purposes, 2 of one kilogram each for occasional use, and one of 5 kilograms for storage. Such an array of ceramics will not only depict the domestic situation in the remote Indian regions of modern Mexico, but will more or less simulate the probable state of affairs in the pre-Hispanic, pre-industrial culture of the pueblos.

In his discussion of durability, Foster says: "Although it is only a guess, I suggest that pre-glaze,pre-kiln cooking vessels in daily use might better be calculated as having an average life of six months, rather than one year." This suggestion is based primarily upon the greater strength of wares fired by European methods and by the greater protection offered in modern times by hearths and stoves raised to waist level above the floor. These factors certainly have exerted an influence upon probable length of life, but they may have been offset by the factor of availability. Today, at the lowest economic level in monetary terms, and at pre-Hispanic sites as measured by expenditure of energy, the cost of pottery is and was far greater than in the homes which Foster observed in Tzintzuntzan. As a result a stronger effort would be made to conserve those articles which already had been obtained. Foster recognizes this motive, when he writes: "Perhaps in villages where it is more costly greater care is taken of it, so that technically inferior vessels would last longer than would be the case in Tzintzuntzan." In view of the relative difficulty in securing an adequate supply of household ware encountered by even advanced pre-Hispanic native cultures, such as at Pecos Pueblo, it will not be unreasonable to increase Foster's estimate and place the life expectancy of a domestic vessel in current use at 9 months. If we adhere to the time estimates suggested previously, we would allow 8 years for vessels in occasional use, and 20 years for the few which served for storage purposes. Then, if the average weights of the three types of vessels were respectively 1, 1, and 5 kilograms, and the number per household were respectively 7, 2, and 1, the annual turnover would be 5.75 kilograms.

These values are only suggestive. It is impossible to achieve real precision with such data. For working purposes we may revert to the estimates for the comparative number of domestic pots and vessels, approximately 50 found by Foster at Tzintzuntzan, and somewhere near 10 among the more primitive indigenous populations in Mexico. The ratio is 5 to 1. The annual loss and replacement, vessel by vessel, because of a series of compensating factors, appears to be more or less the same in both types of environment. At Tzintzuntzan this turnover was found to approximate 25 kilograms per year. Therefore, the gross turnover, per family per year, would be about 5 kilograms in the most primitive areas. Since the latter may be regarded as not very different in broad economic status from that characterizing the pueblos of 1300 to 1700 A.D. we may adopt this rounded value for Pecos Pueblo.

If we ascribe this rate to Pecos Pueblo, we are still confronted with the question whether the inhabitants at the other three sites used pottery as liberally as at Pecos. Undoubtedly the culture was less complex, and pottery less available, although Snaketown was a large community and may well have approached the pueblos in sophistication. At the Davis and the S-U site, however, living conditions were much simpler, there was relatively less ceremonial development, and the domestic arts probably remained at a more primitive level. Therefore turnover rates of 5 kilograms per family, per year, may be assigned to Pecos and Snaketown, and 3 kilograms to the Davis and S-U sites.

It is clear from this discussion that the study of turnover rates are needed and that these must be prosecuted with much greater intensity in order that a sound basis for calculation be established. As matters stand now, with almost total lack of reliable field evidence, values which are tentatively assigned must remain little more than reasonable guesses.

At the present juncture, methods have been outlined whereby it may be possible to determine the number, and the weight of potsherds contained by a specified site, together with the rate of loss and replacement of the original pottery. However, rate implies time. Therefore the final unknown in the equation is the duration of the habitation, or pottery-producing period at the site. Time has always been the central problem for archaeologists, and even with the aid of modern technology, through dendrochronology and radiocarbon, they are still confronted with serious difficulty. Nevertheless, in the present context it will be necessary to use their findings, although these findings may generate more problems than they solve.

With respect to the Pecos Pueblo, there is no alternative but to accept Kidder's statement (Pottery of Pecos, Vol. II, pages XVII and XVIII) that the period encompassed by the ceramic activity with which we are concerned lasted 400 years, specifically from ca. 1300 to ca. 1700. If, now, the various estimates are assembled, which have been proposed, it is found that if the average weight per sherd is taken as 11 grams, and there are 36,506,860 sherds, the total weight is 401,575 kilograms. Spread over 400 years, an annual destruction and production of 1,004 kilograms must be accounted for. If the breakage is assumed to be 5 kilograms per year per household, then the average number of households at Pecos was 201.

The social family, or household number under aboriginal conditions may be set at six. In a population which is merely maintaining itself, the biological family must equal at least four. In one which is increasing, this number must be exceeded. The household, in most societies has embraced additional members. The minimum, for single family dwellings must be regarded as five, and with multi-family dwellings many more. In California we have found consistently six (Cook and Heizer, 1968), and similar values have been reported from other areas. Hence, if there were six members per family at Pecos, the average population throughout the four centuries would have been 1,206.

A further refinement is possible. Kidder's estimate of 400 years may be considered to cover the eight stratigraphic cuts shown in table XII (Pottery of Peco, Vol. 1, page 41). Then in addition it may be assumed that each cut corresponds roughly to fifty years, beginning with 1300 A.D. The mean number of fragements per cut is 492. This number, when used as an average figure per cut of 7/8 foot in thickness, has been shown to correspond to a population of 1,206. It follows then that the ratio

$$\frac{\text{actual fragment number in a cut}}{492}$$

equals the ratio

$$\frac{\text{population in the 50 year period corresponding to the cut}}{1{,}206}$$

If the values given by Kidder for each cut are tabulated, the following populations may be derived.

Cut No.	Secular Period	No. of Fragments	Calculated population
4	1650-1700	562	1,375
5	1600-1650	886	2,170
6	1550-1600	804	1,970
7	1500-1550	620	1,520
8	1450-1500	308	755
9	1400-1450	334	819
10	1350-1400	215	526
11	1300-1350	204	500

A check on the accuracy of these population estimates exists in certain statements derived from historical sources. Kidder (Southwestern Archaeology, page 13) quotes the Memorial of Fray Alonzo de Benevides to the effect that at about 1650 A.D. the town "contains more than two thousand souls". The population estimated by the pottery method for the period 1600-1650 is 2,170. Kidder states that "By 1750, the population had shrunk to one thousand". The figure obtained here is 1,375.

It must be conceded that the correspondence here observed between the pottery and the historical estimates is deceptively close. On the other hand the claim may be advanced that the results by the pottery method fall within the correct range of magnitude, despite the numerous and relatively unsupported assumptions which had to be made.

The George C. Davis site presents problems for which there are no immediate, neat solutions. Concerning duration of occupancy, the authors state in their original work (page 234): "Occupation was continuous through the three 'phases'. . .We do not know whether the total time was one century, five, or ten. Let us say 'several centuries' ". However, it is possible to narrow this estimate to a certain extent.

At the conclusion of their section concerning Middle American affiliations, Newell and Krieger say (page 232): "...nor can it (the Davis site) be said to date as early as 200 or 300 A.D. ". They go on "...we may suppose Phase I to date somewhere around 500 A.D., if not earlier." Consequently the beginning of the village may be put somewhere near 500 A.D.

With regard to the termination (page 235): "After its abandonment by the Alto Focus people, a long time must have passed before a late prehistoric group (Frankston Focus) lived here briefly, leaving a few surface potsherds." In another place it is stated that the Frankston Focus "...is now regarded as entirely prehistoric". Prehistoric is taken as prior to the mid-seventeenth century.

If two hundred years is set as the extreme limits for the Frankston occupation, plus "a long time" before that, the end of the Alto Focus must have occurred no later than the year 1000 A.D. If so, the maximum duration of the latter culture could not have exceeded five centuries. As a first approximation 300 years may be considered as the duration.

Since the publication of the monograph by Newell and Krieger, the time relationships at the Davis site have been thrown into a state of confusion by conflicting radiocarbon dating. Indeed, the controversy is worth describing as an example of the difficulties encountered by even the most exacting archaeologists.

Several years after the original excavations had been completed, Krieger (1951, page 144) reported a date, determined by Libby, of 1553 ± 175 years B.P. (approximately 400 A.D.)for a sample of corn taken from a cache pit of Feature 31. Krieger said: "According to the published interpretation, feature 31 belongs to phase 1 of the Alto Focus, had most of the pottery types of this focus on its floor and probably did not antedate the initial temple mound construction by many years." The implication of Krieger's remarks is that the focus, and hence the habitation of the site did not persist more than two centuries, and that it flourished some time between 300 and 700 A.D.

A decade later Griffin and Yarnell (1963) secured a second sample of corn from a posthole of feature 31, which was dated at the radiocarbon laboratory at the University of Michigan. The date was 655 ± 150 B.P., or close to 1300 A.D. The dilemma is obvious. Two presumably well documented samples of corn are respectively analyzed by two highly competent laboratories, and found to date 900 years apart. Griffin and Yarnell, on archaeological grounds, prefer the later date, although they concede the remote possibility that both may be wrong.

The merits of the controversy cannot be decided here. Of primary interest in the present context is the <u>duration</u> of the culture which produced the potsherds and stored the corn, rather than the absolute date of its existence. It must have been short if Newell and Krieger are at all correct in their view that after abandonment by the Alto Focus people "a long time must have passed" before the late prehistoric group occupied the site - all this after 1300 A.D., according to Griffin and Yarnell.

If the population is computed on the basis of weight of potsherds, the previously stated average weight per fragment of 11 grams may be accepted as valid. Then 288,000 fragments weigh 3,168 kilograms, and, if the culture lasted 300 years, the annual rate of descruction and replacement would have to be 3,168/300, or 10.56 kilograms. For Pecos Pueblo the annual turnover per family was assumed to be 5 kilograms of pottery. This figure may be too high for a primitive group such as that which inhabited the Davis site, and therefore may be reduced from 5 to 3. If this value is applied the outcome is 3.5 families, or 21 persons. If only 200 years of occupancy is allowed, there will be 5.25 families, or 31.5 persons. Although it is admitted that a relatively small settlement is being considered, this result seems unreasonably low. It merits further analysis.

An alternative procedure is to utilize Newell and Krieger's estimate of whole vessels. They found that of the 96,000 sherds collected, 11,840 were capable of being used for typing the pottery from which they came. Of the 11,840 pieces, 10,279 were actually so employed and were found to represent close to 5,031 vessels. Thus the average number of pieces necessary to establish the existence of one vessel was 2.04. The number varied with the form of the vessel, with a range of 1.3 to 3.5.

The remaining 85,000 sherds are considered to have come predominantly, but not exclusively, from the same vessels as those typed by the first 10,279. The final conclusion of the authors is that the "96,000 sherds must have come from not less than 7,000 vessels, and 10,000 is easily possible". If the median of Krieger's estimate is used, 8,500, and if it is assumed that 96,000 sherds corresponded to these 8,500 vessels, all the sherds (288,000) would indicate 25,500 vessels.

The number of families will now depend upon the duration of occupancy and the annual turnover of vessels per family. For the first factor periods of 200 and 300 years have been used. For the second it is necessary to convert the estimate by weight of 3 kilograms per year lost and replaced by a family to one in terms of number of vessels.

The reconstructed vessels shown by Newell and Krieger in their figures 30-43 inclusive, have diameters ranging from 15 to 40 centimeters, and depths from 5 to 40 centimeters. Nothing is stated regarding the relative frequency of occurrence of these specimens, and it must be assumed that the larger sizes illustrated in order to display types of design were actually present in relatively small numbers. Hence we may assign an average weight of one kilogram to the vessels in common daily use. Then, since the annual turnover would have been approximately three vessels, 25,500 vessels over 300 years means a production of 85 per year. If the usage was three per family per year, the families amounted to 28.3, and the persons to 170. If 200 years are assigned as the duration, the corresponding value is 255 persons.

It is evident that the use of potsherd weight and the use of vessel number lead to widely divergent results regarding the population at the Davis site. Of the two methods, the latter produces a much more reasonable estimate. The cause, probably, lies in a failure of Newell and Krieger to find, or to report all the sherds present. On the other hand their reconstructions of whole vessels works out very well, even though the reconstruction was based upon vastly fewer sherds than were in fact produced by the breakage of the vessels concerned.

The lesson to be appreciated is of course that for a valid population estimate based upon sherd weight or number, the total yield of the area must be known, or must be capable of calculation from a series of samples.

If greater flexibility in the result is desired than is possible with a specific numerical estimate, a range of probably values may readily be established. Thus assume durations for the Alto Focus of 100, 200, 300, 400, and 500 years, and turnover rates of 1, 2, 3, 4, and 5 vessels per family per year. Then the calculated populations, at 6 persons per family, would be expressed in a 5 x 5 set

Vessel turnover in kilograms	Years	100	200	300	400	500
1		1,530	765	510	382	306
2		765	382	255	191	153
3		510	255	170	127	102
4		382	191	127	95	76
5		306	153	102	76	61

The most probable values show a range of 127 to 255 persons. A similar procedure may be adopted with any site for which the data do not appear to justify a single, specific estimate.

With respect to Snaketown, the time factor is discussed in detail by Gladwin and his collaborators (1937, pages 170, 178, 184, 189, 192, 197, 202, 273 ff). Haury, who did most of the writing on this subject, held the opinion that the pottery-producing era included six periods (neglecting the earliest, or Vahki period) of approximately 200 years each. The entire interval would thus have lasted from 100 B.C. to 1100 A.D., or 1,200 years. However, Haury (pages 178 and 184) felt that much more than half the total pottery was produced during the last two phases (Santa Cruz and Sacaton), which extended 400 years from ca. 700 to ca. 1100 A.D.

More recent information is provided by Gladwin in his book, A History of the Ancient Southwest (1957, pages 101, 136-147, 295). He makes it clear that the Hohokam settlement at Snaketown, which represents almost the entire habitation of the site, was encompassed by the period 700-1100 A.D. Consequently there is little doubt that 400 years is a full and yet reasonable estimate for the duration of pottery production on a significant scale.

There were derived, and previously described, two values for number of sherds, depending upon alternative methods for computing the surface deposit: 118,850,000, and 125,500,000. At 11 grams per sherd these numbers reduce to 1,307,350 and 1,380,000 kilograms respectively. For the period of 400 years the corresponding production is 3,268 and 3,451 kilograms, when considered on an annual basis. If the breakage and replacement (i.e. the turnover) per family per year was 5 kilograms, the mean number of families would have been 654, or 690. At six persons per family, the 400-year average population would have been 3,924 or 4,140. Since we do not have a precise figure, we set the range of probable number at 3,500 to 4,500.

This value, 3,500 - 4,500, is perhaps too high, and may be due to an overestimate of the number of potsherds in the surface sheet deposit. However, the correct order of magnitude is indicated, for a town covering half a square mile and supporting the pottery manufacture, as well as the other industries of Snaketown, must have contained several thousand persons at its apogee. If further refinements in the sherd calculations were made possible by additional field data, a closer approximation to the truth could be obtained.

The dating and duration of the S-U site is bound up with the controversy which has been proceeding for many years with respect to the chronology of the southwestern cultures. Martin and his co-workers were able to show that the site was representative predominantly of the Pine Lawn phase of the Mogollon cultural complex. Thus, only three houses out of the nearly 30 which were excavated could be ascribed to later periods. Martin expressed the opinion that the Pine Lawn phase antedated the year 500 A.D. and lasted several hundred years.

Gladwin, in his monograph reviewing the work at Snaketown (1948, page 224) attempted a synthesis of numerous southwestern sites, using primarily tree-ring dating. He dated the Pine Lawn phase at the S-U site as from 700 to 850 A.D., a period of 150 years. Contrary opinion has been expressed in a more recent paper by Bluhm (1960) in her study of settlement patterns in Pine Lawn Valley. According to her text, and table 1, the Pine Lawn phase in this area was preceeded by a non-ceramic culture, and lasted from 200 B.C. to 500 A.D. Since she had the advantage of more than a decade of investigation subsequent to Gladwin, her scheme may be accepted.

It has been estimated that the S-U site contained 315,000 sherds, or 3,168 kilograms. From these we wish to eliminate those produced during the 3-circle phase. Martin's count of sherds found in house pits was 42,387. In houses W, X, and Y, from the 3-circle phase, there were 4,683 sherds, leaving 37,704 in those from the Pine Lawn phase. By proportion, in the entire site, there would be 2,818 kilograms of Pine Lawn sherds.

If the Pine Lawn phase at the S-U site endured the full 700 years allocated by Bluhm to the phase in the valley as a whole, and the turnover rate, by analogy with the Davis site, was 3 kilograms per family per year, the average population included 1.34 restricted, or nuclear family, that is, approximately 8 persons. This is clearly an under-estimate and requires adjustment.

Although Bluhm considers that the Pine Lawn phase, as a cultural entity, persisted in the valley for 700 years, she shows in table 1 that there have been discovered 21 sites of this character. There is no implication that any one site endured through seven centuries. Indeed, there is nothing in her analysis to contradict the opinion of Martin that the Pine Lawn phase, at the S-U site, lasted 200-300 years. The probable life span of the site may therefore be reduced to 250 years.

A second adjustment concerns turnover rates. A rate was provisionally assumed throughout the existence of the S-U site of 3 kilograms per family per year, the same as for the Davis site. But it is clear from Bluhm's discussion that at the beginning there was no pottery at all, and that its manufacture developed during the 700 years of the Pine Lawn phase. Therefore, if the rate in 500 A.D. was 3 kilograms per family per year, in 200 B.C. it was zero kilograms. The average of the two extremes might lie somewhere between 1 and 2 kilograms, for example at 1.5.

If, now, we recalculate the population by substituting 250 years for 700, and 1.5 kilograms for 3 kilograms, we get 7.5 families, or 45 persons. This estimate may be regarded as acceptable.

Bluhm's formulation of the data makes possible a few further interesting conjectures concerning total population. She lists in table 1, among other items of information, the number of sites, and the number of rooms known for each cultural phase. Since, in the earlier phases, a room is equivalent to a house, the latter term may be substituted for the former. Then she divides quite empirically the number of sites and that of houses, by the number of centuries during which each phase lasted. Thus for the Pine Lawn phase there are known 122 houses (rooms) and the time interval is seven centuries. There are therefore 17 rooms, or dwelling units per century. The population of the valley is then assumed to run parallel with the houses per century.

The estimate of population for the S-U site, as derived from pottery residues, may now be introduced. This site contained roughly 24 houses from the first, or Pine Lawn phase, and is considered to have had a life of 250 years. Then it contained 10 houses per century, a value which in turn represents an average population of 45 persons. For the entire valley during the Pine Lawn phase, Bluhm gets a value of 17 houses per century. The corresponding level of population is 17/10 of 45, or 76 1/2 persons.

Bluhm says (page 538) that the valley is 10 miles by 3 miles, with 20 square miles of "habitable land". Just what is meant by "habitable" is not clear, but we may use the entire area of 30 square miles, and estimate a density during this period of 2.5 persons per square mile. This is a reasonable magnitude for a culture which is just beginning to acquire agriculture and the ceramic arts.

If, according to Bluhm's hypothesis, population was proportional to dwelling units per century, then that of the Georgetown phase was the same (17 dwelling units and 76 1/2 persons). However, the San Francisco-Three Circle phase saw an increase to 225, and the Reserve phase to 613 persons, or approximately 20 to the square mile. Thereafter, a disastrous decline took place in the Tularosa phase, with rapid extinction of the group as a recognizable demographic unit.

These figures are completely speculative, but are by no means absurd. They illustrate more clearly than any purely relative scale the population status of the cultural complex over a period of several centuries.

The question propounded in the title of this essay (can pottery residues be used as an index to population?) still awaits a final answer. In the meantime, approximate, average populations have been calculated for four representative sites in the southwestern United States, but these values, although they lie within the limits of reasonable probability, are not definitive. The process of estimation has itself encountered new problems, the solutions to all of which are not yet clearly visible. However, progress is being made. The framework of future construction has been put together, and the broad outline of method has been established. Pottery residues, or indeed any residues can serve as an index to population provided the four cardinal parameters can be defined in numerical terms. These are, it will be recalled, total amount of residue, turnover rate, duration of production and use, and association of unit quantity of residue with unit population.

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