

flake is in part determined by where on the chert the coincidence of the wave and the edge of the chert occurs. If you could move the wave back half a wave length so the place of a former peak in the wave becomes the place of a node (Fig. 2), then the wave would meet the edge of the chert in a new spot, changing the length of the flake, but not the width, by a specific amount. The length of a flake and the point at which it breaks free of the core is dependent on the relationship of the shock wave path and the edge of the lithic material. If a peak is within a certain distance from the edge of the core, the flake will separate at that peak; if it is not, the flake will separate at the first peak to come within the requisite distance. If only certain wave lengths can travel through the chert and successfully remove a flake, then only certain length/thickness ratios will occur in the flake assemblage, the results of which would appear as in Fig. 1. One logical extension of this postulate is that a characteristic wave pattern may exist for each stone material of uniform composition.

Our research would indicate one cannot assume that inferences regarding chipped stone which depended on measurement reflect only cultural biases, such as preferred method of manufacture. The assemblages at hand appear to exhibit a noncultural bias demonstrated by the frequency of occurrence of graded length/thickness ratios.

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ASSESSING THE ARCHAEOLOGICAL SIGNIFICANCE OF MAHAMAES

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ABSTRACT

On the coast of Peru farming in *mahamaes* or sunken gardens fed by ground water offers an alternative to canal irrigation. The possibility that *mahamaes* were influential during the early stages of farming is examined and rejected on theoretical and empirical grounds. The possible significance of farming in sunken gardens during later pre-Columbian times is briefly examined. It is suggested that *mahamaes* were important mainly as a supplemental form of farming in areas immediately adjacent to the coast.

ON THE rainless Peruvian coast, watering crops is the critical problem confronting agriculturists. Canal irrigation based on rivers flowing out of the Andes has been and continues to be the main solution to this problem. Other solutions are known. One of these is the use of *mahamaes* or *pukios*. A *mahamae* is a sunken garden excavated to a depth where moisture is supplied by ground water. In-

dividual gardens range in size from several hundred to several thousand square meters. Success is dependent upon reaching ground water, and the depth to which a *mahamae* must be excavated is governed by the level of the water table. *Mahamaes* tend to be located in coastal valleys because rivers and/or subsurface runoff from the mountains maintains a relatively high water table. In particular the sunken gardens are restricted to areas immediately adjacent to the coast. This is due to the fact that the ground surface progressively drops in altitude as it nears the shore. Minimum vertical separation between the land surface and the water table occurs within a few kilometers of the coast. Thus, *mahamaes* are most economical at the mouth of a valley within a short distance of the sea.

Other than Willey's (1953) description of *mahamaes* or *pukios* at the mouth of the Virú Valley, this agricultural technique has received scant attention, and relatively little is known of its role in pre-Hispanic farming. In a laudable article describing some modern and prehistoric *mahamaes*, Jeffrey R. Parsons (1968) considered possible archaeological implications of farming in sunken gardens. In the evolution of coastal subsistence patterns two distinctive roles were suggested for *mahamaes*. Parsons (1968: 85) believed they were important:

(1) During the early stages of agriculture where cultivation was practiced as a secondary activity relative to the exploitation of marine resources.

(2) As a supplement to primary dependence upon canal irrigation after this technique had become well established. Difficulties in maintaining large canal-irrigation systems may have caused a shift to increasing dependence upon *mahamaes* cultivation during the latter portion of the prehispanic period.

These suggested roles impute considerable significance to *mahamaes*, and they must be considered with care. On the basis of 15 months of field work focusing on early coastal agricultural sites, I can offer a limited evaluation of Parsons' suggestions.

Attributing *mahamaes* with a role in the initial development of farming rests, in part, on two assumptions. The first is that early agricultural settlements housed very large populations (a populace of 10,000 has been suggested for one settlement). The second assumption is that agriculture contributed significantly to the maintenance of these population. There are sufficient data to allow critical examination of these assumptions.

A number of large, relatively early settlements have been found on the coast of Peru. These date to the so-called cotton preceramic period (ca. 2500 to 1700 B.C.). Huaca Prieta (Bird 1948) is the most famous of these settlements; however, much larger sites are known, several with the rudiments of public architecture. In approximate order of size, the three biggest settlements are El Paraiso or Chuquitanta (Patterson and Lanning 1964; Engel 1966a), Río Seco (Wendt 1964), and Las Haldas (Engel 1958; Ishida and others 1960). El Paraiso is situated at the mouth of the Chillón Valley next to the river. The other two sites are located adjacent to the shore in desert areas 20 km. or more from arable land.

While substantial populations were certainly present, my examination of these three settlements did not sug-

gest that figures in excess of 1,000 to 2,000 individuals were ever reached. For Río Seco and Las Haldas, Lanning (1967: 64) has estimated populations of 500 to 1,000. This is not unreasonable. The estimate for Río Seco might be slightly conservative; however, it is in general agreement with Wendt's (1964: 243) calculation that there are between 2,400 and 3,000 burials at the site. For El Paraiso, Engel (1966a: 58) has postulated a population of 1,500, and this is certainly not excessive given the magnitude and complexity of the site. Thus, while very large settlements existed during the early stages of agriculture, populations were not of inordinate size. By and large they must have been comparable with the populations at large sites on the Pacific Northwest Coast and at some pueblos of the southwestern United States.

The significance of agriculture produce undoubtedly varied from one preceramic site to another. At most, if not all, settlements it was clearly secondary in importance to marine products. At all the cotton preceramic period sites that I have visited, mollusks, fish, and sea fowl are the primary food elements in the refuse. My examination of the refuse deposits at Río Seco and at Las Haldas suggests that there is considerably less plant material at these sites than at their contemporary sites such as El Paraiso or Huaca Prieta, situated near arable land. Excavations at the Ancón Tank site tend to support this contention. The Tank site is located on the desert coast roughly 18 km. from the banks of the Chillón River. Vegetable produce is quite rare until the end of the cotton preceramic period and the beginning of the Initial period. It is evident that the Tank site populace was not relying extensively upon agricultural products during the cotton preceramic period. Rather, it was supported by a variety of marine resources. Analogous situations very likely existed at Río Seco and Las Haldas. Both the desert location and refuse content of these sites indicate only a minor role for agricultural produce. Given the extreme abundance of marine resources in the coastal waters of Peru, it is not surprising that their exploitation could sustain relatively large sedentary populations. Thus, the subsistence patterns at most desert sites of the cotton preceramic period can be explained without recourse to significant dependence on plant foods or the use of *mahamaes*.

For river valley sites, such as El Paraiso, where agriculture was of more importance, flood-water farming in river bottoms seems to be a more reasonable suggestion than the use of *mahamaes*. As Engel (1966a) noted, El Paraiso is situated adjacent to a large section of river flats that are suitable for flood-water farming, and this may account for the somewhat inland location of the site. El Paraiso is located in an area entirely unsuitable for the use of *mahamaes*.

Thus, the assumptions suggesting *mahamaes* were influential in the early development of agriculture are incorrect. General considerations of cotton preceramic period sites offer no grounds for invoking the use of this agricultural technique.

On the empirical level, there is no evidence suggesting an association of preceramic sites with *mahamaes*.

Sunken gardens are not found in the Chillón Valley. I failed to find them at the mouth of the Quebrada Segundo Leon where Río Seco is located. *Mahamaes* are absent at Las Haldas. However, in one of the plazas that forms part of the ceremonial complex at the site, there is an oval depression roughly 20 m. in diameter and 4 to 5 m. deep today. This might have constituted a walk-in well in the past. The preceramic site of Cerro Prieto is located at the mouth of the Virú Valley, and *mahamaes* are also found along the shore near the valley mouth. However, the sunken gardens are associated with Tomaval and La Plata sites, and this suggests they date late, to the Middle horizon or Late Intermediate period (Wiley 1953: 369). At the mouth of the Chilca Quebrada there are a large number of *mahamaes*, many of which are still in use. There is also a substantial number of preceramic sites in the quebrada (Engel 1966b); however, there is no evidence to link the early agricultural settlements with the sunken gardens. Thus, the data at hand indicate that preceramic sites occur in areas lacking *mahamaes*, as well as in areas where they are present, and in the latter situation there is no evidence linking the two. Hence, there are absolutely no grounds for suggesting early agriculture was dependent upon farming in sunken gardens.

On the basis of theoretical and empirical consideration I believe that *mahamaes* were not significant to the early development of farming on the coast. Indeed, I see little evidence to suggest that they were even known or in use during the cotton preceramic period or the Initial period.

Parsons' second postulated role for *mahamaes* is difficult to evaluate. Other than the Virú Valley study there is very little archaeological information pertaining to the use of sunken gardens, and it is questionable that the history of *mahamaes* in Virú is typical of their history in other valleys. While *mahamaes* certainly supplemented dependence upon irrigation, I think it is premature to suppose, as Parsons (1968: 85) does, that their use was fostered by "difficulties in maintaining large canal-irrigation systems." Parsons' contention is based upon an apparent depopulation of the central portion of the Virú Valley during the La Plata and Estero occupations. La Plata and Estero sites tended to cluster in the upper portion of the valley and at the valley mouth where *mahamaes* occur. Wiley (1953: 394) interpreted the settlement pattern as indicating a breakdown or abandonment of canal irrigation in the central valley, and a reliance upon *mahamaes* by the population at the valley mouth. This is a reasonable interpretation so long as it is assumed that there is a correlation between the number of sites in the central valley and the state of the irrigation system. Of course the drop in population may have been an independent phenomenon. As Wiley (1953: 421) also noted, "Virú may have been depleted of population in the La Plata Period in order to sustain and defend Chanchan." Chanchan is a large urban site in the adjacent Moche Valley, and Virú was probably part of the sustaining area of this city. Thus, it is entirely possible that depopulation does not denote difficulties with the irrigation system.

In assessing the archaeological role of *mahamaes* it may be more instructive to look at a different set of data from the Virú Valley. Willey (1953: 393) believes that the maximum prehistoric population in Virú was attained during the Early Intermediate period and the Middle horizon. The Middle horizon, or Tomaval occupation, was represented by more living-sites than were found for any other period. Many of these were quite large, and it is evident that the population was at a peak at this time. The irrigation system also attained its greatest extent during the Early Intermediate period and Middle horizon. Once irrigation was expanded to its upper limits there was little room for expansion of cultivation. "In effect, a ceiling had been set by a maximum combination of the amount and availability of water and the amount and topography of the land" (Willey 1953: 394). This ceiling on irrigation meant that, if cultivation was to be expanded, new or different systems of farming would have to be used. Therefore, it is not entirely surprising that *mahamaes* first came into use during the Tomaval occupation when both irrigation and population were at a maximum.

These data indicate the Virú *mahamaes* to have been a supplemental agricultural technique whose use was fostered, not by difficulties in maintaining large irrigation systems, but by these systems reaching their upward limits of productivity.

Today it is the arable land in the lower valley that suffers most in times of water scarcity. Water goes first to up-valley land then to land in the lower valley (Thomas Grieves, personal communication). In theory, the further the irrigation system is expanded, the more precarious the land at the valley mouth becomes. The prehistoric irrigation system was roughly 40 per cent larger than the modern system (Willey 1953: 393). Presumably this put land at the mouth of the valley in a particularly insecure situation. It may be that as the irrigation system reached its maximum extent, *mahamaes* became a more secure means of coastal farming in Virú than canal irrigation.

As Parsons (1968) points out in his article, the largest, deepest, and most spectacular *mahamaes* known are those at the site of Chan Chan in the Moche Valley. Some of the larger examples are aligned with the major compounds at the site. This very likely denotes contemporaneity, and sunken gardens were probably important to the site. However, I see little evidence to support Parsons' (1968: 84) statement ". . . the large area once devoted to *mahamaes* cultivation at Chan Chan . . . may indicate some breakdown or disruption of the extensive Moche Valley canal-irrigation system within two centuries of the Spanish Conquest." There is absolutely no reason to assume that the mere presence of *mahamaes* in an area indicates a collapse of irrigation. Very little is known about the settlement pattern or irrigation system of the Moche Valley. It is, however, obvious that there was a substantial urban population at Chan Chan, and this population and its agricultural sustaining area must have demanded considerable water. Kosoc (1966:

84) has reported the existence of a very long canal diverting water from the Chicama Valley to the plains in the area of Chan Chan. This further suggests that the availability and amount of water may have been critical factors on the northern side of the Moche Valley. Given the apparent demands that were being put upon canals, it seems more reasonable to assume that *mahamaes* were a supplement to the irrigation system and not a partial replacement of it. It might be presumed that, as the irrigation system reached its upper limits, alternative water sources for farming were sought, and that sunken gardens offered one such alternative.

In conclusion, it is obvious that the archaeological significance of *mahamaes* is very incompletely known. On theoretical and empirical grounds there is no reason to believe *mahamaes* were influential during the early stages of agriculture. Indeed, there is nothing to suggest they were in use prior to the establishment of canal irrigation. In later times the role of *mahamaes* very likely varied from one area to another. The contention that difficulties in maintaining large irrigation systems fostered dependence upon sunken-garden farming is not well supported by data from the Virú Valley, and there is absolutely no support from the Moche Valley. In general, *mahamaes* appear to have constituted an agricultural technique supplemental to canal irrigation, and one that may have been used primarily when irrigation of coastal land was either unreliable or impossible.

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