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Farming Systems and Political Growth in Ancient Oaxaca

Physiographic features and water-control techniques contributed to the rise of Zapotec Indian civilization.

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During the last 15 years an increasing number of anthropologists and geographers have turned their attention to the pre-Hispanic civilizations of Mexico and Guatemala. The evolution of these ancient complex societies is of general theoretical interest because it seems to have taken place independently of the early Old World civilizations. Given the limitations of the archeological data, there has been considerable latitude for varied and competing theories about the origins of the early New World states.

Some authors have theorized that Mesoamerican civilization arose in the arid highlands, because of the need for a strong centralized government to control large-scale irrigation projects (*1*). Others have argued that civilization began first in the humid tropical lowlands, where irrigation is not necessary (*2*). Still others have sought a middle ground between these positions, maintaining that Mesoamerican civilization began through the "intertwining of many regional strands," both highland and lowland (*3*).

One of the most intriguing hypotheses of the evolution of early Mesoamerican civilization was that of Palerm and Wolf (*4*, pp. 1–37), who over a 10-year period in the 1950's sought to find correlations between social systems, agricultural systems, and their environmental settings. A major process they observed at work in ancient Mesoamerica was the formation and dissolution of "key areas" or "regional nuclei." These they defined as "areas of massed power in both economic and demographic terms" (*4*, p. 9), which at various points in Mesoamerican prehistory had acted as "nodal points of growth" or as nuclei for "symbiotic areas"; these nuclei were instrumental in stimulating cultural evolution over wide geographic regions (*5*). Each time Mesoamerica moved up to a higher level of social and political complexity, this move seems to have been accompanied by a shift of power and influence from one area to another. Some regions were nuclear only in the early (Formative) and middle (Classic) periods; other areas were nuclear only in the late (Post-Classic) periods. Only five regions in Mesoamerica were listed by Palerm and Wolf (*4*, p. 30) as having "maintained their key importance from Archaic times right up to the time of the Spanish Conquest." These areas are the Valley of Mexico, the region of Cholula-Puebla, the Mixteca Alta, the Valley of Oaxaca, and the region of Guatemala City (see Fig. 1).

Why had these five regions attained early nuclearity and retained it throughout the sequence? Palerm and Wolf presented a corollary hypothesis which they felt should be checked by future investigators. They pointed out that all the areas which were nuclear only in the *early* part of the sequence had predominantly slash-and-burn agriculture of lowland (*roza*) type. All areas which rose to prominence only *late* in the sequence were arid regions demanding very efficient irrigation systems. The five *perennially nuclear* regions are ones in which, today at least, virtually every farming technique known in Mesoamerica is applicable. They hypothesized that farming had begun in Mesoamerica as slash-and-burn, and that through time a series of new techniques had been worked out: irrigation, flood-water farming, chinampas, and so on. As such technological innovations appeared, they were "applicable to an ever-decreasing number of areas" (*4*, p. 36). The areas in which the greatest variety of techniques could be assimilated remained nuclear; those in which only the older techniques could be applied gradually lost their influence and assumed a marginal role.

None of Palerm and Wolf's "perennially nuclear" areas has ever been investigated with their hypothesis in mind, though a number of related theories have now been tested in the Valley of Mexico (*6*). However, excavations in a few of Mesoamerica's "fringe" or "marginal" areas—ones which *never* became nuclear—have been carried back to the very beginnings of agriculture by MacNeish (*7, 8*). One of these, in the Valley of Tehuacán, Mexico, has now yielded the longest single stratified sequence in all of Mesoamerica. Publication of the Tehuacán sequence (*9*) places Mesoamerica in a better position than ever before for the testing of theories about the processes involved in the establishment of village life, and about the evolution of chiefdoms and early states (*10*).

In 1966 we selected the Valley of Oaxaca (Fig. 2) as a natural laboratory in which to investigate a number of these hypotheses (*11*). Oaxaca was chosen partly because the outlines of its later prehistoric sequence (see Fig. 3)

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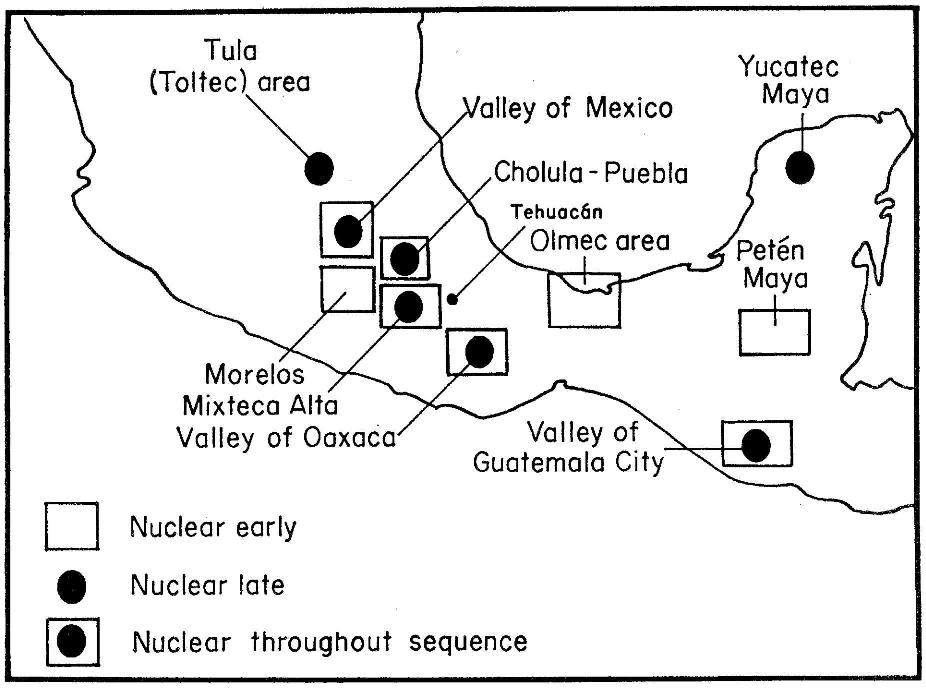


Fig. 1. Outline map of Mexico and Guatemala, showing regions mentioned in the text. "Nuclear" areas listed by Palerm and Wolf (*4*) are indicated by squares or large black circles; Tehaucán, a "marginal" area, is indicated by the small black dot. For the sake of brevity we have adhered to Palerm and Wolf's original classification, although recent archeological data indicate that it needs to be revised and updated.

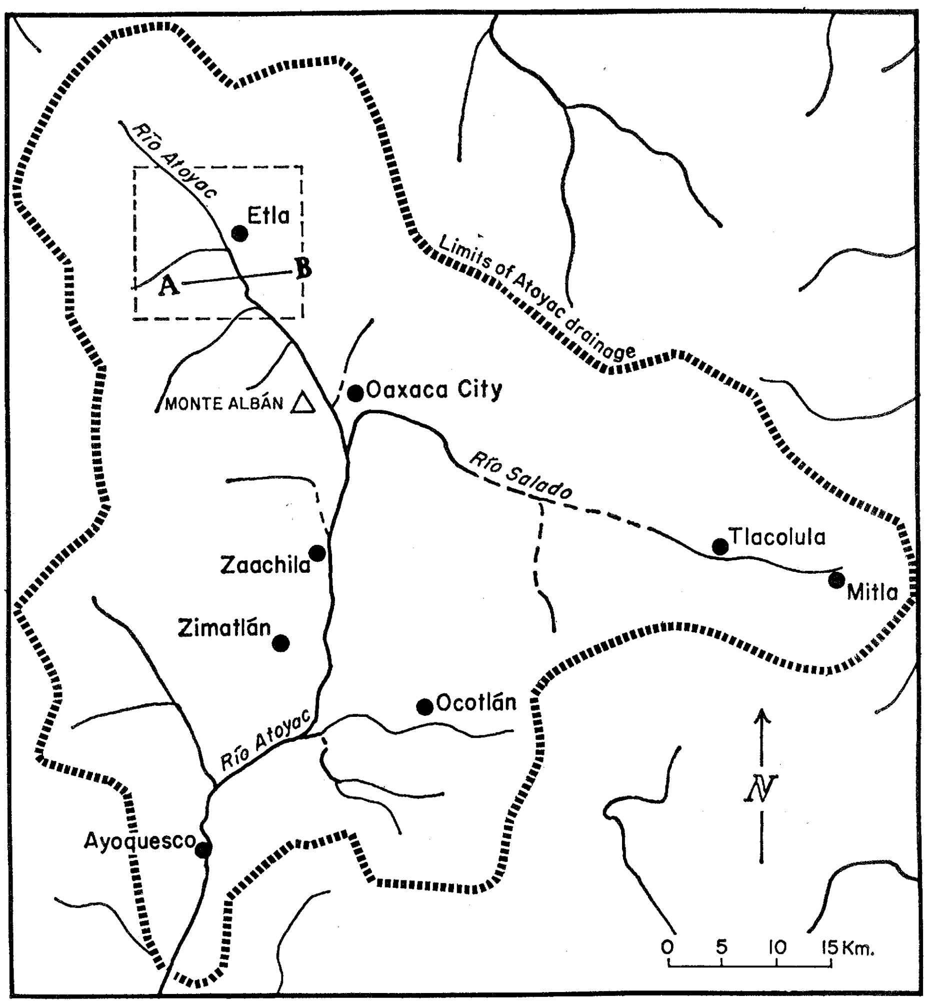


Fig. 2. Map of the upper Atoyac River drainage basin, indicating major towns and archeological landmarks in the Valley of Oaxaca. The rectangle formed by dashed lines delimits the survey area shown in Fig. 5. Line *A–B* locates the cross section shown in Fig. 4.

had been worked out by Caso and Bernal (*12*), and partly because it lay close enough to Tehuacán to be related to it during all or part of its prehistory. This eliminated many of the preliminary steps that would have been necessary were the area totally unknown, and permitted us to concentrate from the very beginning on problems of cultural and ecological process. It also allowed us to compare and contrast the agricultural potential of a nuclear valley (Oaxaca) and a marginal valley (Tehuacán).

Location of the Valley of Oaxaca

The Valley of Oaxaca lies in the southern highlands of Mexico, between 16°40′–17°20′N and 96°15′–96°55′W. It is drained by two rivers: the upper Río Atoyac, which flows from north to south, and its tributary, the Río Salado or Tlacolula, which flows westward to join the Atoyac near the present city of Oaxaca. The valley is shaped like a Y or three-pointed star, whose center is Oaxaca City and whose southern limit is defined by the Ayoquesco gorge, where the Atoyac River leaves the valley on its way to the Pacific Ocean. The climate is semiarid, with 500 to 700 millimeters of annual rainfall, confined largely to the summer months. The valley-floor elevation averages 1550 meters.

Situated in the mountainous central part of the state of Oaxaca, the region is surrounded by valleys with steep sides, narrow floors, and perennially flowing streams. In contrast, the Valley of Oaxaca is a wide, open plain with abundant flat land and streams which are dry most of the year. Yet it was this valley, where moisture is scarce and man must devise means to control it, which became the most powerful nuclear area in the southern highlands. It is generally believed that this development was the work of the Zapotec Indians, who now inhabit the valley and whose history can be traced back many thousands of years in that region (*13*, p. 788; *14*).

Physiography and Vegetation

A typical cross section of the valley (Fig. 4) shows four distinct physiographic zones: (i) the "low alluvium," or present river flood plain; (ii) a zone of "high alluvium," which is mainly an abandoned flood plain of Pleistocene-to-Recent age, formed by the Atoyac River and its tributaries when they flowed at a higher elevation; (iii) a piedmont zone flanking the high alluvium; and (iv) the surrounding mountains.

The river channel is incised no more than 1 to 2 meters into its present floodplain, which is only locally present and nowhere more than 600 meters wide. The main part of the flat valley floor, which varies from 1 to 15 kilometers in width, is formed by the high alluvium; this zone is separated from the low alluvium by a 1- to 3-meter rise in elevation. Between the high alluvium and the mountains lies the piedmont zone, where the land has a slope of 1 to 2 degrees and has been dissected by tributary streams to form low rounded spurs and isolated hills with up to 30 meters of relief. The piedmont was originally formed as a series of coalescing alluvial fans, and remnants of this deposited material remain as fan gravels of probably Pleistocene age. Later stream dissection has exposed underlying rocks which are pre-Jurassic to Miocene. The piedmont zone grades eventually into the true mountain zone, where valleys have up to 1000 meters of relief and slopes are steep. The mountains are formed mainly of pre-Jurassic metamorphic rocks, Cretaceous limestones, and Miocene ignimbrite tuffs (*15*). The tuffs are most extensive in the extreme eastern end of the valley, between Mitla and Tlacolula, where they abound in small caves and rock-shelters which were occupied during the earliest periods of Oaxaca prehistory. In the extreme western part of the valley, where rocks of the basal metamorphic complex are most widely exposed, there are deposits of magnetite and mica which were used and traded by the later occupants of the valley as exotic raw materials.

Originally, each of these physiographic provinces would have had its own distinct vegetational cover. Today, after thousands of years of intensive cultivation, so little remains of the original valley-floor vegetation that it can only be hypothetically reconstructed from pollen grains and carbonized seeds in archeological sites of that zone (*16*). The present Atoyac floodplain may have had phreatophytic species like bald cypress (*Taxodium*), willow (*Salix*), and wild fig (*Ficus*), while the high alluvium was probably characterized by a more open cover of grasses and woody legumes like mesquite (*Prosopis*). The piedmont is still one of the most complex vegetation zones, with varying communities of tree legumes, prickly pear (*Opuntia*), organ cactus (*Lemaireocereus*), maguey (*Agave*), *Dodonaea*, and—at elevations of 1800 meters and above—scattered oaks (*Quercus* spp.). The high mountains have forests of oak, pine, and manzanita (*Arctostaphylos*). It is to be hoped that future work in Oaxaca will greatly enrich this tentative and oversimplified reconstruction.

Agricultural Potential

We feel there are several environmental aspects of the Valley of Oaxaca which make it a better place for agriculture—and especially for primitive, pre-Hispanic types of agriculture—than many adjacent parts of highland Mexico, including some of the other areas described by Palerm and Wolf as nuclear. Second, some of the agricultural techniques worked out by the Zapotec Indian inhabitants of the valley gave them an early advantage over their neighbors. Finally, there are various additional factors, only indirectly related to agriculture, which contributed to the rise of stratified societies in Oaxaca.

In the sections which follow we outline some of the environmental features of the Valley of Oaxaca which may be considered advantageous. We then attempt to show their relevance to the periods of food-collecting and incipient cultivation (8000 to 1500 B.C.), early village farming (1500 to 600 B.C.), and the rise of towns and ceremonial centers (600 to 200 B.C.).

The Valley of Oaxaca has 700 square kilometers of relatively flat land, the largest such expanse in the Mexican highlands south of Cholula-Puebla. Until recently, it was generally believed that the valley was the bed of a former lake, which had dried up prior to 600 B.C. This lake was men-

DATES	TEHUACÁN VALLEY	VALLEY OF OAXACA	CENTRAL CHIAPAS	OLMEC REGION
A.D. 1500		Monte Albán V		
1400				
1300	Venta Salada			
1200				
1100		Monte Albán IV		
1000				
900				
800				
700				
600		Monte Albán III		
500	Palo Blanco		Laguna	
400				Upper Tres Zapotes
300			Jiquipilas	
200				
100		Monte Albán II	Istmo	
0			Horcones	
B.C. 100				Middle Tres Zapotes
200				
300		Monte Albán I	Guanacaste	Lower Tres Zapotes
400	Santa María		Francesa	
500				
600			Escalera	
700		Guadalupe	Dili	La Venta
800				
900				
1000		San José	Cotorra	San Lorenzo
1100	Ajalpan			
1200				
1300				
1400		?	?	
1500				
2000	Purrón			
3000	Abejas			
4000	Coxcatlán	Coxcatlán		
5000				
6000				
7000	El Riego	Guilá Naquitz	Santa Marta	
8000				

Fig. 3. Pre-Hispanic cultural periods in the Valley of Oaxaca, compared with those of adjacent regions, as determined by radiocarbon dating and interregional similarities in artifacts.

tioned in Zapotec legends, and casual inspection of the valley revealed supposed "shorelines" or old "lake terraces," as well as seasonally inundated areas which were reputed to be remnants of the lake (*13, 14*). In 1960, Lorenzo (*17*) presented geological evidence to the contrary. Similarly, our study reveals no evidence of a lake.

The supposed lake "shoreline" is not horizontal but varies in elevation by over 200 meters within a distance of some 40 kilometers. What it really consists of is the break in slope formed where the steeper fan gravels meet the valley alluvium. The fan gravels are clearly fluvial in origin, and no lacustrine deposits or fossils have been found, so the hypothesis of a permanent lake in the valley during the last 10,000 years must be rejected. The seasonally flooded localities reputed to be "lake remnants" are in reality low-lying areas where the water table is close to the ground surface. Many of these occur in clay areas of low permeability, which further tend to maintain standing bodies of water for long periods.

With the rejection of the lake hypothesis, other explanations should be suggested for the Valley of Oaxaca's unusually wide and flat floor. It is known that relatively arid climates favor alluvial-fan deposition, and this tendency toward alluviation in combination with the inability of the upper Río Atoyac to downcut (because of the high resistance of rocks in the Ayoquesco gorge) could explain the great width of the valley. Furthermore, this extensive deposition could have been initiated by downfaulting, for local deformation of Miocene (but not later) sediments shows that some late-Miocene/Pliocene dislocations have occurred in the valley. Thus three factors—aridity, downfaulting, and a low rate of stream degradation—all may have contributed to the alluvial expanses which make the Valley of Oaxaca unique among its neighbors.

Less Severe Soil Erosion

In the mid-1940's Cook studied a number of the higher valleys just to the north of the Valley of Oaxaca—Tamazulapan, Yanhuitlán, and Nochistlán, in the Mixteca Alta. All these valleys have suffered extremely destructive soil erosion, which Cook traced to agricultural activities extending far back into the pre-Hispanic era (*18*).

By comparison, soil erosion is not a severe problem in the Valley of Oaxaca, although there is some local gullying of hillslopes. One reason is that, relatively speaking, little land has so far been cleared in the higher mountains. In the Valley of Oaxaca, accelerated erosion due to clearing of the natural vegetation for agriculture is most severe not only on the steepest slopes but also where the vegetation is densest. This is strikingly shown by our erosion measurements on steep slopes near Mitla, made in 1966 over a period of 2 months during which 237 millimeters of rain fell. Table 1 gives the ratios of the rate of erosion on cleared land and the rate of erosion on land with natural vegetation.

It would appear that agricultural land clearance in the oak-pine forest zone results in an accelerated erosion of 45 times the natural rate, whereas in the cactus-scrub zone, where slopes are already in equilibrium with a sparse vegetation cover, clearing of land does not appreciably increase erosion. The gentle slopes of the valley floor further discourage erosion, and the presence of an extensive flat area lessens the incentive to clear land higher in the mountains. All these factors combine to keep soil erosion to a minimum in the Valley of Oaxaca. It is perhaps worth noting that the most badly eroded valleys of the Mixteca, like Yanhuitlán, occur at elevations of 2000 meters in the pine-oak zone, where the ratio of acceleration on cleared land is highest.

Soils and Water Table

The flat valley floor and the thick alluvial deposits offer clear advantages as a site for early agriculturalists, but these factors are partially offset by the relative aridity, which limits both available water and soil fertility. Soil profiles are poorly developed, and the alluvial structure is retained almost unaltered below the A horizon. Prismatic structure and some salt accumulation is found in the B horizon. Most valley-floor soils belong to the Brown Soils group, but they tend toward Gray Desert soils in the most arid areas, such as the Mitla end of the valley.

Humus and nutrient concentrations in the soils are so low that it is the differences in water availability which constitute the most important determinant of the usefulness of the soils for man. The finest grained soils with the best water-holding characteristics occur on the high alluvium, in a band running parallel to the river, but at distances of 500 to 1500 meters away from it. Except where the high alluvium is more than 2 kilometers wide, this

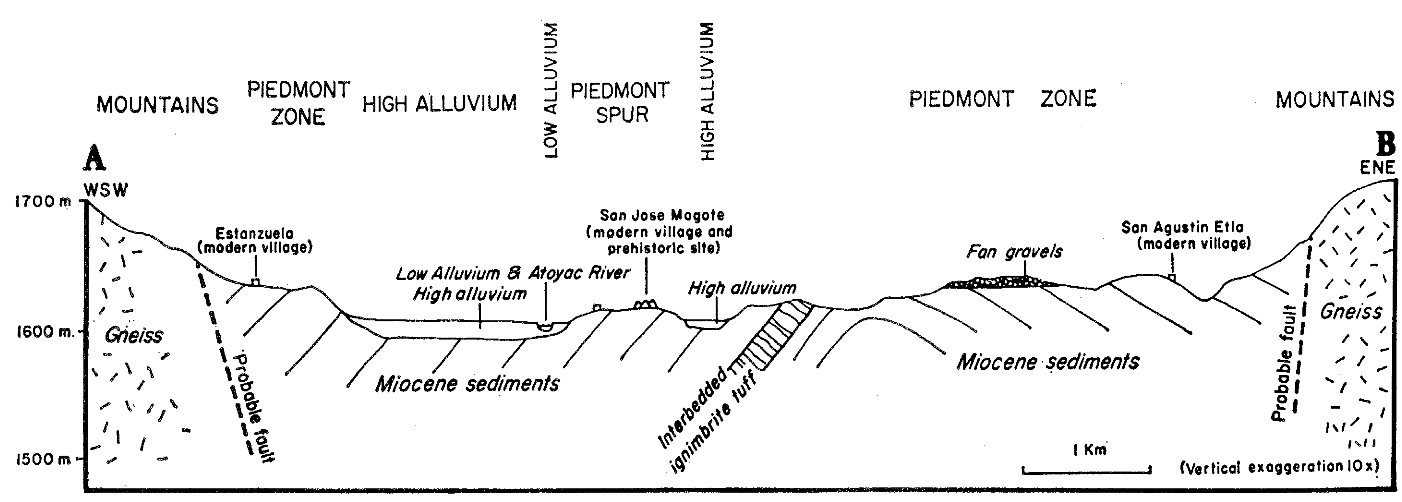


Fig. 4. Cross section of the northwestern Valley of Oaxaca near Etla, showing major physiographic areas discussed in text.

band of fine-grained soils extends to the outer edge of the alluvium, where it meets the piedmont zone.

Soil-grain size influences water retention and is thus important both for (i) dry farming and (ii) commercial crops with high irrigation requirements. In between these two extremes, in cases where more limited types of irrigation are practiced, the depth to water table and the yields from wells are more important than soil texture in determining the value of the soil for farming. This brings to mind recent comments by Stevens (*19*) on Indian farming in general: it is not necessarily the best soils which are the most intensively used, because factors of technology and water table may be the primary ones.

Within the present flood plain of the Atoyac River, well water is within 3 meters of the surface; within the zone of high alluvium, it lies between 2 and 10 meters down. In both these zones, water yields are usually adequate for small-scale irrigation of the specialized types described below. In the fan gravels of the piedmont zone, water is generally more than 10 meters below the surface, and well yields are only sufficient for immediate household needs.

A Relatively Frost-free Climate

At elevations of 2000 to 2800 meters, in areas like the Valley of Mexico or Cholula-Puebla, winter frosts may have been a real deterrent to year-round cultivation of maize until frost-resistant strains were developed, some time after the Middle Formative period. For example, Sanders' figures for the Valley of Mexico (*6*, pp. 20, 23) indicate that between October and February the area may have temperatures which are detrimental to maize. In contrast, temperatures on the floor of the Valley of Oaxaca are well suited to year-round growing of maize, even the primitive strains of the Early Formative.

At the level of the valley floor (1420 to 1740 meters, with an average of about 1550), the mean annual temperature is 20°C, with an annual range of 6°C and a daily range of 15°C. *Extreme* minimum temperatures over a recent 12-year period are close to 0°C. In any one year there is only slight probability of frost, and this largely in the higher parts of the valley. In the main Atoyac River floodplain south of Oaxaca City, all of which lies below 1550 meters, frosts are virtually nonexistent, and the present-day Zapotec of this area cultivate sugarcane, which requires an 18-month frost-free period.

Table 1. Comparison of erosion ratios in three different vegetation zones near Mitla, in the Valley of Oaxaca. [Erosion ratio = C/N, where C = erosion rate on cleared land and N = erosion rate on land with undisturbed natural vegetation. Both C and N were calculated, for slopes of comparable steepness during the same rainy season (1966), by measuring the percentage of surface material moved downslope from a previously established 50-meter line.]

Erosion sites	Elevation (meters)	Natural vegetation	Ratio for rate of erosion: cleared land/land with natural vegetation cover
No. 1	1750	Cactus-scrub	1.0
No. 2	2000	Oak-*Dodonaea*	3.8
No. 3	2300	Pine-oak	45.4

These favorable conditions deteriorate rapidly as one ascends the hills to either side of the Valley of Oaxaca. Above altitudes of about 2300 meters, summer temperatures are low enough to inhibit cultivation of maize, and wheat is at present a more reliable crop. At elevations of 3000 meters, mean daily minima in January are about 0°C, and the dominant cultivar is the potato.

The two ancient indigenous races of maize known so far for the Early Formative period in Mesoamerica—Nal-Tel and Chapalote—do poorly in cold conditions and are sensitive to highland rusts (*20*). The essentially frost-free nature of the southern Valley of Oaxaca probably gave it considerable advantage over the higher valleys of the nearby Mixteca at this early period (1500 to 900 B.C.), when only those primitive races of maize were known. In later periods, with frost-resistant strains of maize, this difference was probably less crucial, as high population densities in the Mixteca and the Valley of Mexico suggest.

Precipitation and Hydrology

Mean annual rainfall on the floor of the Valley of Oaxaca varies from 490 millimeters at Tlacolula to 740 millimeters at Ocotlán. There is a general rise in precipitation with increasing altitude, so that the surrounding mountains at elevations of 3000 meters may receive almost 1000 millimeters annually. Open-water evaporation depends principally on temperature, and decreases with elevation. On the valley floor it averages 2000 millimeters annually (three to five times the precipitation), while at 3000-meter elevations it is only 340 millimeters (one-third the precipitation). Hence the growth of permanent pine forest on the high mountains, and the sparser cactus and mesquite-grassland cover of the lower slopes.

For the growth of annual crops without irrigation, the ratio of rainfall to open-water evaporation must remain close to 1.0 throughout the summer months, with June to August the most critical period. On the floor of the Valley of Oaxaca this ratio ranges from 0.50 near Tlacolula to 0.93 near Ocotlán. This range may be contrasted with similar figures obtained for the floor of the Valley of Tehuacán, which vary between 0.45 and 0.65 (*21*). Thus conditions in the western part of the Valley of Oaxaca are somewhat more favorable for dry farming than are those in Tehuacán, a fact which was probably important during the early stages of agriculture.

Even more striking contrasts between Oaxaca and Tehuacán may be seen, however, when one examines their irrigation potential. The Tehuacán Valley has an extremely low water table (about 20 meters), but the valley lies just to the south and east of a block of limestone-travertine mountains which constitute a major aquifer. Very large quantities of subsurface water emerge from springs at the base of this range, near the western outskirts of the city of Tehuacán (*22*). Thus, shallow-well irrigation is impossible; much more feasible is a large-scale canal-irrigation system to carry water from the prolific springs out to the central and southern parts of the valley. Such a canal system was indeed developed at Tehuacán during later periods of its prehistory, when the population of the valley was already high (*8, 9, 23*).

Canal irrigation on a large scale is nowhere practical in the Valley of Oaxaca, where springs are small and surface flows are insufficient for irrigating more than a small area. However, because of the unusually high water table, shallow-well irrigation is widely practiced, and this technique, which requires relatively little effort and can be performed on an individual family basis, can be traced back to at least 700 B.C. and probably earlier.

Food-Collecting, Incipient-Cultivation Periods: 8000 to 1500 B.C.

The oldest archeological materials recovered in 1966 came from a series of caves and rock shelters near Mitla. These shelters occur in volcanic-tuff cliff faces at elevations of 1900 meters, near the transition from the piedmont to the higher mountains.

For years it had been known that this elevated region, 200 meters or more above the valley floor, was richer in surface finds of the food-collecting era than any other; when a recent lake on the valley floor was still considered a possibility, the hypothetical lake was often used to explain the restriction of these early cultures to the upper piedmont (*24*). The real reason why this zone was so consistently used in early times is that it has the richest and most varied assemblage of edible wild plants of the entire region. For the most part, shelters immediately overlooking the valley floor were used infrequently or not at all before 1500 B.C.; it was full-time agriculture, with its need for flat land and fine-grained soil, which eventually diverted attention from the upper piedmont and allowed the high alluvium to emerge as the zone of major utilization.

Between 7840 and 6910 B.C. (as estimated on the basis of radiocarbon determinations), the Indians who camped seasonally in Guilá Naquitz Cave collected acorns, pinyon nuts, mesquite beans, prickly pear and organ-cactus fruits, wild onion bulbs, hackberry, maguey (*Agave* sp.), *nanche* (*Malpighia* sp.), *susí* (*Jatropha* sp.), and a dozen other species, all of which were preserved within the cave by dessication (*25*). Toward the end of this period, small black beans (*Phaseolus* sp.) and squash seeds (*Cucurbita* sp.) appear in the refuse; thus Guilá Naquitz is added to the list of sites known to belong to the "incipient cultivation" period in ancient Mexico (*26*).

A nearby cave, Cueva Blanca, dated at about 3295 B.C. by the radiocarbon technique, yielded a later food-collecting, incipient-cultivation horizon which is in most respects identical to the Coxcatlán phase (5000 to 3000 B.C.) defined by MacNeish at Tehuacán (*9*). It would appear that at this period the whole of the southern Mexican highlands was occupied by a series of related, seminomadic bands who moved seasonally from resource area to resource area and engaged in increasingly effective experiments with the growing of maize, beans, and squash.

Not only is it impossible to speak of "key" or "nuclear" regions at this time, it is also virtually impossible to define individual "culture areas" within the southern highlands. This suggests that, while cultures were still primarily food-collecting, the individual peculiarities of the various valleys were not especially significant. It was full-time agriculture which brought about specialized adaptations to local peculiarities of soil, rainfall, and water table and gave each valley its regional character. At this point, even slight differences in agricultural potential may have started certain valleys, like Oaxaca, on the path to nuclearity.

Early Village Farming Period: 1500 to 600 B.C.

Several parts of the valley were selected as "pilot areas" in which to survey for early village farming communities, with subsequent test excavations. Chief among these was a 10-kilometer strip in the extreme northwest corner of the valley, near Etla. We concentrated on the Early Formative San José phase (1200 to 900 B.C.) and the Middle Formative Guadalupe (900 to 600 B.C.) and Monte Albán I (600 to 200 B.C.) phases (Fig. 3).

In the Etla region, the most favorable agricultural land is that part of the high alluvium where the water table is within 3 meters of the surface. As shown in Fig. 5, most Formative sites thus far located (including all the Early Formative sites) are concentrated in or adjacent to this zone. In the narrow parts of the valley, prime localities were the tips of piedmont spurs, which raised the villages just high enough above the alluvium so they would not flood in the rainy season. In wider parts of the valley, where the piedmont spurs are too far from the 3-meter water-table belt, villages were built on the high alluvium in areas where sandy soils provided them with the best-drained locations available (see Fig. 6). Our preliminary surveys in other parts of the valley suggest that the pattern observed at Etla is probably typical of the earlier part of the Formative. In areas of low water table, such as north and east of Tlacolula, evidence of Early Formative occupation is correspondingly sparser.

In this belt of high-water-table alluvium, which narrows to 500 meters near Etla and expands to 2 kilometers in the broad plain just south of Oaxaca City, the Zapotec practice a kind of rudimentary water control known as *riego a brazo* or "pot-irrigation" (Fig. 7). This technique was described in 1960 by Lorenzo (*17*), and we have since studied it in detail in the *municipio* of Zaachila.

"Pot-irrigation" involves the digging of a series of shallow wells right in the cornfield, tapping the stratum of water which lies between 1.5 and 3.0 meters from the surface. An acre of land may have ten of these small wells, which are filled in during the plowing season and then reopened when water is needed. Water is drawn up from each well in a 3-gallon pot and poured gently around the individual corn plants. By means of this system, farmers within the 3-meter water-table zone often achieve three harvests a year. At any time of the year, dry season or wet, this belt of pot-irrigated alluvium resembles a huge patchwork of small but highly productive gardens. *Riego a brazo* requires no large labor force or centralized control; it is carried out on an individual-household basis. However, the zone where this technique can be used constitutes a very small percentage of the valley-floor area in Oaxaca, and, as mentioned above, it cannot be used at all in low-water-table areas like the Valley of Tehuacán.

The association of San José and Guadalupe phase villages with this zone of pot-irrigation was very suggestive, but until recently no actual well to demonstrate the existence of the technique in the earlier part of the Formative had been found. In August of 1966, Richard Orlandini and James Schoenwetter of the Oaxaca Project discovered a Formative well which had been exposed by adobe-brickmakers in a bank some 50 meters back from the river at Mitla (Fig. 7). Associated pottery dated the well to the Guadalupe phase, considerably strengthening our evidence for water control in the early village farming period.

Agriculture within this high-water-table zone supported villages of large size and material wealth. The best-known site of the San José and Guadalupe phases is San José Mogote, which we tested in 1966 (see Fig. 5). Here Early Formative artifacts can be picked up over 40 acres of a piedmont spur surrounded on three sides by alluvium. Rows of post molds and burned wall fragments suggest that houses were large and rectangular, with partial stone foundations and wattle-and-daub walls which were plastered with mud and whitewashed. Besides the usual internal features, like hearths and bell-shaped sub-floor cooking pits, one San José phase house had a recessed circular area a meter and a half in diameter, which had been plastered and painted red. Around this circle were scattered fragments of figurines, exotically decorated pottery, fragments of black and white mica, raw chunks and small polished mirrors of magnetite, and ornaments and discarded fragments of imported marine shell (*27*). In levels belonging to the early Guadalupe phase, such scatters gave way to an artificial platform of earthen fill with stone retaining walls oriented almost due north-south, and presumably having had a ceremonial function. Such orientations characterize later ceremonial structures in the valley as well (*28*).

The evidence of long-distance trade in the San José phase (which is lacking in earlier periods) reflects two things: an increasing interest in status differentiation (with artifacts of imported materials serving as insignia of status) and formalized contacts with other Indian groups in differing environmental zones of Mesoamerica. Marine pearl oyster and *Spondylus* shell were imported from the Pacific, while *Neritina* and pearly freshwater mussels came from the Gulf Coast. *Anomalocardia subrugosa*, a mollusk eaten by Formative villagers in the estuary zone of the distant Chiapas-Guatemala coast (*29*), was also imported.

Most important are the chunks and mirrors of magnetite, a raw material native to the Valley of Oaxaca, for nodules of this metal are known to have been polished into concave mirrors and buried in ceremonial caches by the "Olmec" peoples of the southern Gulf Coast (*30*). At present, the Valley of Oaxaca must be considered a possible source for the Olmec magnetite.

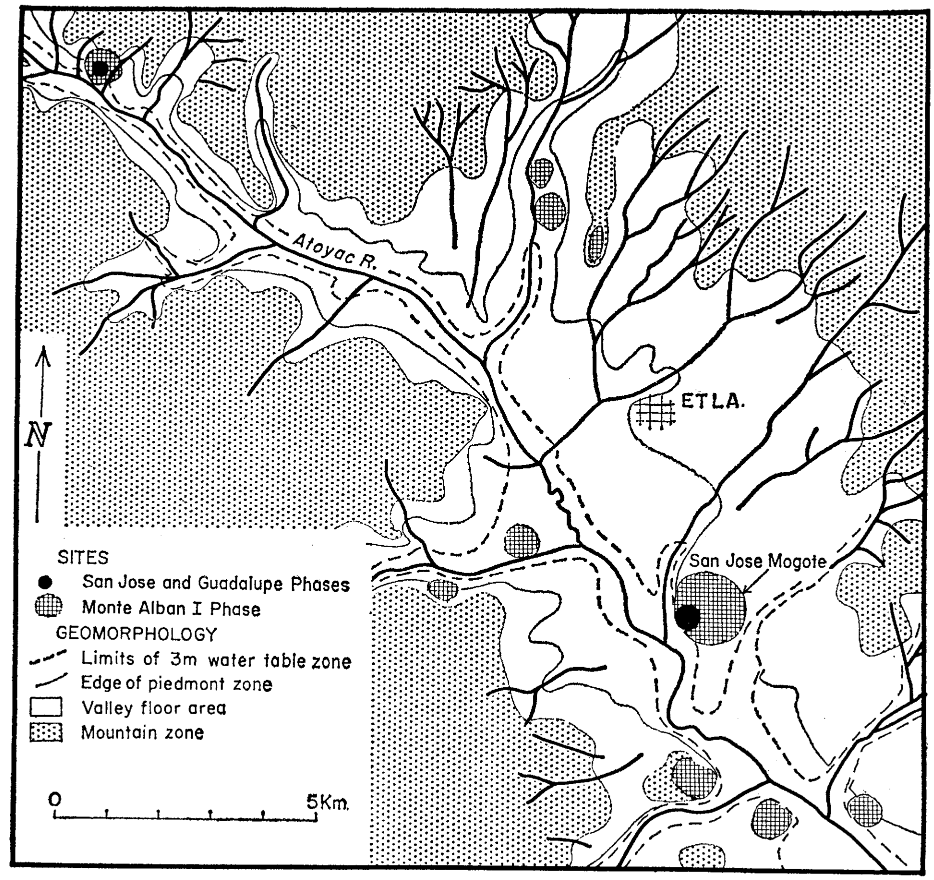


Fig. 5. "Pilot" survey area in the northwestern part of the Oaxaca Valley, showing the distribution of Formative archeological sites with regard to physiographic areas and water resources (see text).

Rise of Towns and Ceremonial Centers: 600 to 200 B.C.

During the later stages of the Middle Formative period, villages within the 3-meter water-table zone increased in size and number. Coupled with this population increase, which we attribute to the success of dry farming and pot-irrigation in that part of the high alluvium, came the first sizable spread of settlement up the more permanent tributaries of the Atoyac into the piedmont (Fig. 5). These latter sites are of two types: "habitation" sites on the first terrace of the stream or a low ridge near it, and "ceremonial" centers on hilltops nearby.

We doubt that this pattern of settlement was random. Most sites outside the high alluvium at this period are on perennial streams, and, like the present villages of the piedmont zone, they are located not downstream, at the point where most water is available, but upstream, where the water can be most effectively diverted for irrigation. Today, these villages divert the water into canals which follow the natural contour of one of the piedmont spurs downstream until they come to the crest of the spur. Here the village and the "master canal" are located, and water is distributed to fields on both sides of the spur.

This technique of small-scale canal irrigation is only feasible along the upper edges of the piedmont zone, where streams have good perennial flows. Moreover, the actual area irrigated is relatively small, and it is the communities upstream that get most of the water. For this reason, villages both in the piedmont and in the pot-irrigation zone augment their water-control farming by cultivating the nearby hillsides. The technique used is simple dry farming with fallowing, called variously *tlacolol* or *barbecho* in different parts of Mexico (*4*), and it profits from the low erosion rate of the lower piedmont zone. Such an agricultural pattern, combining an intensively cultivated (often irrigated) core area with a less intensively cultivated hinterland, has been called the "infield-outfield" system (*31*).

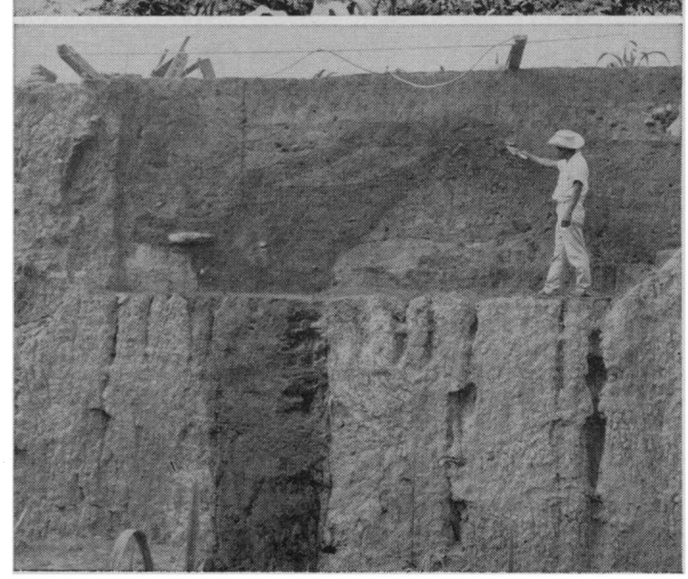
The piedmont areas into which these later Formative farmers expanded have been cultivated for so long that traces of early irrigation canals are virtually eradicated. They remain only in instances where the water used for irrigation was so rich in dissolved travertine that the canals themselves have actually been "fossilized" through deposition of this calcareous material (Fig. 8). In 1966, James Neely of the Oaxaca Project investigated one such area in the mountain zone near Mitla.

This site, called Hierve el Agua (Fig. 8), is a complex of "fossilized" ancient irrigation canals covering a square kilometer of hillside below a spring particularly rich in travertine. A series of dry-laid stone terraces had been irrigated by means of small canals which carried the water down to the fields and along the tops of the terrace walls. Neely's 40 test pits dug into these terraces reveal an occupation beginning before 300 B.C. and expanding through all subsequent periods of Oaxaca prehistory. It is probably no accident that this evidence of small-scale canal irrigation begins during the first sizable expansion out of the 3-meter water-table zone and up the perennial tributaries.

With at least four agricultural systems operating—dry farming and pot-irrigation in the high-water-table zone, canal irrigation and hillside fallowing systems in the piedmont—the Valley of Oaxaca reached another plateau on its climb toward civilization. San José Mogote grew to more than 100 acres, and in the process it differentiated internally into ceremonial and secular precincts, cemetery areas, and probably precincts of craft specialization as well. Similar developments took place throughout the valley, where there were now more than 30 ceremonial mound groups in operation (*13*, p. 797). The most impressive of these was the mountaintop elite center of Monte Albán, which (although still in its initial building stages) already had, according to archeological evidence, monumental construction, bas-relief carving, a stela-altar complex, calendrics, and hieroglyphic writing (*13*, p. 788; *14*).

By now, this area of "massed power" had begun to extend its influence into the surrounding valleys, bringing them rapidly into its sphere. This influence can be seen over an area of tens of thousands of square kilometers, from the Pacific Coast to the Tehuacán Valley. In fact, techniques of pottery design in Tehuacán and adjacent regions swung quickly away from previous traditions and featured, during this and subsequent periods, provincial imitations of the Valley of Oaxaca styles (*9*).

While much of the surrounding area may willingly have entered into a symbiotic relationship with the Valley of Oaxaca for the economic advantages it offered—such as a ready market for their surplus and their locally specialized products—there are hints that not all the marginal valleys joined peacefully. Caso (*32*) believes that at least one set of glyphs carved in stone at Monte Albán represent conquered neighboring towns, and Coe (*33*) has recently suggested that an even earlier series of bas-reliefs, the so-called *danzantes* of Monte Albán I, depict slain and mutilated captives. While these warlike interpretations remain to be proved, they are in no way inconsistent with what is known ethnographically of groups of a chiefdom stage of organization (*10*).



Evaluation of Hypotheses

With these data in mind, we can now tentatively evaluate the relevance of various developmental hypotheses to what happened in the Valley of Oaxaca. First of all, it no longer seems likely that slash-and-burn was the sole early-farming technique in Mesoamerica; in fact, given the locations of the cave areas where farming began, such as the moist barrancas of the arid Tehuacán Valley, it is even possible that some kinds of water control (like the terracing of wet arroyos) are as old as agriculture itself (*34*). However, our work in Oaxaca strongly supports Palerm and Wolf's view that the ability to assimilate new agricultural techniques through time is a key factor in retaining nuclearity.

Furthermore, the four systems we postulate for the Monte Albán I period did not represent the final stage of Zapotec agriculture. In later periods (A.D. 100 to 900), large mound groups and habitation sites cover areas of the high alluvium where only dry farming or flood-water farming is possible; by A.D. 1300 the area farmed included not only the entire valley floor but also the lower slopes of the mountains, which were frequently terraced. The terraces apparently depended on rainfall and on the lower evaporation rate of the north- and east-facing slopes. These data suggest that the assimilation of new farming techniques was also a way of bringing into cultivation more and more of the previously unproductive physiographic units of the valley: the greater the number of systems used, the greater the acreage producing at top capacity.

Our evidence for early irrigation in the Valley of Oaxaca will undoubtedly please advocates of the "hydraulic theory" of state formation (*1*). However, we see no evidence in Oaxaca for irrigation systems so large that they would necessitate a strong centralized authority. In fact, we fear that the hydraulic theory—at least, in its purest form—may at times obscure the real effects of irrigation in ancient society, which are as varied as the techniques themselves. In Oaxaca, canal irrigation of the Hierve el Agua type is applicable to a very tiny portion of the valley, and it is no more productive (in terms of labor input relative to crop yield) than pot-irrigation. Moreover, many canal-irrigating villages are so high in the piedmont that only summer crops can be grown. What canal irrigation *did* do was to open up an additional niche within the valley which had not previously been agriculturally productive.

Perhaps most significantly, in canal-irrigation communities there tends to be less equitable distribution of land and property rights than in pot-irrigating communities. As past writers have observed, irrigated land is "improved" land; it represents an investment which makes it a more scarce and competed-for resource than it previously was, and leads to problems of inheritance of property and differential access to good land. If a developing society has tendencies toward status differentiation

Fig. 6 (opposite page, left). Archeological sites in the Valley of Oaxaca, showing contrasts in land-use patterns. (Top) Cueva Blanca, a cave near the transition from the mountains to the upper piedmont. This zone, which is particularly rich in edible wild plants, was extensively used in the food-gathering era. (Bottom) San José Mogote, a site covering the tip of a low piedmont spur next to the 3-meter water-table zone of the Atoyac River alluvium. The latter was the zone of most intensive utilization during the early village farming era. (The artificial mounds seen just above and to the right of the present-day village indicate the center of the site, which fills the upper two-thirds of the photograph.)

Fig. 7 (opposite page, right). Primitive water control in the Valley of Oaxaca, new and old. (Top) Zapotec farmer engaged in "pot-irrigation" in the high-water-table zone near Zimatlán. Behind him is the shallow well from which the water has been drawn. (Bottom) Prehistoric well belonging to the Guadalupe phase (900 to 600 B.C.), exposed in a high bank near the river at Mitla. [Courtesy, R. Orlandini and J. Schoenwetter]

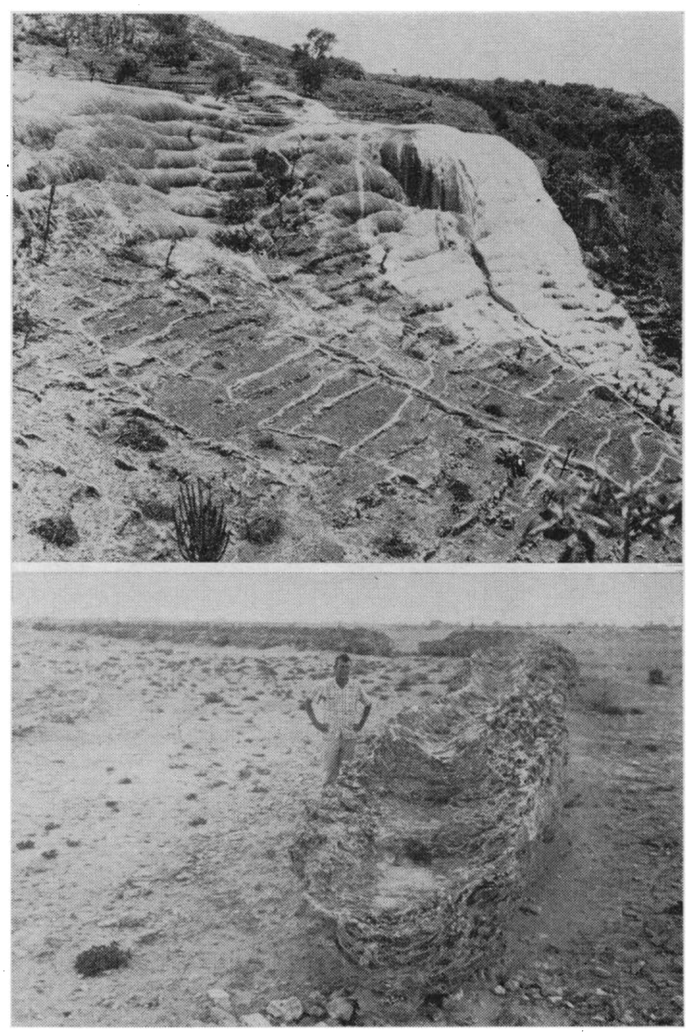


Fig. 8 (right). Prehistoric irrigation canals "fossilized" by travertine deposition, showing contrasts between regions at different periods. (Top) Small-scale canals used to irrigate terraced hillside at Hierve el Agua, near Mitla, Oaxaca [Photo by Chris L. Moser.] Irrigation systems of this type date back to before 300 B.C., clearly antedating the origins of the state. (Bottom) Massive irrigation canal which runs for several kilometers across the Valley of Tehuacán, Puebla. Such canals were apparently constructed only during later periods of Mesoamerican prehistory, after the formation of the state had already taken place. [Courtesy, respectively, J. A. Neely and R. B. Woodbury] already, which the Formative peoples of Oaxaca did have, these tendencies can be aggravated by control and inheritance of irrigation systems. It may be that early irrigation in Oaxaca can be most profitably viewed in these terms.

Summary and Conclusions

The Valley of Oaxaca's large flat floor, high water table, low erosion rate, and frost-free floodplain give it a higher agricultural potential than that of most surrounding areas. The development of the pot-irrigation system early in the Formative period gave it a head start over other valleys, where the low water table did not permit such farming; Oaxaca maintained its advantage by assimilating canal irrigation, *barbecho*, infield-outfield systems, flood-water farming, and hillside terracing as these methods arose. With the expansion of population in the high-water-table zone of the high alluvium, competition for highly productive land and manipulation of surpluses may have led to initial disparities in wealth and status; competition probably increased when canal-irrigation systems were added during the Middle Formative, improving some localities to the point where one residental group owned land more valuable than that of its neighbors.

Trade in exotic raw materials, which appear to have served as the insignia for status over much of Formative Mesoamerica, increased the wealth of the Oaxaca communities, and their elite made contact with the elite of other cultures, such as the Olmec. Such contact probably stimulated exchanges of the "lore" known only to the elite —calendrics, hieroglyphic systems, and symbolic art—thus widening the gap between farmer and chief. Through cooperation or coercion, the Oaxaca Valley chiefdom drew together a symbiotic area of 50,000 square kilometers, commemorating its accessions with stone monuments carved in bas-relief. By the start of the Christian Era it was the dominant political entity in the southern highlands of Mexico, and had become a true state.

The Oaxaca Project has only begun, and our reconstruction must remain a tentative one. We are especially aware that we cannot as yet integrate into this scheme the botanical and palynological materials from Oaxaca which are currently undergoing study. They will make the story still more complex, but civilization is a complex process; single-cause theories, no matter how attractive, are inadequate to explain it.

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