Reports

Teotihuacán: Completion of Map of Giant Ancient City in the Valley of Mexico

Abstract. *The detailed archeological map of Teotihuacán, near Mexico City, demonstrates what the prehistoric city was like from its densely crowded center to its more sparsely settled peripheries. The city's population lived in crowded one-story apartment compounds, grouped into neighborhoods based at least partly on occupation. At its height the city had a minimum population of 75,000, a probable population of 125,000, and a possible population of more than 200,000. Those involved in craft production and associated activities may have numbered in the tens of thousands. The scope and intensity of urbanization at Teotihuacán is not paralleled in other contemporary New World centers. The growth potential of the obsidian and other industries, the rise of Teotihuacán as a market and trade center, and its attraction as a religious center may have combined in a self-generating process that led to the creation of Teotihuacán's unique urban society.*

Teotihuacán, one of the largest preindustrial cities in the world, has been completely mapped in detail. Large-scale photogrammetric maps of the ancient Mexican urban center were used in an intensive field reconnaissance of an area of more than 30 km^2. The first complete map of the entire city may be seen in Fig. 1. The scale of Fig. 1 is about 1 : 41,500. The scale of the field maps and of the final drawings on which Fig. 1 is based is 1 : 2000. Figure 2 covers the same area as Fig. 1 and is a reduction of the 1 : 2000 topographic field map on which Fig. 1 is based.

The map's grid system of 500-m squares follows the north-south orientation of the ancient city, approximately 15°30′ east of astronomic north. The zero point of the grid system is in the center of the city, at the southwest corner of the Ciudadela (Fig. 1, No. 3).

In collecting data for the preparation of the map, we looked for any evidence we could find of ancient occupation. We attempted to recognize separate structural units, such as room complexes, platforms, temples, open plazas, walls, thoroughfares, and other architectural features in the city. We termed each such unit a "site." We took into account mounding, including slight changes in elevation, and the density of potsherds and other objects on the surface. By use of these and other criteria, we defined the limits of a site, made a collection of pottery and other objects, and noted the site limits on the map. We noted on one-page site records the most important characteristics of more than 3000 sites, including such features as structural remains, ceramics, and stone tools. Data from such records have been encoded for computer analyses (*1*).

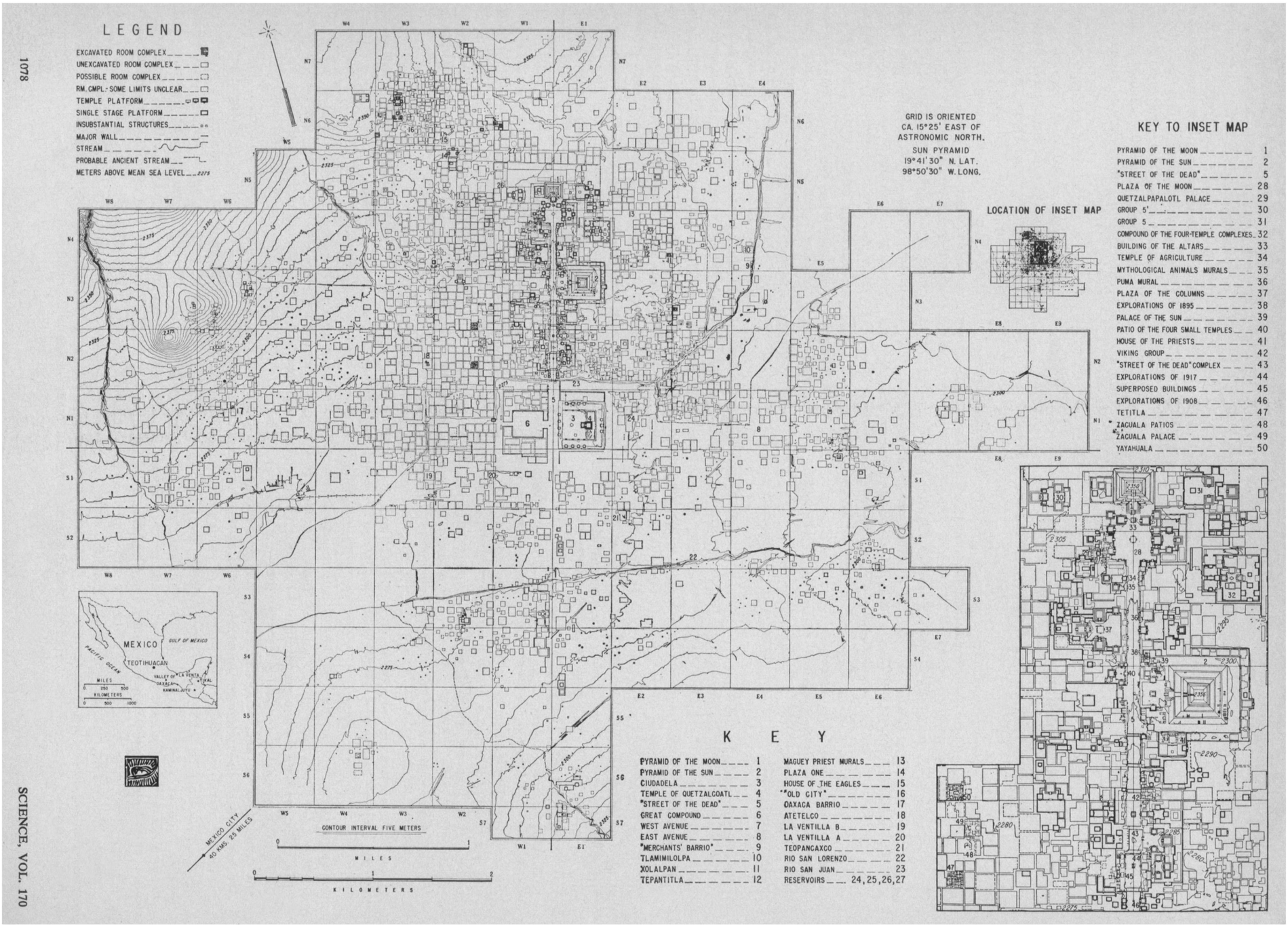
Figure 3 illustrates how we used our 1 : 2000 photogrammetric maps in our field reconnaissance to help determine the forms and boundaries of ruined, buried buildings, the spatial relations among buildings, and how open space was used in forming the architectural complexes. Figure 3B (scale about 1 : 4300) shows the topography in square N4W1, immediately south and west of the Moon Pyramid, together with the data recorded in the course of the archeological survey. Figure 3A shows our hypothetical reconstructions of buildings, which are based partly on these data and partly on a study of the surface collections we made from each building or other numbered unit and on our written observations and photos relating to these structures. The same kinds of data were collected for the entire city. Figure 3 and 150 other similar pairs of facing drawings for the entire city will be published at the 1 : 2000 scale.

The area shown in Fig. 3A extends from the temples and other structures on the west side of the "Street of the Dead" westward to an area of residential room complexes at left, shown as open rectangles. Each of the buildings shown as an open rectangle consisted of rooms, porticos, patios, and access ways similar to, but less elaborate than, the Quetzalpapalotl Palace in the upper right. The reader should bear this in mind when examining Fig. 1.

The reconstructions of hypothetical buildings are based on a vast body of information. This information frequently includes exposed floors, walls, and other structural features. There are more than 2600 room complexes, temples, platforms, and other major stone-walled structures shown in Fig. 1. Of these structures, more than 1200 (46 percent) had walls, floors, or other structural evidence visible in situ. Our other most reliable indicator of major construction in the survey has been a combination of stone cover and crushed volcanic scoria (*cascajo*), the latter being the preferred major ingredient in the foundations of floors and in the outer coverings of walls. The reliability of the presence of this combination of building materials on a site was tested in seven excavations, and in every case its presence proved reliably to predict the existence of major construction. Conversely, in three cases where *cascajo* was not present and where we did not expect to find any major structures, no major structures were found.

Figure 1 is the first map of the entire city, from its center to its outskirts. I avoid the word "suburbs" because that term most meaningfully applies to parts of a city in which, for the most part, people live but do not work, their place of work being in the city (*2*). The separation of place of work from place of residence in a city seems largely to be confined to industrialized societies of recent times.

The city was divided into quadrants by its north-south (Street of the Dead) and east-west axes (East Avenue and West Avenue) (Fig. 1, Nos. 5, 7, and 8). With some exceptions, buildings in Teotihuacán are oriented to the north-south axis which gives the plan of the city an orderly appearance even in areas of great crowding. Figure 1 represents the city as we think it was late in its history (about A.D. 600) when it covered an area of about 20 km^2 (8 mi^2). If the reader will note the scale of the map, he will have some idea of the great size of the city and of the great number of its apartment compounds. Apartment compounds are one-story


LEGEND
EXCAVATED ROOM COMPLEX
UNEXCAVATED ROOM COMPLEX
POSSIBLE ROOM COMPLEX
RM. CMPL.- SOME LIMITS UNCLEAR
TEMPLE PLATFORM
SINGLE STAGE PLATFORM
INSUBSTANTIAL STRUCTURES
MAJOR WALL
STREAM
PROBABLE ANCIENT STREAM
METERS ABOVE MEAN SEA LEVEL 2275
GRID IS ORIENTED CA. 15°25' EAST OF ASTRONOMIC NORTH.
SUN PYRAMID
19°41'30" N. LAT.
98°50'30" W. LONG.
LOCATION OF INSET MAP
KEY TO INSET MAP
PYRAMID OF THE MOON 1
PYRAMID OF THE SUN 2
"STREET OF THE DEAD" 5
PLAZA OF THE MOON 28
QUETZALPAPALOTL PALACE 29
GROUP 5' 30
GROUP 5 31
COMPOUND OF THE FOUR-TEMPLE COMPLEXES 32
BUILDING OF THE ALTARS 33
TEMPLE OF AGRICULTURE 34
MYTHOLOGICAL ANIMALS MURALS 35
PUMA MURAL 36
PLAZA OF THE COLUMNS 37
EXPLORATIONS OF 1895 38
PALACE OF THE SUN 39
PATIO OF THE FOUR SMALL TEMPLES 40
HOUSE OF THE PRIESTS 41
VIKING GROUP 42
"STREET OF THE DEAD" COMPLEX 43
EXPLORATIONS OF 1917 44
SUPERPOSED BUILDINGS 45
EXPLORATIONS OF 1908 46
TETITLA 47
ZACUALA PATIOS 48
ZACUALA PALACE 49
YAYAHUALA 50
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
TEOTIHUACAN
VALLEY OF OAXACA
LA VENTA
TIKAL
KAMINALJUYU
MILES
KILOMETERS
MEXICO CITY 40 KMS. 25 MILES
CONTOUR INTERVAL FIVE METERS
MILES
KILOMETERS
K E Y
PYRAMID OF THE MOON 1
PYRAMID OF THE SUN 2
CIUDADELA 3
TEMPLE OF QUETZALCOATL 4
"STREET OF THE DEAD" 5
GREAT COMPOUND 6
WEST AVENUE 7
EAST AVENUE 8
"MERCHANTS' BARRIO" 9
TLAMIMILOLPA 10
XOLALPAN 11
TEPANTITLA 12
MAGUEY PRIEST MURALS 13
PLAZA ONE 14
HOUSE OF THE EAGLES 15
"OLD CITY" 16
OAXACA BARRIO 17
ATETELCO 18
LA VENTILLA B 19
LA VENTILLA A 20
TEOPANCAXCO 21
RIO SAN LORENZO 22
RIO SAN JUAN 23
RESERVOIRS 24, 25, 26, 27

rectangular structures designated in the legend of Fig. 1 as "excavated" or "unexcavated" room complexes. There are more than 2000 such apartment compounds in the city. Note also the immense size of the Ciudadela and the Great Compound (Fig. 1, Nos. 3 and 6; see also cover photograph). We believe that these two enclosures in the geographic center of the city—enclosures that are so similar and yet so different—together formed the city's religious, bureaucratic, and commercial center.

The most sparsely settled section of the city is the extreme southern extension of the Street of the Dead, at the bottom of the map. It forms a continuous and integral part of the city, despite its low density (*3*, pp. 105–106). The northwest quadrant is by far the most densely settled and presumably the most populous part of the city. It is also the area with the greatest concentration of occupational specialists. The preponderance of residential construction in the northwest may be related to the fact that the southwest quadrant borders the richest cultivable land in the Valley of Teotihuacán and that most of the eastern perimeter also borders cultivable land. In contrast, the northwestern perimeter borders poor cultivable lands. Another and probably related reason for the greater density of settlement in the northwest quadrant is that it was the most densely settled area early in the city's history, around the time of Christ. This area was Teotihuacán's "old city," and it continued to be the most crowded and densely settled section throughout the city's history (square N6W3 and the squares surrounding it; see Figs. 1 and 2).

Evidence from surface survey and from excavation indicates that Teotihuacán was divided into *barrios* or neighborhoods. Some groups of buildings are so clearly set off from surrounding structures that they form easily definable spatial units. Other groups of buildings are distinguished by what we find on their surfaces. There are groups of buildings where the same craft seems to have been practiced (obsidian working, pottery making, lapidary work), where foreigners from the same place lived (*4*) (Fig. 1, No. 17), where foreign pottery from different parts of Middle America, principally from the Gulf Coast, Yucatán, and Guatemala, is found in quantity, and where we think merchants may have lived (Fig. 1, No. 9).

The map of Teotihuacán demonstrates that a great deal of planning must have gone into the building of the city. The length of the Street of the Dead shown in Fig. 1 (it extends to the very bottom of the map) was apparently decided on early in the city's history, perhaps in the second century A.D., before there were many permanent buildings at Teotihuacán other than pyramids and temples. The decision to extend the Street of the Dead over a distance of 5 km was an audacious one. In staking out a claim for the future growth of the city, the early Teotihuacanos were cutting off the narrow waist of the Teotihuacán valley and effectively blocking from open access the most convenient route for trade and travel between the Valley of Mexico and, to the east, the Valley of Puebla and coastal Veracruz (*5*).

The fact of planning is evident, but what is not clear is its nature, its extent, and its sequence. Was there ever some kind of master plan which was slowly fulfilled and modified with the passage of time? Or was the building up of the city the result of a series of piecemeal additions to a basic cruciform plan which, when we see it completed, gives us an impression that it was the product of an overall "master plan" although it may not have been so at all (*6*). The argument that there was no planning outside the city's central core (*3*, p. 172) is contradicted by the map on the south, the west, and the east.

Population estimates based solely on archeological evidence are difficult to make. Nevertheless, such estimates can now be made with greater accuracy than at any time since the fall of the city, for we have a reasonably good minimum estimate for the entire city of the number of major buildings and their nature and disposition. Only the buildings that we have reason to believe were occupied at the same time are shown in Fig. 1. Population estimates are based only on these buildings. We believe that our surface survey techniques make it possible for us to distinguish buildings composed of complexes of rooms from other buildings, such as temples or platforms. We also believe that most, if not all, room complexes were residential, even though most were almost certainly the locus of other activities as well. People who worked in the city seem to have tended to work where they lived. Exceptions or partial exceptions would have been construction workers, marketplace traders, merchants, and some temple workers.

I arrived at the population estimates that follow by examining apartment compounds that have been excavated in various parts of the city (Fig. 1). We know that these buildings were lived in, because our own excavations have established unequivocally that there were kitchens in these compounds. [We stress this fact because it has been raised as a false issue (*7*).] We have postulated that corporate groups of some kind lived in apartment compounds, principally because the prominence within them of one or more temples suggests that compound inhabitants engaged in common ritual activities (*8*). Inhabitants of compounds may have been linked by ties of kinship, may have engaged in common occupations, or more likely both. But we do not know the size or social composition of the domestic or other groups living in these compounds. For this reason, estimates of populations of apartment compounds must be based on other grounds. Also, it seems probable for several reasons that larger buildings did not necessarily house proportionally larger numbers of people.

What I have tried to do is to determine how many potential sleeping rooms there are in excavated apartment compounds. I have defined a potential sleeping room as one that is completely enclosed—that is, it has four walls and one or more doorways. Excluded from this count were enclosed rooms that appear to have been used for other purposes (rooms on temple platforms) or that seem otherwise exceptional and therefore possibly intended primarily for other uses (for example, since mural paintings are exceptional in interior rooms, rooms with murals were excluded).

Apartment compounds vary extensively in the sizes of their rooms and in the way open space is used (principally patios, porticos, and access ways). The most crowded seem to have one en-

Fig. 1. Map of the ancient city of Teotihuacán at its height (about A.D. 600). The city covered about 20 km² (8 square miles). Partially or completely excavated structures, primarily along the Street of the Dead (north-south axis), are shown; also shown are reconstructions based on the Teotihuacán Mapping Project survey of surface remains of unexcavated and partially excavated structures. An undetermined number of structures in various parts of the city have been buried under silt or leveled for agriculture in modern times. Most of the buildings shown were one-story apartment compounds. Note the canalization of most streams within the ancient city.

closed sleeping room (as defined here) for every 40 to 50 m². The most spacious, of which there are few examples, seem to have one enclosed sleeping room for every 150 to 200 m². If we take 120 m² per sleeping room as a basis for calculation (a conservative estimate), we arrive at a total of 30 such rooms in an apartment complex of 3600 m². With the further conservative assumption that such rooms would have provided sleeping space for 1 to 3 people, we arrive at a very conservative figure of 60 persons per apartment compound of about 3600 m² (Nos. 47, 49, and 50 in Fig. 1 are slightly smaller than 3600 m²). I also made estimates for two apartment compounds of successively smaller size, for which I used slightly higher population densities. For an apartment compound of about 1600 m² (No. 11 in Fig. 1 is slightly smaller), I estimated a population of 30. For a compound about 25 by 25 m, I estimated a population of 12. I believe that these are conservative, minimum figures, which more than compensate for rooms included in the count that may not have been used for sleeping. More probable population figures for each of these compound sizes are 100, 50, and 20.

With these two sets of figures, I made population estimates for the entire city, after measuring the sizes of the reconstructed apartment compounds in each of the squares shown in Fig. 1. The three building sizes and their estimated populations served as a guide in estimating proportionally the populations of buildings of other sizes. These calculations yielded a minimum population of 75,000 and a probable population of 125,000 for the city at its height. Since the assumptions about the number of persons who lived in apartment compounds of various sizes may be too conservative, it is possible that the city's population was significantly larger, perhaps exceeding 200,000.

The population of Teotihuacán is impressively large for an early city. Not only was its population large, but it was also relatively highly differentiated, with a significant proportion of the population engaged in craft activities. Although most of the city's population probably cultivated land, more than 500 craft workshops have been found in our archeological survey of the ancient city.

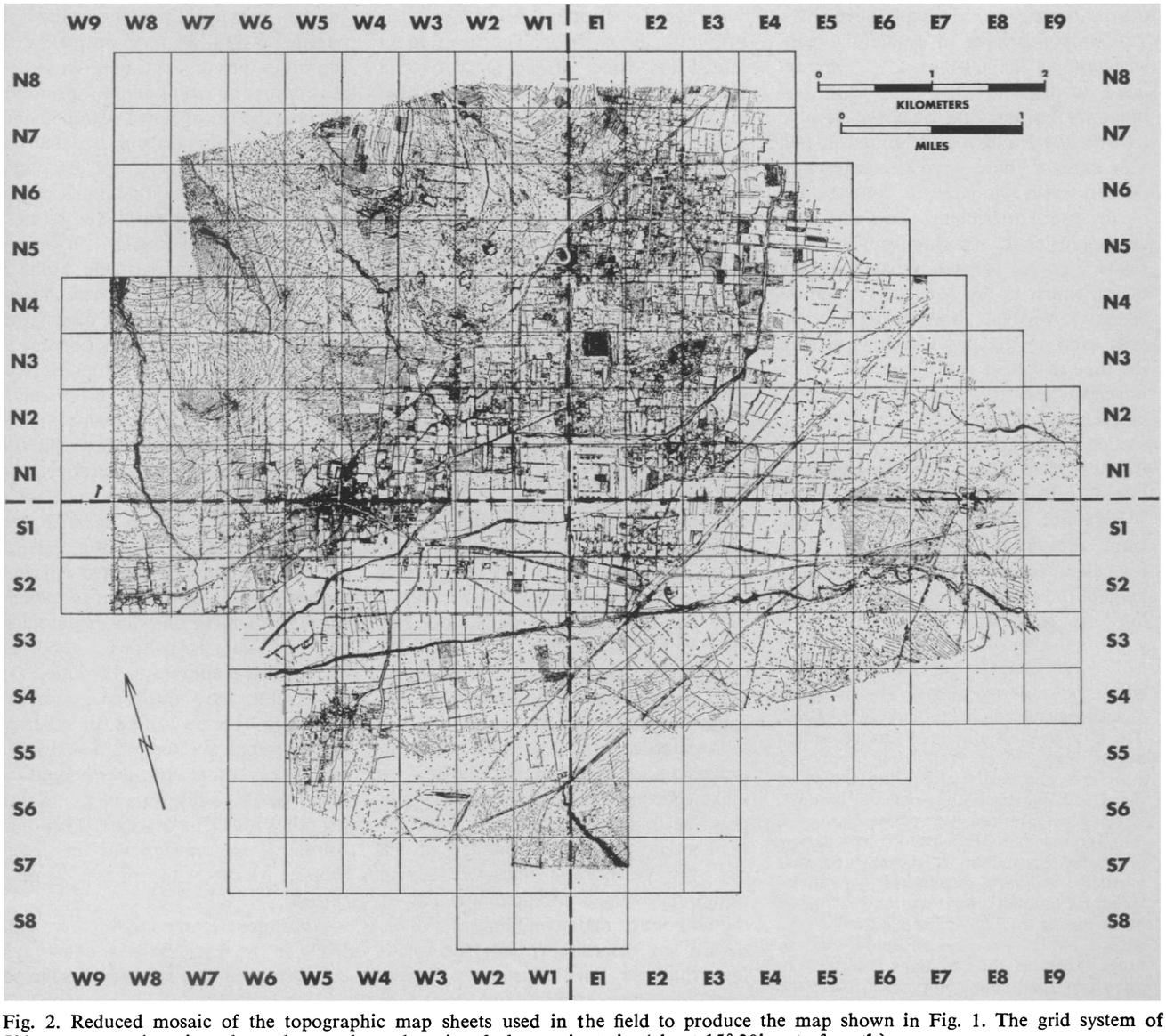


Fig. 2. Reduced mosaic of the topographic map sheets used in the field to produce the map shown in Fig. 1. The grid system of 500-m squares is oriented to the north-south axis of the ancient city (about 15° 30′ east of north).

The vast majority are obsidian workshops, most of which were in use when the population of the city was at its peak (*9*). There are also well over a hundred other workshops—ceramic, stone, figurine, lapidary, basalt, and slate. To this total must be added an unknown number of workshops where the craftsmen worked in materials and with tools that left no traces or that we have not been able to recognize. In addition, there must have been sizable numbers of craftsmen connected with the building of the city's many structures—masons, plasterers, and carpenters, and perhaps others as well.

A significant proportion of the population of Teotihuacán must have been involved in craft production and craft activities. Perhaps it was 25 percent or more, which would mean tens of thousands of people. In addition, an unspecified number of people were engaged in marketplace and long-distance trade. These persons may have been some of the craftsmen themselves or specialized traders or, perhaps more likely, some combination of the two. Did the economic potential represented by the growing obsidian and other industries and the presumed growth of Teotihuacán as a market and trade center, together with the religious attraction that Teotihuacán must have had very early in its history, combine in a self-generating process that that led to the creation of Teotihuacán's unique urban

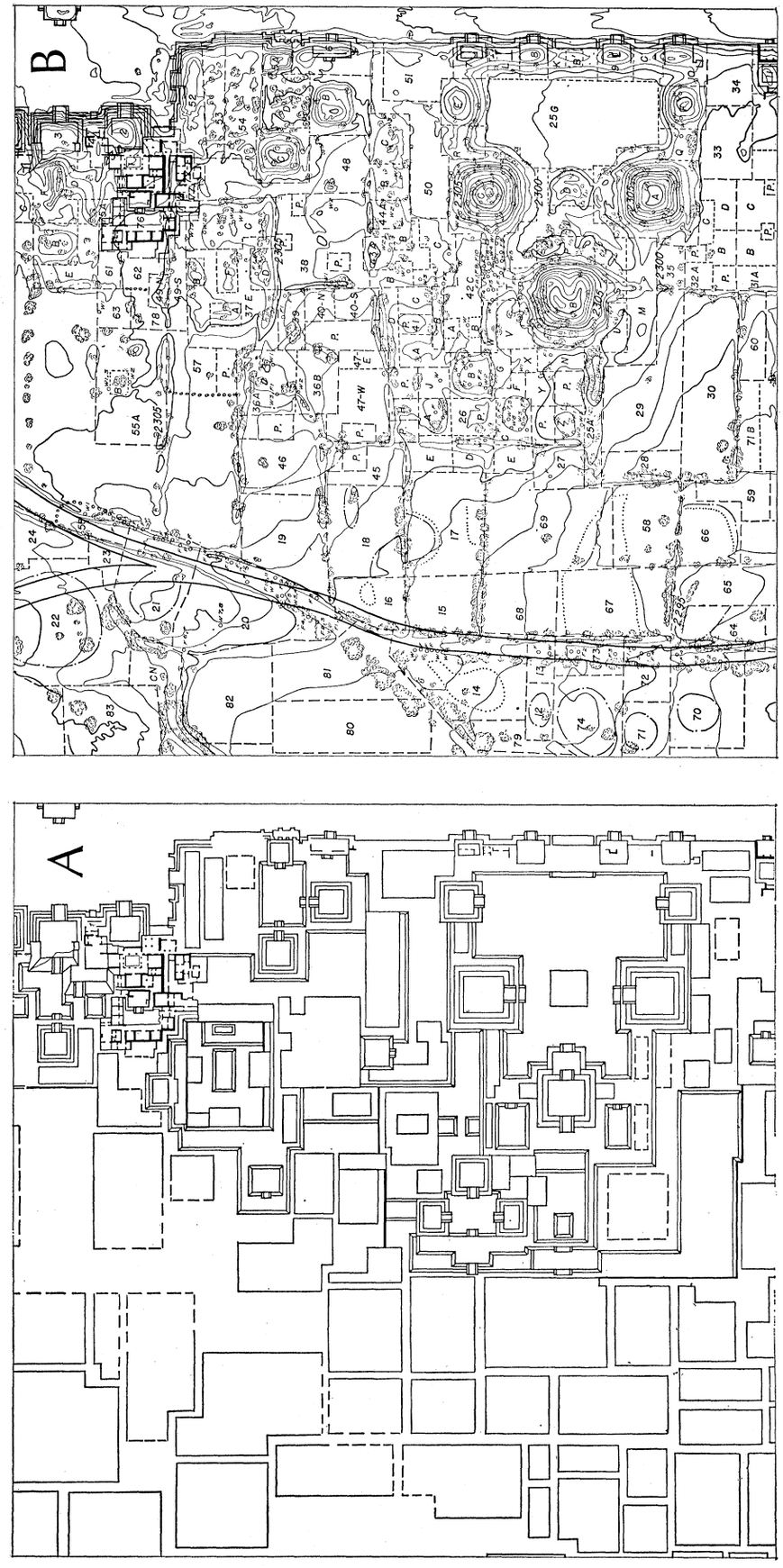


Fig. 3. Detailed drawings of N4W1, the 500-m square southwest of the Moon Pyramid (see Fig. 1). This pair of drawings is one of 150 such pairs covering the entire ancient city. (A) Drawing showing buildings as we think they would have looked anciently, based on the data shown at right and on written descriptive data and surface collections for each numbered site and subsite shown at right. Buildings shown as open rectangles were apartment compounds—complexes of rooms, patios, access ways, and small temples—similar to but less elaborate than the complex of excavated rooms shown in the northeast part of the drawing. (B) Topographic map with 1-m contours, together with data from the Teotihuacán Mapping Project archeological survey of this square, showing site boundaries and numbers, exposed floors (*F*) and walls (*W*), and wholly or partially excavated structures along the Street of the Dead. Contours were drawn photogrammetrically in 1962 from a flight made in that year. The road that runs north-south in the western part of the drawing is the new road around the archeological zone ("Periférico") (see cover). It was built in 1964 after the contours had been drawn and is therefore shown "overriding" them.

society (*10*)? This appears to be the most promising line of investigation in the present state of our knowledge.

Occupational specialization, proliferating craft industries, high urban density, and a large population are differing manifestations of the same intense process of urbanization. Taken in conjunction with the scope of Teotihuacán's exports and imports, they argue that Teotihuacán society was more complex than recent estimates have suggested. The intensity of the urbanization process appears to set Teotihuacán apart from other contemporary centers in Middle America. At the same time, it makes it more similar to Tenochtitlán, the capital of the Aztecs, which rose 40 km from Teotihuacán on the site of modern Mexico City over 500 years after Teotihuacán's fall. Until equivalent comparative data from other parts of the New World are available, comparisons with early Old World centers may be more useful in trying to understand pre-Hispanic urbanization in the Valley of Mexico.

Teotihuacán stands for the present as the most highly urbanized center of its time in the New World (*11*). The extraordinary extent and pervasiveness of its influence through so much of Middle America in the early centuries of the Christian era are now more understandable.

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References and Notes

1. Computer analyses are being carried out by G. Cowgill.
2. See H. Saalman, *Medieval Cities* (Braziller, New York, 1968), pp. 44–45.
3. See W. Sanders, *The Cultural Ecology of the Teotihuacán Valley* (Dept. of Sociology and Anthropology, Pennsylvania State Univ., State College, 1965).
4. R. Millon, *Bol. Inst. Nac. Antropol. Hist.* **29**, 42 (1967); *Gac. Med. Mex.* **98**, 339 (1968).
5. ———, *Sci. Amer.* **216** (6), 38 (1967).
6. D. Robertson, *Pre-Columbian Architecture* (Braziller, New York, 1963), pp. 25–27, 35–36; J. E. Hardoy, *Ciudades Precolombinas* (Infinito, Buenos Aires, 1964), pp. 89–93; *Urban Planning in Pre-Columbian America* (Braziller, New York, 1968), pp. 9, 12, 22–23.
7. G. Kubler, *The Art and Architecture of Ancient America* (Penguin, Baltimore, 1962), pp. 29, 328.
8. R. Millon, *37th Int. Congr. Americanists Actas Memorias* **1**, 113 (1968).
9. For the past several years M. Spence of Southern Illinois University has been analyzing obsidian, obsidian workshops, the obsidian industry, and specialization within the industry in Teotihuacán on the basis of what was found in our excavations and surface survey.
10. This is suggested in part by the stimulating ideas of J. Jacobs on the economic growth of early cities [*The Economy of Cities* (Random House, New York, 1969]. See also R. Millon, in *Teotihuacán, XI Mesa Redonda* (Sociedad Mexicana de Antropología, Mexico, 1967), pp. 149–155.
11. Other contemporary Middle American centers, such as Tikal in Guatemala or Dzibilchaltun in Yucatán, seem to have covered larger areas than Teotihuacán [W. Coe. *Tikal* (University Museum, Philadelphia, 19[illegible] W. Haviland, *Amer. Antiquity* **34** (4), 429 (1969); E. Andrews, Map of Dzibilchaltun, Yucatán, Mexico (Middle American Research Institute, Tulane Univ., New Orleans, 1965); *Archaeology* **21** (1), 36 (1968)]. But so far as is now known, none seems to have been so highly urbanized as Teotihuacán; that is, none seems to have combined great size, high population density, large populations, foreign enclaves, and thousands of craft specialists in a marketplace and ritual center of immense, monumental proportions. Chan Chan, an immense urban center on the north coast of Peru, is now under intensive study by M. Moseley and others. From what is now known of it, Chan Chan, although of great size, also does not appear to have been so highly urbanized as Teotihuacán [M. West, *Amer. Antiquity* **35** (1), 74 (1970)].
12. Supported by NSF grants G23800, GS207, GS641, GS1222, and GS2204. Principal participants with R.M. on the project are G. Cowgill (Brandeis University) and R. B. Drewitt (University of Toronto). J. A. Cerda is chief draftsman. I gratefully acknowledge the assistance of P. Baños, W. Barbour, J. Bennyhoff, D. Blucher, H. Castañeda, J. Dow, A. German, E. Ekholm, P. Krotser, G. R. Krotser, D. Massey, E. Rattray, S. Reichlin, S. Sharnoff, M. Spence, J. Vidarte, M. Wallrath. I thank I. Bernal, I. Marquina, J. Cortina, J. Acosta, J. L. Lorenzo, P. Salazar, E. Matos, E. Contreras, F. Müller, and E. Taboada of Mexico's Instituto Nacional de Antropología e Historia for their assistance in our work. This report benefited from readings and criticisms by W. Barbour, E. Calnek, G. Cowgill, R. B. Drewitt, A. Green, and C. Millon.

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Sulfur Isotope Distribution in Solfataras, Yellowstone National Park

Abstract. *Sulfur isotope data on hydrogen sulfide, native sulfur, and sulfates from acid hot-spring areas at Yellowstone National Park suggest that hydrogen sulfide oxidizes to sulfur abiologically, whereas sulfur undergoes biological oxidation to sulfuric acid. An exception occurs at Mammoth Hot Springs where hydrogen sulfide apparently undergoes biochemical oxidation to sulfur.*

Fumarolic hydrogen sulfide, discharged in sulfurous hot-spring areas known as solfataras, oxidizes to form large quantities of sulfuric acid. Previous studies suggest that bacteria may produce virtually all this sulfuric acid by catalyzing the oxidation of geothermal hydrogen sulfide. These studies dealt with the distribution of sulfur-oxidizing bacteria in solfataras (*1*) and the quantities of sulfuric acid produced in solfataras as compared with the quantities produced by bacteria in the laboratory (*2*). The relative importance of a biochemical versus an inorganic oxidation mechanism, however, has been difficult to determine. The success achieved with the use of sulfur isotope ratios to confirm bacterial processes of sulfate reduction led naturally to their use in studies of the oxidation of sulfides in nature (*3*, *4*). Results thus far, however, have been only suggestive of biochemical involvement.

Because the masses of the S^{32} and S^{34} nuclei are different, these isotopes react at different rates in chemical reactions. If, during the formation of sulfur compounds, the reaction does not go to completion, the ratio of the isotopes in the products will be different from that in the remaining reactants. It is this enrichment or depletion of one of the isotopes that can sometimes be used to infer the genesis of a sulfur compound. Oxidation-reduction reactions in which organisms participate usually show diagnostic shifts in the ratios of isotopes of the reacting elements (*5*). In order to see if the ratios of sulfur isotopes would show shifts that we could interpret as diagnostic of biochemical, as contrasted with inorganic, oxidation, we collected samples of sulfide, sulfur, and sulfate from various hot-spring localities within Yellowstone National Park (*6*).

Table 1 lists the results of our sulfur isotope analyses in terms of δS^{34} values [difference (in parts per thousand) between the S^{34}/S^{32} ratio in the sample and that in the Cañon Diablo meteorite standard]. Table 1 shows that the δS^{34} values of hydrogen sulfide from localities 1 through 5 range from $+0.7$ to $+2.6$ per mil. This small range of δS^{34} values indicates a well-homogenized source and is in agreement with values generally considered to be those of deep-seated sulfur (*7*). Most of the hydrogen sulfide rising to the surface in these areas may come from either a body of degassing magma beneath the park or igneous rocks containing unfractionated sulfur.

The hydrogen sulfide values from localities 6, 7, and 8, however, range from -3.0 to -5.5 δS^{34} per mil. A thick sequence of sedimentary rocks underlies locality 6, Mammoth Hot Springs (*8*). Sulfide minerals in sedimentary rocks usually show depletions of S^{34} because of the biologic reduc-