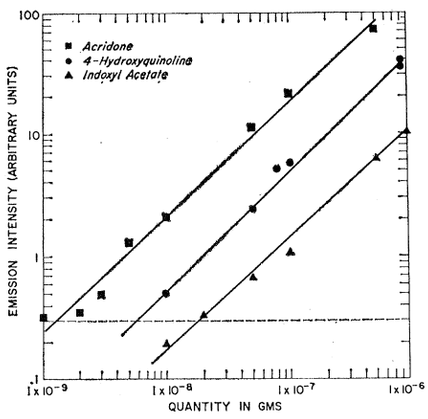

Fig. 3. Chemiluminescent emission on arbitrary units as a function of quantity of compound. 1 unit = 0.2 na at the multiplier anode with 900 volts at the photocathode. Dotted line indicates system noise level. Each point indicates the mean of three determinations.

Table 2. Quantitative estimation (nanograms) of compounds in acetone, or on silica-gel films prepared by drying of acetone solutions; signal-to-noise ratio was one.

Compound	Source (code)*	Amount detected (ng)	
		Dry	Liquid
Acridine orange	E	2	20
Acridone	G	2	10
2-Aminoanthracene	Q	5	1000
3-Aminophthalic acid hydrochloride	G	20	100
8-Aminonaphthalene sulfonic acid	G	5	50
Dimethylamino-benzaldehyde	J	10	500
3,5-Dinitrophenol	Q	6	500
Eosin-Y	F	0.4	100
Fluorescein	G	4	1000
4-Hydroxyquinoline	D	5	100
Iodeosin	G	1.0	50
Indole	J	30	100
Indoxyl acetate	N	20	50
Janus green-B	N	1.0	10
Luminol	G	0.8	50
3-Methyl indole	P	700	1000
Phenosafranin	N	0.001	0.02
Primuline	E	3	50
Quercetin	D	3	100
Rhodamine-B	N	0.1	5
Rubrene	A	3	5000
Safranin bluish (methylene violet)	N	0.001	0.05
Safranin-O	N	0.02	0.1
Salicylic acid	J	300	500
Thionin	E	2	1000

* Commercial sources of compounds conform to the following code: A, Aldrich Chemical Co.; B, American Cyanamid Co.; C, Armour & Co.; D, California Corp. for Biochem. Res.; E, Chroma-Gesellschaft, Stüttgart; F, CIBA; G, Eastman Organic Chemicals; H, E. I. duPont de Nemours & Co.; J, Fisher Scientific Co.; K, K & K Laboratories, Inc.; L, Matheson Coleman & Bell; M, Merck & Co.; N, National Aniline; O, Nutritional Biochemicals Corp.; P, Sigma Chemical Co.; Q, Synthesized.

To confirm the greater sensitivity of the "dry" method, we put the same quantity of sample (1 μl) in 0.2 ml of acetone in the sample holder without the silica gel. The ozone entering the sample chamber was conducted via a piece of stainless-steel hypodermic tubing under the surface of the acetone solution so that the luminescence of the solution was measured by the phototube. The total sample required to match the luminescence of the dry sample was estimated to the nearest order of magnitude and is listed in the last column of Table 2.

While fluorescence techniques are extremely useful for analysis of a large number of compounds, ozone-induced chemiluminescence may be useful in special cases where the fluorescence is rather weak and the background interference from scattered light is a problem, as in chromatogram scans. In the chemiluminescence assay system the phototube can be placed very close to the sample to receive a large percentage of the emitted photons; whereas in fluorescence assay one must consider separating the detector from the exciting light by filters, special placement of parts, and other means.

Substances other than silica-gel film have been tested for suitability as substrates; among them were various papers, plastics, metal foils, and glasses, but these were less satisfactory because of a high blank or a low output of light from the sample. Apparently the substrate medium must be porous enough to have a large surface area onto which the sample can be dispersed and made accessible to the ozone.

The color of the ozone-induced light emission generally is similar to that of the fluorescence excited with ultraviolet light. We are examining this point more closely by obtaining spectra of the solution chemiluminescence with a spectrophotofluorometer (Aminco-Bowman equipped with a liquid-nitrogen-cooled photomultiplier). So far results show that the spectrum of the emission from several compounds is indeed similar to the fluorescence spectrum, but some compounds show changes as ozone is bubbled through and as the compound is transformed to other chemiluminescent materials before exhaustion of the effect.

The chemiluminescence studied was produced with ozone in a stream of pure oxygen. It has been almost axiomatic that oxygen quenches luminescence (*9*), and it is perhaps for this reason that not much study has been directed toward ozone-induced chemiluminescence.

ROBERT L. BOWMAN
NELSON ALEXANDER
Laboratory of Technical Development, National Heart Institute, Bethesda, Maryland 20014

References and Notes

1. K. D. Gundermann, *Angew. Chem. Int. Ed.* **4**, 566 (1965); D. S. Bersis, *Z. Physik. Chem.* **26**, 359 (1960); A. J. Bernanose and M. G. Rene, *Advance. Chem.* **21**, 7 (1959).
2. J. Kroh, "Chemiluminescence in the Liquid Phase," (Translation from Polish), ATD Rep. T65-38, Aerospace Technology Division, Library of Congress (1965), p. 262.
3. "Ozone" as used here implies the few percent of ozone produced in oxygen exposed to an electrical discharge.
4. Eastman Chromagram Sheet, Type K301R2.
5. Lepel High Frequency Laboratories, Inc., Type E7896.
6. Hewlett-Packard dc Microvoltmeter, Model 425A.
7. Texas Instruments Incorporated, Rectilinear Recorder.
8. S. Udenfriend, *Fluorescence Assay in Biology and Medicine* (Academic Press, New York, 1962), p. 17.
9. H. H. Seliger and W. D. McElroy, *Light: Physical and Biological Action* (Academic Press, New York, 1965), pp. 55–56.
10. Metrastar exposure meter, Metrawatt A. G. Nurnberg (U.S. Distribution: Leitz Wetzlar).
11. B. Bush of Washington Sanitarium and Hospital on a fellowship supported by American Instrument Company made most of the preparations and measurements. We thank all concerned.

7 July 1966

Suggested Revision for West Mexican Archeological Sequences

Abstract. *A review of the radiocarbon dates and published and unpublished archeological data from the West Mexican states of Sinaloa, Nayarit, Jalisco, and Colima has resulted in a revised tentative chronology for West Mexico.*

West Mexico, while definitely peripheral to cultural developments in the Valley of Mexico, is an area of considerable importance to any understanding of Mesoamerican and U.S. Southwestern culture history. During the Early Classic Period of the Valley of Mexico, Indians in the states of Colima, Jalisco, and Nayarit developed an elaborate burial complex of shaft-tombs which contained multiple burials and hollow clay figurines. This was a development generally unrelated to that in the Valley of Mexico—in fact it resembled developments in Central and Northern South America. During the Postclassic Period, West Mexico appears to have

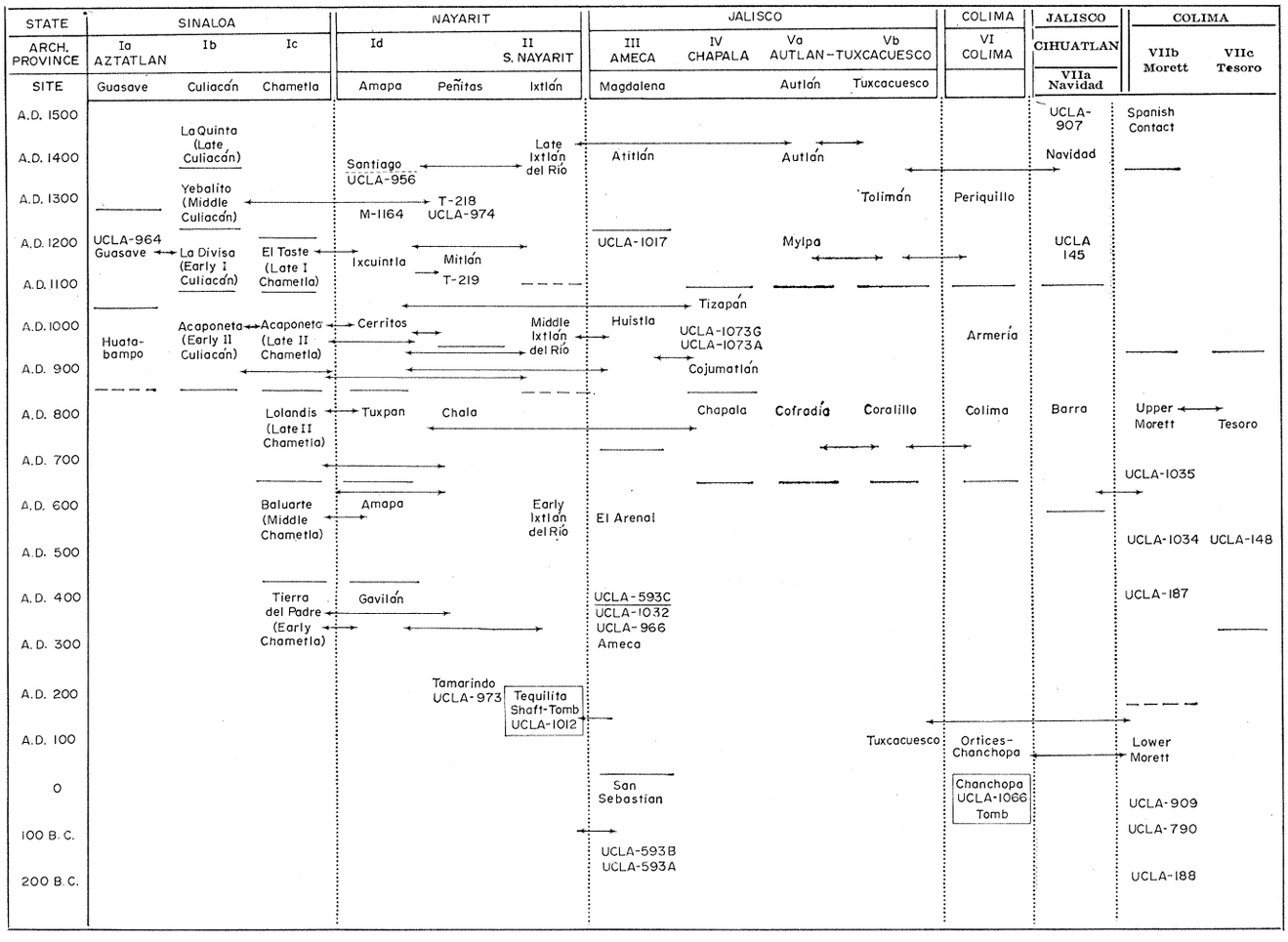

Fig. 1. Chronological chart of West Mexican archeological sequences showing radiocarbon dates and cultural cross-ties. Radiocarbon dates are indicated by laboratory numbers; arrows indicate cross-ties between cultural phases; solid horizontal lines indicate approximate temporal division between cultural phases; dashed lines indicate that the division is merely an educated guess; names in boxes are site names. Radiocarbon dates are given in table below.

Lab. No.	Site	Radiocarbon age	Date	Corrected date	Reference	Sample material
UCLA-964	Guasave, Sinaloa	830 ± 130	A.D. 1120	A.D. 1225 (22)	12	Carbon and pitch
M-1164	Amapa, Nayarit	700 ± 75	A.D. 1250		24	Charcoal (probable mixing)
UCLA-956	Amapa, Nayarit	645 ± 80	A.D. 1305		12	Charcoal
T-218	Peñitas, Nayarit	*	A.D. 1270		11	Charcoal
T-219	Peñitas, Nayarit	*	A.D. 1080		11	Charcoal
UCLA-973	Peñitas, Nayarit	1770 ± 80	A.D. 180		12	Charcoal
UCLA-974	Peñitas, Nayarit	695 ± 100	A.D. 1255		12	Charcoal
UCLA-1012	Tequilita, Nayarit	1850 ± 100	A.D. 100	†	25	Marine shell
UCLA-145	Barra de Navidad, Jalisco	760 ± 80	A.D. 1190		26	Charcoal (younger than expected)
UCLA-907	Barra de Navidad, Jalisco	370 ± 90	A.D. 1580	A.D. 1450 (22)	12	Charcoal (younger than expected)
UCLA-593A	San Sebastian, Jalisco	2090 ± 100	140 B.C.	†	27	Marine shell
UCLA-593B	San Sebastian, Jalisco	2230 ± 100	280 B.C.	120 B.C. (23)	27	Marine shell
UCLA-593C	San Sebastian, Jalisco	1710 ± 100	A.D. 240	A.D. 400(23)	27	Marine shell
UCLA-966	San Sebastian, Jalisco	1730 ± 80	A.D. 220	A.D. 300 (22)	25	Bone collagen
UCLA-1032	San Sebastian, Jalisco	1615 ± 100	A.D. 335		12	Bone collagen
UCLA-1017	Las Cuevas, Jalisco	840 ± 80	A.D. 1110	A.D. 1225 (22)	25	Charcoal
UCLA-1073A	Tizapán el Alto, Jalisco	1000 ± 80	A.D. 950		12	Charcoal
UCLA-1073G	Tizapán el Alto, Jalisco	955 ± 80	A.D. 995		12	Charcoal
UCLA-148	Playa del Tesoro, Colima	1430 ± 100	A.D. 520		26	Charcoal
UCLA-1066	Chanchopa, Colima	2180 ± 80	230 B.C.	A.D. 10 (23)	12	Marine shell
UCLA-187	Morett, Colima	1500 ± 80	A.D. 450		26	Charcoal
UCLA-188	Morett, Colima	2190 ± 90	150 B.C.		26	Charcoal
UCLA-790	Morett, Colima	2000 ± 90	50 B.C.	A.D. 25 (22)	12	Charcoal
UCLA-909	Morett, Colima	2000 ± 80	50 B.C.	A.D. 25 (22)	12	Charcoal
UCLA-1034	Morett, Colima	1030 ± 80	A.D. 320	A.D. 560 (23)	12	Marine shell
UCLA-1035	Morett, Colima	1480 ± 80	A.D. 470	A.D. 710 (23)	12	Marine shell

* The Trondheim Laboratory has not published the B.P. figure for T-218 and T-219. † Situation off the east coast of Mexico is not securely known; no correction made.

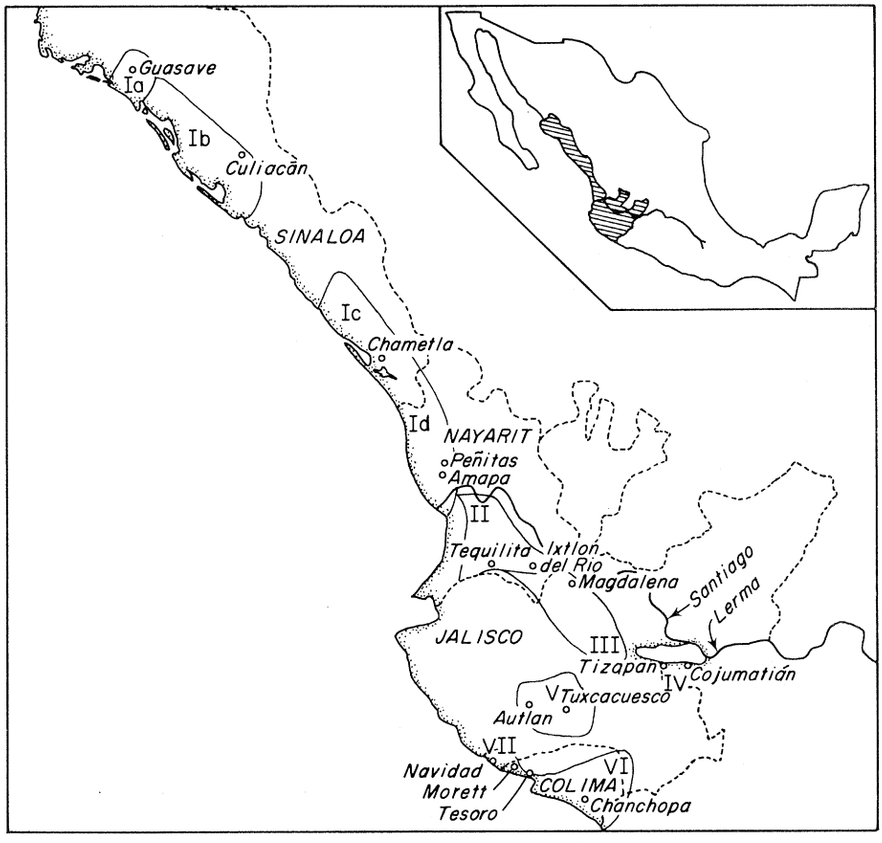

Fig. 2. Map showing states, provinces, and sites in West Mexico.

been heavily influenced by Central Mexico. The shaft-tomb complex disappeared, and Central Mexican traits began to appear in the west as far north along the Pacific Coast as Guasave, Sinaloa, and along the Sierra Madre Occidental. Also influenced was the Hohokam culture of the U.S. Southwest. The course of the Rio Lerma-Santiago which extends from Central Mexico to coastal Nayarit appears to have been a major path of this Central Mexican influence for a long time. After the Early Postclassic Period, West Mexico became an area of small independent states, relatively uninfluenced by Central Mexico. Apparently, Aztec expansion into this area was blocked by Tarascan imperialism spreading from highland Michoacán.

The archeological sequences of West Mexico were generally established before the advent of radiocarbon dating in 1949. During the past 17 years, additional work has been conducted in the area, and some 36 radiocarbon samples have been dated (*1*). The results of some of the work (and many of the radiocarbon dates) have appeared in scattered articles, date lists, and doctoral dissertations. Some of the work, and a number of the dates, remain unpublished. The following is an attempt to synthesize this information and to publish a current, though very tentative, chronology for the core area of West Mexico.

For our purposes, we have defined West Mexico as the area included within the states of Sinaloa, Nayarit, Jalisco, and Colima. Most of Michoacán has been excluded because of the relative lack of archeological and radiocarbon data (*2*). In general, the tentative ceramic provinces established by Kelly (*3*) have been utilized as the regional framework for our chronological chart (Fig. 1). An additional province (Chapala) was added in order to include the published sequences which resulted from excavations at Cojumatlán, Michoacán (*4*). Ceramic provinces with no established archeological sequences have been omitted. In the case where several or conflicting sequences have been established for one province (for example, Aztatlán) the sequence which best agreed with current data was accepted. The time placement of phases or periods within a sequence were modified to agree with radiocarbon dates or the occurrence of time markers (Mazapan figurines, Plumbate pottery, or copper artifacts).

A sequence for the sites of Chametla and Culiacán, Sinaloa, was established by I. Kelly (*5*). Ekholm added the northern site of Guasave to this sequence (*6*). The sequence was modified by J. Kelley and H. Winters who correlated it by means of trade sherds with one they had established for Durango (*7*). Grosscup (*8*) established a sequence for Amapa, Nayarit, and correlated it with a slightly modified version of the Kelley and Winters' sequence. Finally, Bordaz outlined a sequence for Peñitas, Nayarit, a site geographically and culturally close to Amapa (*9*).

We have accepted the Kelley and Winters' sequence, and have added Grosscup's Amapa and Bordaz's Peñitas sequences to it without modification. Grosscup has disagreed with Kelley and Winters in their placement of the Guasave phase. Bordaz suggested that Guasave did not extend as late in time as Kelley and Winters believed. A recent radiocarbon date from Guasave (see *10*) suggests that the Bordaz modification is in large part correct.

Only one sequence has been established in the Southern Nayarit Hinterland. Gifford defined a rough chronology for the Ixtlán del Río area based on surveys. This sequence was further defined by Grosscup (*8*). Since the Ixtlán material correlated fairly well with the material from Amapa, the Grosscup revision has been accepted.

The Tepic-Compostela ceramic zone has been included on the chart under the Ixtlán Archeological Province even though no sequence has been established for the area. There is one radiocarbon date (UCLA-1012) from a shaft-tomb near Tequilita (*11*); this date may have some bearing on a suggested shaft-tomb, hollow figurine horizon extending from highland Nayarit to Colima (*3*).

One sequence has been established for the Magdalena Lake Basin which is located in the northern part of the Ameca province. The sequence is based on excavations of both cemetery and habitation sites, measurements of hydration in obsidian, and six radiocarbon dates (*12*).

Lister established two ceramic phases for the site excavated at Cojumatlán,

Michoacán (*4*). His placement of the phases in time has been changed in accordance with the current dating of time markers (Mazapan figurines, Plumbate pottery, and copper artifacts) found at the site. It is also in accordance with cross-ties of a radiocarbon-dated ceramic sequence established for the geographically close site of Tizapán el Alto excavated by Meighan and Foote (*13*).

Sequences have been published for both the Autlán and the Tuxcacuesco zones. The Autlán sequence (*5*) was defined on the basis of surface surveys and cross-ties with the ceramic sequence established for the excavations at Tuxcacuesco (*14*). The Colima sequence was based on surveys, excavations of tombs (*5*), and ceramic cross-ties with the Tuxcacuesco sequence (*14*).

Kelly's sequences have been accepted without modification with the exception of the dates of a suggested correlation with the Basin of Mexico (*14*). The lower limits of her "coeval" complexes at Tuxcacuesco and Colima (Tuxcacuesco and Ortices-Chanchopa) have been pushed back in time. This has been done in order to correlate with a radiocarbon date (UCLA-1066) (*10*) from the rifled tomb at Chanchopa, near Tecomán and four radiocarbon dates from early stratigraphic levels at Morett, Colima, which have ceramic cross-ties with the Tuxcacuesco complex of the Tuxcacuesco sequence.

Both the Tuxcacuesco and Ortices complexes have been provisionally correlated with Teotihuacán III (*14*) of the Basin of Mexico, on the basis of a Thin Orange, Chanchopa tomb association. However, the Thin Orange restorable vessel came from a Chanchopa tomb with pure Chanchopa contents, while the radiocarbon-dated shell bracelet fragments came from another Chanchopa tomb with mixed Chanchopa and Ortices contents. The temporal relationship between the Chanchopa and Ortices complexes is not yet clear (*15*).

Both the middle and upper phases of the Autlán, Tuxcacuesco, and Colima sequences have been temporally modified. However, the changes are not based directly on radiocarbon dates, but on the current dating of the appearance and disappearance of such time markers as Mazapan figurines and copper artifacts.

Stratigraphic excavations were conducted in the Cihuatlán province at Barra de Navidad, Jalisco (*16*), Playa del Tesoro, Colima (*17*), and Morett, Colima (*18*) by UCLA in 1961–62. A tentative sequence has been established on the basis of preliminary ceramic analysis and 11 radiocarbon dates (*19*).

S. V. Long
Department of Anthropology, University of the Andes, Bogotá, Colombia

R. E. Taylor
Department of Anthropology, Institute of Geophysics, University of California, Los Angeles

References and Notes

1. Twenty-six radiocarbon dates have been utilized for the chronological synthesis reported in this paper. Ten additional dates are available from the Morett Site, Colima, on experimental sample materials.
2. Three radiocarbon dates from Michoacán are available: UCLA-269 and 270 from Melchor Ocampo (*11*), and M-861 from El Ticuiz (*20*).
3. I. Kelly, "Ceramic Provinces of Northwest Mexico," *Cuarta Reunion de Mesa Redonda sobre Problemas Antropologicos de Mexico y Centro America*, **55**, (1948).
4. R. Lister, *Anthropol.* **5**, (1949).
5. I. Kelly, *Ibero-Américana* **25**, 1 (1945).
6. G. F. Ekholm, *Anthropol. Papers of the Amer. Mus. of Nat. Hist.* **38**, 1 (1942).
7. J. C. Kelley and H. Winters, *Amer. Antiquity* **25**, 547 (1960).
8. G. L. Grosscup, thesis, University of California, Los Angeles, 1964.
9. J. Bordaz, thesis, Columbia University, 1964.
10. S. V. Long and R. E. Taylor, *Radiocarbon*, in press.
11. G. J. Fergusson and W. F. Libby, *ibid.* **6**, 318 (1964).
12. S. V. Long, thesis, University of California, Los Angeles, 1966; S. V. Long and and R. E. Taylor, *Nature*, in press; M. Glassow, *Amer. Antiquity*, in press.
13. C. W. Meighan, private communication.
14. I. Kelly, *Ibero-Américana* **27**, 1 (1949).
15. I. Kelly, private communication.
16. S. V. Long and M. Wire (University of California, Los Angeles), unpublished manuscript.
17. R. Crabtree and B. Fitzwater (University of California, Los Angeles), unpublished manuscript.
18. M. Susia (University of California, Los Angeles), unpublished manuscript; H. B. Nicholson, *Katunob* **4**, 39 (1963).
19. Radiocarbon dates are based on the carbon content of sherds and wattle-and-daub fragments.
20. H. R. Crane and J. B. Griffin, *Amer. J. Sci., Radiocarbon Suppl.* **1**, 173 (1959).
21. Radiocarbon dates have been corrected where necessary for secular variation (*22*), and in the case of marine shell where the data is available for upwelling (*23*). The significance of the differences between the uncorrected published date and the corrected date must always be considered in light of the statistical error assigned to the date. Not corrected for the 3 percent difference between the half-life of the year 5568 and the accepted best value of the year 5730 as discussed by H. Godwin, in *Nature* **195**, 984 (1962).
22. H. E. Suess, *J. Geophys. Res.* **70**, 5937 (1965).
23. R. Berger, R. E. Taylor, W. F. Libby, *Science* **153**, 864 (1966).
24. H. R. Crane and J. B. Griffin, *Radiocarbon* **5**, 228 (1963).
25. R. Berger and W. F. Libby, *ibid.* **8**, (1966).
26. G. J. Fergusson and W. F. Libby, *ibid.* **5**, 1 (1963).
27. R. Berger, G. J. Fergusson, W. F. Libby, *ibid.* **7**, 336 (1965).
28. Supported by NSF grants GP 1893 and GS 911. Archeological investigations were made possible through the cooperation of the Mexican Federal Government. We thank I. Kelly for permission to utilize the Chanchopa tomb radiocarbon date, and for supplying additional data on the Chanchopa complex and the Chanchopa Thin Orange association. We also acknowledge the guidance of R. Berger, W. F. Libby, C. W. Meighan, H. B. Nicholson and I. Kelly in the preparation of this paper.

23 August 1966

Isopiestic Technique: Measurement of Accurate Leaf Water Potentials

Abstract. *Sunflower leaf tissue of known potential was obtained by equilibrating an interveinal leaf sample, at constant temperature in air, with a potential determined by sucrose solutions. Equilibration occurred within 17 hours. Except for one determination, all measurements of the water potential of the equilibrated samples with an isopiestic technique were within 0.1 bar of the known potential of the tissue. This finding indicates that thermocouple psychrometers can measure accurate values of water potential when an isopiestic technique is used.*

There are many methods of measuring the water potential of leaves (*1*). Often, however, different methods do not give the same answer, although water potentials may be similar (*2*). There have been studies of errors that affect measurements of water potential (*2, 3, 4*) but there are none which demonstrate that, once the errors have been corrected, the technique is an accurate or absolute measure of water potential.

When first introduced, thermocouple psychrometers were expected to provide values close to actual leaf water potentials. However, the heat produced by respiration (*5*), the adsorption of water vapor on the walls of psychrometer chambers (*6*), and the resistance of leaf tissue to vapor transfer (*3*) cause inaccuracies in determinations. Readings may be corrected for these errors, and in some instances the errors may be eliminated altogether.

A modification of psychrometer practice has been suggested which incorporates all the above corrections in a single method and is called the isopiestic technique (*4*). Basically, the method consists of finding a solution which neither loses nor gains water from the plant sample. The potential of the solution, which is known, is then equal to the potential of the