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Use of diatom biostratigraphy in determining a minimum (Sangamonian = 80,000–ca. 220,000 yr. BP) and a maximum (Illinoian = ca. 220,000–430,000 yr. BP) age for the Hueyatlaco artifacts, Puebla, Mexico

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With 6 figures, 2 plates and 2 tables

Abstract: The diatom biostratigraphy presented herein establishes a minimum (Sangamonian) and a maximum (Illinoian) age for the younger (bifacial) artifacts at the Hueyatlaco archaeological site in units B, C, and E, Puebla, Mexico. One of the 13 samples in this study is from a position of Sangamonian age which is stratigraphically slightly higher than the artifacts. The minimum age of this sample (from unit B) is demonstrated by 6 taxa which became extinct at the end of the Sangamonian, and its maximum age (also Sangamonian) is denoted by 3 taxa with earliest known first occurrences in the Sangamonian. The diatoms of the remaining 12 samples have a minimum age of Sangamonian. Three of the 13 samples are in unit I and no Hueyatlaco artifacts are known below this unit.

Introduction

The great antiquity of the artifacts at the Hueyatlaco site, 10 km southeast of the city of Puebla (Fig. 1) has been determined by various methods (including uranium-series, fission track and paleontology). The Hueyatlaco archaeological site is significant because age determinations on its artifacts have placed humanity in the Western Hemisphere before post-glacial times and the end of the Wisconsinan (Last Ice Age) which is much older than the oldest dates for New World artifacts advocated by the current American archaeological establishment (vide Hardaker 2007). Irwin-Williams (1967a, 1967b) conducted extensive excavations at Valsequillo (Hueyatlaco) and presented reasons for the in situ deposition of the artifacts. VanLandingham (2000, 2004, and 2006) contributed diatom evidence for a minimum age of Sangamonian (ca. 80,000–220,000 yr. BP) for the artifacts and for their autochthonous deposition. Some have tried to discredit the older dates for the Hueyatlaco artifacts. Such claims as those of Pichardo (1997) of 30,000 yr. BP or less for the Hueyatlaco artifacts are still inconclusive (see Covey 2002).

Pleistocene to Recent non-marine diatom sequences at the Hueyatlaco site and in the associated Valsequillo region are among the most complex and important in the world. In my experience, only in the upper Miocene and Pliocene of the Central Massif region of France and in the Sonoma volcanics-Petaluma Formation of northern California (q.v. Zeeb et al. 1996, p. 80) have more prolific, complicated non-marine diatomaceous sequences been observed. The greatest significance of this is that, unlike these older sequences, the Valsequillo sequences represent a span

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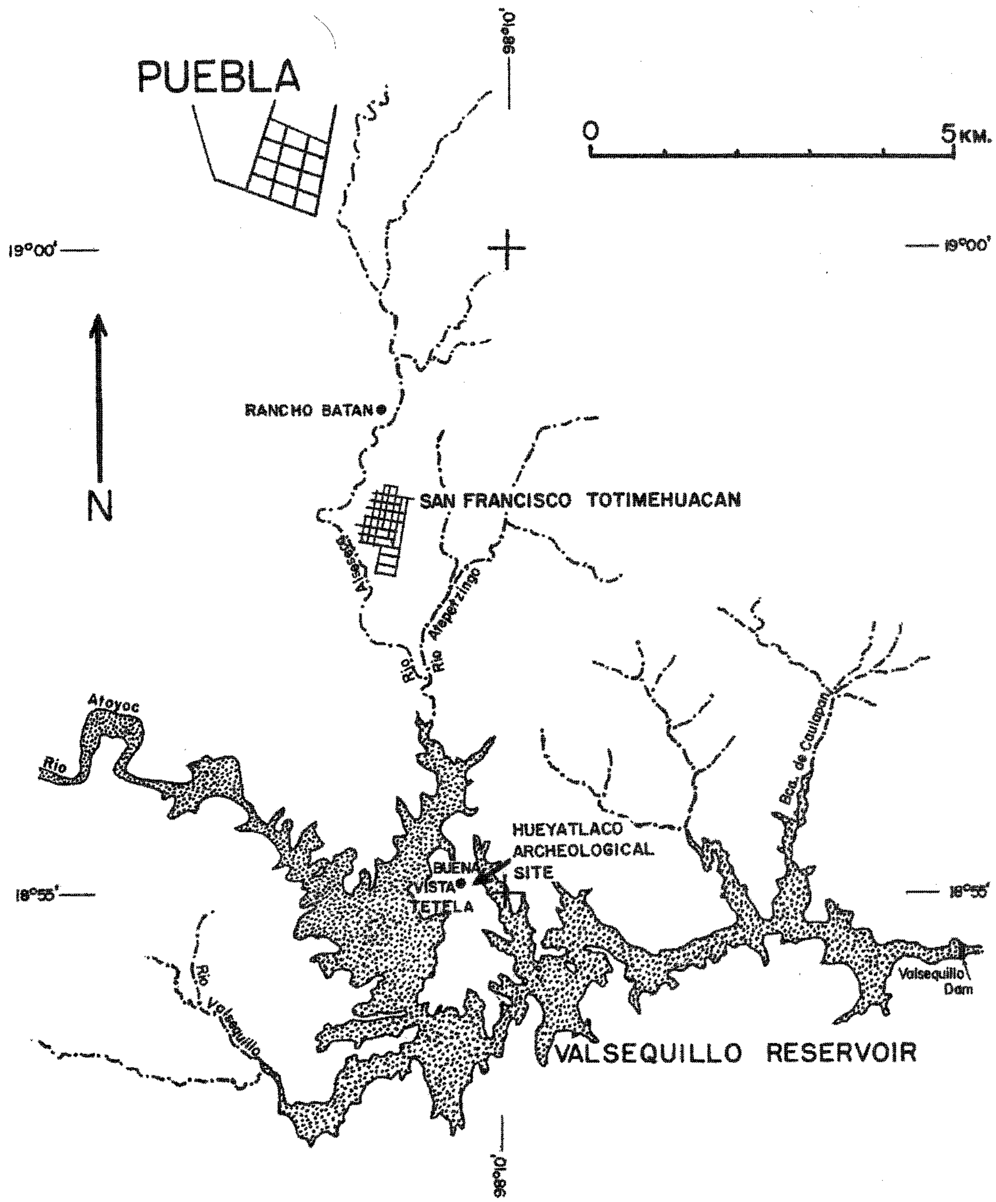


Fig. 1. Map of Hueyatlaco site in the Valsequillo Reservoir area south of Puebla, Mexico.

of less than a million years, rather than the several million years in these older sequences. Because so much lithostratigraphy is compressed into such a relatively short time in the Valsequillo sequences, there is much more available biostratigraphic information and evidence than usual to determine the age and environment of deposition of the Hueyatlaco artifact layers. Few (if any) archaeological sites are known to be directly associated with such highly significant age indicative fossil diatom evidence as the Hueyatlaco site (and the Valsequillo region): those who would

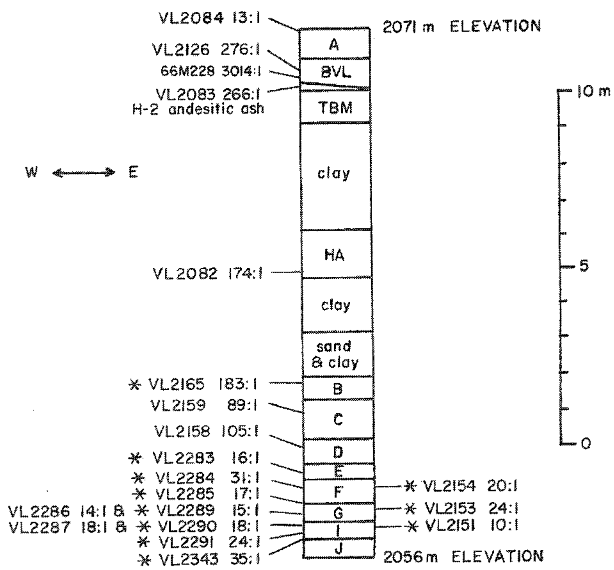


Fig. 2. Idealized composite stratigraphic section at the Hueyatlaco archaeological site, modified from Steen-McIntyre et al. (1981) and Irwin-Williams (1967b and 1973). A-J = Irwin-Williams units (unit H is not shown). BVL = Buena Vista Lapilli. TBM = Tetela Brown Mud. HA = Hueyatlaco Ash. P:C ratios are shown to the right of each sample. The 13 samples in this study are designated with an asterisk (*).

wish to argue against the case for the great antiquity (prior to the Last Ice Age) of humanity in the New World by attacking the veracity of the compelling diatom evidence have picked the wrong place to make such an argument at Hueyatlaco (and its associated area, Valsequillo) which displays one of the most prolific, dynamic, and diagnostic diatom sequences in the world. No other archaeological site in the world is associated with such a variety of diatoms and in such profusion!

The Hueyatlaco artifacts are found in units B, C, E, and the top half of unit I of Irwin-Williams (1967b) (Fig. 2). Previous diatom studies by VanLandingham (2000, 2004, and 2006) at Hueyatlaco dealt mainly with the younger Sangamonian deposits, i. e., beds between unit A and unit B, unit D and the top half of unit E. The present investigation concentrates on the diatoms of Sangamonian age in unit B to determine a minimum age for the artifacts and on the diatoms of Sangamonian to Illinoian age in the bottom half of unit E through unit I to determine a maximum age for the artifacts (Figs 2–6).

Methods and Materials

After crushing, each samples was suspended in distilled water for two hours in 250 ml flasks. To remove the fine clay particles, the water was siphoned. This process was repeated three times. Each sample was then suspended in distilled water and siphoned after two minutes to remove silt, sand, and larger particles. The suspension of the fine material that remained in the water was poured off and allowed to settle. Excess water was siphoned and the remaining diatomaceous material was allowed to dry. This dry material was scraped from the flask and stored in 10 ml glass vials. Strew preparations on 18 X 18 mm cover slips were heated five minutes at 225°F on a hot plate and mounted in Hyrax mounting medium on 3 X 1" glass microscope slides.

Table 1. Percentages of extant taxa in the 13 samples from Hueyatlaco. X = presence of taxon but with a frequency less than 1 %. Percentages which are underlined indicate dominance or codominance; percentages with asterisk (*) denote subdominance. Based on counts of 100 diatoms in each sample.

	VL2151	VL2153	VL2154	VL2165	VL2283	VL2284	VL2285	VL2286	VL2287	VL2289	VL2290	VL2291	VL2343
Achnanthes near *affinis*				X									
A. exigua	X	X	X	1									
A. hauckiana									X				
A. hauckiana v. *rostrata*	X												
A. inflata				X									
A. lanceolata	X		1	1									1
A. lanceolata v. *rostrata*													X
A. minutissima v. *cryptocephala*				1									
Amphicampa mirabilis				X									
Amphipleura pellucida			1	X		1		X		1			
Amphora coffeaeformis				X					X				
A. delicatissima				X									
A. exigua				X									
A. ovalis	X		X	3			X		X	X			1
A. ovalis v. *affinis*	X	X	1	2		2	X	4*		3	X	3	
A. ovalis v. *lybica*	X								X				
A. ovalis v. *pediculus*	4*	6*	4	2	2		2	4*	3	4	7*	<u>10</u>	4
A. perpusilla				X		X				X			
A. sp.				X					1				
A. veneta				X			X	1					X
Anomoeoneis sphaerophora	1	X		X	1	1	1	1	1	X	1	X	X
Bacillaria paradoxa		X						1		1			
Caloneis alpestris								X					
C. bacillum	X						X	X				X	
C. bacillum v. *lancettula*				X				X		X	X		
C. formosa									X				X
C. lewisii		X					X	X	1	X	X	X	X
C. schumanniana		1	1	X				2	X		X		
C. shumanniana v. *biconstricta*			X					X	X			1	
C. schumanniana v. *linearis*								X					
C. silicula v. *truncatula*		X			X			X	1				
C. silicula v. *tumida* ?							X						
C. spp.			X			1	1	X			1		X
Cocconeis placentula	1	4*	2	2	4*	2	3	X	3	1	3		7*
C. placentula v. *euglypta*	X	2	1	3	X	2	2	1	X	X	1	1	X
C. placentula v. *intermedia*	X		X	X	X	1		X	X	X			2
C. placentula v. *lineata*	X	2	2	2	1	2	6*	2	6	2	6*	3	5
Cyclotella bodanica	X												
C. catenula	X												
C. glomerata ?													X
C. meneghiniana	1	X	1	X	1	1		2	1	1	1	1	1
C. striata								X	1				
Cymatopleura elliptica							X	X					X
C. elliptica v. *constricta*					X								
C. elliptica v. *nobilis*											1		
C. solea	X	1	X	X	1	2		1	X	X	X		
C. solea v. *regula*										X			
Cymbella affinis	X							X	1			1	X
C. amphicephala											1		
C. cistula		X	X		X		X	X	X	X			
C. cymbiformis							1						

Table 1. (continiued)

	VL2151	VL2153	VL2154	VL2165	VL2283	VL2284	VL2285	VL2286	VL2287	VL2289	VL2290	VL2291	VL2343
Cymbella delicatula								X					
C. lunata	X												
C. mexicana	2						2						
C. pusilla											X		
C. spp.								1					1
C. triangulum	X		1		1	X	2	1	1		X		
C. turgida	X	1	X			1		X	X	X		X	
C. turgida v. *pseudogracilis*	1												
C. ventricosa		X		X	X	1	X	X		X			1
Denticula elegans	X			X			1	2	1		1		X
D. elegans f. *valida*				X			X	X	X		1		
D. elegans v. *kittoniana*	X	1		X			X	X	X			X	X
Diatoma sp.						1							
D. vulgare	X									X			
D. vulgare v. *capitata*										X			
D. vulgare v. *grandis*					1							X	X
D. vulgare v. *producta*	X	X	X	X	X	2							
Diploneis oculata	X												
D. ovalis													X
D. ovalis v. *oblongella*												1	
D. puella				X									
Epithemia argus						2	X	X	X				
E. argus v. *alpestris*								X					
E. cistula								X					
E. sorex													1
E. turgida	4*	4*	2	1	1		7*	1	3	2	3	1	
E. zebra	X	X	X					X	1			2	
E. zebra v. *porcellus*							X	X	X				X
E. zebra v. *proboscidea*	X			X			X	X	X			1	
Eunotia formica							X		X		X		X
E. gracilis					X								
E. monodon v. *major*													X
E. pectinalis				X									
E. sp.								X					
Fragilaria brevistriata	2												
F. brevistriata v. *inflata*	X							1	X				
F. brevistriata v. *subcapitata*			X		X	X							
F. crotonensis	7												
F. crotonensis v. *oregona*	3*												
F. pinnata													X
Frustulia sp.									X				
F. vulgaris	X												
F. vulgaris v. *capitata*									X				
Gomphoneis herculeana v. *minuta*								X					
Gomphonema acuminatum v. *trigonocephala*				X									
G. affine									X	X			
G. angustatum				1									X
G. angustatum v. *producta*				1									X
G. constrictum					X								
G. constrictum v. *capitata*							X	1		X	X		
G. gracile				X				X	X				X

Table 1. (continiued)

	VL2151	VL2153	VL2154	VL2165	VL2283	VL2284	VL2285	VL2286	VL2287	VL2289	VL2290	VL2291	VL2343
Gomphonema gracile v. *lanceolata*		X		X					1				
G. gracile v. *subclavata*									1				
G. intricatum			X					1	X				
G. lanceolatum v. *insignis*									X				
G. montanum v. *acuminatum*				X									
G. olivaceum				X									
G. parvulum	X	1	X	1	2	1		2	2	X	1	1	X
G. spp.	1	1					1	1	1			X	
G. sphaerophorum						X							
G. subclavatum		X	X					X	X	X			
G. subclavatum v. *commutatum*				X									X
G. subclavatum v. *mexicanum*		X		X			X	X	X	1	X		1
G. tergestinum								X					
G. ventricosum										X			
Gyrosigma acuminatum								X		X			
G. kuetzingii												1	
G. scalproides			2	X			X		X		1		
G. spencerii					X								
G. sp.				X									
G. wansbeckii						1							
Hantzschia amphioxys	X		X	X	1	X	2	X	1				
H. amphioxys v. *capitata*			X	1		X		X	1	X			
Mastogloia elliptica v. *dansei*							X	X					
M. smithii v. *lacustris*	1				X			X	X				
Melosira ambigua	X			X	X				X				X
M. distans	X				X	X	2	1	1		1	1	X
M. granulata	6	X					X	X			1		
M. granulata v. *angustissima*	3*										1		1
M. italica	X	1	1	X	2	X	2	1	1	1	1	1	
M. italica v. *subarctica*	1									X			
M. juergensi v. *bothnica*					X								
M. sp.		1		X					1	X			1
M. undulata				X			1	1	X	X			
M. varians	1			X		1	X	1	X	X	X	X	
Navicula anglica	X			X		X		1	X	1			1
N. anglica v.				X									
N. arenaria			1	X									
N. atomus				X									
N. bacilliformis							X						
N. bacillum				X			X	X					
N. cincta		1		X							X		
N. cincta v. *heufleri*				X		X			X				X
N. circumtexta	X		1		X	2	1	X	1	X	X	X	X
N. cocconeiformis		1											
N. confervacea						X	X						
N. near *confervacea*									1				
N. contenta				X									
N. cryptocephala	2	10	5	11	9	3	1	X	1	4	4*	8*	4
N. cryptocephala v. *veneta*	3*	4*	2	3	1	3			2	X	1	2	1
N. cuspidata	X	1		X			1	1	X	1			
N. cuspidata v. *ambigua*			X	1		X	X	X		X			X

Table 1. (continiued)

	VL2151	VL2153	VL2154	VL2165	VL2283	VL2284	VL2285	VL2286	VL2287	VL2289	VL2290	VL2291	VL2343
Navicula elginensis	X		X					X	X	X			
N. exigua	X	X		X			X			X		X	X
N. gottlandica	1		1			1							
N. graciloides	1											X	
N. grimmei	X			X					X		X		
N. hungarica	2	X	2	4*	X	X							1
N. hungarica v. *capitata*	1			X	1	X			X	X	X		1
N. incerta				X									
N. lanceolata				X			X						
N. menisculus v. *upsalensis*				X									
N. minima				X									
N. mutica	X		X	1	X		1	1	2	X		X	1
N. mutica v. *cohnii*				X		X			1		X		
N. mutica v. *goepertiana*				X									
N. mutica v. *nivalis*	X			X									
N. peregrina	X	1	X	X	X	X	2	X	X	X	X	1	X
N. placentula v. *rostrata*		2								X			
N. protracta									X			X	
N. pupula	X			2	2	X		X			X	X	2
N. pupula v. *capitata*	1	1		X				1	1	X		1	
N. pupula v. *elliptica*	X												
N. pupula v. *rectangularis*	X		1		X	X						1	
N. pygmaea			2	1	X	1			1	1	1		1
N. radiosa	1	X	4	X	1	X	X	1	X	X	6*		1
N. rhynchocephala									1				
N. rhynchocephala v. *germainii*				3									
N. roteana				X									
N. schadei				1									
N. schoenfeldii											X		
N. near *seminulum*										X			
N. soodensis				X									
N. spp.	X		X	1	X	X		1		X	4*		
N. symmetrica	1	X										2	
N. texana				X									
N. tripunctata				X									
N. tripunctata v. *schizonemoides*				X									
Neidium affine v. *amphirhynchus*	X			X	2								
N. affine v. *longiceps*	X												
N. dubium								X					
N. iridis	X				1			X	X				1
N. iridis f. *vernalis*		X					X		X		X	1	
N. iridis v. *amphigomphus*				X			X		X				
N. iridis v. *ampliata*			X			X	X	X					
N. productum					X		X						
N. sp.							1	X			1		
Nitzschia acuta	3*	5*	2	2	3*	2		X		3	2		3
N. amphibia	X			X	X	1	1	1	X	1	1	2	1
N. angustata	1		1	X	X			X	X	X			1
N. apiculata	1	X	1	5*	1	1			2	X		X	1
N. communis				1						X			
N. commutata					X								X

Table 1. (continiued)

	VL2151	VL2153	VL2154	VL2165	VL2283	VL2284	VL2285	VL2286	VL2287	VL2289	VL2290	VL2291	VL2343
Nitzschia denticula				X	X		X	3	2		X	1	
N. dissipata		X	3	X	1	X							2
N. dubia										2			
N. fasciculata	1												
N. filiformis		X				X							
N. fonticola	1	1		X									X
N. fonticoloides				3									
N. frustulum		X				4				1			1
N. frustulum v. *perpusilla*				X									
N. frustulum v. *subsalina*				X									1
N. gandersheimensis				X	6*	2				2	3		
N. gracilis			1	X		1				1	2		1
N. hantzschiana				X						1			3
N. heufleriana				X		1							
N. holsatica		1								X			
N. hungarica					X					X	X	X	
N. hybrida			1			1				2			
N. near *ignorata*						1							
N. innominata				1									
N. kittlii									X				
N. kuetzingiana	X	2		2									
N. lancettula				1	1								
N. linearis	2	10	7*	9*	8	6*	9*	2	5	16	9	10	6*
N. microcephala				X							X		
N. obtusa										1			
N. oregona				X									
N. palea	2		1	1	2	1		X	X	X	X		3
N. paleacea			2		1	X							
N. pumila	6												
N. recta					X					1	1		
N. romana					X								
N. sigma	X	X	1	1	2	3	X	X	X	1	1		2
N. sigmoidea	1		X	X	1	2	1	10	5	1	3	1	
N. spp.	2	3	1	7*	4*	6*		3	X	3		3	5
N. sublinearis	4*	6*	8*	X	5*	5	6*	3	3	3	4*	4*	X
N. subtilis		1	1							2	X		
N. thermalis			1	X			1				1		
N. tryblionella					X	1							
N. tryblionella v. *debilis*				X									
N. tryblionella v. *levidensis*				X	X								
N. tryblionella v. *victoriae*	X	X	X	X				X	X	X		X	
N. vitrea				X				X					
N. vivax					X					X			
Pinnularia appendiculata				X									
P. borealis		1											
P. braunii v. *amphicephala*	X							X	X	1			
P. brebissonii	X				1		X	1	1		1	X	1
P. gibba f. *subundulata*								X			X		
P. gibba v. *linearis*				X									
P. gibba v. *parva*							X						
P. hemiptera				X				X					

Table 1. (continiued)

	VL2151	VL2153	VL2154	VL2165	VL2283	VL2284	VL2285	VL2286	VL2287	VL2289	VL2290	VL2291	VL2343
Pinnularia hilseana													X
P. leptosoma				X				1					
P. polyonca											X		
P. sp.		X						X	X		1		
P. stauroptera v. *parva*		1											
P. subcapitata			X										
P. viridis											X		
P. viridis v. *sudetica*							X						
Pleurosigma sp.											X		X
Rhoicosphenia curvata	1	X		3	X	1	X	X	X	2	1	3	1
Rhopalodia gibba	1	2		X	X	X	2	1	1	3	1	3	2
R. gibba v. *ventricosa*	X		1	X	1		X	X			X	2	1
R. gibberula	3*	X		X	X		1	1	3	X	2	1	X
R. gibberula v. *musculus*	X			X	X			X	X				
R. gibberula v. *vanheurckii*			1	X						X	X		X
Stauroneis kriegeri								X					
S. near *obtusa*	X												
S. phoenicenteron				1			2	1				X	X
S. thermicola				X	X								
Stephanodiscus astraea	X												
S. hantzschii				X									
S. niagarae		X											
Surirella angustata	X				1								
S. biseriata				X				X					
S. elegans										1			
S. linearis													X
S. ovalis	X				X							1	
S. ovata			1		1	X	X						
S. ovata v. *crumena*		1	X	X	X			X		X			X
S. ovata v. *pinnata*			1										
S. ovata v. *salina*	1	X	1	X	2	2	X	X	X	X	X	1	
S. sp.			X					X		X	X		X
Synedra acus				X									
S. goulardi				X									
S. pulchella	3*		1		2	1						7	
S. ulna	6	6*	16	9*	9	17	17	11	20	10*	10	8*	16
S. ulna v. *contracta*	1	1	X	1			X		X	1			
S. ulna v. *oxyrhynchus*	2	8*	6*		9	5	8*	12	10*	13*	4*	3	3
S. ulna v. *oxyrhynchus* f. *contracta*		1			1	X	2	X	X	1	1		X
S. vaucheriae	2	1		1				1		X			
TOTAL EXTANT TAXA	103	69	72	145	80	71	75	114	100	90	74	57	87
TOTAL EXTANT TAXA WITH SANGAMONIAN EARLIEST KNOWN FIRST OCCURRENCES				2									
TOTAL EXTANT TAXA WITH ILLINOIAN EARLIEST KNOWN FIRST OCCURRENCES				1									

Table 2. Percentages of extinct taxa in the 13 samples from Hueyatlaco. See Table 1 explanation for further details.

	VL2151	VL2153	VL2154	VL2165	VL2283	VL2284	VL2285	VL2286	VL2287	VL2289	VL2290	VL2291	VL2343
Amphora minuscula				X									
Cocconeis grovei					X								
Cyclotella comta v. *trinotata*											X		
Cymbella cistula v. *lacroixii*					X								
C. grandi								X					
C. sturii	X								X				
Epithemia cistula v. *lunaris*				X			1					X	
E. turgida v. *crassa*							X	X					
Eunotia hungarica												1	
E. hungarica v. *gracilior*	X			X									X
E. japonica					X								
Gomphonema brasiliense v. *demerarae* f. *obtusa*								X					
G. cholnokyites								X	X				
G. parvulum v. *clavatum*								1					
G. parvulum v. *fossilis*											X		
G. subclavatum v. *fossilis*			X	X	X	X							X
Hantzschia amphioxys v. *karelica*					X			X	X				
Melosira italica v. *irregularis*			X		X		X	X					
M. turgida							2	X	X				
Navicula bronislaae	1												
N. exigua v. *transitoria* ?				X									
N. oberoensis	1			X									
N. peregrina f. *parvaparallela*				X									
N. schoenfeldii v. *rostrata* ?													X
N. starmachii				X									
Nitzschia angustata v. *minuta*			X			X							
N. denticula v. *pliocenica*	X			X	1	X	X	1	1	X		X	X
Pinnularia esox v. *recta*							X						
P. kotoriensis							X	X					
P. subrostrata				X			1	1	X	X			
Rhopalodia arcuata v. *incisa*			X							X			
R. gibba v. *iugalis*	X	X	X		X	1	X	2		X			
Stauroneis near *hercynica*				X									
Surirella bifurcata										X			
TOTAL EXTINCT TAXA	6	1	5	11	8	4	9	12	6	5	2	3	4
TAXA EXTINCT AT END OF SANGOMONIAN	5	1	4	6	4	3	4	6	2	3	1	3	2
TAXA EXTINCT AT END OF ILLINOIAN							1?	1?					
EXTINCT TAXA WITH SANGAMONIAN EARLIEST KNOWN FIRST OCCURRENCES				1									
EXTINCT TAXA WITH ILLINOIAN EARLIEST KNOWN FIRST OCCURRENCES										1			

Biostratigraphic determinations were based on microscopic examinations of 13 samples in which 329 taxa of diatoms were identified (Tables 1 and 2). All 13 samples in this study are from the Hueyatlaco archaeological site at 18°55'9.6" N X 98°10'23" W (Fig. 1). Repository of all samples and the stabilized stratigraphic monolith WSU73V16 is the California Academy of Sciences, Invertebrate Zoology and Geology Department, Golden Gate Park, 55 Concourse Drive, San Francisco, California 94118.

VL2151. Collected June 12, 2001 by Sam L. VanLandingham from C. Irwin-Williams 1966 wall, 7 m from SW corner, unit I, 30 cm from top of unit J (Figs 2–4).

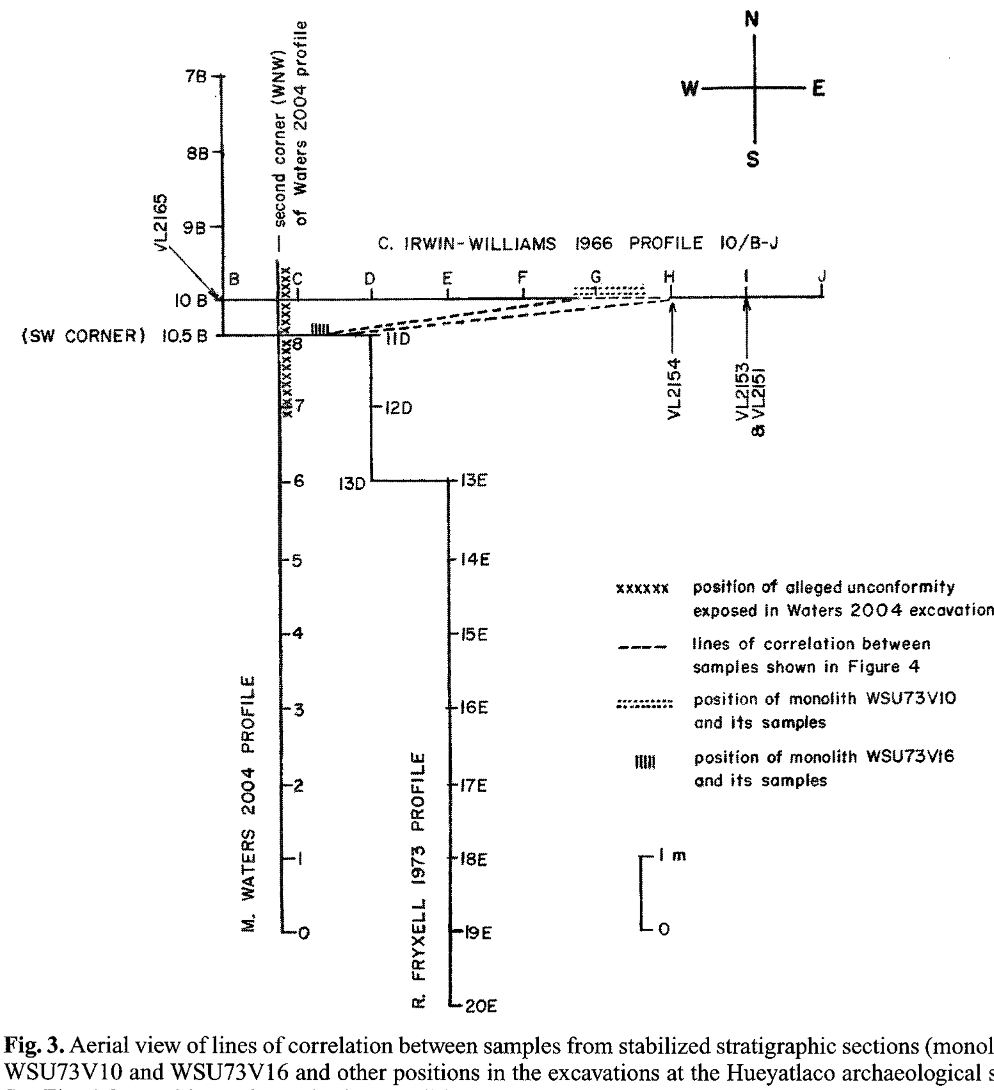


Fig. 3. Aerial view of lines of correlation between samples from stabilized stratigraphic sections (monolith) WSU73V10 and WSU73V16 and other positions in the excavations at the Hueyatlaco archaeological site. See Fig. 4 for positions of samples in monoliths.

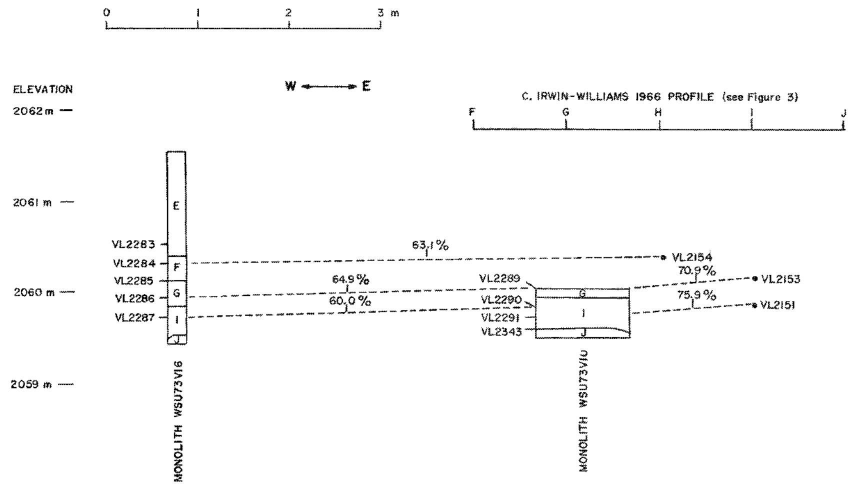


Fig. 4. Horizontal perspective of five lines of correlation between samples from stabilized stratigraphic sections (monoliths) WSU73V10 and WSU73V16 and other positions in the excavations at the Hueyatlaco archaeological site.

VL2153. Collected June 12, 2001 by Sam L. VanLandingham from C. Irwin- Williams 1966 wall, 7 m from SW corner in unit G (Figs 2–4).

VL2154. Collected June 12, 2001 by Sam L. VanLandingham from C. Irwin-Williams 1966 wall, 6 m from SW corner, in unit F (Figs 2–4).

VL2165. Collected June 15, 2001 by V. Steen-McIntyre from C. Irwin-Williams 1966 trench at SW corner, 20 cm below plow layer, in unit B (Figs 2 and 3).

VL2283. Collected March 10, 2002 by Sam L. VanLandingham in unit E, 100 cm below top of 200 cm long stabilized stratigraphic monolith WSU73V16 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 between C and D (Figs 2–4).

VL2284. Collected March 10, 2002 by Sam L. VanLandingham in unit F, 120 cm below top of 200 cm long stabilized stratigraphic monolith WSU73V16 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 between C and D (Figs 2–4).

VL2285. Collected March 10, 2002 by Sam L. VanLandingham at unit F-G contact, 140 cm below top of 200 cm long stabilized stratigraphic monolith WSU73V16 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 between C and D (Figs 2–4).

VL2286. Collected March 10, 2002 by Sam L. VanLandingham in unit G, 160 cm below top of 200 cm long stabilized stratigraphic monolith WSU73V16 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 between C and D (Figs 2–4).

VL2287. Collected March 10, 2002 by Sam L. VanLandingham in unit I, 180 cm below top of 200 cm long stabilized stratigraphic monolith WSU73V16 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 between C and D (Figs 2–4).

VL2289. Collected March 10, 2002 by Sam L. VanLandingham in unit G, top 2 cm (left corner) of 50 cm high stabilized stratigraphic monolith WSU73V10 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 cm west of H (Figs 2–4).

VL2290. Collected March 10, 2002 by Sam L. VanLandingham in unit I, 16–29 cm below top 2 of 50 cm high stabilized stratigraphic monolith WSU73V10 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 cm west of H (Figs 2–4).

VL2291. Collected March 10, 2002 by Sam L. VanLandingham in unit I, 16–18 cm above bottom of 50 cm high stabilized stratigraphic monolith WSU73V10 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 cm west of H (Figs 2–4).

VL2243. Collected March 10, 2002 by Sam L. VanLandingham at the unit I–J contact, about 49–50 cm below the top of 50 cm high stabilized stratigraphic monolith WSU73V10 which was extracted May of 1973 by R. Fryxell et al. from wall 10.5 cm west of H (Figs 2–4).

Results

Generalities

A minimum age of Sangamonian (= 80,000–ca. 220,000 yr. BP) for the Hueyatlaco artifacts in Irwin-Williams units B, C, E, and I at the Hueyatlaco site is indicated by sample VL2165 from the top of the unit B (at a position which is stratigraphically slightly higher than the artifacts). This sample contains 6 taxa which became extinct at the end of the Sangamonian and 3 taxa with earliest known first occurrences in the Sangamonian (Fig. 5). Details of these extinctions and earliest known occurrences are presented below under correlation criteria items 2 and 3. A minimum age of Sangamonian for all 13 samples in this study is established by the 17 diatoms which were extinct at the end of the Sangamonian and which are described in detail under correlation criteria item 2 below (see also Figs 5 and 6). Although older artifacts (edge-retouched) may have been found at Hueyatlaco in unit I, the maximum age of Illinoian (ca. 220,000–430,000 yr. BP) for all artifacts in the younger units (B, C, and E) is indicated by the earliest known first occurrence of *Surirella bifurcata* Lohman in sample VL2289 from unit G which is stratigraphically lower than the younger units (Figs 2 and 6). The author has found this species in sample VL1786 from the top of the Kelseyville Formation in Lake County, California, USA, which corresponds with sample # 11 (ca. 10 m above the Kelsey Tuff Member) of Bradbury (1988, p. 104) and an age of ca. 160,000 to 400,000 yr. BP (see Rymer 1981, p. 12, fig. 6)

Correlation criteria

The ages and biostratigraphic correlations between the 13 samples were based mainly on the following taxonomic criteria: (1) percentage correlation factor of taxa (% of all shared taxa between any two samples under consideration); (2) taxa extinct at the end of the Sangamonian; (3) earliest known first occurrences; (4) pennate to centric (P:C) ratios; and (5) dominance/subdominance associations.

(1) Percentage correlation factor of taxa. The correlation factor is the percentage of all shared taxa between any two samples being compared (considering the sample with the smallest number of total taxa as the basis for the percentage calculation between the two). A taxonomic correlation

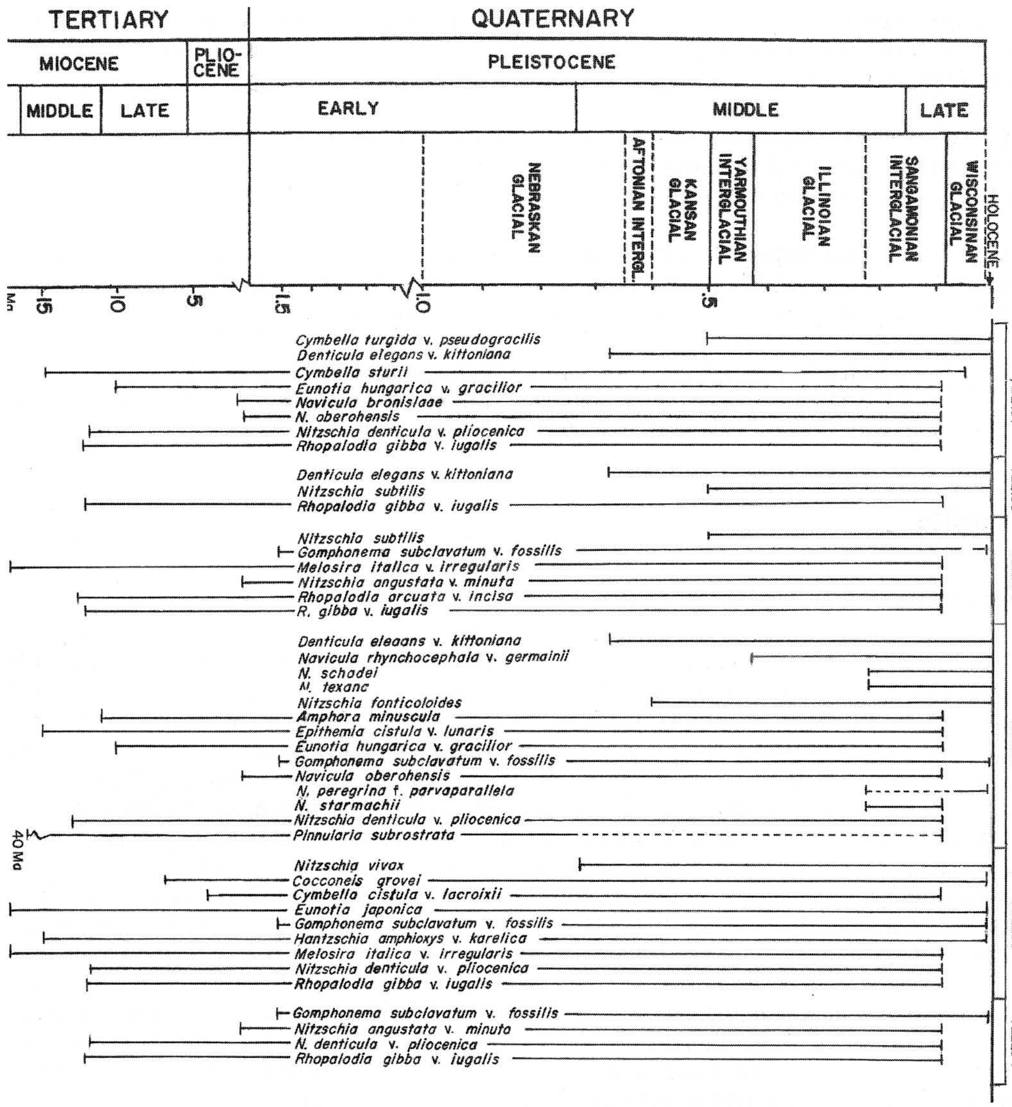


Fig. 5. Stratigraphic ranges of extant (earliest known first occurrences, post Early Pleistocene) and extinct taxa from samples VL2151, VL2153, VL2154, VL2165, VL2283, and VL2284. Range lines are dashed where uncertain or implied.

factor of > 60 % is fairly good, over 75 % is excellent. The five lines of correlation shown in Fig. 4 range from 60.0 % to 75.9 %. Sample VL2165 is distinct from the other 12 samples and has 39 taxa which are not found in these other samples: the remaining 12 samples taxonomically are fairly similar and have numerous taxa in common (Tables 1 and 2).

(2) Taxa extinct at the end of the Sangamonian. An age later than the Sangamonian for all of the 13 samples is eliminated by the presence of 17 diatoms which were extinct at the end of the Sangamonian, and each of these 17 taxa is followed by illustrations (if any) of that taxon in the

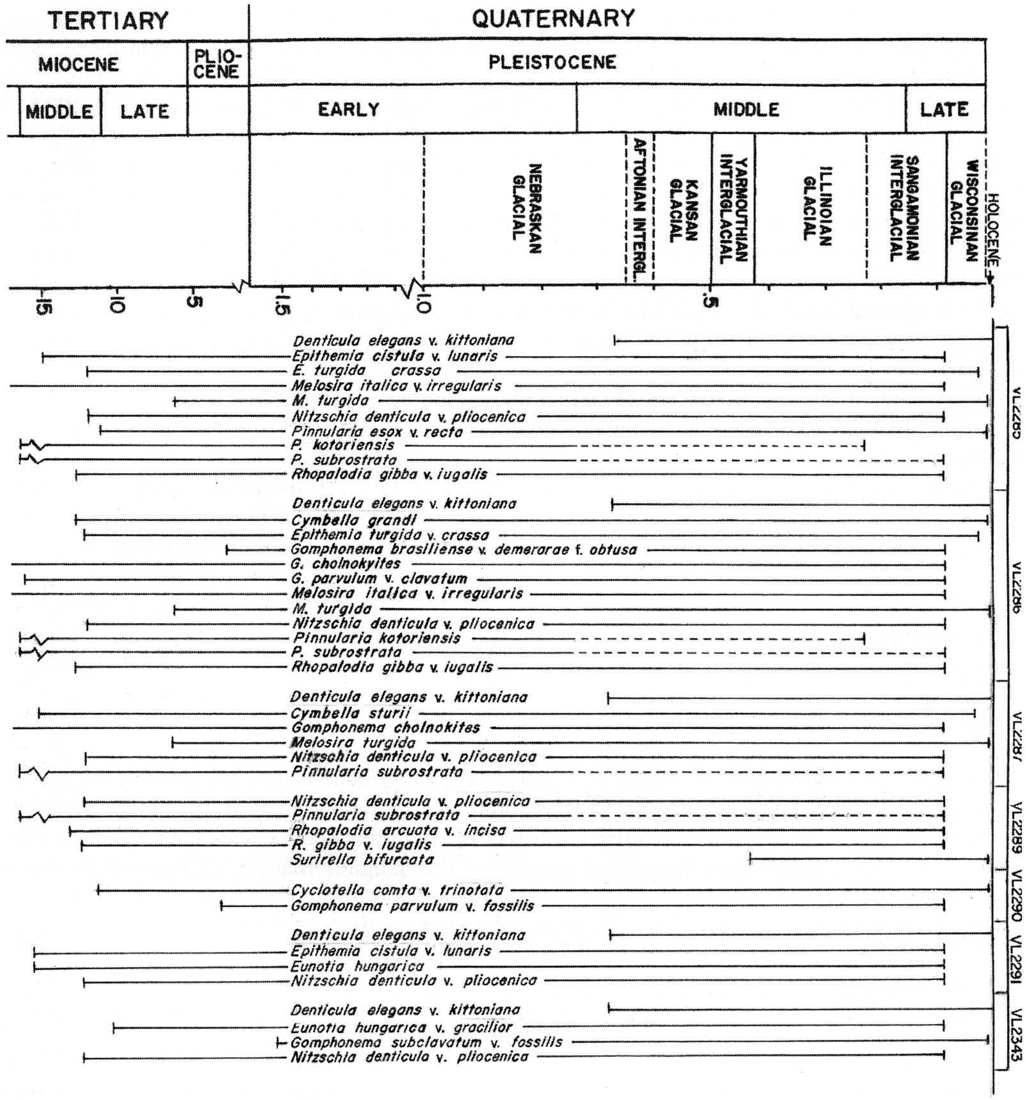
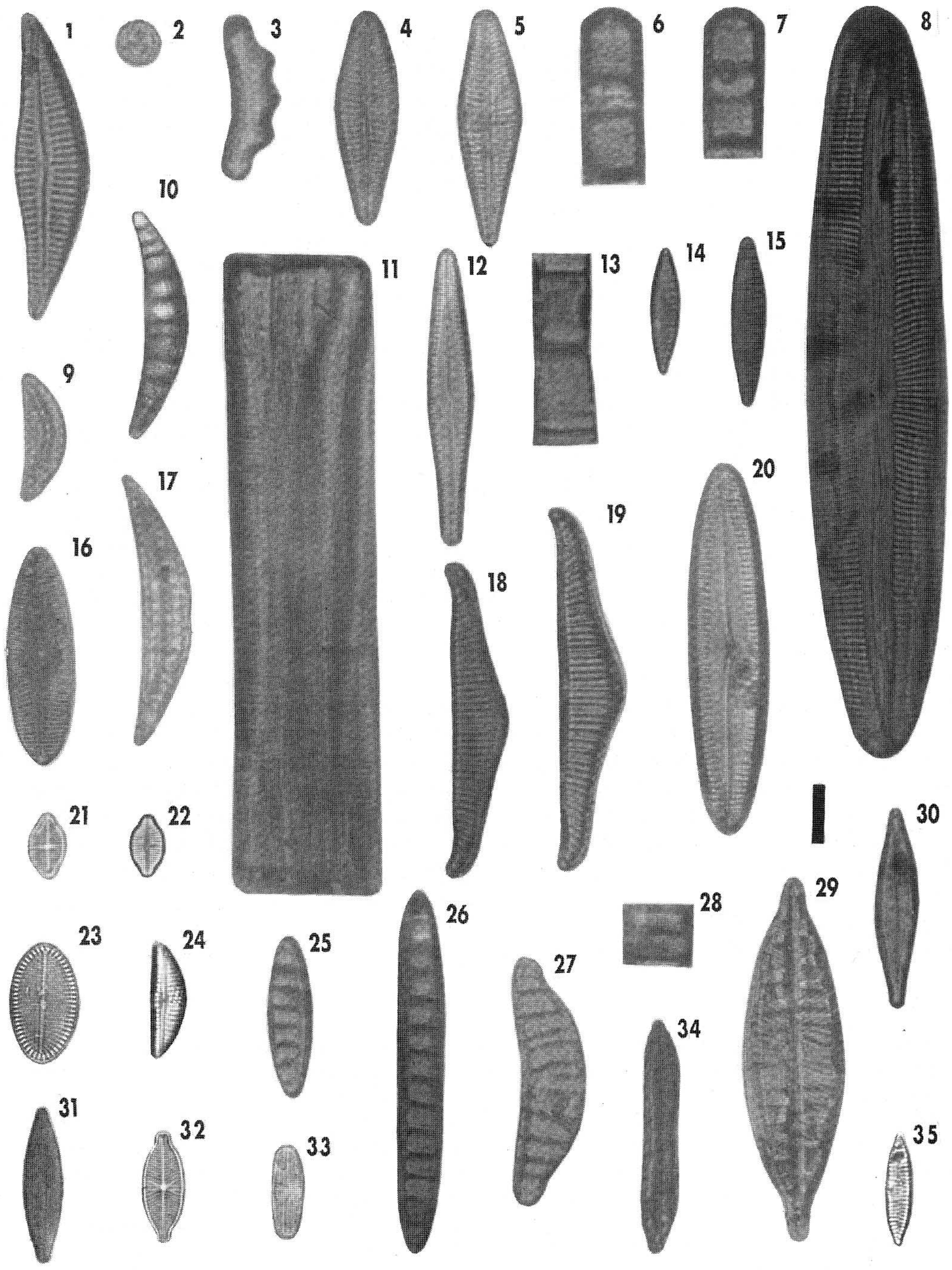


Fig. 6. Stratigraphic ranges of extant (earliest known first occurrences, post Early Pleistocene) and extinct taxa from samples VL2285 - VL2287, VL2289 - VL2291, and VL2343. Range lines are dashed where uncertain or implied.

present work, sample number(s), location(s), age(s), and citation(s) which are associated with its time of extinction (see Figs 5 and 6): (1) *Amphora minuscula* Frenguelli, VL1907 (= VL1904), Elko County, Nevada, USA, upper Hay Ranch Formation = middle Pleistocene (see VanLandingham 2000, p. 83); (2) *Cymbella cistula* v. *lacroixii* Lauby (Plate 2, fig. 1), VL2118 (CAS611422), Aydat (= Verneuge) deposit, Auvergne, France, "Altdiluvial" (probably Eemian or = age) (vide Stoller 1926, p. 14); (3) *Epithemia cistula* v. *lunaris* Grunow (Plate 1, Figs 9–10; Plate 2, fig. 4), 66M285, core 4 from Rancho Batan, Puebla, Mexico, Sangamonian (VanLandingham 2004, p. 315 and 321, text-fig. 2 and 4; VanLandingham 2006, p. 102 and 105, Figs 1 and 2, plate 1, fig. 34–36); (4) *Eunotia hungarica* Pantocsek (Plate 2, fig. 2), VL2168, Barranca de Caulapan, Puebla, Mexico, Sangamonian (VanLandingham 2004, p. 323, text-fig. 4; VanLandingham 2006, p. 105); (5) *E. hungarica* v. *gracilior* Pantocsek (Plate 1, fig. 11; Plate 2, fig. 3), VL2173, Barranca de Caulapan, Puebla, Mexico, Sangamonian (VanLandingham 2004, p. 323, text-fig. 4); (6) *Gomphonema brasiliense* v. *demerarae* f. *obtusa* Manguin (Plate 1, fig. 12; Plate 2, fig. 5), 64M45, south of San Baltazar Tetela, Puebla, Mexico, Sangamonian (vide VanLandingham 2004, p. 315, text-fig. 20; (7) *G. cholnokyites* VanLandingham (Plate 2, fig. 6), 66M286, core 4 from Rancho Batan, Puebla, Mexico, Sangamonian (VanLandingham 2004, p. 323, text-fig. 4); (8) *G. parvulum* v. *clavatum* Okuno (Plate 2, fig. 7), VL1972, south of Cuidad Puebla, Mexico, Sangamonian (VanLandingham 2004, p. 322, Table 2); (9) *G. parvulum* v. *fossilis* Manguin (Plate 2, fig. 8), VL2124, Barranca de Caulapan, Puebla, Mexico, Sangamonian (vide VanLandingham 2004, p. 315, text-fig. 2); (10) *Melosira italica* v. *irregularis* Lohman (Plate 1, fig. 13; Plate 2, fig. 9), 65M259, .7 km west of San Francisco Totimehuacan, Puebla, Mexico, Sangamonian diatomaceous bed in Valsequillo Gravels (vide VanLandingham 2006, fig. 1); (11) *Navicula bronislaae* Kaczmarska (Plate 2, fig. 10), 27, 41, 45, 48, 65, 68,80, and 84, Imbramowice near Wroclaw, Poland, Eemian Interglacial (Kaczmarska 1976, table 1); (12) *N. oberoensis* Hustedt (Plate 2, fig. 11), obh o.1, Oberohe in the Lueneburger Heide, Germany, Riss-Mindel Interglacial (Hustedt 1954, p. 441, 454); (13) *N. starmachii* Kaczmarska (non Witkowski) (Plate 2, fig. 12), 41, 48, 58, 65, 68, 80, 83, and 84, Imbramowice near Wroclaw, Poland, Eemian Interglacial (Kaczmarska 1976, table 1); (14) *Nitzschia angustata* v. *minuta* Krasske (Plate 2, fig. 13), 66M286, core 4 from Rancho Batan, Puebla, Mexico, Sangamonian (VanLandingham 2004, p. 323, text-fig. 4); (15) *N. denticula* v. *pliocenica* Frenguelli (Plate 1, Figs 14–15), VL2171, Barranca de Caulapan, Puebla, Mexico, Sangamonian (vide VanLandingham 2004, p. 315, text-fig. 2; VanLandingham 2006, p. 105, plate 1, fig. 39–43); (16) *Rhopalodia arcuata* v. *incisa* Pantocsek (Plate 1, fig. 17; Plate 2, fig. 15, 66M286, core 4 from Rancho Batan, Puebla, Mexico, Sangamonian (VanLandingham 2004, p. 323, text-fig. 4); and, (17) *R. gibba* v. *iugalis* Bonadonna (Plate 1, Figs 18–19; Plate 2, fig. 16), diatomite, Cornazzano (Bracciano, Roma), Italy, Nomentano = Riss Interglacial (Bonadonna 1964, p. 399). These 17 extinct diatoms occur commonly in the fossil record, and their occurrences have been reported throughout their stratigraphic ranges but none after the Sangamonian, e. g., Hustedt (1954) in Lueneburg Heide, Kaczmarska (1976) at Imbramowice, and VanLandingham (2000, 2004, and 2006) at several locations in Puebla state (none of which are from the Hueyatlaco archaeological site). *Navicula starmachii* evidently has a very short stratigraphic range and is restricted to the Sangamonian (or =) age, vide Kaczmarska (1976). All of the 13 samples in this study contained at least one of these diatoms which were extinct by the end of the Sangamonian (Figs 5 and 6).

Plate 1. Extinct (Figs 1–20) and extant (Figs 21–35) Hueyatlaco diatoms from the 13 samples. Extinct after the Sangamonian: Figs 1–8. Extinct at the end of the Sangamonian: Figs 9–19. Black bar = 10 μ: all magnifications = X 1000.

1. *Cymbella grandi* Héribaud; 2. *Cyclotella comta* v. *trinotata* Lauby; 3. *Eunotia japonica* Pantocsek; 4–5. *Gomphonema subclavatum* v. *fossilis* Manguin; 6–7. *Melosira turgida* Ehrlich; 8. *Pinnularia esox* v. *recta* Héribaud; 9–10. *Epithemia cistula* v. *lunaris* Grunow; 11. *Eunotia hungarica* v. *gracilior* Pantocsek, girdle view; 12. *Gomphonema brasiliense* v. *demerarae* f. *obtusa* Manguin; 13. *Melosira italica* v. *irregularis* Lohman; 14–15. *Nitzschia denticula* v. *pliocenica* Frenguelli; 16. *Pinnularia subrostrata* Lohman and Andrews (non Cleve-Euler); 17. *Rhopalodia arcuata* v. *incisa* Pantocsek; 18–19. R. *gibba* v. *iugalis* Bonadonna; 20. *Pinnularia kotoriensis* Okuno; 21. *Achnanthes exigua* Grunow, rapheless valve; 22. *A. exigua*, raphe valve; 23. *Cocconeis placentula* v. *intermedia* Héribaud, raphe valve; 24. *Cymbella ventricosa* Agardh; 25–26. *Denticula elegans* v. *kittoniana* Grunow; 27. *Epithemia zebra* v. *proboscidea* Kuetzing; 28. *Melosira distans* Ehrenberg; 29. *Navicula cuspidata* v. *ambigua* Kuetzing; 30–31. N. *cryptocephala* Kuetzing; 32. *N. exigua* Gregory; 33. *N. mutica* Kuetzing; 34. *Nitzschia apiculata* Gregory; 35. *Synedra vaucheriae* Kuetzing.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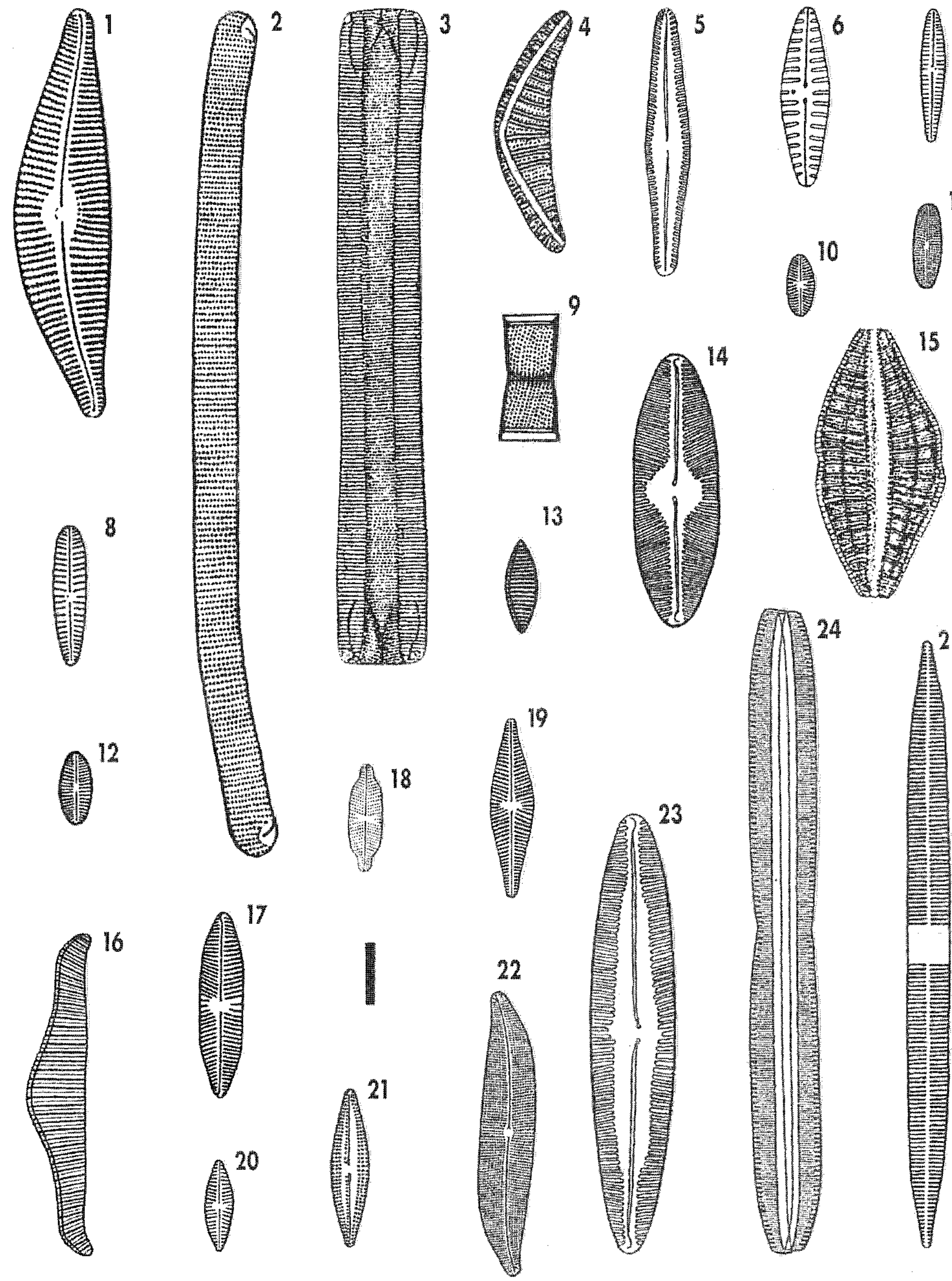
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Nitzschia denticula v. *pliocenica*, present in 10 of the 13 samples (Table 2), was the most common extinct diatom.

(3) Earliest known first occurrences. A pre-Sangamonian age for sample VL2165 is eliminated by the presence of two extant taxa which have earliest known first occurrences in the Sangamonian (or =) age (Fig. 5): *Navicula schadei* Krasske and *N. texana* Patrick (Plate 2, fig. 18). The earliest known reports of occurrences of *Navicula schadei* are from: Hollerup (Interglacial) by Foged (1962); Mikulinian (Late Pleistocene) bore 78 by Loseva (1997, p. 269); and Mikulinian sediments (ca. 70,000–110,000 yr. BP) by Loseva (2000, p. 196). The report of Bradbury (1971) of *Navicula texana* from the Tarango Formation (at 44–46 m, ca. 100,000 yr. BP in the Reforma Havre core from Texcoco, Mexico) evidently is the earliest known. An age no older than Sangamonian for sample VL2165 is indicated by the presence of *Navicula starmachii*, an extinct diatom which has its earliest first occurrence reported in Eemian (= Sangamonian) deposits from Imbramowice near Wroclaw, Poland (Kaczmarska 1976). An age no older than Illinoian for sample VL2289 is indicated by *Surirella bifurcata* Lohman (Fig. 6) which has its earliest known first occurrence in the Illinoian (which was detailed above).

(4) Pennate to centric (P:C) ratios. Diatom assemblages in the Centric Paucity (CP) zone must fit at least one of the following criteria: (1) over 80:1 ratio of pennate taxa frustules and valves to centric taxa frustules and valves or (2) minimum of 18 pennate taxa with no centric taxa. This zone (or series of zones) is associated with Miocene to Holocene non-marine diatomaceous sequences over the world in which centric diatoms are very rare or totally absent. The CP zone and the ratio of pennate to centric diatoms are very important in the artifact-bearing sediments of the Valsequillo/Hueyatlaco region, because they help to define the extent of the interglacial (Sangamonian) deposition and the age of the artifacts (VanLandingham 2004). The first descriptions of the CP zone were provided by VanLandingham (1988 and 1990). By definition, the CP zone contains only fossil assemblages and may include some postglacial fossil deposits but does not include active, living, and modern diatom communities. The few Pleistocene CP zone occurrences in North America are restricted to interglacial deposition in Aftonian, Yarmouthian, and Sangamonian Interglacial times: e. g., in sample 4 in the Aftonian part of the Lower Lake Formation in Lake County, California, USA (Rymer et al. 1988, p. 49, Table 3; Rymer 1981, p. 12, fig. 6); in the Yarmouthian of the Sappa Formation near Mullen in Hooker County, Nebraska, USA (Elmore1921; Bates and Biemesderfer 1960); and, in sample 4 in the Sangamonian of the Don Formation from the Don Valley brickyard at Toronto, Ontario, Canada (Duthie & Rani 1967). The CP zone evidently is associated with warmer climatic conditions (including interglacial and

Plate 2. Extinct diatoms from Hueyatlaco: Figs 1–17 and 23. Extant diatoms from Hueyatlaco: Figs 18–22 and 24–25. Black bar = 10 µ: all magnifications = X 1000. Figs 2, 5–6, 9–10, 12, 14, 16, 18–20, 23, and 25 are originals from Hueyatlaco samples. Fig. 1 is from Lauby (1910); 3 and 15 from Pantocsek (1903); 4 from Pantocsek (1913); 7 from Okuno (1952); 8 from Manguin (1949); 11 and 13 from VanLandingham (2004); 17 from Hofmann (1914); 21–22 from Patrick & Reimer (1966); and 24 from Hustedt (1930).
1. *Cymbella cistula* v. *lacroixii* Lauby; 2. *Eunotia hungarica* Pantocsek; 3. *E. hungarica* v. *gracilior* Pantocsek; 4. *Epithemia cistula* v. *lunaris* Grunow; 5. *Gomphonema brasiliense* v. *demerarae* f. *obtusa* Manguin; 6. *G. cholnokyites* VanLandingham; 7. *G. parvulum* v. *clavatum* Okuno; 8. *G. parvulum* v. *fossilis* Manguin; 9. *Melosira italica* v. *irregularis* Lohman; 10. *Navicula bronislaae* Kaczmarska; 11. *N. oberohensis* Hustedt; 12. *N. starmachii* Kaczmarska (non Witkowski); 13. *Nitzschia angustata* v. *minuta* Krasske; 14. *Pinnularia subrostrata* Lohman and Andrews (non Cleve-Euler); 15. *Rhopalodia arcuata* v. *incisa* Pantocsek; 16. *R. gibba* v. *iugalis* Bonadonna; 17. *Navicula peregrina* f. *parvaparallela* Hofmann; 18. *N. texana* Patrick; 19. *N. cryptocephala* Kuetzing; 20. *N. cryptocephala* v. *veneta* Kuetzing; 21. *N. circumtexta* Meister; 22. *Gyrosigma scalproides* Rabenhorst; 23. *Pinnularia kotoriensis* Okuno; 24. *Nitzschia linearis* Agardh; 25. *Synedra ulna* v. *oxyrhynchus* Kuetzing.

interstadial times) in diatomaceous deposits from middle Miocene to present times. Apparently no CP zone occurrences of > ca. 15,000 yr. BP in the Wisconsinan or = age are known in the Western Hemisphere. In the Pleistocene, the CP zone corresponds with interstadial and interglacial times. VanLandingham (2004) described numerous Sangamonian samples in the CP zone which occur stratigraphically above and below sample VL2165 at the Hueyatlaco archaeological site. In Fig. 2 the P:C ratios of all samples from the bottom half of the Irwin-Williams unit E through the top of unit I are similar and do not occur in the CP zone.

(5) Dominance/subdominance associations. In this investigation, the taxon with the largest percentage of the total in the assemblage is defined as the dominant, as codominant if two or more taxa equally share the largest percentage of the total (or are within 90 % of the total of the largest dominant), and/or as subdominant, if a taxon composes at least 5 % of the total and is as great or greater than 33 1/3 % of the largest dominant taxon but is not > 90 % of the total of that dominant taxon.

The *Navicula-Nitzschia-Synedra* dominance/subdominance association is common in assemblages from the Late Pleistocene to Illinoian (e. g., Kashima et al. 1996, Marciniak 1994, etc.); but, whenever this association is found in the CP zone, it is restricted to the Sangamonian in the Western Hemisphere (where it occurs only in the Valsequillo region). An age no younger than Sangamonian for sample VL2165 (in the CP zone, P:C ratio = 183:1) is established by the *Navicula-Nitzschia-Synedra* dominance/subdominance association (see Table 1), and this sample is stratigraphically above the artifact-bearing beds at Hueyatlaco and aids in establishing a minimum age of the artifacts. In sample VL2151 (see Table 1), the *Fragilaria-Navicula-Nitzschia* dominance/subdominance association is not known below the upper part of the middle Pleistocene (= Tyrrhenien) and has been reported frequently from sediments of Illinoian to Sangamonian or younger age by such investigators as Tempère and Peragallo (1910) from Lamiouze-Rochefort & Krasske (1933) from Oderberg-Bralitz. In samples VL2290 and VL2343 (see Table 1), the *Cocconeis-Navicula-Nitzschia* dominance/subdominance association is unknown below the upper part of the middle Pleistocene (= Tyrrhenien) and has often been reported from the Illinoian to Sangamonian (or =) age, e. g., Tempère & Peragallo (1910) from Lamiouze-Rochefort & Marciniak (1994) from Zbytki (Eemian). The *Cocconeis-Navicula-Synedra* dominance association in sample VL2290 (see Table 1) is known from modern assemblages, e. g., from Puget Sound, Washington (Tempère & Peragallo 1909, sample 332–333), but evidently it is unknown in the entire fossil record except from the Last Interglacial (= Sangamonian, Riss-Wuerm, etc.), exemplified by the Zbytki occurrence in Poland (Marciniak 1994). The *Cocconeis-Navicula-Nitzschia-Synedra* dominance/subdominance association found in sample VL2290 is unknown after the Sangamonian and can be noted in such references as Marciniak (1994) from the Eemian of Zbytki.

Discussion

The present work serves to help define the age limits of the artifacts at the Hueyatlaco site by corroborating the minimum age (Sangamonian) evidence for this site presented by VanLandingham (2000, 2004, and 2006) and Covey (2002) and the maximum age (Illinoian) presented by VanLandingham (2006).

On the Center for the Study of First Americans web site, www.centerfirstamericans.com, the Hueyatlaco, Mexico item under the topic of research states, "An unconformity separated the alluvium containing the bifacial material (Bed E and C)." In the group 3 samples of VanLandingham (2004), the direct NNW-SSE line of correlation between 66M239 and VL2121 (in text-fig. 2 of VanLandingham 2004) passes through this alleged unconformity (in the north end of the 2004 excavation, see Fig. 3) at Hueyatlaco. In the group 2 samples of VanLandingham (2004), the direct NE-SW line of correlation between 66M191 and VL2120 (in text-fig. 2 of VanLandingham 2004) passes within 2 m of the questionable unconformity. Samples VL2120 and VL2121 are less than 2 m from the alleged unconformity. Samples 66M239 and VL2121 (group 3) and samples 66M191 and VL2120 (group 2) also are closely related ecologically to each other as well as to other samples in groups 2 and 3, as indicated by VanLandingham (2006). Diatom correlations and paleoecology of these samples would negate the likelihood of the nearby "unconformity" which would be associated with an interruption of the deposition and the associated paleoecology (which is not displayed in the samples).

Diatom assemblages from 12 of the 13 samples in the present study form 5 lines of correlation (Figs 3 and 4). Three of these lines link to a position less than 1/2 m from the unconformity in the Waters 2004 trench (Fig. 3) at the Hueyatlaco site and discount the unlikely occurrence of any major interruption in the depositional sequence (i. e., unconformity, redeposition, etc.) in the vicinity.

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