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The stratigraphic debate at Hueyatlaco, Valsequillo, Mexico

Harold E. Malde, Virginia Steen-McIntyre, Charles W. Naeser, and Sam L. VanLandingham

ABSTRACT

We review the history of investigations at the Valsequillo archaeological area south of Puebla, Mexico, from the early 1960s to 2010. Evidence from diatoms, (U-Th)/He measurements, early uranium-series dates, later zircon fission-track dates, mineral weathering, tephra hydration dates, and vertebrate fossils imply that the principal archaeological site, Hueyatlaco, could be older than 250,000 years. Hueyatlaco rests unconformably on Xalnene Tuff (basaltic ash) dated at 1.3 Ma by whole-rock argon-argon analysis. This finding differs greatly from a recent interpretation that the site is 40,000 years old.

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INTRODUCTION

Charles A. Repenning, during the last years of his life, took an active interest in issues that surrounded the archaeological investigations at the Valsequillo Reservoir, south of the city of Puebla, Mexico, where four separate sites had been located (Figure 1). Thus, he corresponded with paleontologists who had preceded him, and he studied all written aspects about the archaeology and geology. Repenning brought to Valsequillo his vast knowledge of Pleistocene geology and paleontology. At the time of Repenning's death, many of the Valsequillo issues that concerned him were incompletely understood and remain unresolved. Also, new investigators with new interests have begun to study the sites. Therefore, we judge it fitting to offer this brief history of past and current work at Valsequillo as a tribute to Repenning and his scientific efforts on our behalf.

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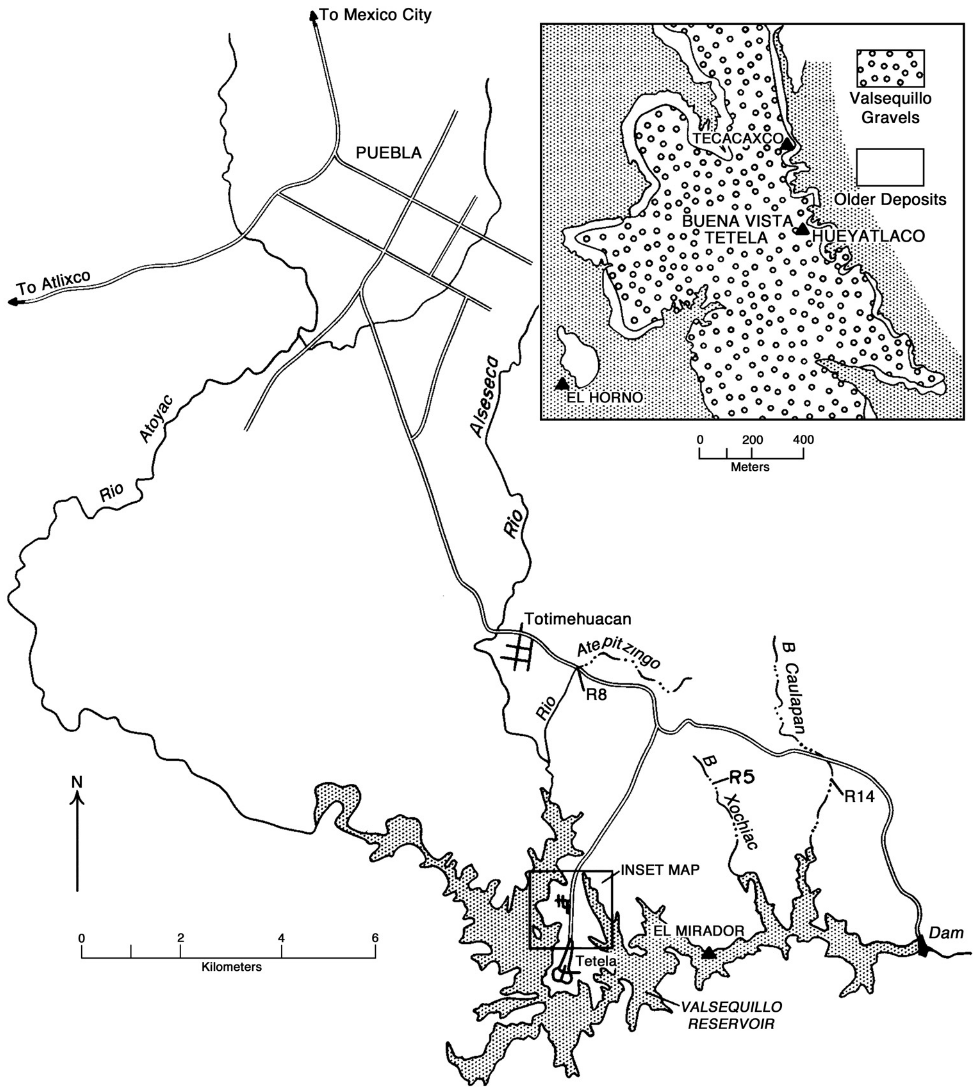

FIGURE 1. Index map of the Valsequillo area showing the archaeologic sites El Horno (2040 m), El Mirador (2049 m), Tecacaxco (2055 m), and Hueyatlaco (2056 m).

Significant among current scholars with an interest in Valsequillo is a British group headed by S. González of Liverpool John Moores University, UK. González and her associates, based on their work since 2003 and published reports that date from 1957, put forward their digest of the archaeological discoveries at Valsequillo (González et al., 2006). They asserted that the artifacts and associated megafauna are reworked, not indigenous (*in situ*) to a widespread geologic unit called the Valsequillo Gravels, as described by the original investigator, C. Irwin-Williams (1967a, 1978; Irwin and Armenta Camacho, 1963). They further reported a new chronology of the stratigraphy, founded on the premise that a unit of basaltic ash, known as the Xalnene tuff, which underlies the Valsequillo Gravels, is about 40,000 years old, not 1.3 Ma, as previously reported by Renne and others (Renne et al., 2005; Feinberg et al., 2009). Our stratigraphic work at Hueyatlaco, the principal archaeological site at Valsequillo, is described here. It supports the older chronology. An earlier comprehensive history of the Valsequillo investigations was presented by Hardaker (2007).

BACKGROUND

The Irwin-Williams Legacy

In 1962, 1964 and 1966, C. Irwin-Williams, working at times with J. Armenta Camacho of the University of Puebla, excavated the Hueyatlaco site as part of a Valsequillo Project (Figure 1) (Irwin

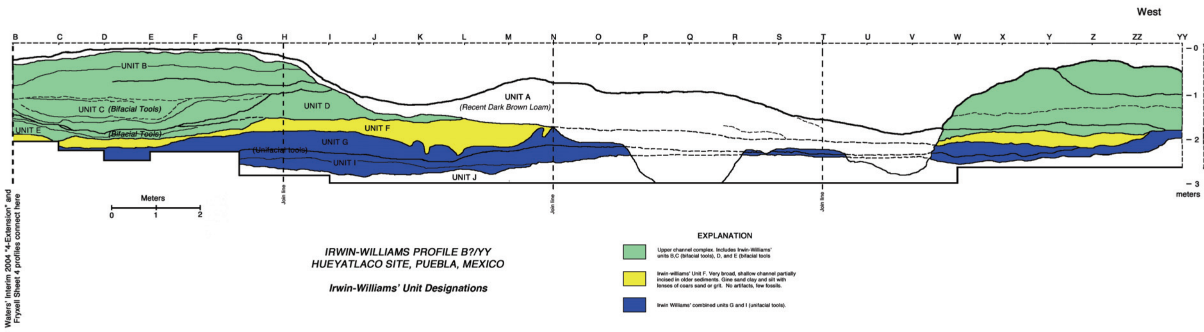

FIGURE 2. Irwin-Williams profile B?/YY, with Irwin-Williams' unit designations,1964?, Hueyatlaco Site (redrafted from Irwin-Williams' original by VSM).

and Armenta Camacho, 1963). Altogether they had located four sites in 1962, including Hueyatlaco, where a number of stone artifacts had been found in situ, all associated with extinct fossil vertebrates. From the articulated remains and the proximity of the artifacts, Irwin-Williams interpreted many of these localities to be preserved "kill sites." These discoveries and their stratigraphic context were described in some detail in unpublished, open file progress reports submitted to the Instituto Nacional de Antropología e Historia (INAH), Mexico City (Irwin-Williams, 1962, 1964, 1966). The important artifacts were later illustrated by Irwin-Williams (1967a, 1978; Szabo et al., 1969), and many prominent archaeologists, both from Mexico and from the USA visited Hueyatlaco and other Valsequillo sites during excavation (Irwin-Williams, 1969.)

Irwin-Williams obtained several bifacial tools from the upper part of the Hueyatlaco site, in deposits she designated as Units C and E. She obtained a few unifacial tools (Figures 2, 3, and 4) from the lower part, in units designated as H (a local feature) and I. Units C and E were mingled with Units B and D that contained no artifacts. Together they formed a set of cross-bedded channel deposits about 2 m thick. Units H and I were overlain by the stream deposits of Units F and G, and underlain by Unit J, all of which yielded fossils but lacked artifacts. An exploratory pit in the western part of Hueyatlaco showed underlying coarse gravel (Unit K) that in part contained fragments of Xalnene tuff, and, below, gravel mixed with reworked pink clay (Unit L), thought by one of the authors (HEM) to have been derived from the underlying Amomoloc lake beds (Figure 5). The main excavation, which extended downward to the upper part of Unit J, was 3 m deep.

Irwin-Williams worked at Hueyatlaco after, or during, a prolonged drought, when the level of the Valsequillo Reservoir was at 2049 m, or about 7 m below the lowest part of Hueyatlaco. Earlier in 1962 when she and Armenta Camacho made an initial survey and excavated the El Horno site (Irwin and Armenta Camacho, 1963), the water level was phenomenally low, at about 2030 m, as determined from photographs. Hence, González and her associates were misinformed when they say (2006, p. 612) that ". . . high water . . . plagued the archaeological excavations during the 1960s."

Information about the Irwin-Williams excavation of Hueyatlaco comes from three brief open-file progress reports to the INAH (1962, 1964, 1966) and from Irwin-Williams (1967a, 1967b, 1969, 1978), but she never prepared a final comprehensive report prior to her 1990 death. Also, her voluminous field records, including her field notes, all but two of her trench profiles, and thousands of her photographs and sketches, have not been located. However, M.A. Waters, the current Principal Investigator, may have had access to certain notebooks kept by workers. These notebooks are stored in the Smithsonian Institution archives.

Also lost was the evidence from two "in block" specimens collected from Hueyatlaco in 1962 for museum display, where closely associated artifacts and fossil remains had been preserved in situ. The artifacts had been forcibly removed from the exhibits, thereby destroying the evidence of the association (Irwin-Williams, 1967b.) Despite these losses, Irwin-Williams' detailed descriptions of the numerous stratigraphic features imply studious attention to the intricate features of the site. In this light, the basis of a remark by González et al. (2006, p. 615) must be questioned. Speaking of Irwin-Williams, they reported that ". . . there was an apparent lack

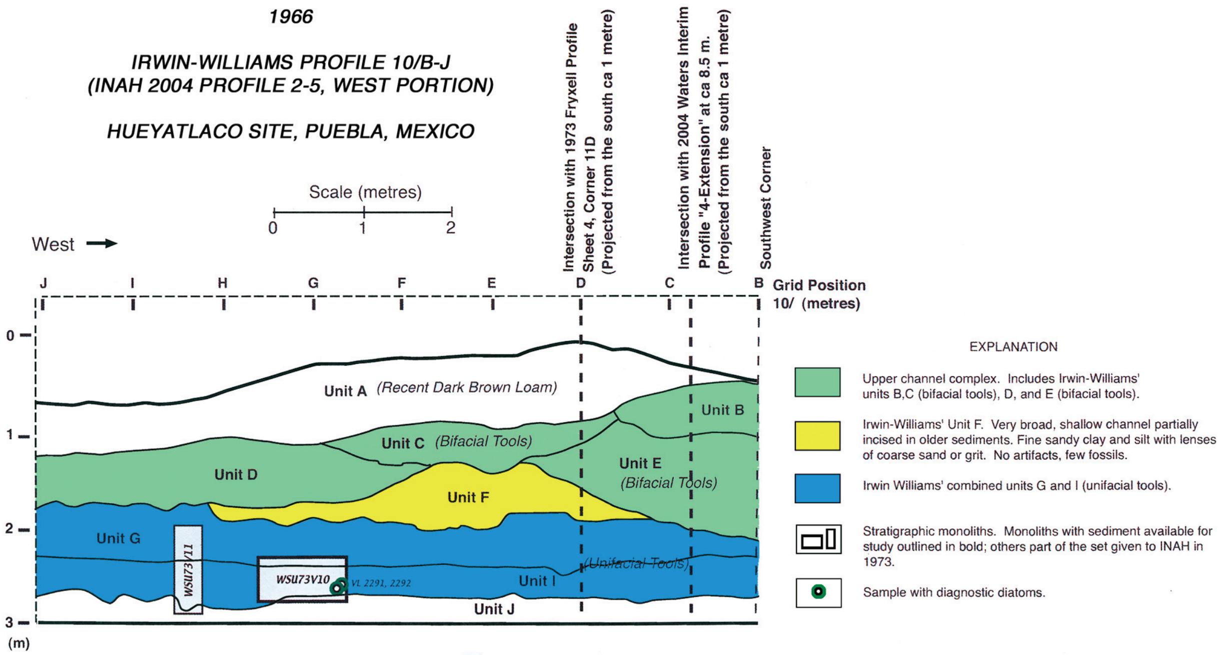

FIGURE 3. Irwin-Williams profile 10/B-J, with Irwin-Williams' unit designations,1966, Hueyatlaco Site (adapted from Irwin-Williams' original by VSM to include VanLandingham (2006) diatom localities 1973 stratigraphic monolith positions, and 1973 and 2004 trench wall intersections.

of understanding of the site formation processes at the time and of the sedimentology."

After Irwin-Williams completed her work, 565 vertebrate fossil specimens and the artifacts were deposited with the INAH, where they presumably remain. However, except for one bifacial object (Irwin-Williams, 1978, Plate 1, Number 4), which was displayed, unlabeled, in 2003 in the national archaeological museum, the artifacts have not been located. Fortunately, plastic replicas of the artifacts are stored at the Smithsonian Institution (Payn 2006, time 0:10-0:11, 0:22, Stanford interview). This circumstance suggests that other items of the Irwin-Williams legacy may eventually come to light.

Irwin-Williams (1967a, p. 339) judged that ". . . the materials employed in artifact manufacture were of nonlocal origin." This was also noted by González et al. (2006). The inference probably resulted from the site's lack of obsidian and the variable colors of the chert fragments that were utilized in the area. The modern surface is littered with fragments of obsidian tools and debitage.

Geologic Studies

H. Malde, who had joined the Valsequillo Project as project geologist in 1964, completed two geologic maps during the 1964 and 1966 field seasons. One map (Figure 6) of the area around the Valsequillo Reservoir shows the Tetela Peninsula where the Hueyatlaco site is located. The other is a more general geologic map of the southern part of the Puebla Valley, reaching from Puebla and Cholula south to Atlixco. The original maps, not yet published, are stored in the Field Records Library of the USGS in Denver, Colorado. Copies have been widely distributed among participants in the Valsequillo investigations. J. Feinberg, Department of Geology and Geophysics, University of Minnesota is digitizing Malde's Valsequillo maps and field report for publication (Feinberg, personal commun. to VSM, 2008).

In 1966 and 1968, Malde was joined by V. Steen, then a graduate student at the University of Idaho. Their geological investigations were mainly on La Malinche, a volcano just north of Puebla, in an effort to define the stratigraphy of the volcanic eruptions and to sample the tephra sequence for petrographic examination. No 14C dates had been possible for the Valsequillo sites, as no carbon was preserved there, and the bones were all permineralized. The working hypothesis was that tephra from the Malinche eruptions reached the Valsequillo area and that the sites could be dated indirectly by correlation of the tephra layers there with dated strata on the mountain. Previously, Malde's

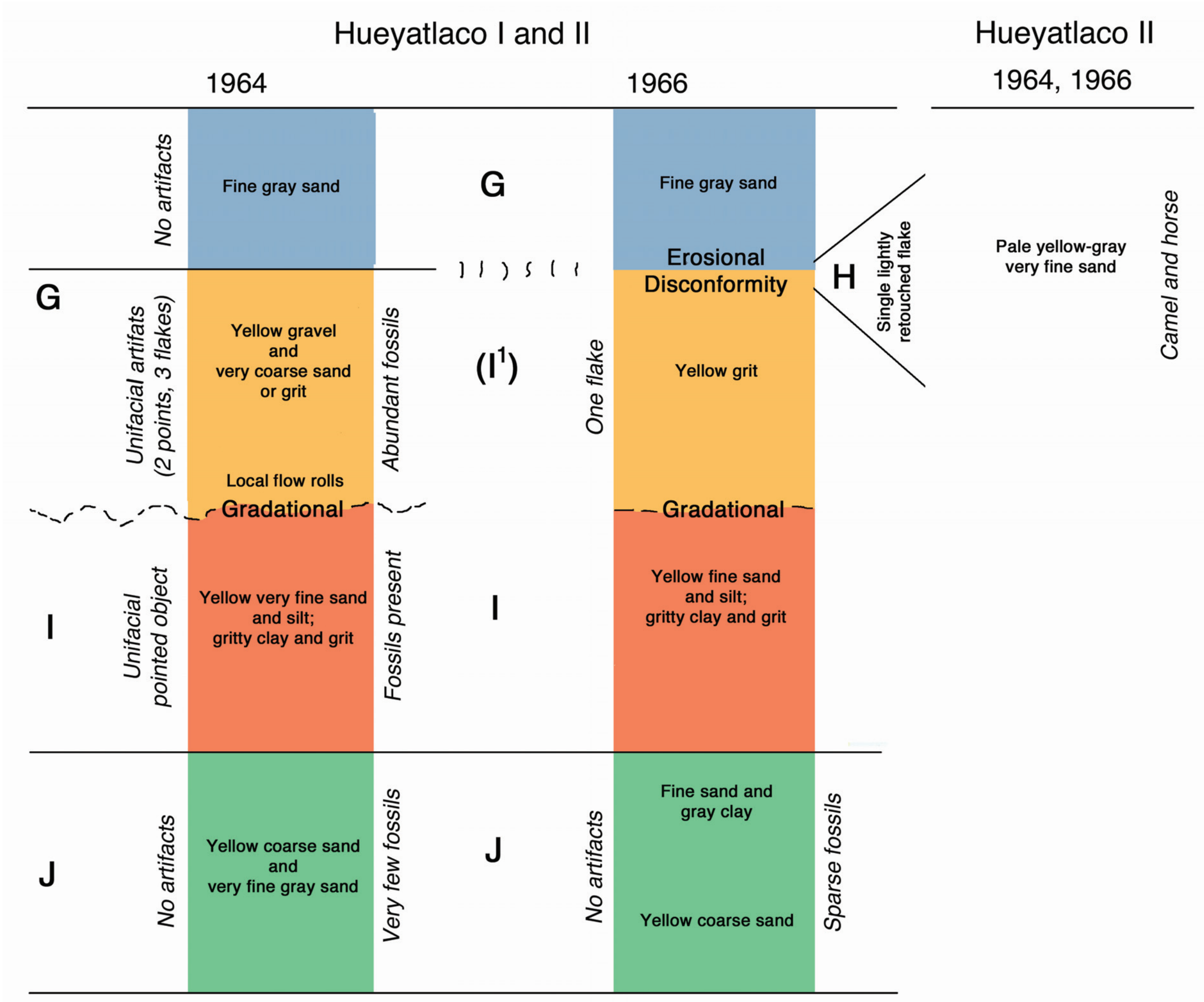

FIGURE 4. Chart compiled from the Irwin-Williams open file INAH reports (1964, 1966), showing her changes in names for deposits G through J, and her assignments of artifacts and fossils.

field work on La Malinche had disclosed many volcanic events and glacial features, as well as buried soils for which USGS radiocarbon dates in the ca 7,000 - 26,000 year age range exist (Malde, 1966; Kelly et al., 1978). At the time it was thought that the Valsequillo sites, including Hueyatlaco, were on the order of 20,000 years old. Unfortunately, no volcanic units that could be reliably correlated with beds of volcanic ash at Valsequillo were found (Steen-McIntyre and Malde, 1970). Similarly, reconnaissance on the eastern slope of Popocatépetl volcano across the valley proved unrewarding.

In 1964 and 1966, C.E. Ray, a vertebrate paleontologist at the U.S. National Museum, collected fossil vertebrates at 25 localities in the Valsequillo area under the guidance of J. Armenta; one locality from which Ray collected was at Hueyatlaco itself. In 1964 Ray was joined by M. Pichardo, then a graduate student. Pichardo's interest in Valsequillo continued, and he has recently published papers on the horses (Pichardo, 2002, 2004) and the mammoths (Pichardo, 2005). Ray, however, soon delegated work on the Valsequillo vertebrates to R. Graham, then at the Illinois State Museum. Graham's research on Valsequillo fossils remains unpublished. The fossil collections have long since been returned to Mexico. A partial list of the fauna prepared by Pichardo (2005, table 1) enumerates many larger forms but, curiously, none that are typical of a riparian or lacustrine habitat; animals such as beaver, muskrat, otter, waterfowl, amphibians, and fish are absent. Also, Arvicoline rodents (microtines) considered to be particularly precise for biochronological dating, have so far been generally overlooked, although Armenta Comancho (1978, Figure 7-1) illustrated a small fully articulated rodent skeleton.

TABLE 1. Partial list of the Valsequillo fauna, by M. Pichardo, 1966. The Tetela fauna includes collections from the Valsequillo Gravels peripheral to the Valsequillo Reservoir. The Barranca fauna includes collections from detached alluvial outcrops north of the reservoir, thought at the time to be graded to the Valsequillo Gravels. *Equus* sp. B from the Barranca fauna was found at Bca. de Santa Tlanepantla with shells dated 20,780 ± 800 BP (W-1897). Molars of *Equus* sp. C from the Barranca fauna was found as "float" at Bcas. Caulapan and Xochiac (Zacachimalpa). *Equus* sp. D from the Tetela fauna is known only from La Mata on Rio Alseseca near Totimehuacan. *Camelops* from the Barranca fauna was found at Bca. de Caulapan about 1.6 km upstream from locality R14 and tentatively assigned to beds higher than the basal part of R14.

TAXA	BARRANCA 'FAUNA'	TETELA 'FAUNA'
Equus sp. A	X	
Equus sp. B	X	X
Equus sp. C (stilt-legged horse)	X	X
Equus sp. D		X
Camelops	X	X
Tanupolama		X
Platygonus		X
Mylohyus		X
Tetrameryx		X
Capromeryx		X
Odocoileus	X	
Euceratherium		?
Bison	X	
Mammuthus	X	X
Cuvieronius		X
Mammut		?
Canis (large)		?
Canis (small)		X
Urocyon		X
Felis (large)	X	
Dinobastis		X
Neochoerus		X
Other rodents	X	X
Sylvilagus		X
Megalonyx	X	
Dasypus	X	
Chlamytherium	X	X
Brachyostracon	X	X

In the 1960s, the German Society for Scientific Research (Deutschen Forschungs-gemeinschaft) mounted a broad interdisciplinary study of the Puebla-Tlaxcala region that embraced geological and paleontological investigations. Conspicuous among the numerous book-length reports, is an opus by Guenther et al. (1973). This report, along with less comprehensive reports by Graham (1978) and Pichardo (1999) that together assigned the Valsequillo fauna to the late Pleistocene, was summarized by González et al. (2006). On the other hand, C.A. Repenning (Repenning, personal commun. to HEM, 2002) took a broader view. After discussing the presence of *Bison,* which is limited to the "Barranca fauna" (from the Caulapan barranca some 5 km northeast of Hueyatlaco), Repenning pointed out that *Smilodon gracilis* from El Horno (Kurtén 1967), which is at the base of the Valsequillo Gravels, is at least 840,000 years old. Repenning then referred to two pronghorn genera, *Tetrameryx* and *Capromeryx,* as being Irvingtonian age or older. To summarize, Repenning concluded that several forms of fauna from the Tetela Peninsula, where the Hueyatlaco and nearby El Horno sites are located, are distinctly NOT known to be as young as *Bison*. According to Bell et al. (2004), *Bison* is associated in North America with a maximum date of about 200 k.y.

USGS geologist D.W. Taylor (Taylor, personal commun. to HEM, 1967) described the ecology of fossil mollusks that were collected from alluvium at locality R14 in Barranca de Caulapan, a tributary of the Valsequillo Reservoir some 5 km northeast of Hueyatlaco, where one artifact had been found (Figure 7). His report is of interest because it classified the more than two dozen species according to habitat and age ranging from about 9 k.y. at the top of the section to more than 35,000 k.y. at the bottom, according to radiocarbon dates reported in 1966 by M. Rubin of the USGS radiocarbon laboratory (Malde, 1966; Kelly et al., 1978). Taylor concluded that the environment changed from perennial fresh water in the lower, coarser part of the section to seasonal or intermittent flow at the top. None of the species is extinct, but a few of the forms are not known to live presently in the area.

The dated Caulapan sequence also contained several tephra horizons and a single worked chert flake from near the base, associated with a 14C age of about 22 k.y. (sample 66-R-14, E, W-1895, Malde, 1966; Kelly et al., 1978) and a similar U-series age (Szabo et al., 1969.) There was hope that the tephra layers would correlate with the volcanic units exposed at the reservoir sites and that

AGE			DESCRIPTION	
Recent	Lava flows		Basalt, in part covered by pumice lapilli	
			ARROYO CUTTING	
Pleistocene	Valsequillo Gravels		Alluvial sand, clay, and gravel, 30 m thick. Lahar member from La Malinche in middle part and Tetela mud member with pumice boulders from Popocatépetl at top. Vertebrates and artifacts. Volcanic ash and lapilli markers..	
			ENTRENCHMENT OF VALLEY	
Pleistocene	Basin Deposits	Surficial deposits	Bedded lacustrine and subaerial clay and sand, 20 m thick. Local basaltic lava.	
Pleistocene	Basin Deposits	Batan lahar	Mudflow 25 m thick, from Popocatépetl.	
Pleistocene	Basin Deposits	Atoyatenco lake beds	Bedded lake clay and sand, 36 m thick, in massive brown and gray layers.	
Pleistocene	Basin Deposits	Xalnene tuff	Water-laid basaltic tuff from subaqueous vent surmounted by subaerial cinder cone and lava.	
Pleistocene	Basin Deposits	Amomoloc lake beds	Red and gray lake clay, silt, and nodular limestone, 30 m thick.	
			DEVELOPMENT OF THICK CALICHE	
Pliocene	Aguayo lahar		Dissected mudflow 100 m thick from Popocatépetl Other lahars of comparable position classed as Undifferentiated mudflows.	
			EROSION AND GENTLE WARPING	
Pliocene	Ixcalo lava		Basaltic andesite flows aggregating 200 m thick that form ridge of hills at south border of Puebla Valley.	Undifferentiated volcanic rocks
			CONFORMABLE CONTACT	Undifferentiated volcanic rocks
Pliocene	Caulapan tuff		Well-bedded to massive siliceous tuff, tuff-breccia, and volcanic conglomerate at least 400 m thick that forms dissected upland at south edge of Puebla Valley.	Undifferentiated volcanic rocks
			EROSION	Undifferentiated volcanic rocks
Miocene	Intrusive Igneous Rocks		Felsic volcanic plugs at Cerro Coatepec and Cerro Navajas.	Undifferentiated volcanic rocks
			MAJOR FOLDING AND EROSION	
Oligocene and Eocene	Balsas Group		Limestone conglomerate; red mudstone matrix.	

FIGURE 5. Chart showing the main stratigraphic units in the Valsequillo region.

their age could be implied that way, but again, disappointment. No correlation was possible.

The Early Uranium-series Dates

In 1969, B. Szabo of the USGS measured several uranium-series ages on specimens from

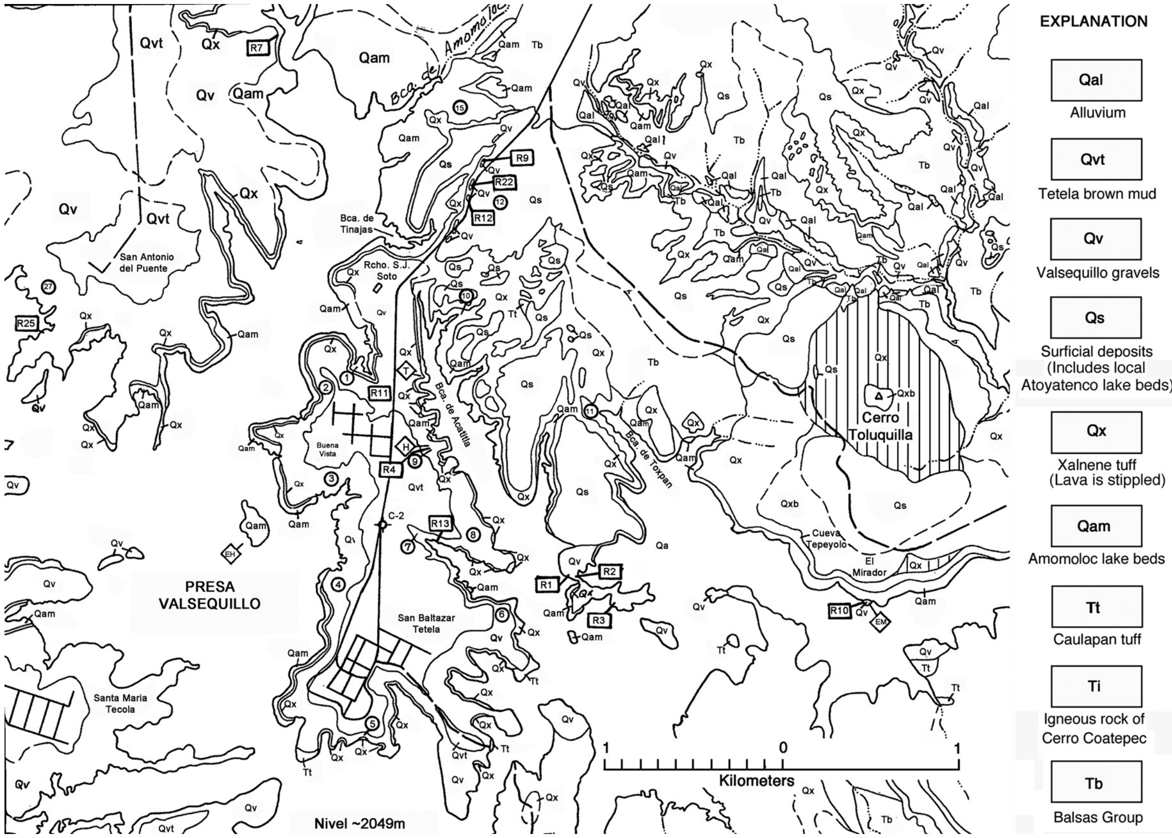

FIGURE 6. Geologic map of the Tetela Peninsula area, Valsequillo, Mexico, completed by Harold E. Malde, 1964-1966.

Valsequillo (Szabo et al., 1969; Steen-McIntyre et al., 1981). This technique was then in its infancy for application to terrestrial deposits, and Szabo chose to analyze a variety of materials, including a bone and a tooth fragment from Valsequillo; proboscidean bones from Barranca de Caulapan (where shells had previously been dated by the radiocarbon method); a bison bone from the Lindenmeir site in Colorado; and a bison skull from an alluvial terrace, also in Colorado. In general, his ages for Caulapan and the Colorado samples agreed with other determinations, but the results for the Valsequillo specimens were considered by Irwin-Williams to be wildly too old—in a word, “impossible” (Irwin-Williams, personal commun. to HEM, 1969). In particular, bone from an articulated camel pelvis in Unit C, a layer with bifacial tools, gave a protactinium-231 age greater than 180 k.y. and an open-system thorium-230 age of 245 ± 40 k.y. Furthermore, a tooth from a butchered mastodon at the El Horno site, 16 m topographically and stratigraphically lower than Hueyatlaco (Figure 1), gave a protactinium-231 age greater than 165 k.y. and an open-system thorium-230 age greater than 280 k.y. Because Irwin-Williams judged these dates to be incompatible with her archaeological findings, and indeed with all prior archaeological thought (Szabo et al., 1969; Irwin-Williams, 1981), she essentially dropped interest in Valsequillo. The Valsequillo dates were also rejected by González and her associates (Gonzalez et al., 2006) on the grounds that leaching or recent uptake of uranium by the bones was possible, even though Szabo (Szabo et al., 1969; Steen-McIntyre et al., 1981; Malde and Steen-McIntyre, 1981) had used an open-system model for some measurements and further obtained results essentially concordant with ages derived by independent means.

Fission-Track Dates

Three volcanic deposits are preserved at Hueyatlaco, topographically above the layers with artifacts. The oldest layer is the Hueyatlaco ash, a 1 m thick layer 2.5 m above the highest artifact-containing bed. Next is the Tetela brown mud, a lahar 1 m thick and 4 m above the Hueyatlaco ash. The Tetela brown mud contains abundant pumice fragments of varying size. Above the Tetela brown

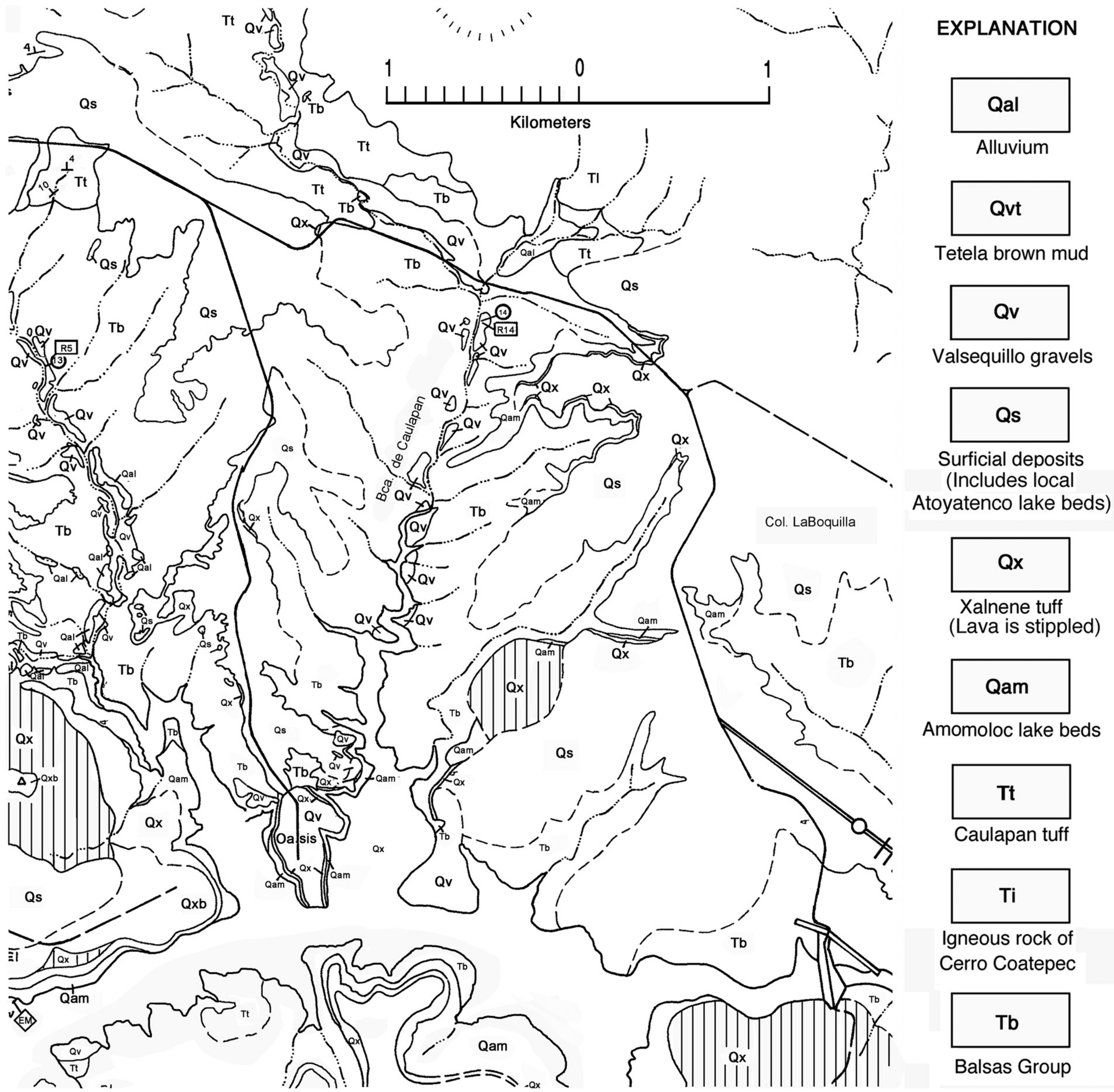

FIGURE 7. Geologic map of the Barranca de Caulapan area.

mud is the Buena Vista lapilli, an air fall layer as much as 30 cm thick that is preserved in places directly on the Tetela brown mud (Figures 8, 9, and 10). In 1973, one author (CWN) using small samples of 10 grains each, obtained 2-sigma fission-track ages of 370 ± 200 k.y. for zircons from the Hueyatlaco ash and 600 ± 340 k.y. for zircons from pumice in the Tetela brown mud (Steen-McIntyre, 1981, 1985; Steen-McIntyre et al.,1981). The small numbers of fossil tracks counted (12, 13) account for the relatively large uncertainty. Naeser's results were later confirmed by R. Donelick and K. Farley (Payn, 2006, Farley and Donelick interviews). González et al. (2006) rejected Naeser's fission-track ages relying instead on radiocarbon dates from Barranca de Caulapan (Szabo et al., 1969, Kelly et al., 1978) that are judged by them to be more compatible with archaeological thought. They further comment (p. 617) that Naeser's dates, together with the Szabo et al. (1969) uranium-series results, are ". . . rejected by the majority of archaeologists and paleontologists."

Tephra Hydration Ages, Mineral Etching

Between 1970 and 1973, Steen-McIntyre continued her examination of pumice and ash from the Hueyatlaco area and the flanks of the surrounding volcanoes. She examined hundreds of tephra

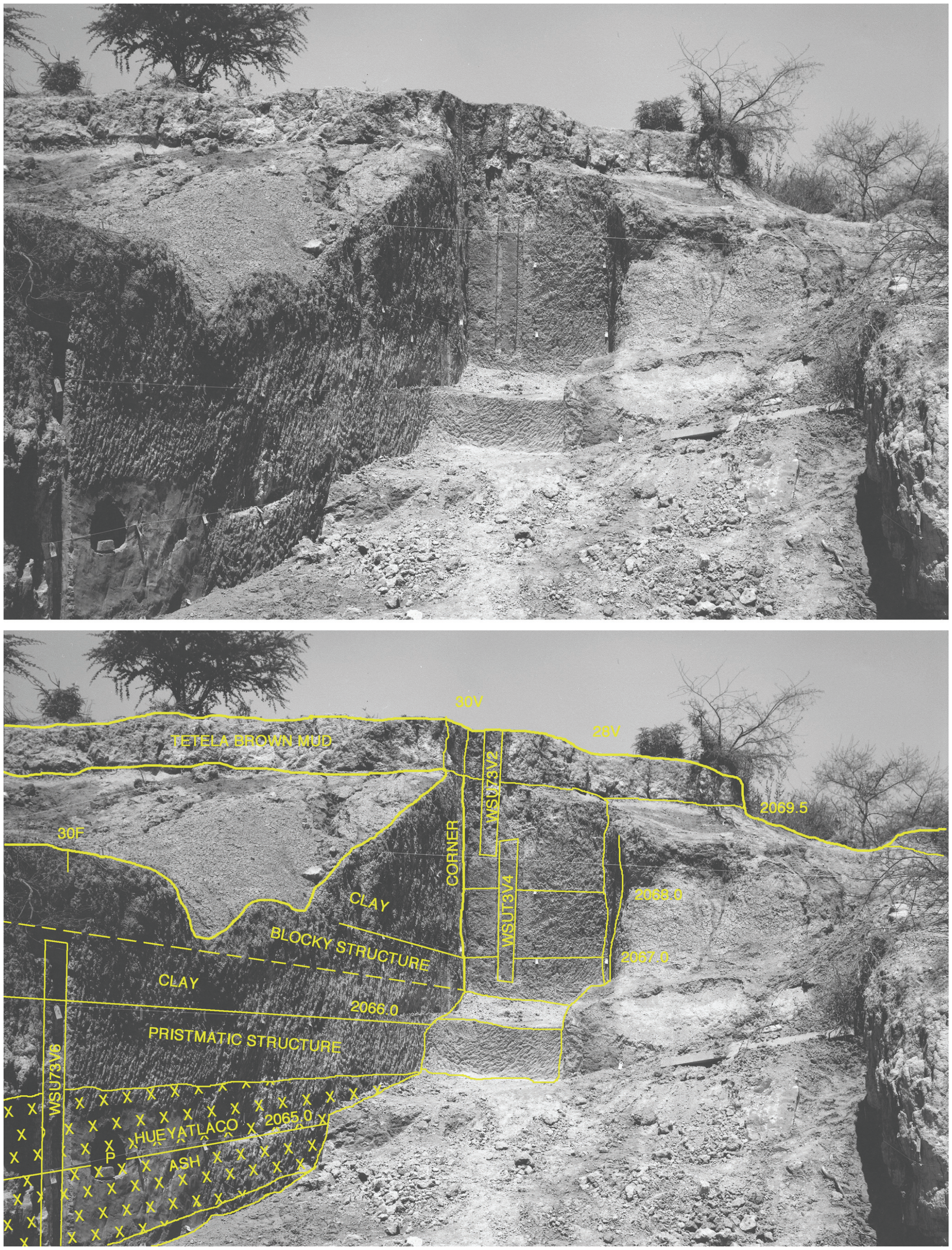

FIGURE 8. Fryxell photo 315, showing Hueyatlaco ash overlain by Tetela brown mud 4 m higher at 1973 grid points 28V to 30F.

samples with the same results: no recognized correlations. Only gradually did the idea surface that Szabo's U-series ages (Szabo et al., 1969) could be correct, and that correlations were not possible because tephra layers correlative with the Hueyatlaco material were much older and deeply buried in the flanks of the volcanoes, making sampling impossible.

As a parallel research project, Steen-McIntyre had been studying Friedman's obsidian hydration dating technique, which had been used to rough-date obsidian artifacts (Friedman and Long, 1976; Friedman and Smith, 1960.) Not only could the

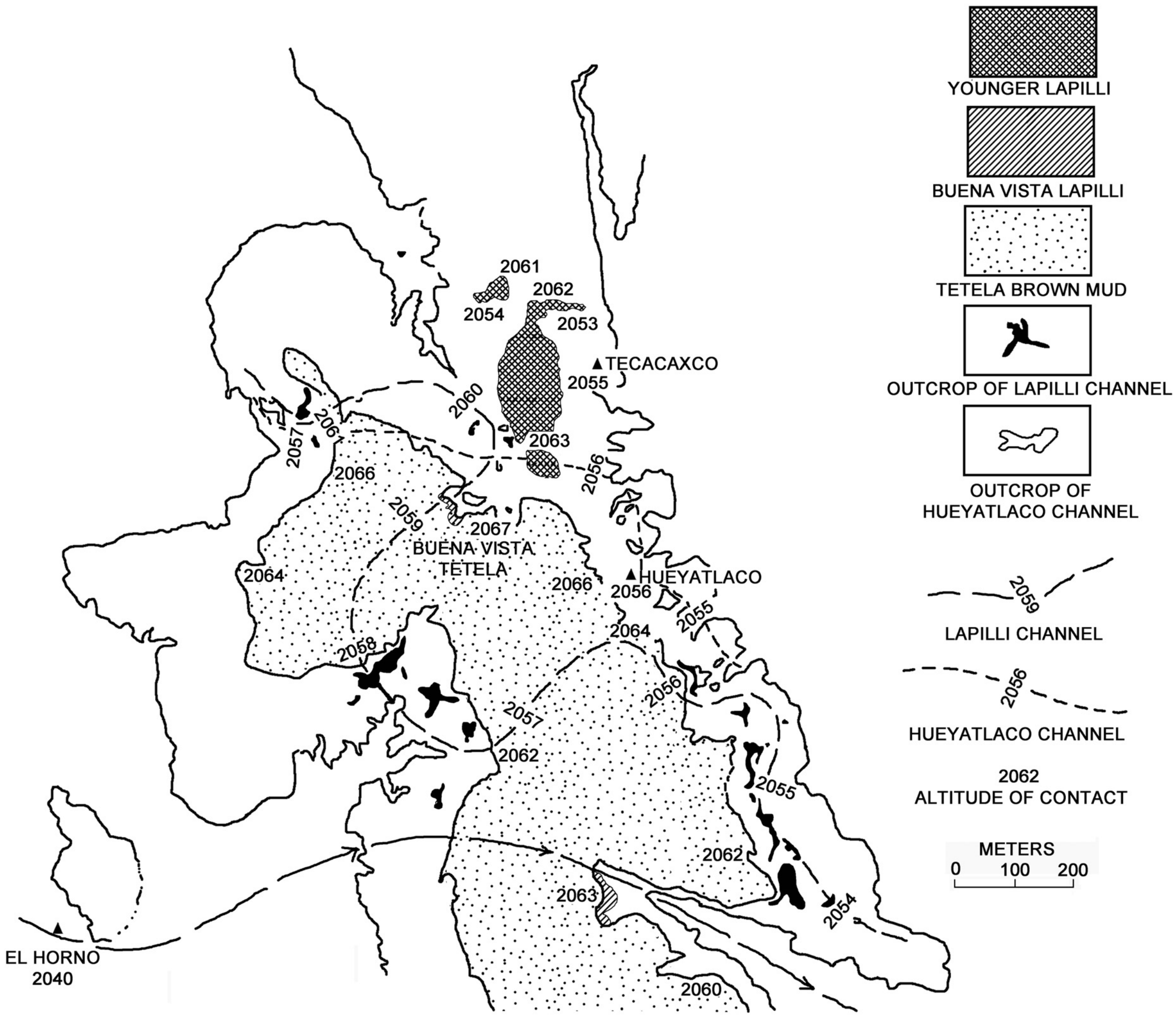

FIGURE 9. Map of the northern part of the Tetela peninsula, showing outcrops of Tetela brown mud, Buena Vista lapilli, and a younger lapilli.

same technique be used on tiny, silica-rich volcanic-glass shards, but Roedder and Smith (1965) found that after the volcanic glass was completely hydrated, water continued to accumulate, molecule by molecule, in bubble cavities enclosed in the glass, a process that could take millions of years.

Combining these two techniques, which she called the tephra hydration dating method, Steen-McIntyre found that, indeed, the extent of hydration and superhydration of the glass shards were very different for the suite of samples collected on the volcanoes and from the Hueyatlaco suite. Dated samples from La Malinche volcano, ranging in age from roughly 7 to 26 k.y., were mostly incompletely hydrated, with only the oldest specimens showing complete hydration and only a minute amount of water in the tip of small spindle-shaped vesicles. In contrast, all of the volcanic glass samples from the Hueyatlaco suite were completely hydrated and showed considerably more water in the vesicles (Steen-McIntyre, 1975, 1977, 1981, 1985, 2006.) Further comparison with silica-rich volcanic glass shards dated from other areas placed the Hueyatlaco tephra samples at roughly 250 k.y. (Steen-McIntyre, 1977, 2006; Steen-McIntyre et al.,1981).

In addition to the extent of superhydration of the volcanic glass shards from the Hueyatlaco tephras, hypersthene phenocrysts found in them showed excessive etching by groundwater (Steen-McIntyre, 1977, 1985; Steen-McIntyre et al., 1981.) By contrast, hypersthene phenocrysts from tephra samples from the region dated at 22-24 k.y. showed only incipient etching. Younger units completely lacked etching (P.W. Lambert, personal commun. to VSM, 1973.).

FIGURE 10. Malde photo taken June 6, 2004, showing outcrop of Tetela brown mud overlain by light-colored Buena Vista lapilli at an ensenada 600m south of Hueyatlaco.

The 1973 Geologic Excavation

In 1966, J.L. Lorenzo dug two parallel east-west trenches some 10 m south of the area excavated by Irwin-Williams (Irwin-Williams, 1967b; Lorenzo, 1967). Lorenzo's southernmost trench proceeded eastward from the Tetela brown mud and reached a depth, in places, as much as 5 m below the Hueyatlaco ash (Figure 11). In 1973 two of the authors (HEM and VSM) connected Lorenzo's trench with the area excavated by Irwin-Williams to determine the stratigraphic relationship between the Hueyatlaco ash and higher deposits to the layers containing her artifacts. They collaborated with R. Fryxell of Washington State University. Fryxell brought to Hueyatlaco his considerable experience mapping microstratigraphy at archaeological sites and his knowledge of preserving important artifacts in situ in blocks of undisturbed sediment. Fryxell's skill was particularly useful in collecting stratigraphic monoliths from the trench walls, stabilized sediment sections up 2 m tall that sampled the total exposed section at the site (Figure 12). These monoliths have since proven to be a valuable resource. Fryxell also took many high-resolution photographs of the excavation, some of which are discussed here. Although Fryxell died in 1974, his Hueyatlaco research unfinished, his profile drawings, photographs, and the stratigraphic monoliths survived.

The 1973 excavation confirmed the stratigraphy described by Irwin-Williams, namely that the layers with bifacial artifacts (Units C and E) overlaid the layer with unifacial artifacts (Unit I). Of greater interest, however, was the discovery of a layer called "sand grading laterally to clay" that continued beneath the Hueyatlaco ash. This layer was mapped as resting on Units B, C, and E, placing all the artifacts below the Hueyatlaco ash and, therefore, also beneath the Tetela brown mud and the Buena Vista lapilli (Figures 13, 14, 15). (Steen-McIntyre et al., 1981).

In a further attempt to establish a chronology for the Hueyatlaco deposits, two oriented samples for paleomagnetic measurement were collected from the Hueyatlaco ash and from underlying clay (Figures 8 and 13). These samples were both found to exhibit normal polarity (Liddicoat et al., 1981), interpreted to represent the Brunhes magnetozone. However, González et al. (2006) consider this attempt to place the Hueyatlaco site within the paleomagnetic time scale unsuccessful.

New Ages for Hueyatlaco Volcanic Ash Deposits

In 1997, M. Payn, an engineer, organized further fieldwork at Hueyatlaco, and began a video record of the work. One of his first tasks was to obtain additional dates from the volcanic deposits. Consequently, Steen-McIntyre aided A.L. Martín, a volcanologist at the Mexican National University (UNAM), in collecting samples from the Hueyatlaco ash and what they mistakenly thought to be an outcrop of Buena Vista lapilli. Later petrographic work by D. Geist, University of Idaho, showed the latter

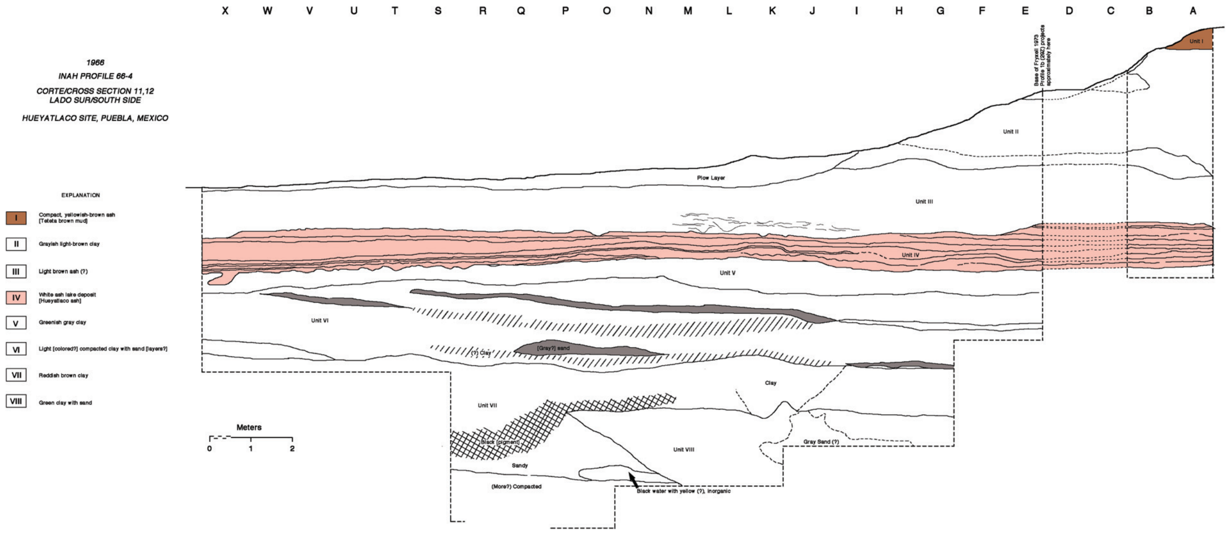

FIGURE 11. INAH profile 66-4 (1966), extending from Tetela brown mud at the upper right to a depth about 11 m lower. Irwin-Williams, in her unpublished 1966 open-file report to the INAH, considered Unit VIII to be equivalent to her Unit I.

to be a somewhat younger lapilli of andesitic composition (Figure 9).

In 1998-1999, T.A. Dumitru of Stanford University concentrated zircon crystals from these samples, and R.A. Donelick, then at Rice University, determined fission track ages of the zircon crystals. Zircon (U-Th)/He isotopic ages for the Hueyatlaco ash were determined by K.A. Farley of the California Institute of Technology. The dating had been conducted with contracts from M. Payn, to whom these investigators independently reported their results. Later they wrote a joint preliminary report and submitted it to Payn. These dates are discussed in the report and in a Payn video (2006, OCLC number 76906782,).

Donelick obtained a fission-track age of 212 ± 47 k.y. (212 ± 94 k.y. two standard deviations, CWN) from one sample of Hueyatlaco ash zircons and an age of 250 ± 52 k.y. (250 ±104 k.y. two standard deviations, CWN) for a second sample. Using two other splits, Farley got a zircon (U-Th)/He isotopic age of from 413 to 505 k.y. for one split and from 406 to 504 k.y. for the other, indicating excellent agreement between the two samples. Donelick determined fission-track ages of 232 ± 86 k.y. (232 ±172 k.y. two standard deviations, CWN) and 303 ± 58 k.y. (303 ±116 k.y. two standard deviations, CWN) for two splits from the andesitic lapilli (Payn, 2006, time ca 0:40-0:50, Donelick and Farley interviews.)

These are fairly consistent results in the realm of isotopic dating, considering that the samples are relatively young; but the question of why the reported ages don't agree more closely remains. However, Donelick and Farley, in their report to M. Payn, pointed out that the fission-track dates are a minimum and that the zircon (U-Th)/He method is inherently more precise. Donelick agreed with the judgment that the helium dates were more accurate, but in the end they chose to report, impartially, an age for the Hueyatlaco ash between 212 ± 47 k.y.(212 ± 94 k.y. two standard deviations, CWN) and 406 - 505 k.y., thus covering the full range of the analyses. Even so, their final word in the report was that "the true age of these zircons lies closer to 0.406 Ma than to the upper limit" (Payn, personal commun. 1999.)

Early Diatom Studies by S.L. VanLandingham

About 30 years ago, diatom paleontologist S.L. VanLandingham, stumbled onto a reference slide of diatoms at the California Academy of Sciences in San Francisco, which had been scraped from diatomite inside a fossil human skull. The Dorenberg skull, which has been missing since the World War II bombing of Leipzig, had been collected south of the city of Puebla in 1899. VanLandingham identified the diatoms as being of Sangamon (or Late Tyrrhenian) age, about 80-220 k.y.). Because such knowledge being made public has been anathema to other careers, VanLandingham kept these data to himself until 1999, when he first read about Valsequillo in Cremo and Thompson's (1993) popular book on Early Man. He then contacted Steen-McIntyre, who had collected sediment samples from Hueyatlaco in 1973 (Figure

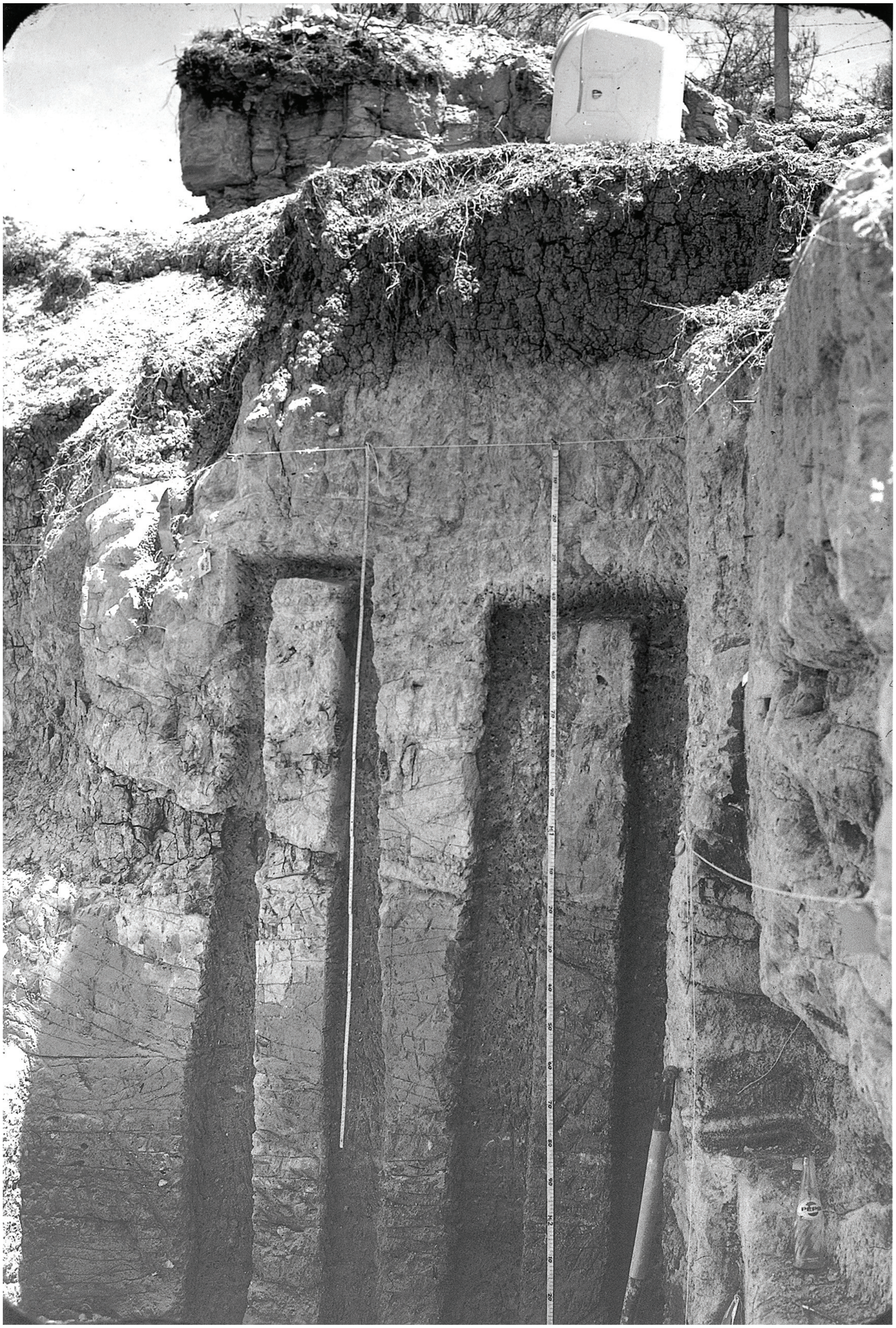

FIGURE 12. Steen-McIntyre photo, 1973, showing monoliths WSU73V16 and WSU73V17 between grid points 10.5 B and 11D.

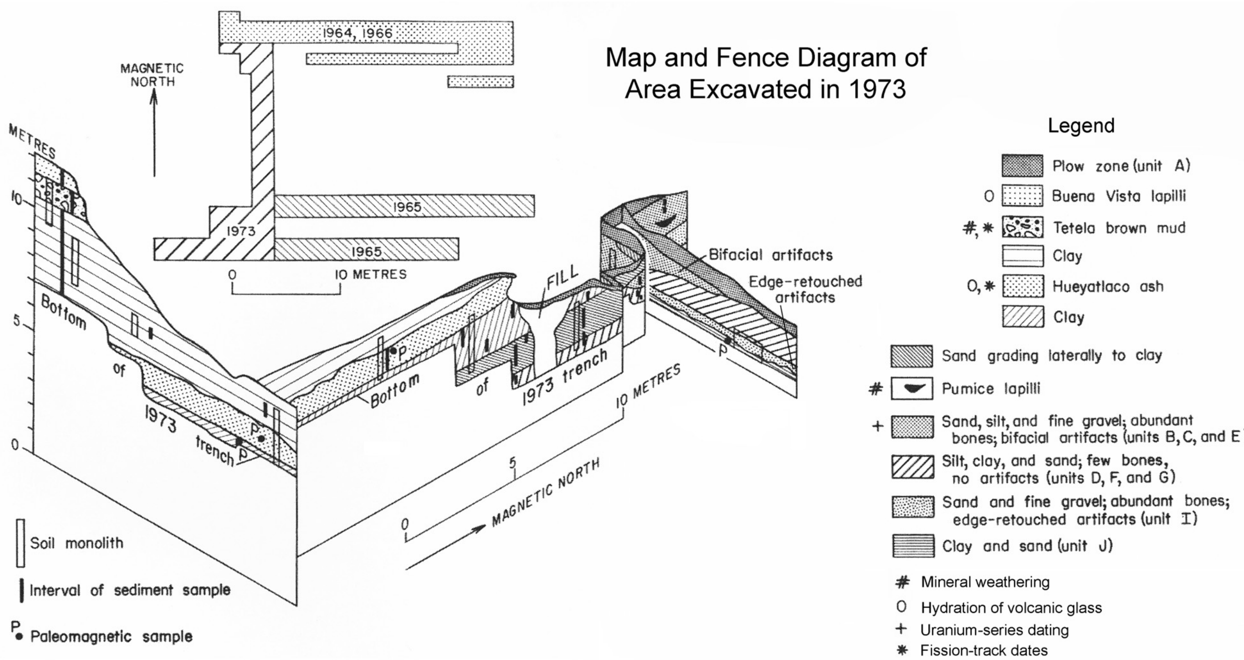

FIGURE 13. Map of area excavated in 1973 and fence diagram based on mapping done in profile at a scale of 1 to 20. The east-west section along the 1964-1966 trench is generalized from unpublished open file reports by Irwin-Williams to the INAH. Stratigraphic units identified by letter refer to units designated by her. Marginal symbols indicate various methods of dating: # mineral weathering; 0 hydration of volcanic glass; + uranium-series dates; and * fission-track ages. The positions of samples taken for sedimentary analysis and for paleomagnetic measurement are marked. Only one set of soil monoliths is shown, but a duplicate set was taken for the INAH. (Reproduced from Steen-McIntyre et al., 1981.)

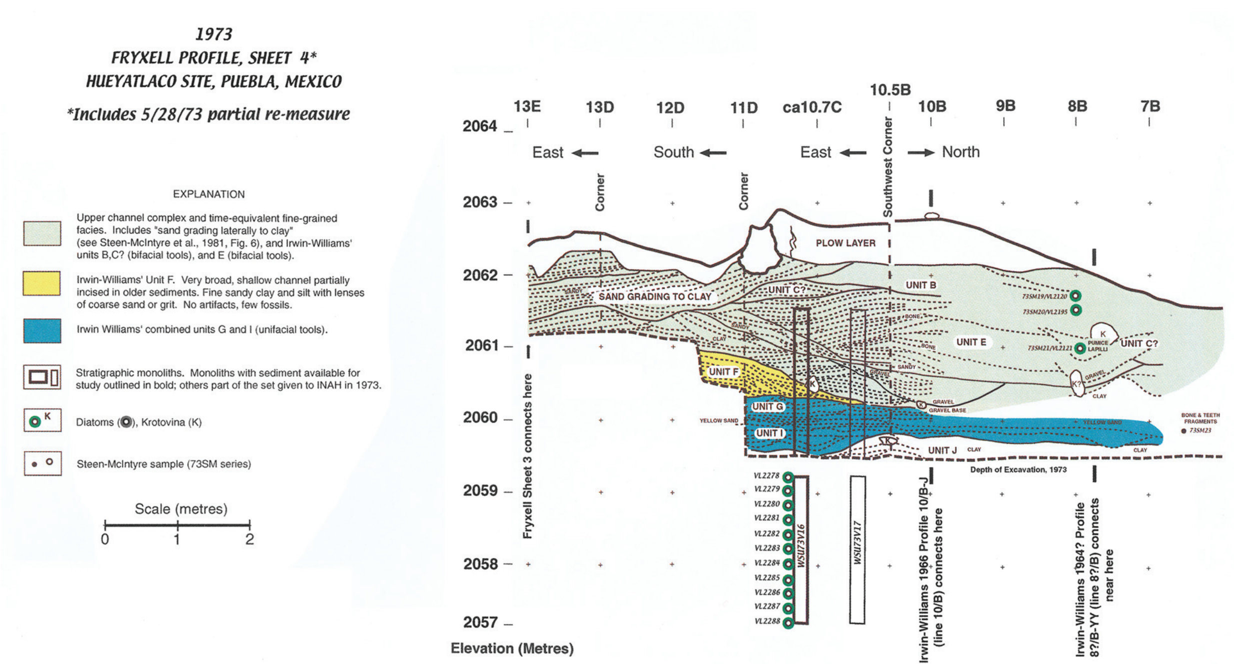

FIGURE 14. Fryxell Profile Sheet 4, Hueyatlaco site, 1973, with VanLandingham diagnostic diatom locations.

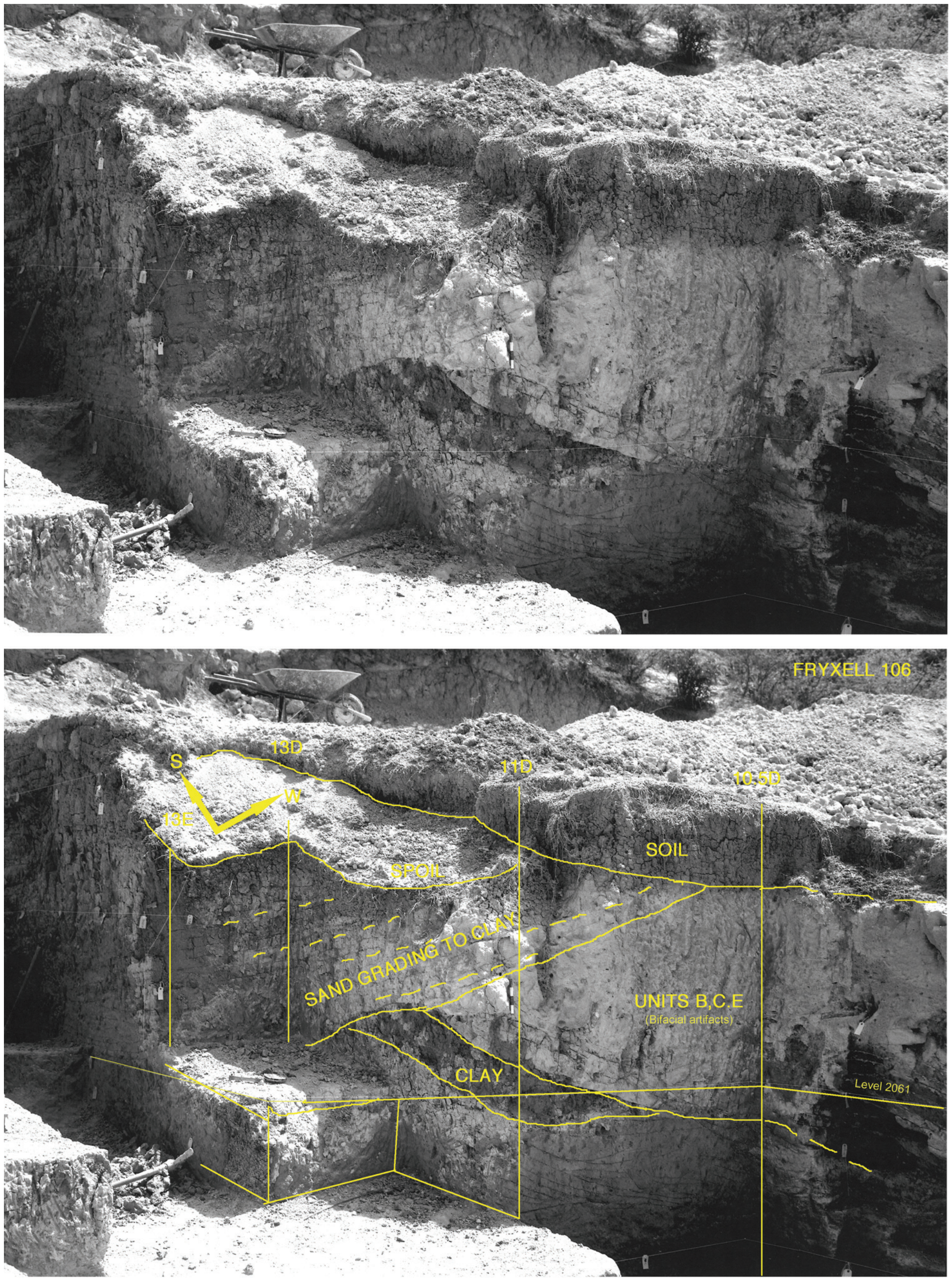

FIGURE 15. Fryxell photo 106, showing the 1973 trench from 13E to 9.5B. Level 2061 is marked by a string just below the middle. Above a dark lenticular layer of clay at the center and extending to the right are channel deposits designated as Units B, C, and E by Irwin-Williams (1967a), which yielded bifacial artifacts. These are steeply overlain at the center and to the left by southward dipping sandy beds. Because these beds flatten to the south and become clayey, they were described as "Sand grading laterally to clay" (Steen-McIntyre et al., 1981).

13). VanLandingham identified Sangamon aged diatoms in these samples. Furthermore, he found similar diatom taxa in his study of cores and samples that had been collected by Malde in the 1960s. (VanLandingham, 2004). He joined the Hueyatlaco field party in 2001.

The 2001 Field Season

Under the patronage of M. Payn, new archaeologic excavations were conducted at Hueyatlaco in 2001. A number of fossil vertebrates were found, but only a single problematical flake was recovered (Ochoa-Castillo et al., 2003). However,

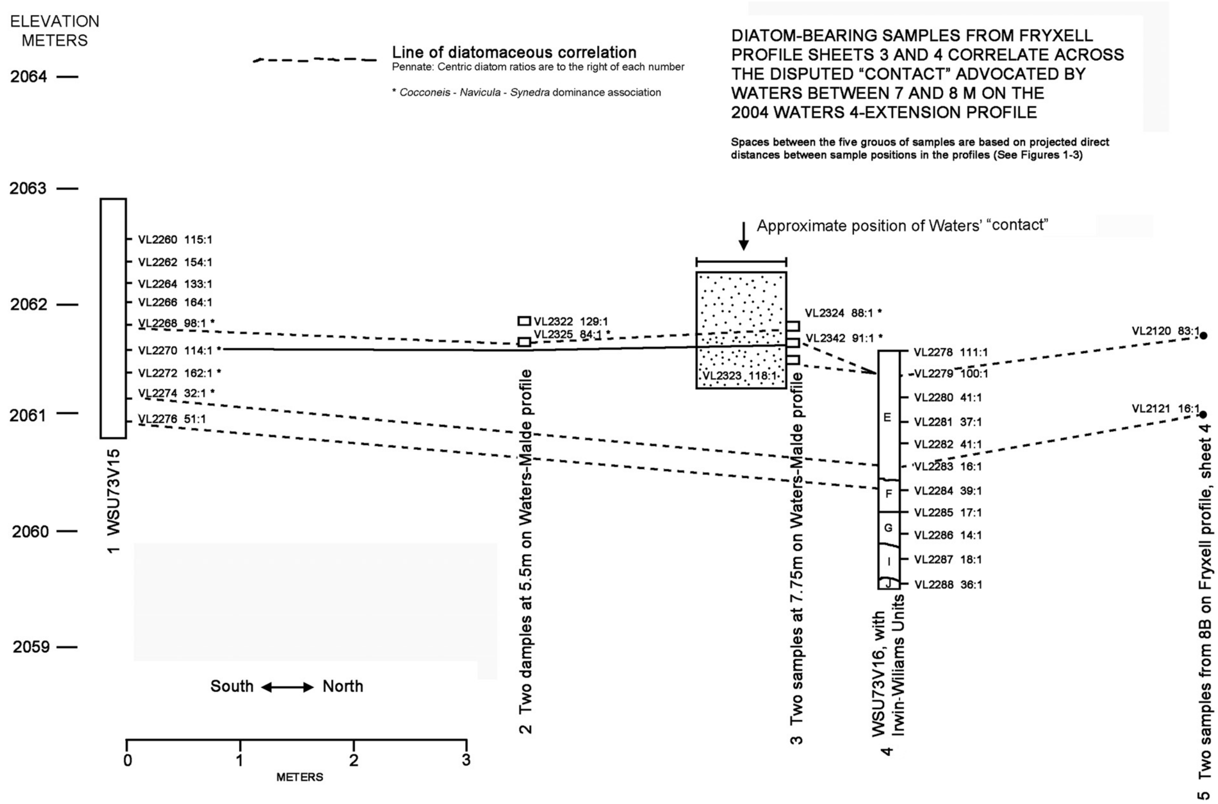

FIGURE 16. Chart showing diatom-bearing samples plotted on Fryxell Profile Sheets 3 and 4 (1973) and the 4-Extension Trench profile, which correlate across the disputed "contact" advocated by M. Waters.

Steen-McIntyre and petroleum geologist R. McKinney conducted geological studies, C. Hardaker video-recorded the work, and VanLandingham sampled and examined for diatoms. The Mexican contingent consisted of J. Arroyo-Cabrales, a vertebrate paleontologist from the INAH; P. Ochoa-Castillo, a ceramic specialist at the INAH; A.L. Martín, a UNAM volcanologist; and M. Pérez-Campa, an administrative archaeologist at the INAH. McKinney gave particular attention to collecting samples for thin section preparation and petrographic analyses. In the Hueyatlaco ash, McKinney found flattened bubble cavities, indicating that the material was hot when it landed, confirming its origin as an air fall.

The 2001 dig focused on three issues: 1) to dispel a charge of planting artifacts put forth by Lorenzo (1967); 2) to test the fission-track ages reported by Naeser (Steen-McIntyre, 1981, 1985; Steen-McIntyre et al.,1981); and (3) to allay the suspicion that the artifacts and bones had been redeposited.

In the eyes of the Mexican contingent, the unethical procedure of planting artifacts was ruled out by the continuity of the sediment. The fission-track age of the Hueyatlaco ash was confirmed by its similarity to new fission-track determinations and by the helium isotopic ages described above. Redeposition was refuted by the presence of articulated bones, suggesting deposition under relatively tranquil sedimentary conditions, and confirming conformable bedding in the geologic section.

Un-crating and Sampling the 1973 Monoliths

The stratigraphic monoliths originally collected at Hueyatlaco in 1973 by Fryxell and Steen-McIntyre, and which had been packed in five wooden crates, took several years to reach Denver. The fate of a duplicate set collected for the INAH is still unknown. In Denver, the sealed crates languished for several more years in various storage areas at the USGS Denver complex. Eventually, they were released to the care of Steen-McIntyre. The monoliths remained with her until 2002, when VanLandingham transported them to his laboratory in Midland, Texas. There, the opening of the crates was recorded on video, and the contents were examined and sampled by VanLandingham, Steen-McIntyre, and McKinney. Each monolith, still

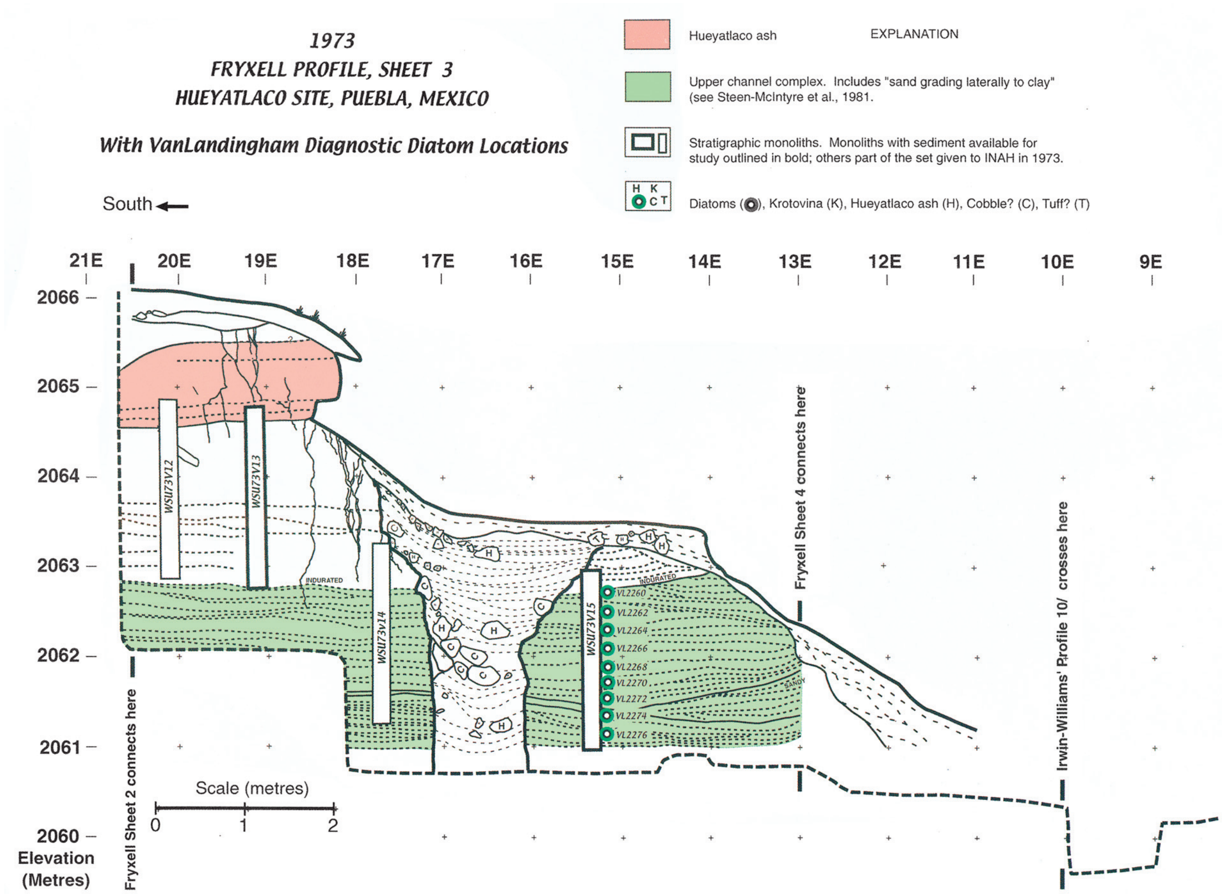

FIGURE 17. Fryxell Profile Sheet 3, Hueyatlaco site, 1973, with VanLandingham diagnostic diatom locations.

wrapped in burlap and tied to the board used to remove it from the trench wall in 1973, was mapped and photographed to provide an accurate record for selecting diatom samples as well as for other purposes. Monoliths WSU73V10, WSU73V15 and V16 were closely sampled for diatoms (Figures 14, 16, and 17). A sample from monolith WSU73V10 (Unit I, Figure 3) was sent to C. Falguéres at the Institut de Paleontologie Humaine, Paris, for possible Electron-Spin-Resonance (ESR) dating. C. Repenning was examining fossil hash from Units G, I, and J in monolith WSU73V10 provided by VanLandingham when he was killed.

The 2004 Field Season

Beginning in the 1990s, J.L. and R. Cramer of Denver established five archaeological research endowments for Paleoindian studies at western universities, one of which was Texas A&M University, where M. Waters manages the funds. Waters visited Hueyatlaco with J. Arroyo-Cabrales in 2003, and a new project was born. He located some of Irwin-Williams' files at the Smithsonian in 2003 and launched an excavation in May and June 2004, with colleagues Arroyo-Cabrales and P. Ochoa-Castillo. Steen-McIntyre and Malde joined the field party, and A.L. Martin made several brief visits. The 2004 excavation opened three trenches: one at the south boundary of the Irwin-Williams dig; another perpendicular to this at a place 7 m east of Irwin-Williams' southwest corner; and, of special importance for this discussion, a trench named the 4-Extension Trench that exhumed the Irwin-Williams west wall and extended more or less southward to the Hueyatlaco ash (Figures 18 and 19). The Irwin-Williams west wall also had been exhumed in 1973, as had some of her south wall. The 4-Extension Trench angled a bit to the southwest in order to end at an outcrop of the ash, and it missed the Irwin-Williams southwest corner by 0.75 m.

Also, three exploratory pits were dug west of the west wall, and an earlier Irwin-Williams pit in the eastern part of Hueyatlaco was reopened to obtain a sample of Xalnene tuff.

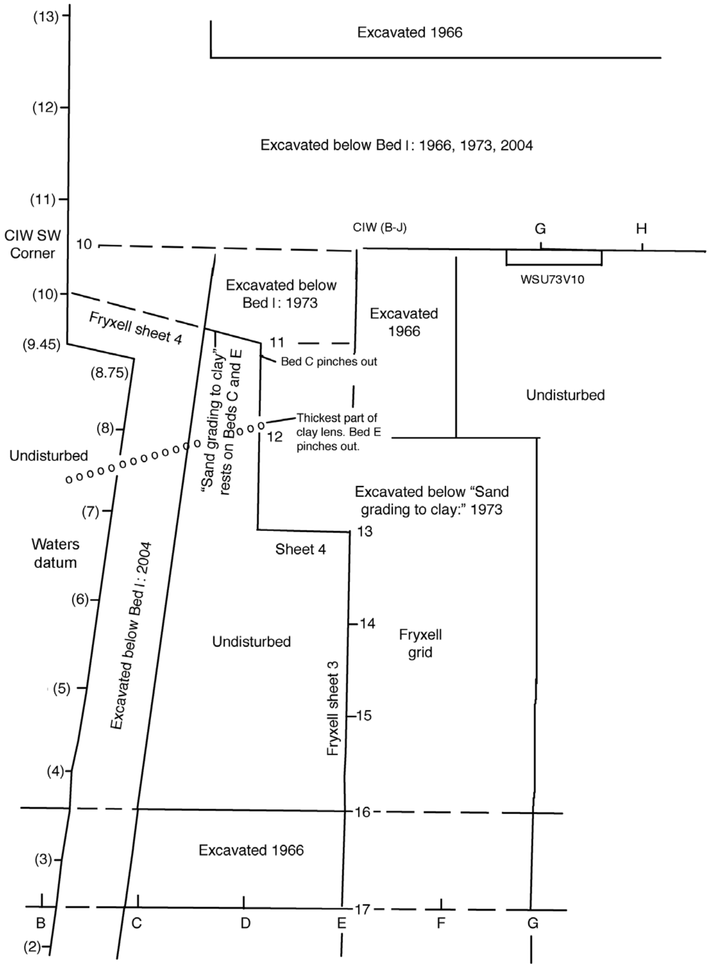

FIGURE 18. Map of the western part of the area excavated in 1966 and the northern part of the area excavated in 1973 and 2004. Grid marks for 1973 were established by Roald Fryxell, and those for 2004 were used by Michael Waters.

During the 2004 season, Steen-McIntyre collected samples for petrographic study (by McKinney) and for study of diatoms (by VanLandingham). A duplicate set of her samples also was submitted to the INAH for diatom analysis.

S.L. Forman of the University of Illinois at Chicago collected samples for, as it turned out, unsuccessful thermoluminescence dating. Also, P.R. Renne and K.B. Knight of the Berkeley Geochronology Center, California, collected samples of Hueyatlaco ash, Tetela brown mud pumice, Buena Vista lapilli, and Xalnene tuff for argon-argon dating (Figure 10).

The 4-Extension Trench showed that Irwin-Williams' Unit I, the layer that had produced unifacial artifacts, is about 4 m stratigraphically beneath the Hueyatlaco ash. The channel deposit Units C and E with bifacial tools, however, and the associated sterile Units B and D, were considered by Waters to be inset and unconformable with respect to the Hueyatlaco ash and the higher deposits, and much younger. This interpretation differs from the conformable stratigraphy interpreted by us in 1973 and reconfirmed in 2001. This conflict has led to the current debate, discussed in this paper.

The González Ages

González et al. (2006, Table 1) proposed a new series of ages for the Valsequillo Basin sequence and for the Hueyatlaco artifacts that are much younger -- 8-40 k.y. -- than our ages discussed in this paper This series was based on samples collected from Barranca Caulapan and on an erroneous age of ca 40 k.y. for the Xalnene basaltic ash/tuff from near the base of the exposed basin sequence. This last age was later retracted in favor of Renne?s 1.3 m.y. argon-argon age

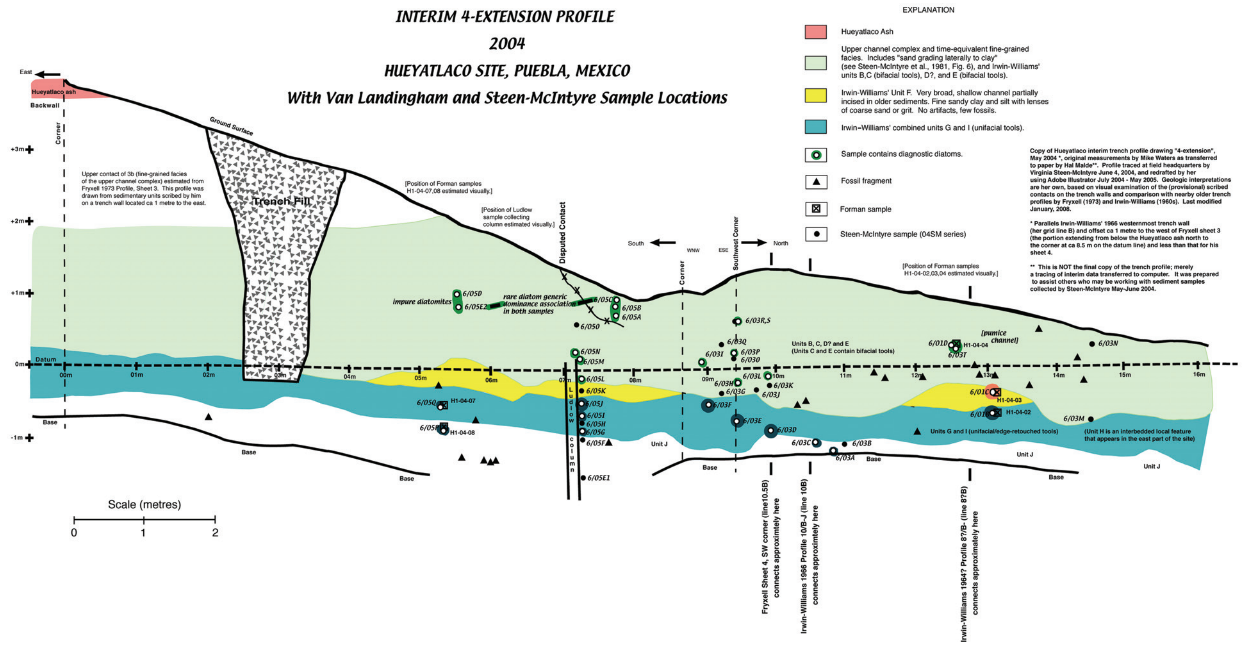

FIGURE 19. Waters 4-Extension Profile, Hueyatlaco site 2004, with VanLandingham and Steen-McIntyre sample locations (redrafted by V. Steen-Mcintyre, 2005). See also VanLandingham (2010a, Figure 4).

(Renne et al., 2005; Feinberg et al., 2009; Mark et al., 2010),

González et al. (2006) dated four shell samples from the Caulapan section using the radiocarbon AMS method and four samples from a mammoth tooth collected there using ESR/U-Series analysis. They (González et al., 2006, page 216) concluded "The Valsequillo Gravels in the Barranca Caulapan range in age from 9 to over 38 ka BP. These dates are more or less in agreement with the dates obtained in the 1960s and 1970s (Szabo et al., 1969, figure 5A)." They were unable to collect samples from the reservoir sites because the water level was too high, but they believed their Caulapan ages would apply there, assuming the (erroneous) 40 k.y. age for the Xalnene basaltic ash/tuff uncovered at the base of the Hueyatlaco excavation.

THE STRATIGRAPHIC DEBATE

The Inset Idea Proposed by Waters

On the Waters 4-Extension Profile (Figure 19), between horizontal datum 7.00 m and datum 7.75 m, a steeply inclined partial line marked with crosses is labeled as a "Disputed Contact." The upper half of this contact, the upper half-meter, is in modern soil, so the disputed portion is but 0.5 m thick. When this line is traced northward, it marks the base of a series of cross-bedded channel deposits that is about 2 m thick (preserved) at datum 11 m and datum 14 m. Using the nomenclature of Irwin-Williams, these channel deposits are designated Units B, C, D, and E, which include the layers that yielded bifacial artifacts. Waters identifies this contact as an unconformity and projects the contact upward through the disputed interval to the modern surface of the Tetela Peninsula some 10 m higher. In other words, he reconstructs an ancient stream channel 11 m deep, cut through the sediment stack containing the Buena Vista lapilli, the Tetela brown mud, and the Hueyatlaco ash, and of which only the lowest 2 m of sediment are preserved.

A related idea proposed by Waters is that the thick section of clay south of the disputed contact, and under the Hueyatlaco ash, is a vertisol. Bates and Jackson (1980) define a vertisol as "... a soil order that contains at least 30% clay, usually smectite ... found in regions where soil moisture changes rapidly from wet to dry, and is characterized by pronounced changes in volume with changes in moisture, and by deep, wide cracks and high bulk density between the cracks when dry."

Further, Waters questions the stratigraphic position of the unifacial artifacts assigned to Unit I (Payn, 2006, time ca 1:29-1:32, Waters interview). In particular, Waters has compiled a "statistical cross section" of the position of the artifacts based on notebooks kept by workers at the dig, presum-

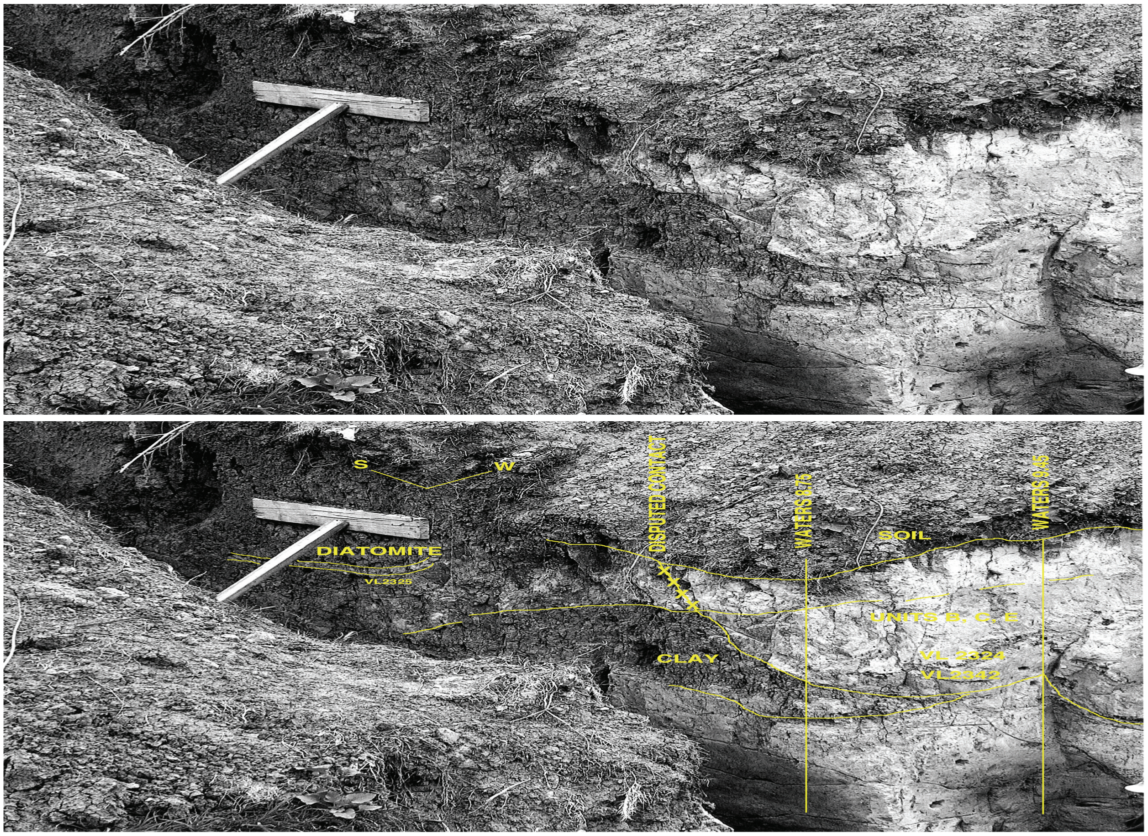

FIGURE 20. Malde photo taken June 4, 2004, showing the area of the disputed contact in the Waters 4-Extension Trench. The board on the right side of the trench is 0.8 m long.

ably reviewed by Irwin-Williams. Our interpretation of Waters' "statistical cross section" is that he reassigned some artifacts that he thought were mistakenly logged in an older bed (Payn, personal commun., 2006.) Waters seems to have repositioned repositioned the artifacts into a higher unit, not Unit I.

The Waters' concept of a younger stream channel inset, that is, cut down to its present level from somewhere above the Tetela brown mud unit and is now represented by 2 m of preserved sediment and 9 m of missing section is a "vacant hypothesis," in the sense that much of the evidence for its existence is assumed to have eroded away. The presumed unconformable relation of these deposits to topographically higher beds such as the Hueyatlaco ash and Tetela brown mud cannot be directly demonstrated. Where does this deep channel cross the Tetela Peninsula, given that the Tetela brown mud is continuously preserved on the peninsula above it, with no evidence of its being cut through by an ancient stream? (Figures 6 and 9). The evidence that follows makes us question the presence of Waters' deep channel.

The Levee Model

The concept of a deep inset may have resulted from digging a trench in a poor place to expose the "sand grading laterally to clay." This circumstance can be appreciated by comparing photographs of the disputed contact in the 4-Extension Trench and Fryxell's photo 106, which shows the area of Sheet 4 in the Fryxell profile (Figures 15 and 20). A comparison shows that outcrops of a lens of dark clay in the center of each photo are strikingly similar, and they both are overlain by lighter colored sandy material that dips southward, except that the lighter layer in Trench 4-Extension is thinner and less pronounced. Therefore, assuming that the outcrops of lighter material are correlative, part of the layer in Trench 4 may have been eroded, or otherwise reduced in thickness, leaving a layer only 1.5 m thick. This difference in thickness of the lighter layer was apparently a pitfall for Waters, and he drew the base of the channel steeply upward through the remaining 1.5 m of the lighter layer, making this the disputed contact. Nonetheless, as the photo shows, the lighter layer on the lens of dark clay in Trench 4-Extension con-

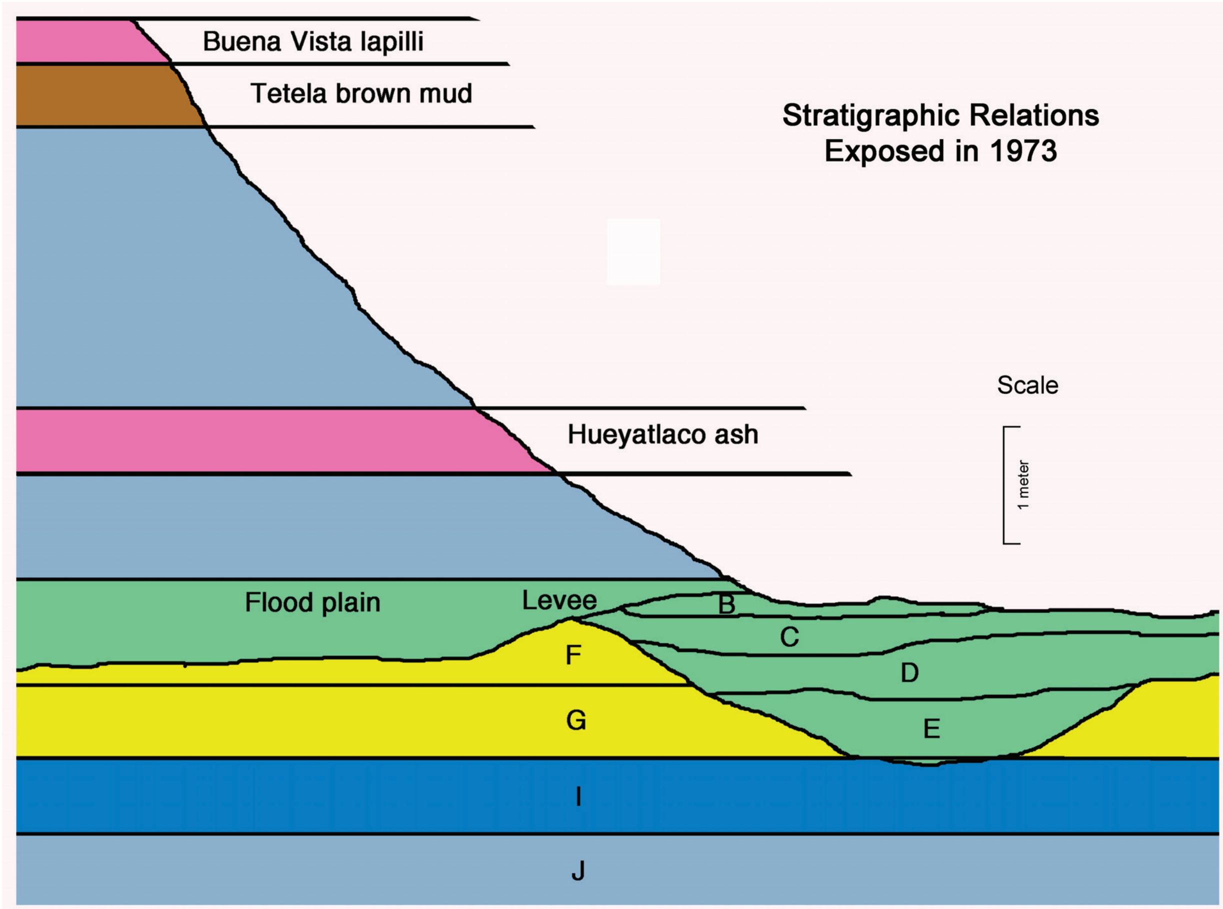

FIGURE 21. Diagram of the stratigraphic relations exposed in 1973, showing the inferred levee and its adjoining flood plain to the south, which were formed as a consequence of the channel (with Units B, C, D, and E) becoming filled to capacity, causing it to overflow.

tinues to the south at a downward dip, as does the "sand grading laterally to clay" in Fryxell's photo of the 1973 trench.

Waters did not ignore this lighter layer south of his unconformity. He attributed it to a "drying phenomenon," (Payn, 2006, time 1:22, Waters interview) which he suggests accounts for its lighter color. Our explanation for the lighter layer in Trench 4, and for the "sand grading laterally to clay," has nothing to do with drying, however. Rather, we conclude that this deposit can be understood as a culminating part of the channel, namely a consequence of the channel becoming filled with muddy water and overflowing. We interpret the "sand grading laterally to clay" to be a levee and its related flood plain.

Specifically, as the channel, with its bifacial artifacts, became filled with Units E, D, C, and B, the river overflowed, building a sandy levee on higher ground closest to the channel and depositing progressively finer sediment to the south (Figure 21).

A consequence of this inferred process is that the sediment south of the channel is bedded, not a structureless vertisol as interpreted by Waters. The light colored diatomite layer visible in the Malde photo (Figure 20) immediately beneath the wooden brace in Trench 4 contains evidence of the bedding. Indeed, the diatomite layer becomes flatter to the south, just as our interpretation requires. Also, evidence of bedding to the south is visible in Fryxell's photo 106 (Figure 15), and Sheet 3 (Figure 17) of his profile shows many flat-lying beds.

Diatoms vs. the Inset Idea

Numerous lines of diatom correlation contradict the proposed inset of Waters (VanLandingham, 2006, 2009a, 2009b, 2010a, and 2010b). Two sets of diatom samples link the deposits under the Hueyatlaco ash to the channel deposits of Waters' proposed inset (Figure 16). One set consists of

VL2268 (monolith WSU73V15, Figure 17), VL2325, (a diatomite 1.5 m south of the disputed contact, Figure 20), and VL2324 in the channel just north of the disputed contact, Figure 20. The second set consists of VL2270 (just below VL2268), and VL2342 (just below VL2324).

The above monoliths contain 209 diatom taxa. Many of the diatoms identified were extinct by the end of the Sangamon. Some of the extinct forms are not found in deposits older than the Sangamon, or older than Illinoian (VanLandingham, 2006). Extant taxa identified in the monolith first occurred in the Sangamon or the Ilinoian. Finding Sangamon diatoms and even older microflora has become the rule for Hueyatlaco (VanLandingham, 2004, 2006, 2008, 2009a, 2009b, 2010a, and 2010b.)

VanLandingham's unique diatom associations included a rare correlative link called the "*Cocconeis-Navicula-Synedra* generic dominance/ subdominance association." Previously recognized only from the last interglacial in Poland, it occurs in six of VanLandingham's samples from the Hueyatlaco site: VL2268, VL2270, VL2272, and VL2325 (all beneath the Hueyatlaco ash); and VL2324 and VL2342 (both in the channel north of the disputed contact). VanLandingham (2009b) identified another unexpected correlation, a link between VL2270 (beneath the Hueyatlaco ash in monolith WSU73V15, Figures 16, 17) and VL2342 (channel deposit north of the disputed contact, Figure 16). This correlation, represented by a *Cocconeis-Navicula-Nitzchia-Synedra* dominance/ subdominance association, is known in the Western Hemisphere only at this site.

Based on the stratigraphic positions of these diatom correlations, we conclude that all of them were deposited more or less late during filling of the channel, when the water overflowed to the south from time to time. Some of them are below the Hueyatlaco ash, in the interpreted flood plain deposits, and others are from the channel deposits that yielded bifacial artifacts. VanLandingham's correlations make the Waters idea of a much younger inset for the channel deposits untenable.

Waters vs. Irwin-Williams

As noted above, Waters suggests that Irwin-Williams may have misplaced the unifacial artifacts in the stratigraphic section.While she did indeed change the nomenclature she used for the stratigraphy between 1964 and 1966 (Figure 4), she did not reassign the unifacial objects to a different layer from the one where they were originally described, suggesting that there was no ambiguity from which layer they came. She did not have doubts, however, about the assignment of the few unifacial objects to a particular layer, regardless of its name. She found and collected five artifacts in 1964, and two in 1966. For Irwin-Williams, conversion of the names was "simply a matter of terminological designation," as she pointed out in her open file 1966 progress report to the INAH. Our experience with the excavations with Irwin-Williams is that they were rigorously conducted and that Irwin-Williams herself insisted on removing any artifacts and recording their source (Irwin-Williams, 1967b).

We find it improbable that the unifacial artifacts were somehow incorporated in Unit I when the overlying channel deposits were laid down, for example, by being intruded into the upper part of the layer. In particular, from the Irwin-Williams account of the intimate relation of Unit G and Unit I (Unit H was a local feature), and from her description of the channel deposits, the channel was not closely above Unit I from which she collected the artifacts. Furthermore, Irwin-Williams, in her open file1964 progress report to the INAH, described a "unifacial pointed piece" as being found "nearly touching" an elephant's hipbone. The entire assemblage was removed in a single block. Also, "A second unifacial pointed piece was recovered underneath a camel rib a short distance from the first." Such descriptions give confidence that the artifacts were found in place, not as intrusive objects (Irwin-Williams, 1964).

CONCLUSION

Diatom correlations, isotopic dates (U-series, fission track, and U-Th/He), stratigraphy, tephra hydration rates, mineral weathering, and vertebrate paleontology all suggest that the sediments exposed at the Hueyatlaco archaeological site, as well as bones from butchered animals found both at Hueyatlaco and at the nearby El Horno site are at least 250,000.

ACKNOWLEDGMENTS

C.A. Repenning, whom we honor in this volume, was in the beginning stages of his study of fossil fragments from Units G and I at Hueyatlaco (unifacial tools) at the time of his death, and was excited about what he was finding. We would like to think he would be pleased with this summary and the stratigraphic evidence presented here, and with his part in the work. "Rep" shared much of his knowledge with us, encouraged us, and gave us friendly advice. He is fondly remembered.

The authors would especially like to thank M. Payn for his support of field work at Hueyatlaco from 1997 to the present and for financial support of several new dating attempts, and for sharing the results with us. His 2006 award-winning documentary video, *Valsequillo, an Archaeological Enigma* resulted from his insistence that any new work at the Hueyatlaco site and in the laboratory be recorded on film.

The authors wish to acknowledge editors L.H.Taylor, C.J. Bell, and L.L. Jacobs for kindly allowing us to submit our manuscript and for their patience. Also, our deepest thanks to C. Malde, HEM's widow, who supplied much-needed critical information.

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