STATUS OF VOLCANIC ASH CHRONOLOGY AT VALSEQUILLO ARCHAEOLOGIC SITES, PUEBLA, MEXICO

Third rough draft of a joint paper by V. Steen-McIntyre and H.E. Malde presented at the 35th annual meeting of the Society for American Archaeology in Mexico City, April 30 -May 2,1970

Prepared by Virginia Steen-McIntyre, July 2003

Following is the copy of an abstract and talk concerning the distribution and petrography of isolated tephra deposits in the vicinity of the Hueyatlaco archaeologic site, Tetela Peninsula, north shore of the Valsequillo Reservoir, State of Puebla, Mexico. It was presented in 1970 by Hal Malde at the 35th annual meeting of the Society for American Archaeology, Mexico City. Steen-McIntyre was living in Puerto Rico at the time, and was unable to attend.

In 1970, we thought that three of the coarse tephra layers exposed near Hueyatlaco possibly correlated with three dated layers on nearby La Malinche volcano ranging in age from greater than 26,000 to 8,000 14C years. Later radiometric and fission-track dates on the tephra units exposed at the site itself (Hueyatlaco ash, Tetela brown mud) and a younger unit (Buena Vista lapilli) in 1973 and 1998 showed that these correlations were not valid, and that our estimate for the age of the Hueyatlaco site was ten times too young (not 26,000 years but rather ca. 250,000 years.) Special weathering characteristics (extent of hydration/superhydration of the volcanic glass shards and the intrastratal solution of hypersthene phenocrysts), plus subsequent diatom studies of the Hueyatlaco sediments (shown by them to be Sangamon age or older) agree with this ancient date.

The paper offers valuable information on the distribution and petrographic properties of various isolated tephra deposits that occur on the Tetela Peninsula. Other than the abstract, it has never been published. It is presented here in hope that it will aid a new generation of scientists working in the area.

Information updates are set off with brackets and my initials [. . . VSM]; additions and corrections by brackets [...].

At the time the paper was first conceived, it was thought that the “Valsequillo surficial lapilli” map unit and the “Buena Vista lapilli” unit probably were from the same eruption. Samples that Steen-McIntyre later called Buena Vista lapilli (66M281/V28, 64M50) shown above the red line in slides 8 and 9 were correlated with an isolated outcrop we also had called Buena Vista lapilli (66M229/V27). [See page 8 for mention of two of these samples.] We later discovered that the samples didn’t correlate — 66M229/V27 lacks beta quartz xenocrysts while 66M281/V28 and 64M50 contain them. Unfortunately, when the slide copy was prepared for the talk we didn’t know this. What actually are samples of Buena Vista lapilli are labelled Valsequillo surficial lapilli on Slide 10 and in the body of the text. Malde’s field notes record the Buena Vista lapilli as occurring in an “upper brown mud” unit, overlying the Tetela brown mud (“lower brown mud”), i.e. younger. *This is important!* Buena Vista lapilli sample 66M281/V28 was collected from an outcrop that later was re-collected and dated by others in 1997 at ca. 250,000 years (unpublished). This makes a stack of sediment containing three tephra units (Buena Vista lapilli, Tetela brown mud, Hueyatlaco ash, all dated at roughly 250,000 years) that direct tracing of beds shows to overlie (is younger than) the artifact-bearing beds at Hueyatlaco.

Slide 10 is of special interest. It shows three dated tephra samples: $M7_L$ and $M7_U$ at 8,000 years, and “VS” (actually Buena Vista lapilli sample 66M281/V28) at ca. 250,000 years. How similar their petrographic properties look! It had me fooled until I checked the extent of hydration/superhydration of the volcanic glass shards, which easily separated the two sets.

Note that the samples in Slide 10 all have beta quartz xenocrysts in various stages of dissolution, i.e. not in equilibrium with the fluid phase at or shortly preceeding the time of eruption. Their presence is uncommon. They are found on La Malinche in the 8,000-year-old unit, then not again until the very base of the section at considerably more than 26,000 years. In the Hueyatlaco area they are found in the 250,000-year-old Buena Vista lapilli and the lapilli channel tephra (middle unit, Slide 9). The one unit occurs in sediments overlying the Tetela brown mud and the other beneath it, and are separated by at least two erosional unconformities. Both units lie well above the Hueyatlaco and Tecacoxco archaeologic sites.

Virginia Steen-McIntyre Aug. 4, 2003

Society for American Archaeology, 35th Annual Meeting, April 30, May 1, 2, 1970, Mexico City.
Book of Abstracts, P. 76-77.

239- Steen-McIntyre, V. and Malde, H.E. (U.S. Geological Survey) Session 13

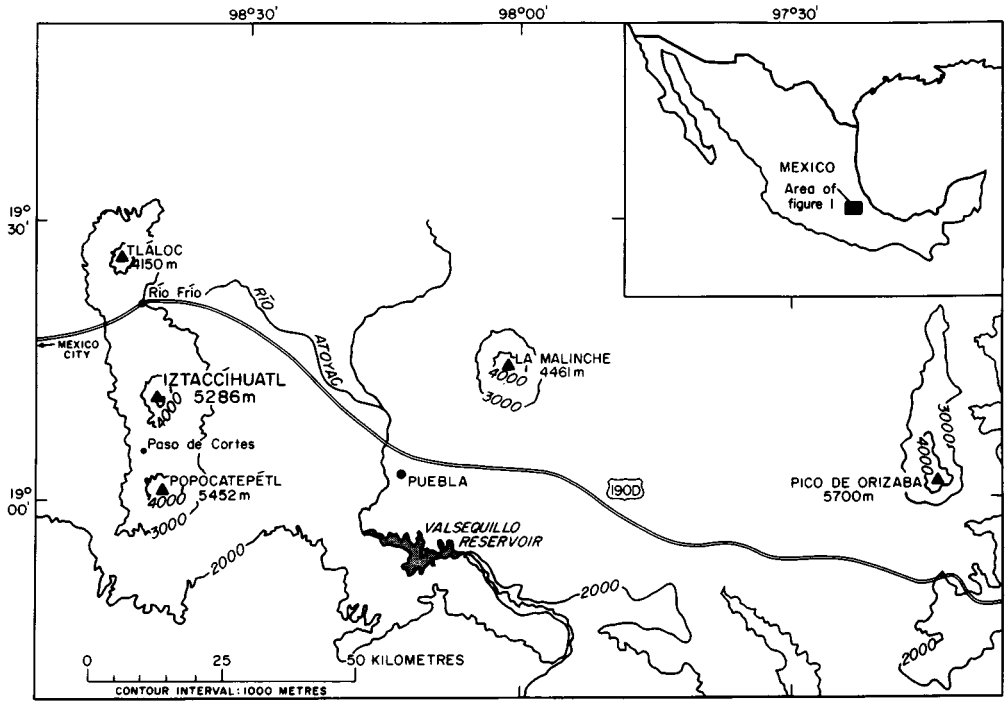
STATUS OF VOLCANIC-ASH CHRONOLOGY AT VALSEQUILLO ARCHAEOLOGICAL SITES, PUEBLA, MEXICO

Petrographic study of pyroclastic layers at Valsequillo and nearby La Malinche volcano since 1966 has thus far resulted in detailed information about the properties of 25 samples and in less complete data for 250 other samples. The detailed work includes determining histograms of refractive index for the shards of volcanic glass, identifying and counting the heavy and light phenocryst minerals, measuring the refractive index for several representative phenocrysts and describing the mineral inclusions.

Incomplete study on 55 samples at Valsequillo from several distinct pyroclastic layers suggests at least five different eruptive sources. The youngest known pyroclastic layer [surficial lapilli], which is draped on the dissected surface of the Tetela Peninsula some 10 meters stratigraphically above the highest archaeological site (Hueyatlaco), is tentatively correlated with crystal-rich ash and lapilli 6 m. thick on the summit area of La Malinche that overlies an organic soil dated at about 8000 years B.P. (W-1909, W-1912, W-1923). A channel deposit of lapilli younger than the Hueyatlaco site possibly correlates [does NOT correlate. VSM] with another eruptive layer at La Malinche on organic soil dated at about 17,000 years B.P. (W-1913, W-1925). Detailed petrographic work is needed to test these correlations. (This study is supported by the National Science Foundation).

Volcanic ash chronology, or tephrochronology as it sometimes is called, developed out of the growing need of scientists working in Pleistocene and Holocene deposits for wide-spread time-stratigraphic marker horizons and out of the potential use of volcanic ash layers to meet this need. In the United States, pioneering work in this field was done in the early 1960's by Ray Wilcox and Howard Powers of the U.S. Geological Survey, when they used a combination of chemical and petrographic characteristics to "fingerprint" several major ash horizons that originated from volcanic eruptions in the Cascade Range. Since that time, there has been an ever increasing number of studies related to volcanic ash chronology, and many new and exciting correlating techniques have been developed.

In early 1966, work was begun by Virginia Steen-McIntyre under sponsorship of the National Science Foundation on an ash chronology problem whose ultimate goal was to help establish absolute dates for the very important but controversial Valsequillo Early Man sites excavated by Dr. Cynthia Irwin-Williams and Professor Juan Armenta [Camacho] in 1962-1966.



SLIDE 1: LOCATION MAP

The sites are located on the north shore of the Valsequillo Reservoir on or near the Tetela Peninsula, approximately 100 km southeast of Mexico City and 10 km south of the City of Puebla. Previous field work by Harold Malde in the Valsequillo area and on the slopes of the three major nearby volcanoes, Popocatepetl, Iztaccihuatl, and La Malinche had confirmed that four of the five conditions necessary for effective use of volcanic ash chronology had been met. First, the three volcanoes had been active in relatively recent time, producing thick, coarse blankets of pyroclastic ejecta that almost certainly had reached the Valsequillo area. Second, these ejecta blankets, especially on La Malinche, were well-exposed and relatively easy to sample. Third, a few of the pyroclastic deposits were associated with carbonized wood or organic soils, so that absolute dates of some of the ejecta blankets could be obtained by carbon 14 methods. Fourth, pure deposits of volcanic ash and lapilli had been preserved as isolated outcrops on the Tetela Peninsula so that material for comparison with the pyroclastic layers on the flanks of the volcanoes was available. Thus, only one condition was lacking before a volcanic ash chronology for the area could be established and ash correlation begin, and that was the "fingerprinting" of the major pyroclastic horizons on the flanks of the volcanoes and at the Tetela Peninsula through examination of physical, chemical, and petrographic properties. This work is under way at the present time.

SLIDE 2:
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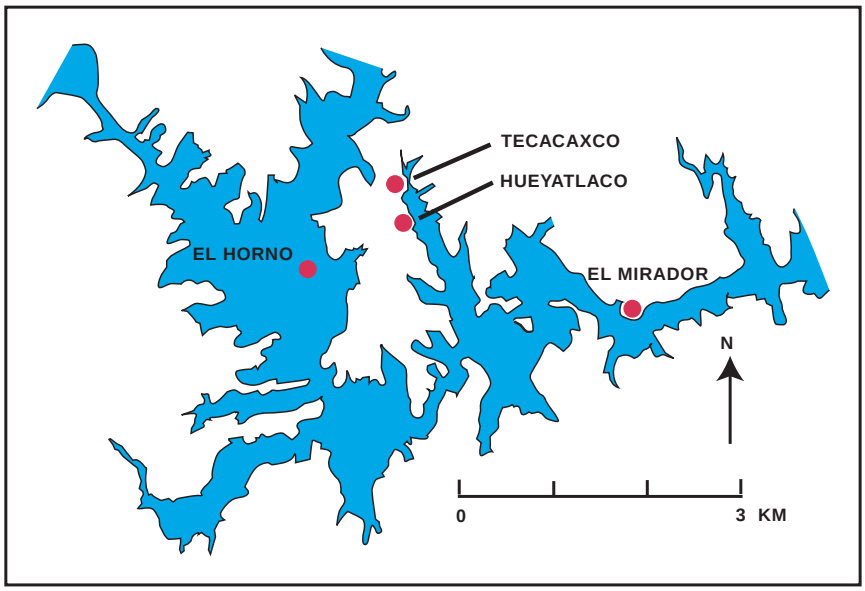
Since its beginning in 1966, Valsequillo ash chronology work has been divided into two distinct problems—the petrography and chronology of the well exposed pyroclastic sections on the flanks of La Malinche [volcano], and the petrography and chronology of the Tetela Peninsula ash and lapilli material. Both studies require petrographic examination of pyroclastic samples on a reconnaissance and a detailed level, supplemented by additional correlation techniques such as trace element and particle size analyses. Both studies must guard against contamination in the selection and study of the samples. Altogether, some 250 pyroclastic samples have been examined, 90 per cent of these by reconnaissance in which was noted the modal refractive index or modal N of the volcanic glass, type and relative amount of heavy mineral phenocrysts, and appearance of the light-mineral phenocrysts. Ten per cent have received more detailed attention. In these samples, mineral grains and glass shards have been counted to more accurately determine volume per cent histograms of the mineral phenocrysts and N mode and range of the volcanic glass, and the optical properties of several mineral crystals have been measured using spindle stage and focal masking techniques.

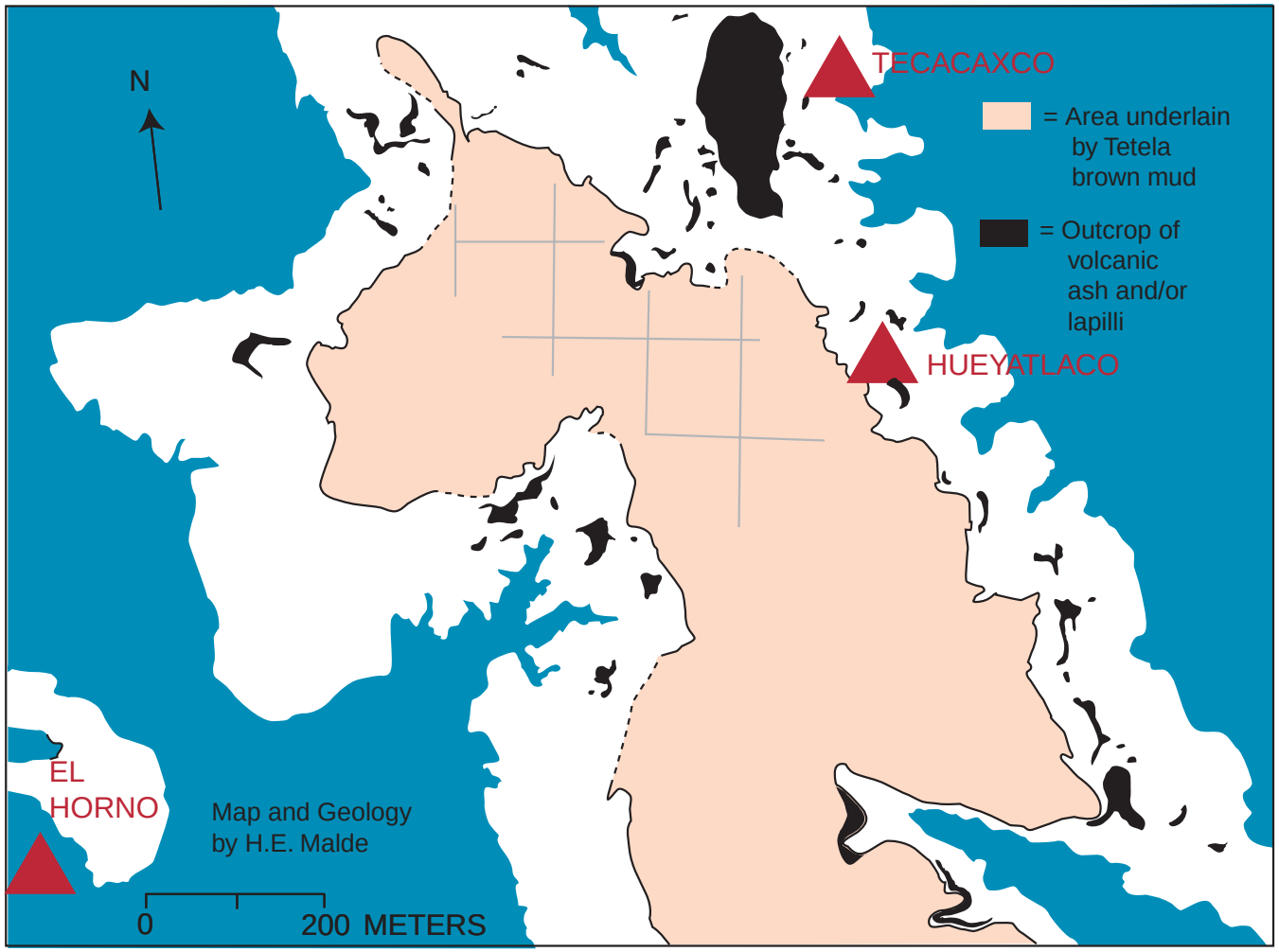
Since it is impossible to review all the work we have done on the Valsequillo ash chronology problem in the short time available today, I will concentrate on the part that should be of most interest to you, namely the status of volcanic ash chronology at the Valsequillo archaeologic sites on the Tetela Peninsula.



SLIDE 3: MAP OF RESERVOIR AND ARCHAEOLOGIC SITES

The Tetela Peninsula lies on the north shore of the Valsequillo Reservoir. It is the site of two small villages, Buena Vista Tetela and San Baltazar Tetela, and of the two highest [in elevation] archaeologic sites—Tecacaxco and Hueyatlaco. The two lower and presumably older sites, El Horno, and El Mirador lie respectively to the west and east of the peninsula.

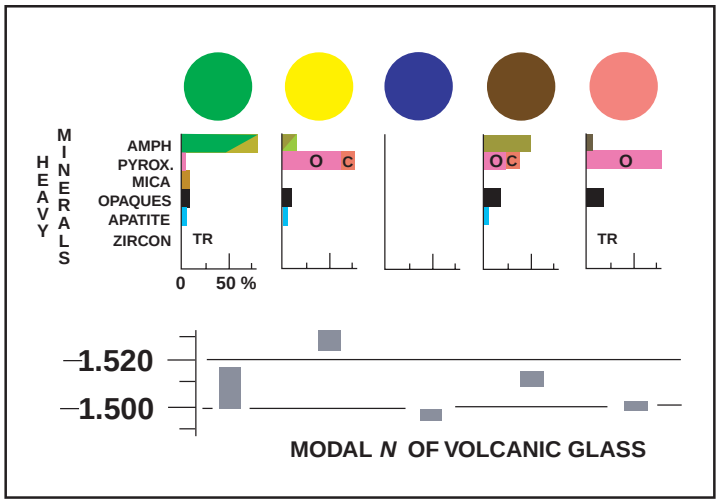
Here (Slide 4, below) is an enlarged map of the northern half of the Tetela Peninsula with the town of Buena Vista shown by the thin black lines, and three of the archaeologic sites, El Horno, Tecacaxco, and Hueyatlaco indicated by the red triangles. The area now covered by water of the reservoir is outlined in blue.



SLIDE 4: MAP OF NORTHERN HALF OF TETELA PENINSULA

Black-colored outcrops represent the isolated deposits of rather pure, fine-grained volcanic lapilli or volcanic ash. To date, ____ per cent of the samples collected from these outcrops have received petrographic examination. (Hal: According to my notes I have looked at 53 samples from 36 different outcrops. Can you compute the percentage from your knowledge of how many ash and lapilli samples you have actually collected in the area?)

Both Hueyatlaco and Tecacaxco [El Horno as well.], and most of the ash and lapilli deposits occur in a complex series of cut-and-fill stream channels. This series is overlain by the Tetela brown mud [an informal mapping unit] here shaded pink. This is a mudflow containing large chunks of pumice [of the same petrographic type, i.e. a volcanic mudflow.], and it originally was deposited over an erosional surface of low relief cut into the complex of channel deposits. The mud unit itself was subsequently covered by a surficial layer of fine-grained material, including a volcanic lapilli horizon not shown here and the whole sequence—surficial layer with lapilli, mud unit, and complex channel unit, was eroded to its present configuration. Today, topographic relief in this area is more than _____meters.



SLIDE 5: GENERAL PETROGRAPHIC CHARACTERISTICS, TETELA TEPHRA

In general, the Tetela lapilli and ash deposits we have examined so far group themselves into five petrographically distinct sequences. Each sequence will be represented here, and on following maps and diagrams by symbols of a specific color—green, yellow, blue, brown, or pink. In this diagram, I will only compare the volume per cent and type of heavy minerals, and modal refractive index (N) of the volcanic glass, but even limiting comparisons to these three parameters, there is a clear distinction between the five series.

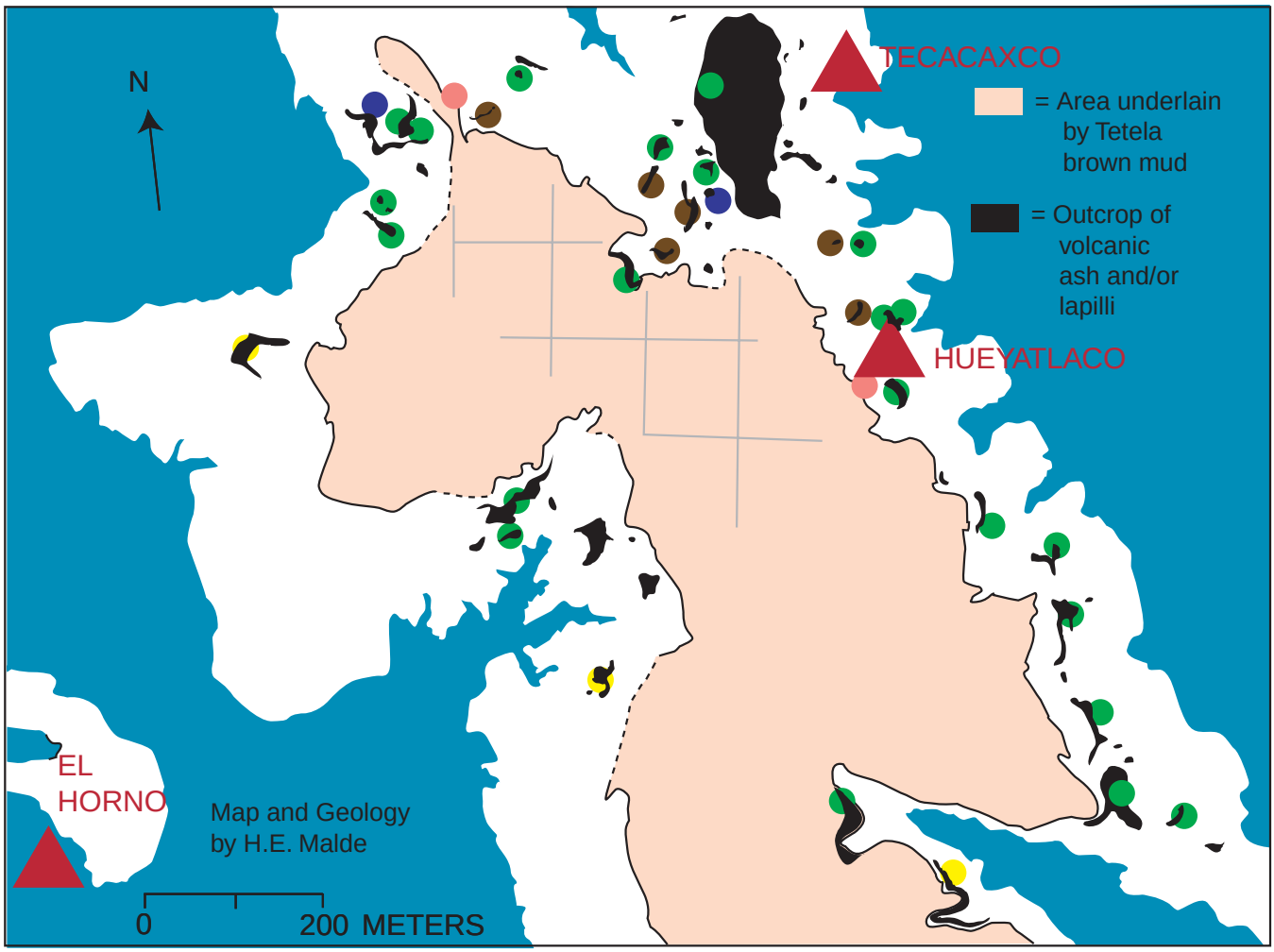
The samples denoted by the green symbol can be characterized by the first figure. Heavy minerals in this series are mostly green to olive green amphibole, with a trace to 5 per cent pyroxene, less than 10 per cent each of mica and opaques, a trace to 2 per cent apatite, and a trace of zircon. Modal refractive index of the volcanic glass ranges from 1.500 to 1.516, depending upon the sample.

The samples with the yellow symbol, which occur in a southeast trending channel well south of Hueyatlaco and as reworked lapilli grains in the upper part of the Hueyatlaco trench, are represented by the second figure. This figure is not a generalized one, and represents only the reworked material from the Hueyatlaco trench. It differs from the channel samples mainly in the relative percentages of the heavy minerals and in the absence of mica. All samples in this series however, have olive to olive-brown amphiboles, ortho- and clinopyroxene, opaques, apatite, and a [glass] modal refractive index between 1.526 and 1.532.

The third petrographically distinct series, represented by the color blue, is shown in the third figure. It is composed almost entirely of platy shards of volcanic glass with modal N from 1.496 to 1.499.

The samples with the brown symbol are characterized by the fourth figure. They have almost equal volumes of olive-brown amphibole and pyroxene, and the pyroxene is almost equally divided between the ortho- and the clinopyroxene varieties. They usually have about 10-12 per cent opaques and two per cent apatite. Modal refractive index [for the volcanic glass] lies between 1.510 and 1.514.

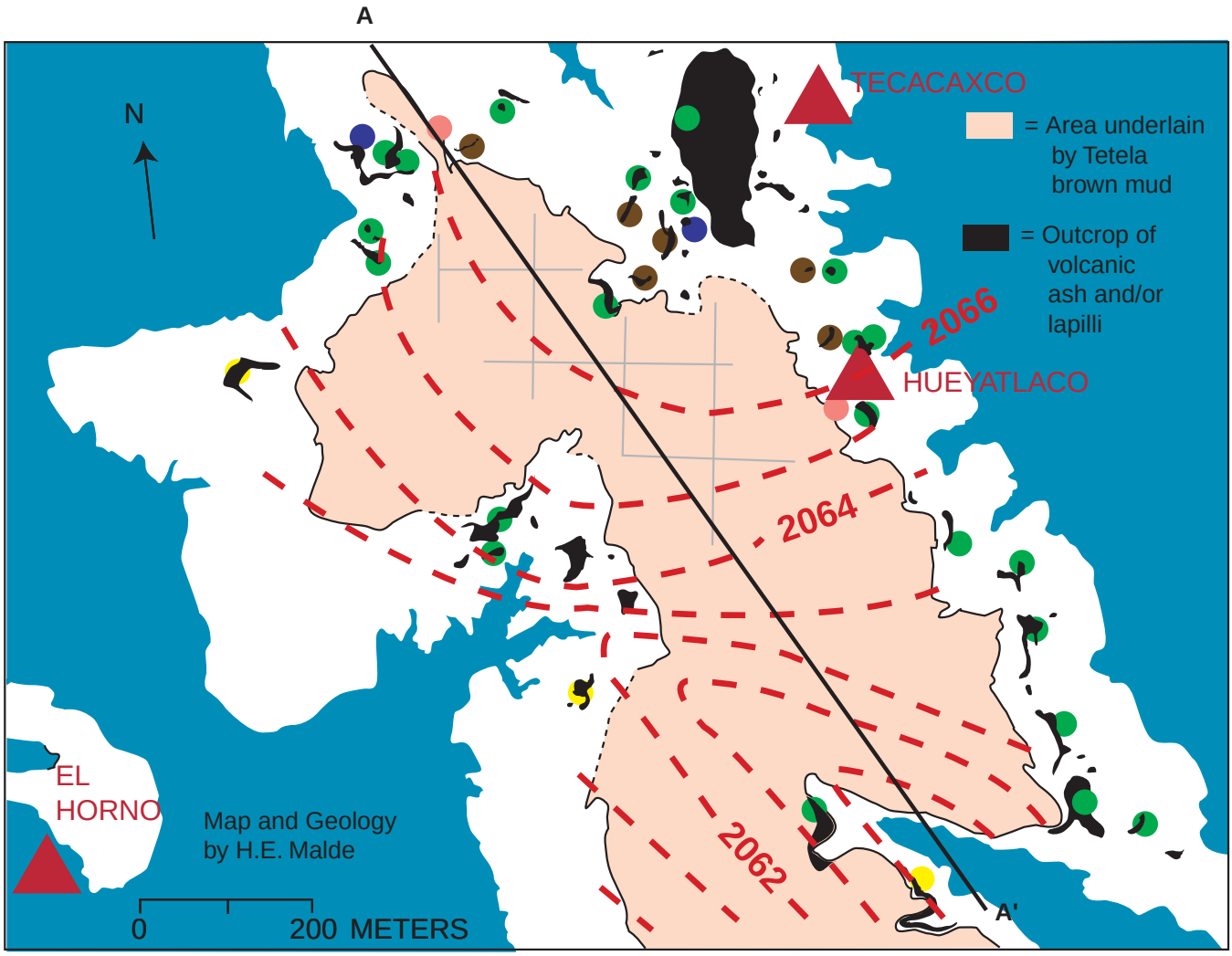
The fifth figure, denoted by the color pink, represents the large pumice lump fragments in the Tetela brown mud unit. These samples have [a low volume of] brown amphibole and high orthopyroxene content, a significant amount of opaques, and a trace of zircon. Modal refractive index of the volcanic glass lies between 1.500 and 1.502.



SLIDE 6: NORTHERN HALF TETELA PENINSULA MAP WITH PETROGRAPHY

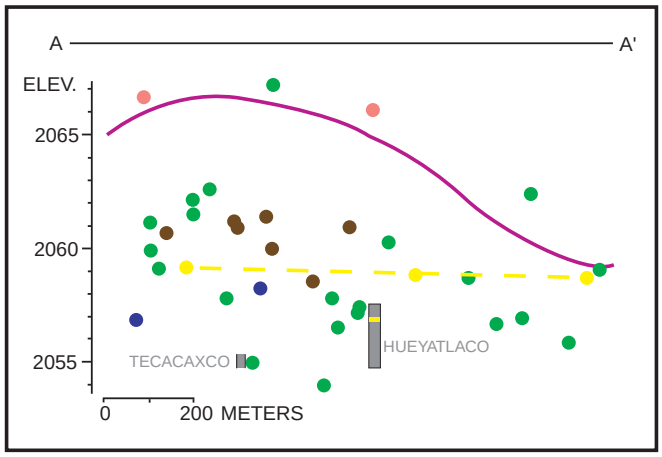
Here again we have a map view of the northern half of the Tetela Peninsula with the archaeologic sites indicated by the red triangles and the Tetela brown mud unit by the color pink. Each colored dot you see represents an outcrop of volcanic ash or lapilli whose petrographic characteristics have been determined, and the color of the dot indicates the petrographic series to which the outcrop material belongs.

Notice that although the distribution of dots is rather widespread, dots of the same color, representing outcrops of ash and lapilli with similar petrographic characteristics, tend to group themselves in patterns and to be limited to rather restricted portions of the map. This is especially clear for the yellow series, which follows a southeast trending buried stream channel; for the blue series, which is confined to the northern third of the map; the pink series, which is found only in the Tetela brown mud unit; and the brown series, which follows a stream channel that outcrops just north of Hueyatlaco. The green series appears more ubiquitous, but this color represents several ash fall units, at least three of which can be distinguished by other petrographic characteristics, and these three units also have their distinctive map patterns and restricted areas.



SLIDE 7: SLIDE 6 WITH METER CONTOURS

This is the same map view we had in the previous slide, except that we have added a series of meter contours. These contours represent the topography developed on the complex stream-channel unit just prior to burial by the Tetela brown mud. The line labeled A-A' indicates the position of the vertical cross-section shown in the next slide.



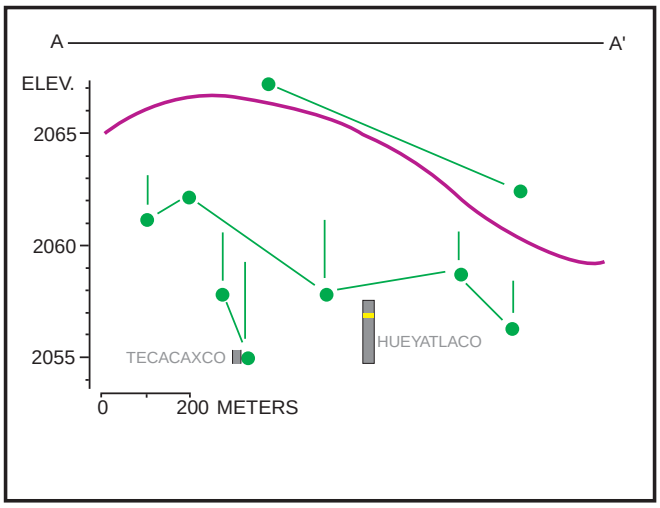
SLIDE 8: VERTICAL CROSS-SECTION

We are now looking at the vertical cross-section along line A-A' shown in the previous slide. The curved line represents the topography of the complex channel unit beneath the Tetela brown mud; the shaded rectangles represent the positions of the Tecacaxco and Hueyatlaco trenches. The El Horno trench and reservoir water level would project well below the bottom of the slide. Vertical scale has been highly exaggerated to show detail—it is 54 times greater than the horizontal scale.

We have projected on this cross-section, all the lapilli and ash outcrops that were shown by the colored dots on the map view in the previous slide. They are shown at their actual elevations. You will notice that the four series of ash deposits represented by the colors blue, yellow, brown, and pink tend to group themselves in this vertical view as they tended to group themselves in the map view. The blue series is found near the base of the complex stream channel unit. The yellow, brown, and pink series are confined to elevations higher than the Tecacaxco and Hueyatlaco culture-bearing horizons. Field evidence at the Hueyatlaco trenches shows that the brown and pink series of deposits are stratigraphically as well as physiographically higher than this site and that Hueyatlaco is therefore older than these series. Evidence for the relative age of the yellow series of deposits cannot be obtained directly, although physiographic position would indicate that is is younger than Hueyatlaco.

As for the source of these materials, we think that the brown series may have originated from a vent near the south slope of Popocatepetl, as we have some coarse ash and lapilli from that area with similar petrographic characteristics. Vents for the blue, yellow, and pink series of materials have yet to be located. We have no absolute dates for these materials. [In 1973 the pink series tephra was dated by the zircon fission-track method at 600,000 plus/minus 340,000 years. VSM]

The green series of lapilli and ash resembles coarse-grained pyroclastic material found on the flanks of La Malinche [volcano]. We have made some progress with correlations between the Tetela and La Malinche samples, although these correlations remain tentative until the pertinent samples are examined in detail. [Subsequent work showed that the samples did NOT correlate. VSM] This will take several more months.

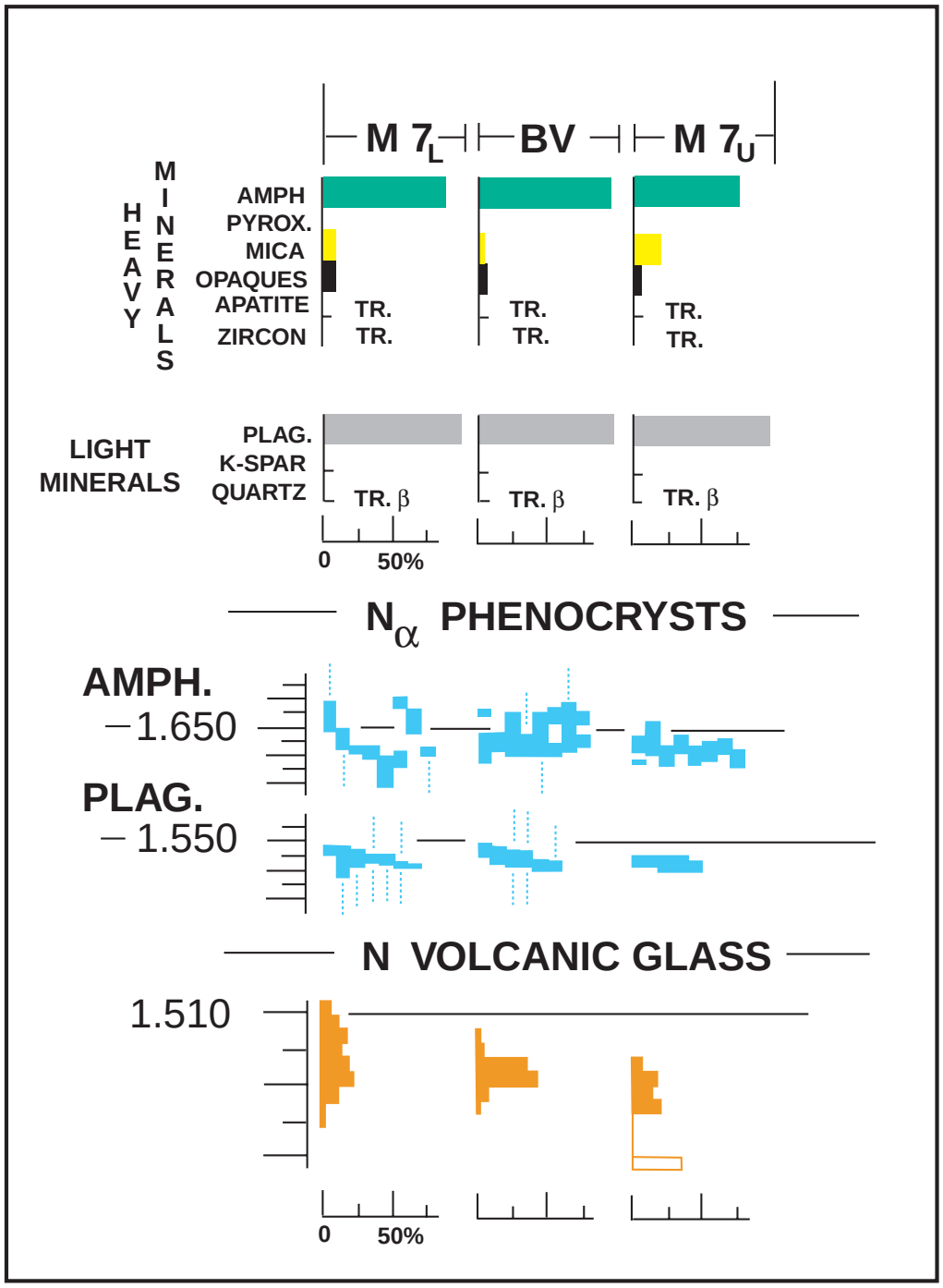


SLIDE 9: CROSS-SECTION SHOWING THREE SERIES OF "GREEN" TEPHRA

We have been able to distinguish three different ash and lapilli horizons within the green series by petrographic examination, and they are shown in this diagram. The vertical lines shown here do not represent outcrop thickness, but rather topographic relief of each outcrop's basal contact, Material from the lower horizon on the diagram has petrographic properties similar to two series of dated pyroclastic materials on La Malinche, one lying beneath a soil dated 26,000 years B.P, and the other including soil dated at 17,000 years B,P. Detailed petrography of these samples and of the two Malinche series should show whether a correlation exists. The middle horizon is part of Malde's lapilli channel unit, which he believes is related to a series of

ash flow deposits on La Malinche dated at 26,000 years. The petrographic properties of material from this horizon and from the ash flow units indeed look similar, but there seems to be minor differences. Again, more detailed petrography of the ash flow deposits and lapilli channel material is needed to test this potential correlation [They did not correlate — VSM].

The upper lapilli horizon lies above the Tetela brown mud unit and here is called the Valsequillo surficial lapilli. (Hal:. I've examined a sample of this material from your measured section 7. Properties are internally consistent with sample 66M281/V28 and different from B.V. Lapilli sample 66M229/V27. Almost assuredly they are separate horizons..) [The B.V. lapilli has recently been radiometrically dated at around 250,000 years. VSM] It has petrographic characteristics which are quite similar to a crystal-rich pyroclastic layer on the upper slopes of La Malinche that has been dated at 8,000 years B.P. Petrographic similarity between this Valsequillo surficial lapilli and the Malinche 8,000 year material is shown in the next slide.



SLIDE 10

In this diagram, a "fingerprint" is shown for the Valsequillo surficial lapilli, labeled VS [actually, Buena Vista lapilli— VSM], and for a sample from the lower and upper part of the 8,000 year eruption on La Malinche, labeled $M7_L$ and $M7_U$ respectively, As you can see, the values of the various petrographic and optical properties of the Valsequillo surficial material either match or lie between the values for the samples from the lower and upper portions of the 8,000 year Malinche eruption... [Although a recent radiometric date for the Buena Vista lapilli shows to be older by a quarter-million years! — VSM]

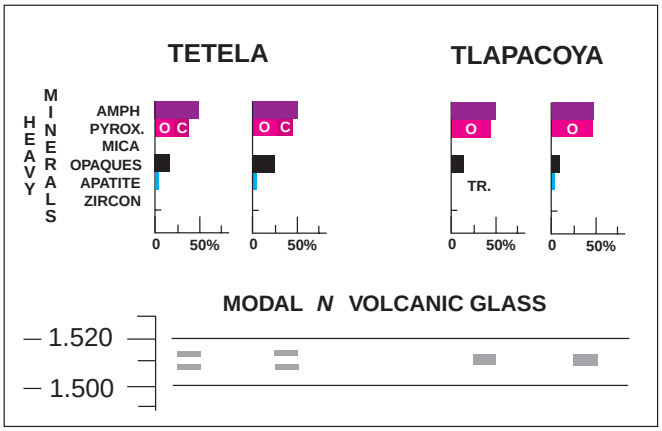
Thus, at the moment [in 1970, not 2003– VSM], we have three possible correlations between green-series volcanic ash and lapilli at the Tetela Peninsula and dated pyroclastic layers on La Malinche — the

Valsequillo surficial lapilli with the 8,000 year old Malinche eruption, the lapilli channel material with the 26,000 year Malinche ash flow unit, and an unnamed, physiographically lower lapilli with either a series of Malinche pyroclastic material dated at approximately 17,000 years or a series dated at greater than 26,000 years. The two upper horizons at Tetela can be shown by field evidence to be younger than Hueyatlaco, the highest and youngest archaeologic site. Thus obtaining good correlations between these upper Tetela horizons and dated horizons on La Malinche will automatically give a firm minimum date for the Valsequillo Early Man material, At the present time, volcanic ash data permit this minimum age to range from 26,000 years to approximately 17,000 years. However, the key ash samples and localities where the answers can be found have now been clearly identified, and we are confident that the additional detailed studies we have planned will resolve this problem. [Additional studies included direct radiometric dating of the tephra layers exposed at the Hueyatlaco site (1973, 1998) and weathering studies, including hydration/superhydration of the volcanic glass and extent of etching of hypersthene phenocrysts (crystals). Our age estimate in 1970 was found to be off by a factor of 10. VSM]

SLIDE 11: BLANK BLUE

Perhaps you are wondering at this stage whether we have been able to make any correlations between ash layers on the Tetela Peninsula and ash layers from other archaeologic sites. To date we have examined the pyroclastic layers from only one other site—Tlapacoya trench B excavated by _____ in 19__. This site is located approximately 25 kilometers southeast of Mexico City and 85 kilometers northwest of Tetela.

We have found no one-to-one correlation between material at Tlapacoya B and the material of the Tetela Peninsula, but we have found striking similarities between the Tlapacoya ash horizon labeled “Ceniza pumitica. de grano fino” and the “brown” series of ash and lapilli outcrops at Tetela. The Tlapacoya horizon lies 4 meters above a layer of carbonized wood dated at approximately 22,000 years B.P., and is separated from it by two erosion surfaces, The Tetela “brown” series is stratigraphically higher and therefore younger than Hueyatlaco, the youngest Valsequillo archaeologic site.



SLIDE 12: TETELA “BROWN” AND TLAPACOYA ASH HORIZONS COMPARED

Here is a comparison between the Tetela. and Tlapacoya ash horizons in question. The Tetela samples are quite fine-grained, with ash particles less than 1/4 millimeter in diameter. The Tlapacoya samples are coarser, with particles as large as 4 millimeters.

Note that both sets of samples have similar amounts of brown amphibole, pyroxene, opaques, and apatite, and that modal refractive indices of the volcanic glass lie between 1.508 and 1.514, The two series differ from each other mainly in the pyroxene content and in the modal refractive index of the volcanic glass. Tetela samples have both fresh orthopyroxene and altered clinopyroxene while Tlapacoya samples have only the fresh orthopyroxene. The N volcanic glass from the Tetela samples is bi-modal while that from Tlapacoya is unimodal.

Differences notwithstanding, Steen-McIntyre believes [in 1970, not in 2003. VSM] that the vent or vents which produced these two horizons are closely related in space and time, and that petrographic examination of additional ash horizons from the two areas may produce the needed one-to-one correlation.

Until that day, archaeologists working in the area should take note that there appears to be a fortuitously located vent or vents that have produced large-scale eruptions, and that the volcanic ash blankets from these eruptions have extended both into the Valley of Mexico and into the Puebla-Tlaxcala Basin. When excavating archaeologic sites it will be advantageous to collect and preserve any pyroclastic horizons that occur in the excavation walls for future study and comparison. The prospect of correlating between archaeologic sites in this area by use of volcanic ash chronology looks bright indeed!