The Hopi Calendar and Some Archaeological Correlates of Horizon Markers

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We follow [the days] on calendar, but they follow on rocks, by markers.
Elsie Clews Parsons (1920)
Hopi cosmology is utterly entrenched in the proximate landscape; it is not a cosmology, like that of a world religion such as Christianity or of a nomadic society such as the Navajo, which is easily transportable from one geographic locale to another.
Peter Whiteley (1989: 84)
Then the sun rises at the "announcement point" [tingappi]. And when it has risen at that marker [tuvoyla] there, the person who announces Wuwtsim alone knows it, and therefore people learn of it after he has announced it.

Anonymous Hopi (Malotki, 1983: 453–454)

1 Introduction

Since I began studying Hopi astronomy, I have been trying to unravel the details of the horizon calendars of the major Hopi villages. Documentary sources, academic publications, and fieldwork at Hopi provided many clues to the calendars, which led to a general understanding of the framework of the First Mesa horizon calendar (McCluskey, 1990). However, as late as 1996, when Clive Ruggles and I visited Walpi Pueblo to see its scarcely perceptible horizon calendar, I still did not fully understand the details of the planting calendar at First Mesa.

Each Hopi village regulates the times of planting and of some ceremonies using observations of the Sun at natural markers on its own local horizon (Ellis, 1975). This discussion primarily considers the horizon calendar used at the First Mesa

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E. Boutsikas et al. (eds.), *Advancing Cultural Astronomy*, Historical & Cultural Astronomy, https://doi.org/10.1007/978-3-030-64606-6_4

villages of Walpi, Sichomovi, and Hano, the latter having been formed by eighteenth-century Tewa immigrants from the Rio Grande Valley. Most of the agricultural and ceremonial activities of the First Mesa villages were regulated from Walpi Pueblo (Crow Wing, 1925; Parsons, 1926: 210). Occasionally we will draw on the less completely documented horizon calendars from Second Mesa (Forde, 1931: 386, Fig. 6b) and Third Mesa (Voth, 1901: 149–152; Titiev, 1938; Malotki, 1983) for comparative insights.

The topography of the Hopi country consists of flat topped mesas that have been deeply cut to form steep-sided valleys. When seen from the valley floors, the relief of the horizon is quite irregular, but when seen from a mesa top, the horizon seems almost flat, with only slight irregularities. Such minor irregularities as mounds, notches in the distant horizon, or the apparent intersection of different ridges that define the horizon are most commonly used as calendric markers. There are a few exceptions to this general pattern, where distant high mountains provide more prominent, isolated horizon markers. The relatively inconspicuous Hopi horizon markers differ from the more prominent markers noted in other archaeoastronomical studies (e.g., Thom & Thom, 1980) and can be taken as representing the least prominent markers known to regulate an astronomical calendar.

2 Types of Markers

Horizon markers are known as tuvoyla (Malotki, 1983: 435, 440), a generic term that applies tomany different kinds of markers (Hopi Dictionary Project, 1998: 697). We can distinguish three particular kinds of Hopi horizon markers: agricultural, ceremonial, and cosmological markers. The agricultural markers, specifically called uyispior naatwànpi (planting points),[1] are common Hopi knowledge (hopinavoti) and are frequently described in the ethnographic literature. Usage examples given for the Hopi word "wuwani'yta, have an understanding of," use the same form for "one who understands the nature of the sun's movement" and "one who understands the workings of an automobile, car mechanic" (Hopi Dictionary Project, 1998: 761), suggesting that the sequence of markers to determine the days of the planting season may not be highly restricted knowledge.

The days of ceremonies, which fall outside the planting season, are determined by distinct observations of the Sun at specific markers, of the phases of the Moon, or of the state of the crops, the details of which are specialized religious knowledge (*wimnavoti*). This esoteric learning (*meewànpi*) is closely held by the leaders of individual rituals and rarely communicated, even to leaders of other rituals,[2]

[1] *Uyispi*is related to *uyis*, at planting time, (Malotki: 1983, 393–403), while *naatwànpi*relates to the broader concept of *natwani*, cultural or agricultural practices related to the renewal or rejuvenation of life. (Hopi Dictionary Project: 1998, 307–308).

[2] See Reed's discussion (2018: 127–134) of the place of restricted knowledge (*meewànpi*) in various forms of Hopi traditional knowledge. See also Hopi Dictionary Project (1998: 829, *s.v.* knowl-

although occasionally "the people" criticized the observations of these leaders, insisting "they must watch the sun very closely" (Crow Wing, 1925: 101–102). The markers used to determine ceremonial days have only been described in a few rare cases (Zeilik, 1985: S89–S92; McCluskey, 1990: S2–S3, S7–S9).

The four solstitial directions are indicated by cosmological markers, are the named directions for the Hopi and, with the above and the below, have long been recognized as providing a basic organizing framework to the Hopi cosmos (Geertz, 2003; McCluskey, 2015). This cosmological framework is known to all initiated Hopi (McCluskey, 2010: 16–17) and has now become common knowledge among students of the Hopi. The Hopi recognize two kinds of cosmological markers: one is a series of four ritually important natural places which symbolically mark the four directions; the other are direction markers, which accurately mark the places and times of solstitial sunrise or sunset, either on the exact date of the solstice or as an anticipatory marker a few days in advance of the solstices (Zeilik, 1987; McCluskey, 1990).

Observations of the Sun at these agricultural, ceremonial, and cosmological markers provide the detailed structure of the Hopi solar calendar.

3 The Ethnographic Evidence

The identification of the geographic position of horizon markers, the determination of their use, and the consideration of their precision for astronomical observations depends on several different kinds of ethnographic evidence.

3.1 Lists of a Sequence of Markers

The markers on First Mesa's eastern horizon have frequently been described by ethnographers between the 1890s and the 1930s. Alexander Stephen (1893b) wrote a detailed description of these markers in a letter to J. W. Fewkes; his list was incorporated with modifications in Fewkes (1897: 258–259) and in Stephen (1936). Parsons (1920) collected a list of nine plantings which "they follow on rocks, by markers;" she subsequently published (1933: 59–60) their names and general characteristics based on her field work in the 1920s and that of a local Tewa consultant whom she called Crow Wing. All nine of Parsons's markers were identified with the ordered sequence of plantings. Seven of the thirteen horizon markers listed by Stephen and Fewkes can be associated with planting observations.

These lists (Table 1) were collected in different research contexts. In the late 1890s Fewkes and Stephen were investigating the Hopi calendar and its place in

edge) and Ferguson et al. (2015: 258).

Table 1 Early Lists of Hopi Horizon Markers. Names from Stephen's (1893b) and Parsons's (1933) lists spelled as in original sources; dictionary names provided for comparison with modern Third Mesa orthography (entries in brackets are compounds constructed from dictionary entries)

Hopi dictionary	Stephen's eastern landmarks	Parsons's planting calendar
Taawaki(var. Tawaki): Sun house	1. *Tawaki*: Sun's house	
[Masnamuru]: gray ridge	2. *Masnamüzrü*: gray wooded ridge	
[*Pavöntsomo*]: young corn plant hill [*Koyongqötö'uyisti*]: turkey head planting	3. *Pavüñ'tcomo*: young corn mound	1. *Koyöngkopĕöisti*: turkey's head
	4. *Hoñwitcomo*: derivation obscure; hóñwi, erect	
[*Neveqtsomo*]: side by side hill	5. *Nüvéktcomo*: standing side by side	2. *Nevechumuvayama*: two buttes standing together
Pölmo'okiwta: be hunched over	6. *Pülhomotaka*: a multi-hunch-backed-man	3. *Pölhumuvayama*: round hill
Kwìitsala: narrow neck of mesa top	7. *Kwitcála*: a gap; a narrow mountain pass	4. *Atkyaöisti*: way down planting time
		5. *Pövaimükpöveöisti*: when the wash spreads it
	8. *Taíovi* (?)	
Töötölö: grasshopper		6. *Telĕoitó*: grasshopper planting
Isso'wùuti: coyote woman		7. *Iswurtixöito'*: coyote bitch planting
Owatsmo: rocky hill with boulders all around.	9. *Owátcoki*: rock mound house	8. *Owatsmutix*: rock hill planting
Natalhötsi: a hole through which an opening can be seen at the other end.		9. *Natalöitstix*: rock with hole all the way through
Wunasaqa: ladder made of lumber.	10. *Wü'nacakabi*: wü'na, pole; cáka, ladder	
[*Wakaspaa*]: cow spring	11. *Wakácva*: cattle spring	
[*Pavawkyayki*]: swallow house	12. *Paváukyaki*: swallow house	
Tuyqa: point of a mesa *Hopoqki* northeastern country [at the summer solstice cardinal direction]	13. *Tü'-yü-ka*: the cape *Ho'pokyüka*: summer solstice	

Hopi cosmology; their lists surveyed the major landmarks marking sunrise on the Eastern horizon from winter solstice to summer solstice. Stephen (1893b) added the two cardinal points on the Western horizon: *po-nó-tü-wi,* belly wrinkle, the place of summer solstice sunset, and *lü-há-vwü tcó-tco-mo*, testicle mounds, the place of winter solstice sunset, which are not given by Fewkes. Parsons and Crow Wing were less concerned with cosmology than with the place of the planting calendar in Hopi society, so their lists itemize every stage in the planting cycle, noting minor planting

markers separated by as little as Four days. This difference in focus is reflected in the names given to the markers. When a marker has a similar name in both lists, the name is a physical description of the marker; when a marker is unique to Parsons or the same marker has different names in the two lists, Parsons's names frequently end with forms similar to *-öisti,* variants of the terms *-uyis* and *-úyisti,* planting time[3] (Malotki, 1983: 393–400); when a marker is unique to Stephen and Fewkes, or has different names in the two lists, Stephen's names focus more on the physical description of the marker and do not refer explicitly to a planting event. One example of this difference is that Stephen names one site *Owátcoki,* rock mound house, while Parsons names the same site as *Owatsmutix,* rock hill planting. We should recognize that the names appearing in our sources reflect the concerns of the ethnographers who collected the data. Fortunately, our diverse sources provide complementary Hopi perspectives on their horizon calendars.

There are similar lists of horizon markers from the Third Mesa village of Oraibi. One list appears in a transcription of a planting song transcribed by H. R. Voth (1901: 149–152), which lists the names of 11 sunset markers and 10 sunrise markers; many of Voth's markers also appear in a list of 12 sunrise markers prepared by Titiev (1938). These lists have been further discussed in Malotki's (1983: 432–434) detailed linguistic analysis of Hopi temporal concepts. Although these sources provide sequential lists of the horizon markers, they only provide sufficient details to establish the location of a few of these markers.

3.2 Horizon Diagrams Created by Ethnographers or Native Observers

In the 1890s Alexander Stephen drew several horizon diagrams (Fig. 1; Stephen, 1893a, 1936: Maps 4, 12), which clarify the topography and provide measured magnetic azimuths to some of the local landmarks, including two planting markers. Additional horizon diagrams were published by C. Daryll Forde (1931: 386–387) some of which drew on his own field work in the 1930s and the 1913 field notes of Barbara Freire-Marreco and her Tewa consultant, Leslie Agayo. Figure 2 by Agayo associates planting of specific crops with eight horizon markers while Forde (Fig. 3) gives magnetic bearings from an unspecified location, apparently a field located in the valley of Polacca Wash, to six horizon markers, four of which Forde associated with preparing fields or planting crops. Forde also provides (Forde, 1931: 386, Fig. 6b) a "native drawing" of planting markers from the village of Shungopavi on Second Mesa which depicts ten horizon markers from winter to summer solstice, three of which are also used as planting markers in the First Mesa calendar. Titiev

[3] Parsons does not give names ending in the uncommon term *uyispi*, planting place (Malotki, 1983: 435), which ends with the nominalizing suffix *–pi*, indicating a place (Hopi Dictionary Project, 1998: 409, *s.v. –pi* **1**).

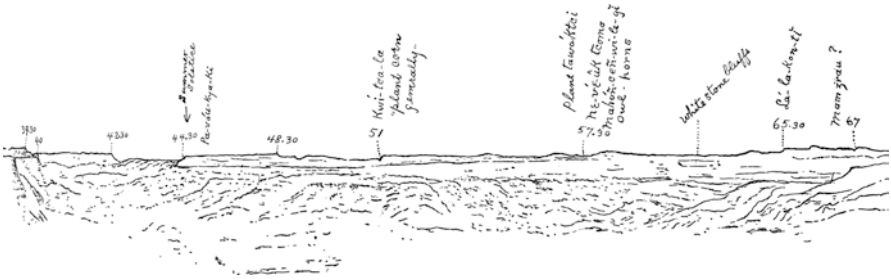

Fig. 1 First Mesa Eastern Horizon from Hano by Alexander Stephen, ca. 1893. (Stephen, 1936: Map. 12). Horizontal scale digitally warped to fit Stephen's magnetic azimuth measurements. Reading from right to left, the more significant markers include two unnamed markers for the autumn Mamzrau and Lalakonti festivals; the marker for the planting of sweet corn, *Nevéûktcomo* or *Mahóñceñwilegĭ* (Owl Horns); the marker for the beginning of general corn planting *Kwí-tca-la*; and the marker for the summer solstice, *Pa-vaú-kya-ki* (Swallow House). Public domain

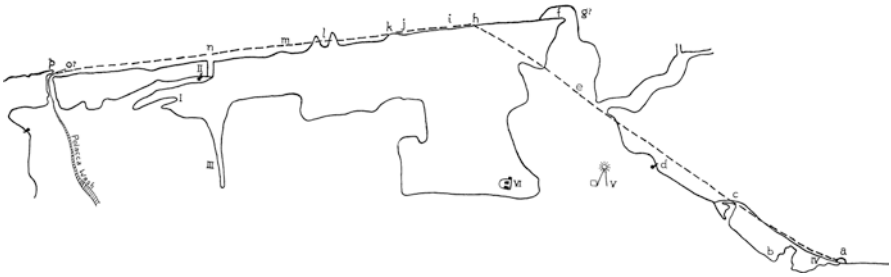

Fig. 2 First Mesa Eastern Horizon by Leslie Agayo, Tewa Corn Clan, obtained by Barbara Freire-Marreco (later Mrs. Robert Aitken) ca. 1913 (Forde (1931: 387). Reading from right to left, the dashed line indicates the path of the Sun from the winter solstice at *a* to the summer solstice at *p*; the upper lines from *a* to *c* and from *f* to *p* indicate significant details on the local horizon; the remaining elements depict local topography. Point *a* indicates winter solstice sunrise marked by IV, *Kwaatipkya* (Eagle Point); *h* through *j* indicate various early planting points; *k, Pelühomo* (perhaps Fewkes's (1897) *Pavüñ'tcomo*); *l,* Owl Horn Lane (Stephen's (1893b) *Neveqtsomo,* Between Two Mounds); *m,* main corn planting; *n,* the lane (Stephen's *Kwí-tca-la*); *p,* water cellar—point of rocks promontory, summer solstice position

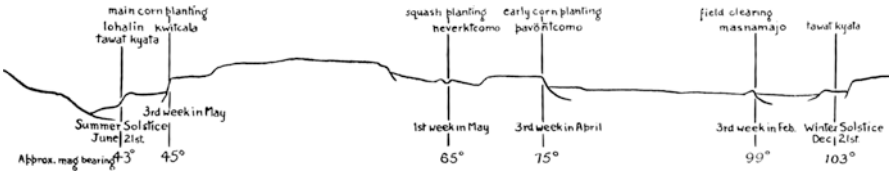

Fig. 3 First Mesa Eastern Horizon from the Valley Floor (Forde, 1931: 386). The horizon details, which contrast significantly with the Sun-watcher's view shown in Stephen's diagram drawn from the mesa top, correspond roughly to the view from a field in the valley of Polacca Wash. Figures 2 and 3 republished with permission of John Wiley & Sons, from C. Daryll Forde, Hopi Agriculture and Land Ownership, *Journal of the Royal Anthropological Institute*, vol. 61, 1931; permission conveyed through Copyright Clearance Center, Inc.

(1938) gives a diagram by Jim Kewanytewa of the sunrise planting markers at Oraibi on Third Mesa.

3.3 Systematic Records of Planting Dates

Parsons (1920) provided the dates of planting at her nine named markers, presumably for the year 1920 and Crow Wing (1920–1921, 1925) gave the dates of planting in 1921 at eight of those nine markers. These two records of Hopi observations are generally consistent and according to Parsons (Crow Wing, 1925: 120, n. 184), Crow Wing's further memoranda of planting and solstice dates for the period 1921–1924 were consistent to within a day or two. Searches of the Parsons archives at the American Philosophical Society have not located these records.

3.4 Interpretation of the Ethnographic Evidence

These planting dates, when combined with astronomical calculations of sunrise and satellite imagery, make it possible to explore the regions indicated by the computed azimuths of sunrise. Google Earth provides several powerful tools to locate the horizon markers. One is its computation of elevation profiles along lines from the presumed location of an observer in the computed direction of sunrise. The highest point on the elevation profile indicates the point on the horizon that is a possible horizon marker. Once such a candidate marker has been identified, its height and geographic coordinates and the height and coordinates of the observing station can be extracted from a map and used to compute a precise azimuth of sunrise or sunset on the recorded dates and a precise distance to the marker.[4] Google Earth's ground view provides a second tool, allowing us to compare the appearance of the horizon (labeled at azimuths corresponding to the planting dates) with the appearance of the horizon markers in drawings from the ethnographic literature, see Fig. 4. In many cases, the name of the marker provides a description that can be compared with the resulting imagery.

Since Sun's houses (*Tawaki*) marking the solstices have been described as being short distances across the valleys on either side of First Mesa (McCluskey, 1990), it has commonly been assumed that, with few exceptions, the ethnographically attested planting markers would also be found in similar locations, which would put them atop the mesa some 9–13 km from the villages of First Mesa. While this is the case for the Third Mesa village of Oraibi (Voth, 1901: 149–152; Titiev, 1938), at First Mesa those horizon markers whose geographic locations have been identified

[4] The National Geodetic Survey (2012) has produced a useful program for these computations, INVERS3D, which is available as FORTRAN source code, as a PC executable file, or for online interactive computation.

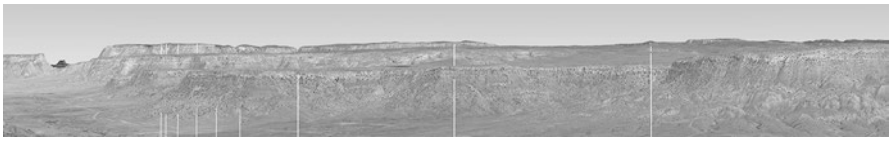

Fig. 4 First Mesa Planting Markers. Google Earth ground view; vertical exaggeration 3:1. White lines indicate planting markers, either computed from dates of plantings in 1921 (Crow Wing, 1925) or other identified markers

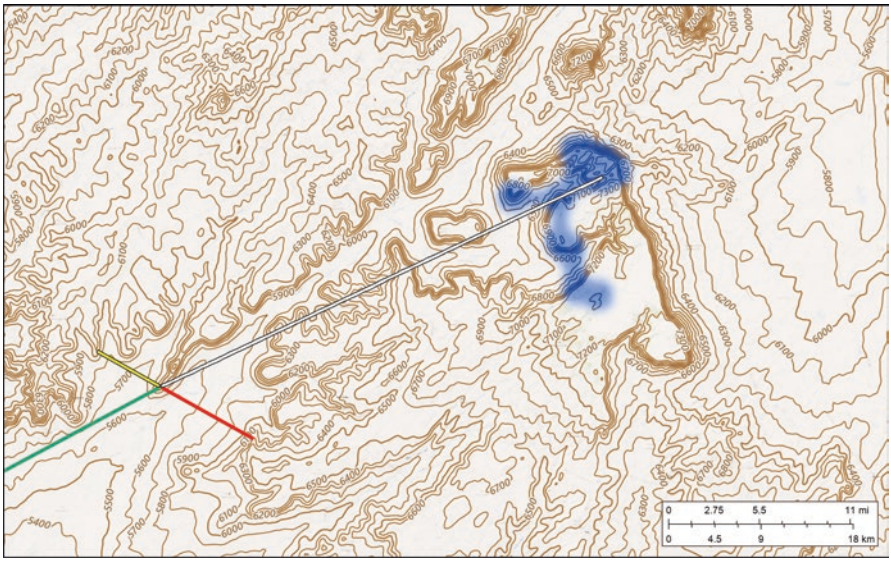

Fig. 5 Map of region of First Mesa Horizon Markers. Lines from First Mesa indicate cosmological direction markers, reading counter-clockwise from four o'clock position: winter solstice sunrise marker, summer solstice sunrise anticipatory marker, summer solstice sunset marker, and winter solstice sunset anticipatory marker (in San Francisco Peaks 127 km to the southwest). Shaded area indicates the general region of Balakai Mesa where calendar markers have been identified. Base map shows contour intervals in feet; from USGS, *The National Map*

(Fig. 5) lie at more distant points that define the horizon, varying from 40 to 50 km from the First Mesa villages.

Since the highest points on elevation profiles in the directions of sunrise on the recorded planting dates indicate that the points defining the horizon on those dates lie at similar distances, it can be assumed that those named horizon markers which have not been precisely identified also lie on the distant horizon. This continuous series of ten distant horizon markers is admirably suited for highly precise observations anticipating the solstice.[5]

[5] It is worth noting that a change of the observer's position by 800 m (the distance from Red Cape, at the south end of Walpi, to Hano Village) changes the azimuth of these markers by less than 0.6°.

Table 2 Attributes of First Mesa Planting Markers

Name	Type	Distance (km)	Angular width	Angular height
Pavöntsomo young corn mound	Mound	45	0.55°	2.0′
[a]***Hoñwítčmo*** (alternate)	Mound	40	–	–
[a]***Hoñwútčmo***	Mesa edge	40	–	–
Neveqtsomo two mounds side by side	Gentle "u" notch	40	0.70°	1.0′
[a]***Pülhomotaka*** multi hunch-backed man	Group of mounds	40	1.83°	1.6′
Kwiitsala narrow neck of a mesa top	Notch	50	0.10°	3.6′
Pövaimükpöveö[i]sti	Notch	50	0.55°	3.1′
Telěo[i]tó Grasshopper planting	Overlapping notch	40	–	–
Iswurtixö[i]to' Coyote Bitch planting	Mound	50	0.47°	2.5′
[a]***Owatsmutix*** Rock Hill planting	Group of mounds	45	–	0.5′
[a]***Natalö[i]tstix*** Rock Hole Through planting	Group of mounds	45	–	–

Markers are listed sequentially beginning with early plantings and ending before the summer solstice, thus they appear from right to left on the horizon calendar. Angular heights were computed using different simple refraction models with no significant change in the results. Distances are approximate, rounded to the nearest increment of 5 km.

[a]The exact location of starred markers is uncertain; alternate identifications are given for *Hoñwítčmo*.

4 The Planting Markers of First Mesa

The First Mesa planting markers are at the edge of Balakai Mesa, which is generally some 40–50 km away from the Sun-watchers. It may be significant that this mesa edge formed part of the boundary, described in 1938 as marking the limits of the land claimed by the people of First Mesa (Whiteley, 1989: 28). The markers for the First Mesa planting calendar extended to, and may have defined, the limits of this claim of Hopi territory. Table 2 summarizes the principal attributes of these markers, although it deliberately rounds the distances of markers to the nearest 5 km and excludes their exact physical locations, which are culturally sensitive.

The following brief descriptions provide the appearance of the markers, the ethnographic evidence supporting their locations, the planting activities that they regulate, and the appearance of the markers as seen from Walpi Pueblo.

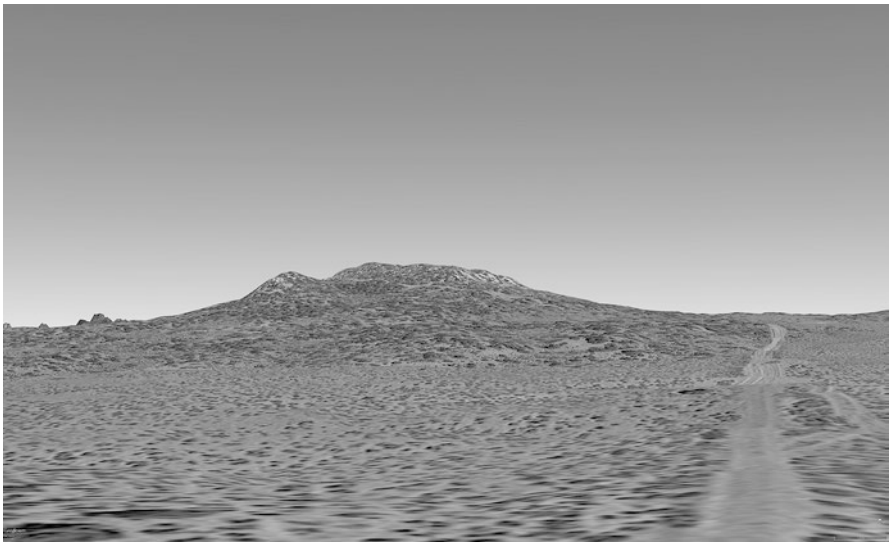

Fig. 6 *Pavöntsomo* from trail. Google Earth ground view, vertical exaggeration 3:1

4.1 Pavöntsomo *(Young Corn Mound)*/Koyöngkopěö^{i}sti *(Turkey's Head)*

This mound, extending about 800 m from northeast to southwest, rises about 25 m above the general surface of the mesa. Stephen and Fewkes describe it as "located on the old wagon trail to Fort Defiance, a little beyond the head of Keam's Canyon." The mound is just north of what is now an unpaved dirt road (Fig. 6), and about 10 km (6 miles) beyond the Keam's Canyon drainage area. Stephen (Map 12) describes "white stone bluffs," Forde associates *Pavöntcomo* with early corn planting, while Agayo's horizon diagram depicts a mound at this point which he calls *Pelühomo* (rock becomes a mound) and describes it as a marker for early corn planting and watermelon planting. Forde's Second Mesa horizon calendar identifies a similarly named and located marker, which it names in the plural form, *Pavüntcotcomo*, young corn mounds; this may refer to the other mounds found in the vicinity. Parsons calls this marker *Koyöngkopěö^{i}sti* (Turkey's head) and, like Crow Wing, describes it as marking the early planting of corn for the katsinas. *Pavöntsomo* is close to the azimuth inferred from Crow Wing's planting dates.

4.2 Hoñwítčmo *Uncertain Location*

The identification of this planting marker is uncertain. It is only mentioned by Stephen and Fewkes, who place it between *Pavöntsomo* and *Neveqtsomo*, but give no further details. Stephen gives its etymology as: "Hoñ-wítč-mo; Hoñ'-wi, pl. of Wü'-nü, erect;" Stephen's glossary (Stephen, 1936: 1319) gives *wü'nü* as "vertical, upright" and Benjamin Whorf's annotation to the glossary gives *wene'fte* as "comes to a standing position, arises." The *Hopi Dictionary* gives *hongva* as the plural of "stand up, get to a standing position," while *-tsmo* is the singular combinative form of *tsomo,* hill. Seen from Walpi, *Pavöntsomo* is separated from *Neveqtsomo* by 8.0°; within that space there is a place 1.4° to the right of *Neveqtsomo* where the distant edge of the mesa begins to rise above a closer ridge line; alternately there is a small upright mound 1.3° to the left of *Pavöntsomo.* Since none of our recorded planting dates or measured azimuths include this site, we lack evidence to resolve this identification.

4.3 Neveqtsomo *(Two Mounds Side by Side)*

The location of this marker is taken as the center between two mounds, which lie about 560 m apart on a north-south line and rise about 10 m above the general surface of the mesa. This marker is almost universally described by some form of this name, although Fewkes contradicted Stephen's translation by reading *neveq*, side by side, as *nuvaq*, snow, and interpreting the Hopi term as "snow mound." Stephen's horizon diagram labels this marker both *Nevéûktcomo* and *Maho'ñsheñwilegĭ* (Owl Horns); Agayo's horizon diagram calls it Owl Horn Lane. The USGS National Map shows an Owl Hat Point within 1.5 km of the marker. It is variously described as marking a time to plant sweet corn, squash, gourds, or melons. Besides being a planting marker, *Neveqtsomo* also marks the *Niman* festival in August, when the Sun rises there on his return to the south (Stephen, 1893b). The marker is close to the azimuth inferred from Crow Wing's planting dates.

4.4 Pülhomotaka *(Multi Hunch-Backed Man)*

Stephen describes this marker as "a series of curves thus ~~~~, a multi-hunched-back-man". The marker is also named by Fewkes and Parsons but with no further specification as to its appearance or location. Stephen and Fewkes associate it with corn planting by the Patki (Water) clan. Agayo's diagram indicates an unnamed gentle undulation in this region which he associates with the main corn planting on level fields. Parsons associates *Pülhomotaka* with the second planting of watermelon. Crow Wing mentions that there would be a second planting of watermelon

five days after *Neveqtsomo*, although he was occupied with other ritual activities on that date. Stephen's description suggests that this marker is an extended region on the horizon rather than a single point. Besides being a planting marker, Stephen (1893b) notes that the assembly before the Snake-Antelope Festival occurs when the Sun rises at *Pülhomotaka* on his return to the south. This series of curves is probably a series of mounds atop a ridge located between *Neveqtsomo* and *Kwiitsala*. Although the group of mounds making up this marker has been located, the marker itself spans almost 2° and the specific marker used to establish the planting date cannot be precisely located.

4.5 Kwiitsala *(Narrow Neck of a Mesa Top)*/Atkya'ùyisti *(Way Down Planting Time)*

The topography of *Kwiitsala* is complex; it is a notch in the horizon formed by the two sides of a steep, curved valley cut into Balakai Mesa. Seen from First Mesa, the defining edges of the notch are scarcely separated, yet along the line of sight they are separated by about 5 km. The left edge of the notch is about 5 km farther from Walpi Pueblo than the right edge. The ridge over which the Sun rises is even farther up the valley, about 50 km from Walpi.

Kwiitsala is found in all the ethnographic accounts; it is one of the first planting markers Stephen mentioned in his correspondence with Fewkes (Stephen, 1893a), giving its magnetic azimuth, an etymology, and the fact that it marks the beginning of general corn planting. Crow Wing and Parsons name it *Atkyaö'sti*, or "way down planting time", describing it as the first day of corn planting. The meaning of their term can be related to the Hopi directional term *atkya*: below, lower, or the valley floor,[6] and *'ùyisti*: planting time; from which we might interpret *Atkya'ùyisti* as time for planting in lower fields. Agayo's horizon drawing depicts "the lane" as a marker for later corn planting in the washes in spring; he understands the term "the lane" as a notch in a mesa top as he uses the same term elsewhere (Forde, 1931: 396) to describe the gap (*wala*) separating the villages from the rest of First Mesa.[7] Forde describes *Kwiitsala* as marking the time of main corn planting. The marker is close to the azimuth inferred from Crow Wing's planting dates and to Stephen's measured bearing to the notch; Forde's measured bearing differs significantly, but it is uncertain where he took his measurements. Forde's Second Mesa horizon calendar also uses this notch, which it calls *Wokwalca*, the large gap or large pass. The topography of the notch is so distinctive that there is no reason to doubt its identification.

[6] Malotki (1979: 151–152) notes that the Hopi morpheme *?oo-* (above) can be identified with the upper surface of the mesa and the morpheme *?at-* (below) with the desert unfolding beneath the mesa plateau.

[7] Compare the dictionary definition of lane: "A narrow way between hedges or banks; a narrow road or street between houses or walls" (OED Online 2019).

4.6 Pövaimükpöveö^{i}sti *(When the Wash Spreads Planting*[8]*)*

Parsons's name for this marker appears to refer to a planting in a field where the wash spreads, reflecting a common location of Hopi fields at the mouths of arroyos, so that rainwater running down these washes spreads over the fields (Bradfield, 1971: 17–19; Forde, 1931: 361–366). Crow Wing associates it with a planting in the Sun-watcher's field, the date of which yields a computed azimuth that can be associated with a distinctive notch on the horizon. The notch as depicted by Stephen in his horizon diagram (Fig. 1) is not as sharply defined as the narrow notch at *Kwiitsala*; Forde's Second Mesa horizon calendar calls this notch *Walcahoya*, the small gap or small pass.

4.7 Teleö^{i}tó *(Grasshopper Planting)*

The significance of Parsons's name for this marker is uncertain; it is not descriptive and is not a clan name, as there is no Grasshopper clan in Stephen's (1936: 1067–1073) list of clan names. Its use to mark the specific date of planting associates it with the place on the horizon where Smoke Signal Point overlaps the more distant parts of Balakai Mesa to form a notch.

4.8 Iswurtixö^{i}tó *(Coyote Bitch Planting)*

The significance of Parsons's name for this marker, which we may also translate as Coyote Old Woman, is uncertain. It may be a clan name, referring to the Coyote maternal family of the Kokop (fire spindle) clan (Stephen, 1936: 1068, 1071) but Crow Wing (1925: 91) notes that it marks a planting for the Eagle family of the Reed clan. The computed azimuth for this planting date indicates a subtle rise on the horizon, which is probably this marker. The exact location of this marker calls for further investigation.

4.9 Owatsmutix *(Rock Hill Planting)*

The planting date indicates a region on the north edge of Balakai Mesa where there are a series of mounds extending over some 700 m. There is a widespread scatter of large boulders in the area, making it difficult to define the intended rocky mound.

[8] I have modified Parsons's translation to reflect the Hopi name's reference to a planting (*-öⁱsti* = Hopi Dictionary, *uyisti*).

Crow Wing's (1920–1921) manuscript names this "stone fall planting," which may indicate the scatter of boulders below a rocky mound.

4.10 Natalö'tstix *(Rock Hole Through Planting)*

Parsons glosses this marker as Perforated Rock. Since the Sun moves very slowly along the horizon in the days leading up to the solstice, this planting marker is not very far from the previous Rock Hill planting. It is probably a particular mound in the group of rocky mounds associated with Rock Hill planting.

5 Archaeological and Ethnographic Correlates

Such a well-documented and well-defined set of horizon markers identifies attributes of horizon markers that can, in turn, be used as correlates for evaluating other sites that archaeological studies suggest may have been used to establish a horizon calendar. We will consider three such correlates for which the Hopi horizon markers provide evidence. The first is the distance of purported horizon markers from the observer; the second is the form or shape of the markers, which is related to the markers' perceptibility and precision; and the third are the markers' names, which only become applicable when we have ethnographic or historical evidence for the names that can be traced back to the culture associated with the markers.

5.1 Distance as an Archaeological Correlate

If we consider the distance to the planting markers as a means to identify potential archaeoastronomical sites, we find that the distance to these markers depends on the topography of the particular village where the Sun-watcher makes his observations. At Walpi on First Mesa, the distance to the planting markers ranges from about 40–50 km. At Shungopavi on Second Mesa, which shares a number of planting markers with Walpi, the few identified markers are from 55 to 75 km distant. The recorded sunrise and sunset planting markers at Oraibi on Third Mesa, which have not been identified precisely but are only located in general on the nearby ridges that define the local horizon, are only some 6–12 km from the village. Finally, some well-attested cosmological horizon markers have been found to be as distant as 127 km from Walpi Pueblo (McCluskey, 1990: S5–S7). Although the distance to the Hopi calendar markers varies significantly with the topography surrounding the particular village, the markers are consistently on the most distant visible ridge.

The great distance to the markers enables more precise observations of the direction of sunrise or sunset, and consequently of the day when the Sun arrives at this

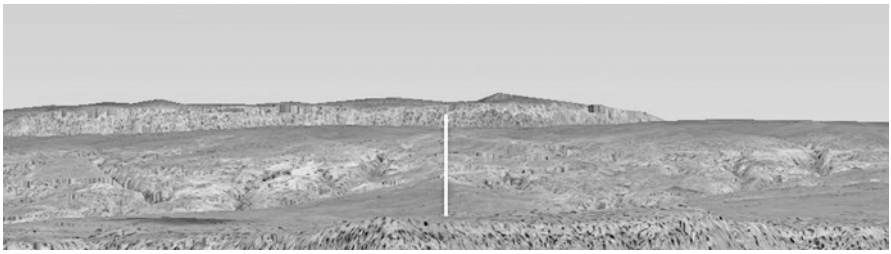

Fig. 7 Neveqtsomo (Two Mounds Side by Side). Google Earth ground view; vertical exaggeration 3:1

marker. One of the markers, *Neveqtsomo* (two hills side by side) illustrates this effect (Fig. 7). Seen from First Mesa, the highest points of the two hills appear to be separated by about 42 arc min. It takes about two days for the Sun to traverse this distance along the horizon, indicating that the place of sunrise can be determined with at least this precision. Estimates of the Sun's rising at the low point between the two hills would allow for even greater precision.

5.2 Form of the Marker as an Archaeological Correlate

Thom and Thom (1980) proposed a typology of horizon markers or foresights, as they called them. Seeking to establish highly precise astronomical observations, they proposed a model in which the form of the marker governed the way the upper or lower limb of the Sun or Moon appeared to graze the markers on the horizon. Most of the calendar markers used by the Hopi can be placed in the Thoms' type V, where the Sun "appears or disappears behind a small irregularity in an otherwise relatively flat part of horizon." A few markers fall in other categories: *Kwiitsala*, for example, might be considered as a variant of type I, where the "limb reappears momentarily in a notch" (Ruggles, 1983: S9) and the cosmological marker for winter solstice sunset is a valley in a distant range of mountains (McCluskey, 1990: S5–S7) that can be placed in type IIIa. Thus we find that the majority of the markers used in this well-documented horizon calendar would fit into a category that Ruggles (1983: S27) considered to be least effective. The flat surfaces and occasional vertical edges provided by the mesas of Hopi country differ from the more irregular profiles found in surveys of British megalithic sites. When we couple this with the steeper rising and setting of the Sun at Hopi versus British latitudes (35° N vs. 55° N), the Thom model is not strictly applicable to the Hopi case.

Our approach to the form of the markers, as summarized in Table 2, is to consider their general shape, for example a mound, a notch, or a more complicated shape, and two elements of their dimensions: the angular width of the marker, as measured from one extreme azimuth to the other, and the angular height or the marker, as measured from its lowest to its highest point.

The angular width is an indicator or the precision with which a single site may yield a precise observation. The least precise site in our data is the series of mounds called *Pülhomotaka,* which spans a range of almost 2° in azimuth; the most precise site in our data is *Kwiitsala,* which spans an azimuth range of only 6 arc min.

In all cases the angular height is significantly less than the angular width. *Kwiitsala,* the most prominent of the markers, has an angular height of 3.6 arc min. Such a compact, well defined site seems to have been favored by Hopi observers, as *Kwiitsala* appears in both the First Mesa and Second Mesa planting calendars. One factor that reinforces the visibility of markers with small angular height is that they are found in a sequence of regular planting markers. The presence of a sequence of markers may be taken to increase the likelihood of markers that would be considered marginal if considered in isolation.

Three First Mesa planting markers, *Pavöntsomo, Kwiitsala,* and *Pövaimükpöveöisti* also appear in the horizon calendar for Shungopavi on Second Mesa, under the names *Pavüntcotcomo*, *Wokwalca*, and *Walcahoya.* These shared markers are all characterized by an angular height in excess of 2 arc min when seen from Walpi Pueblo, or in excess of 1.4 arc min when seen from Shungopavi.

The two hills of *Neveqtsomo* stand only some 10 m above the local terrain; an observer at First Mesa would see them protruding only 1 arc min above the horizon line. This is very close to the limit of visibility and, as Fig. 7 indicates, they are scarcely visible even with considerable magnification and a vertical exaggeration of 3 to 1. And yet these mounds are widely named in the ethnographic literature as planting markers, and Forde (1931: 384) noted that the name *Neveqtsomo* was one of two markers that would be known by "a well-educated Hopi of Walpi" to have a "precise significance." Although *Neveqtsomo* is only scarcely visible to an uninformed observer, it was recognized by the Hopi as an important part of the planting calendar.

5.3 Names as Ethnographic Correlates

The ethnographic sources provide us with an extensive sampling of the names associated with the markers in the Hopi planting calendar, which indicate the kinds of names that we can expect to find in other horizon calendars. There are four independent sets of names collected at First Mesa by Stephen (1893b) and Fewkes (1897: 258–259), by Agayo and Freire-Marreco (Forde, 1931: 387), by Crow Wing (1925) and Parsons (1920, 1933), and by Forde (1931: 386, Fig. 6a); additional sets of names were collected at Second Mesa by Forde (1931: 386, Fig. 6b) and at Third Mesa by Voth (1901: 149–152) and Titiev (1938). In two of the three cases where the same marker is used at both First and Second Mesa, the markers have distinctly different names at First and Second Mesa, indicating that the planting calendars of nearby villages had a degree of independent development.

The names of these markers (Fig. 8) can provide additional evidence for identifying and locating specific places of sunrise or sunset. The most common names (50%) describe the marker itself, for example *Neveqtsomo*, two mounds side by

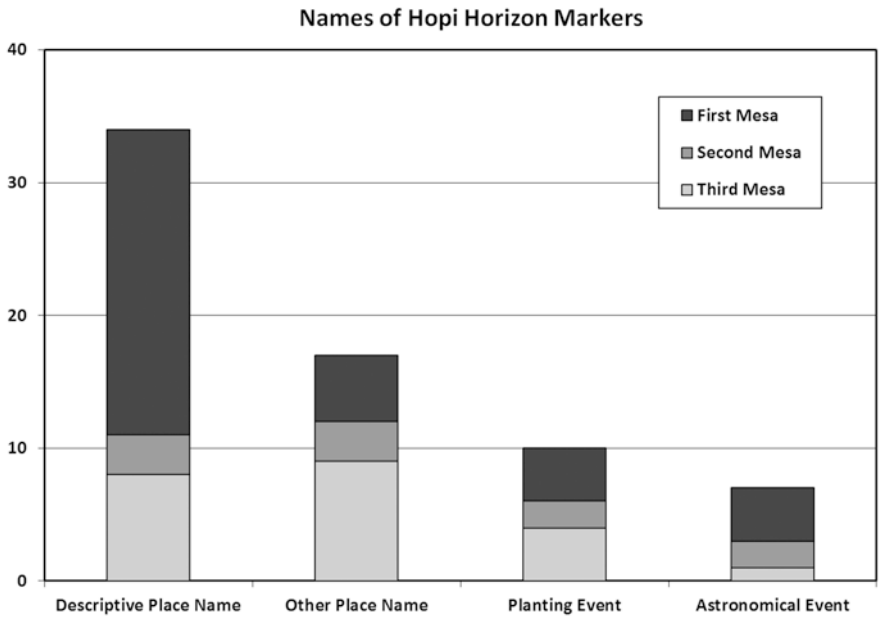

Fig. 8 Types of Names of Hopi Horizon Markers

side; *Kwiitsala*, a narrow neck of a mesa top; or *Natalöitstix,* Rock Hole Through Planting. In some cases the name is sufficiently descriptive to assist the Sun-watcher's observations; in other cases the name refers to such a small detail (a perforated rock) that the description alone does not suffice to identify the marker. The next most common kind of name (25%) is a specific name of a marker that doesn't describe its physical attributes, such as *Polìi-ki*, Butterfly House; *Angwuski,* Crow House; or *Lohalin,* Fish Spring (Navajo *łóó'háálį* (Linford, 2000: 106)). Names of specific plantings such as *Pavöntsomo,* Young Corn Mound (a specific crop); *Akpitö,* Late Planting (description of a planting), and *Iswurtixöito',* Coyote Bitch Planting (a named planting) form the next 15% of the planting calendar. Markers named after astronomical events are rarely found (10%) in the horizon calendar. There are two *Tawaki* or *Tawat Kyata*, Sun's Houses, marking summer and winter solstice sunrise; in one account the direction of the summer solstice is called *Ho'pokyüka,* the place to the northwest. These unique astronomical names refer to the places where the Sun turns back in his annual travels along the horizon and they thereby identify the places where the Sun rises or sets at the solstices. The rarity of astronomical or calendric references indicates that their absence in the name of a potential horizon marker is not satisfactory evidence against the validity of the marker itself.

6 Conclusions

We must now consider how to apply the correlates derived from the Hopi horizon markers to evaluate the significance of purported archaeoastronomical sites.

The distances found for Hopi horizon markers vary widely from about 5–127 km, depending on the topography of the particular village, so we cannot specify a specific distance criterion; rather any site within this range of distances could be considered acceptable as a potential astronomical marker. The one limiting aspect of the distance correlate is that all agricultural or ceremonial horizon markers[9] are found at the most distant part of the local horizon. Any potential natural marker less than 5 km from the observer, or which does not define the limits of the local horizon, must be considered suspect.

To the extent that the form of Hopi horizon markers is strongly influenced by the local topography of the Hopi country, which yields a horizon of relatively flat plateaus and deeply incised valleys, we cannot insist on the subtle relief found in most Hopi horizon markers. Other, more striking forms of horizon markers are found among the Hopi horizon markers and are *a priori* more acceptable. The surprising result of this investigation is that scarcely perceptible horizon markers, near the limits of human perception, cannot be ruled out as potential astronomical markers.

In ethnoastronomical investigations, we may find a culture's names for sites that are potentially horizon markers. As with the form of a horizon marker, the name of a marker is not determinative. However, given the rarity of astronomical names in the Hopi examples, a name that corresponds to a potential astronomical observation would be a strong indicator of the astronomical use of a horizon marker.

The Hopi horizon calendars, especially the very well-documented calendar of First Mesa, clearly meet Cotte and Ruggles's (2011: 271–272) criteria for the most credible category of archaeoastronomical site: one that is generally accepted within the scholarly community. Although some details of these calendars remain to be determined, there is no doubt whatsoever that the Hopi horizon markers were used to mark the passing of time. It would not be unwarranted to claim that the First Mesa planting and ceremonial markers establish the most well-documented solar horizon calendar known. The correlates derived from these markers provide criteria in response to Ruggles's (2015) call for "more sophisticated methods to assess archaeoastronomical credibility [that]… reflect the current state of theory and practice in the discipline."

Acknowledgments I am grateful for the long-term assistance of many experts on Hopi language and culture, both academics and Hopi people. I also thank the American Philosophical Society for access to the papers of Elsie Clews Parsons and to the National Anthropological Archives for access to the Fewkes – Stephens correspondence. Finally, I thank my wife, Connie, for her years of careful editing which made this paper, and others on the Hopi, much clearer than they would otherwise be.

[9] The two cosmological markers of the Sun's Houses, where ritual offerings are deposited at the solstices, are not the most distant points at the solstitial directions (McCluskey, 1990).

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