The 2012 Transit of Venus Observed at Real de Santa Ana, Baja California Sur, Mexico:

A Tribute to the XVIII Century Mexican Astronomer Joaquín Velázquez de León

By

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Introduction

A series of cultural and scientific activities were organized along the Baja California Peninsula both to observe the transit of Venus of June 5, 2012, and to commemorate the transit of June 3, 1769, by measuring the shadow of Venus from the same location.[1] The events were coordinated by the Universidad Nacional Autónoma de México (UNAM) and local authorities. Major celebrations took place in the central plaza of San José del Cabo, not far from where the combined French/Spanish expedition observed the transit in 1769, and a search was carried out to find the location of the previous effort. Upon finding clear evidence of the 1769 site, an observatory was built and the transit measured from where Joaquín Velázquez de León held his telescope in June 1769.[2]

Finding the place was not an easy task because no information had been discovered to pinpoint the precise location. For instance, it is unclear how accurately Velázquez was able to describe the position indicated in his manuscript. The determination of the geographic longitude on land was based on reasonable

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Joaquin Velázquez de León

precision in 1769, but it is necessary to take into account that an error of one arcminute near the Tropic of Cancer is equivalent to 1.8 kilometers. According to Velázquez, he was able to determine the location of his observatory with a discrepancy of only a few arcseconds using a gnomon.[3] Additionally, he made careful observations of Jupiter moon eclipses to determine time differences with respect to similar observations by the official observers in San José del Cabo.

Previous publications about the observations by Velázquez have reported that he built his observatory on the top of the highest hill west of Santa Ana and that the longitude of his observatory was 267° 49´ West of Hierro Island.[4] Those authors quoted gave coordinates that translated to the Greenwich Meridian, reporting 110° 11´ W. We noticed, however, that this coordinate, as stated in a letter by Velázquez, does not refer to the location of the observatory, but to the longitude at the tip of the peninsula.[5] Velázquez discussed on that page how previous maps of the region gave a longitude between 263 and 261 degrees counting from the *Isla de Hierro*, and how his careful observations from Santa Ana corrected the datum to 267° 49´.

A preliminary investigative trip to 110° 11´ W was made by members of the La Paz planetarium in early April 2012. The explorers reported that the highest elevation was at most 400 meters, and that it was impossible to find a location where the Pacific Ocean and the Sea of Cortés both could be seen. We know today that the reported position is located almost 17 linear kilometers west of Velázquez's observatory. We decided then to first identify the place where Real de Santa Ana once stood, and for this task, we contacted the office of the National Commission of Natural Protected Areas (Comisión Nacional de Areas Protegidas, or CONANP) for South Baja California. They informed us that information existed about the location of the former mining offices at Real de Santa Ana: CONANP registries reported that the place was currently occupied by two small ranches: Rancho El Dátil and Rancho Santa Ana. The ranches were accessible from San Antonio de la Sierra, a small town located two hours from San José del Cabo.

The Historical Relevance of the 1769 Transit of Venus

German astronomer Johannes Kepler, the first astronomer in modern history to predict that the planet Venus would pass over the disc of the Sun in 1631, had previously enunciated the Laws of Planetary Motion.[6] These laws allowed English

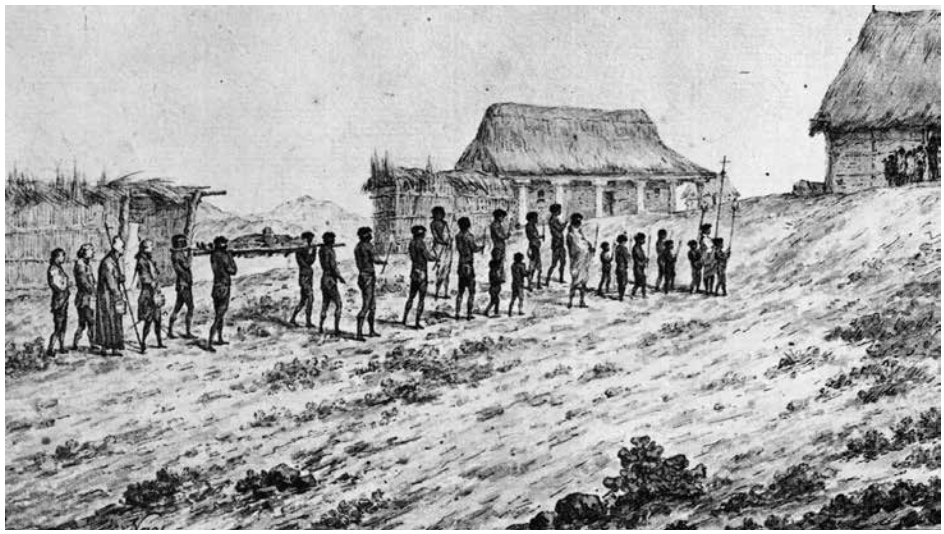
astronomers Jeremiah Horrocs and William Crabtree to deduce that a second passing of Venus would occur eight years later, and that the next one would happen after 121.5 years.[7] During the second half of the seventeenth century, formidable advances in celestial mechanics and astronomy were at the forefront of scientific knowledge. In just a few decades, research groups were created, specialized journals were founded, and meetings were organized for the exchange of the latest discoveries.

In 1716, Edmund Halley submitted a now famous proposal to the Royal Society in London outlining the significance of measuring the transits of 1761 and 1769. Precise observations of the phenomenon would allow astronomers to calculate the difference in position of the Sun from different locations on the Earth and then obtain the distance between the Earth and the Sun, a measurement required to determine precise geographical locations and produce accurate maps. Halley therefore recommended that various countries direct their efforts and resources to organizing expeditions to suitable areas around the globe to observe the transits, and later to compare measurements. More than one hundred astronomers were appointed to the task of organizing large, costly, and sometimes very dangerous trips to obtain data. The relevance of the project justified the generous funds provided by scientific societies that had been created just for that purpose.[8] Nowadays, this endeavor may be comparable only to the construction of large-scale astronomical observatories, or planetary exploration by international consortiums. It is fair to say that the transit of Venus observations in 1761 and 1769 comprised the first large scale, international astronomical project in modern history.[9]

The French-Spanish Expedition to Baja California in 1769

The French astronomer Abbot Jean-Baptiste Chappe d'Auteroche organized one such expedition to San José del Cabo in the southernmost region of the peninsula of Baja California. The trip was laden with misadventure from beginning to end. Chappe d'Auteroche was, without a doubt, a scientist with a determined outlook, having already conducted a complicated expedition to the Siberian steppe to observe the transit of 1761. His observations were successful, despite the fact that the Russian sky had been completely cloudy the previous night before the observation and cleared just a few hours before the event.[10]

Abbot Jean-Baptiste Chappe d'Auteroche.



Funeral procession for Chappe d'Auteroche. Drawing by Alexander-Jean Noël. From the Cabinet des Dessins, Musée du Louvre, Paris, Inventory No. 31478.

In 1765, Thomas Hornsby recommended that in order to avoid potential failures of observations performed in the southern hemisphere, new expeditions should be sent to the northern regions of the American continent.[11] Chappe d´Auteroche, who had learned his lesson in 1761, decided that warmer and dryer climates would be more advantageous to measure the transit of 1769, so he selected the northern territories of New Spain. In order to organize the expedition, however, skillful diplomatic abilities were needed because of Spain's political position aimed toward protecting its colonial territories. Because a petition by the Royal Society of London to send an expedition to observe the transit in New Spain had previously been rejected by Carlos III, the French were up against strong opposition when they requested the king's permission for this new expedition. It was approved only after difficult negotiations. The key members of the expedition were Jean Pauly, engineer and royal geographer who acted as the main scientific advisor; instrument expert Jean Jaques Dubois, who was in charge of telescopes and clocks; and Jean Noël, a student from the Painting Academy, who was appointed to document the trip in a series of drawings.[12]

The French-Spanish expedition left Paris for the port of Le Havre-de-Grâce on September 18, 1768. They stopped first at the Port of Cádiz, Spain, where they were detained for weeks. Their departure was finally permitted in mid-November 1768 under the condition that Vicente Doz, an experienced astronomer, and Salvador de Medina, both qualified officers from the Spanish navy would join the expedition. They reached the coast of Veracruz on May 6, 1769. After a

long and uncomfortable journey, the expedition reached Mexico City, where they presented credentials to the Viceroy. After lengthy interviews, they continued to San Blas, Nayarit, where they crossed the Sea of Cortés.

Chappe and his men finally reached San José del Cabo on May 18, 1769, with only a few days left to prepare their instruments for the observations. In addition, they received the frightening news that an outbreak of fever (possibly yellow fever, also known as *matlazahuatl* disease, or black vomit) had killed many natives in the area. In order to save time, Chappe decided that the expedition should stay in the area and immediately start observing the stars to establish their geographical position.[13] This decision, crucial to achieve the objectives of the expedition, turned out to be fatal because Chappe d´Auteroche and almost his entire crew lost their lives to the disease. Only Pauly, Noël and Doz returned to Europe.

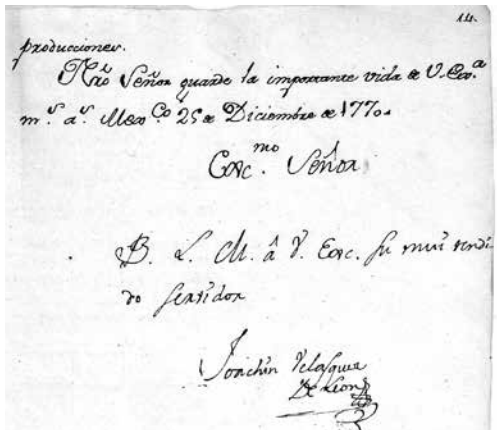
Joaquín Velázquez de León: an Astronomer from New Spain

An important addition to the arrival of the French-Spanish expedition in Baja California was the entrance of the Mexican astronomer Joaquín Velázquez de León into the historic scenario. Velázquez de León, one of the driving forces of the scientific movement in New Spain during the second half of the eighteenth century, was born in 1732 into a family of long-standing mining tradition at the hacienda of Acevedocla in the district of Sultepec in the state of Mexico. Velázquez began his career studying law and in time attained a broad knowledge of mathematics, chemistry, geology, physics, natural history and poetry.[14]

From 1765 on, he directed efforts to enhance the mining activities in New Spain, which caught the attention of José de Gálvez, the royal emissary sent there to apply the administrative reforms by Carlos III. Gálvez invited Velázquez to accompany him to Baja California and organize its mining activities there. They arrived on the peninsula in 1768 and quickly established their headquarters in Real de Santa Ana, the first non-religious settlement in the peninsula. Velázquez remained there for almost three years, during which time he performed numerous astronomical and geographical measurements that were essential to correct the scale of the maps from New Spain.[15] He also described the local natural resources and made other scientific studies, but it is without a doubt that the observations of the transit of Venus in 1769 became one of the most important and transcendental achievements of his life.

The Observations of Velázquez de León in Baja California

As soon as Velázquez learned that a French-Spanish expedition had arrived



A fragment of the letter from Velázquez de León to Marqués de Croix. Museo Naval, Ministerio de Marina, Madrid, Spain.

in the peninsula to observe the Venus transit, he communicated his interest to join and help them with such an important task. The European group suggested that he stay in Santa Ana and measure the transit there: "in case we miss ours because of clouds; and even if this was not the case, it would be beneficial none the less to practice the observation from two different posts."[16] Without knowing it at the time, this answer would save the life of Velázquez, because he avoided contact with the epidemic that killed almost the entire expedition of the French Academy.

In his report to Viceroy de Croix, Velázquez wrote that because Santa Ana was located at the foothills of a mountain that elevated westward, covering the view of the Sun much before it set in the horizon, he decided to establish his observatory on the highest summit west from Santa Ana, where "without losing sight of the Sea of Cortés and the Cerralvo inlet at the North Northeast [he] could see the sun set in the Pacific Ocean." Velázquez calculated the geographic position of his

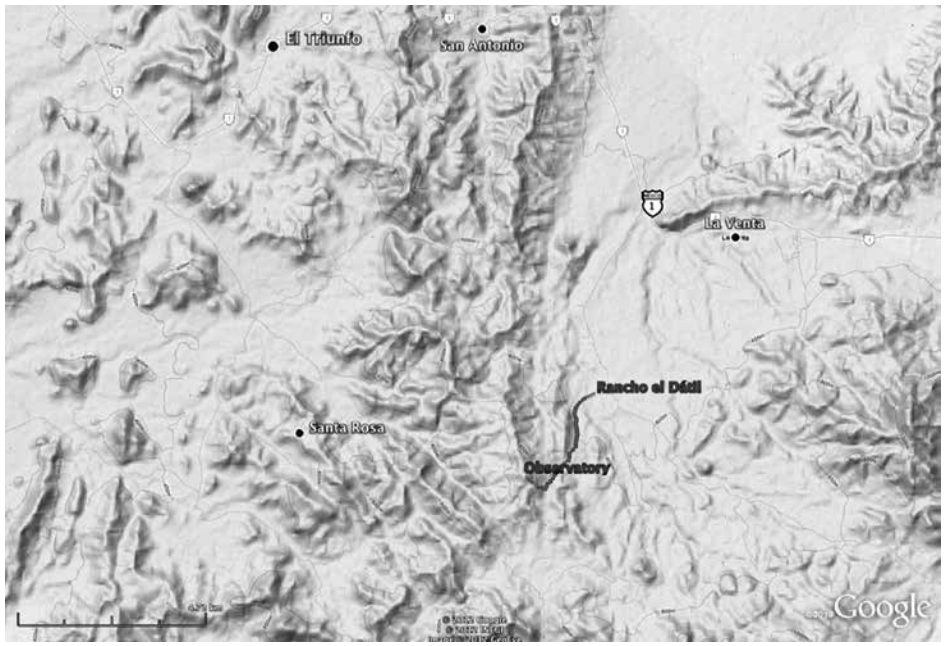
Ruins at Real de Santa Ana, c. 1973. Photograph by Harry W. Crosby, courtesy of Mandeville Special Collections Library, UC San Diego.

From left to right: Carlos Román, Xavier López, and Francisco Salvatierra.

observatory with as much precision as possible, reporting "a northern latitude of 23 degrees 39 minutes 55 seconds." After the transit, he made more observations with instruments of the late Chappe to determine the longitude of his observatory: "I have found the difference of longitude between the Royal Observatory in Paris and the post from which I observed to be 7 hours 29 minutes 33 seconds east."[17] From this observatory, Joaquín Velázquez de León measured the transit of Venus in June 1769 and sent his results to the survivors of the French-Spanish team, who took them to France to be compared and published with the rest taken around the world.[18]

The 2012 Expedition to Rancho El Dátil

The commission assigned by UNAM to find the Observatory of Velázquez de León was formed by Carlos Román and Xavier López-Medellín. We traveled to San José del Cabo on June 3, and made a first trip to San Antonio on the fourth of June. We arrived at the area with hopes of reaching the highest peak near El Dátil, indicated by satellite images. Our first approach was to start off from San Antonio, traveling south to a small, active mine called "La Testera." The chief engineer told us that it was theoretically possible to reach the highest hill from the mine, and that it was indeed linearly closer, but the slope from there was too steep. He recommended instead that we take the simplest approach: return to the highway and take the detour to San Antonio de la Sierra toward Rancho El



A map of the neighboring region of San Antonio de la Sierra and El Triunfo, Baja California Sur, indicating the location of Rancho el Dátil and the observatory.

Dátil. By mid-afternoon, we arrived at El Dátil where we were kindly received by Francisco Salvatierra, one of the current owners, who showed us the landscape from his backyard. We immediately identified the highest hill, straight west from his ranch. After engaging in a long but amiable negotiation, we settled upon an arrangement for Salvatierra to guide us to the top of the hill. Since he had only one mule, he would ride it, carrying the telescope and tripod, while we would walk with the rest of the equipment and provisions, which we now had to limit as much as possible.

In the early morning of June 5, we returned to El Dátil and met Francisco´s wife, Manuela Cota Rivera, present legal owner of El Dátil. She explained that the main building at El Dátil, an old adobe house, was in fact the ancient warehouse of Real de Santa Ana where, by orders from José de Galvez himself, provisions, goods, and materials were concentrated and distributed to the mining camps in the region. Some other barely discernible ruins of a church and smaller buildings in the area were evidence of former prosperous times in the area.[19]

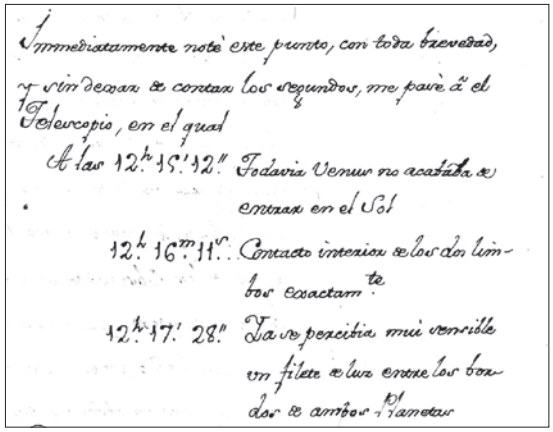
We started the journey to the top of the highest hill just before 9 a.m. with a relatively easy walk following a dry brook covered with riparian vegetation until the hill started to become fairly steep. After a four-kilometer walk, López-Medellín climbed to the first visible elevation, from where he saw the Island of Cerralvo, but

not the Pacific Ocean because there was a higher hill blocking the view. Román and Salvatierra joined him to climb the next hill, and reached the summit at 11:30 a.m. At the top, we clearly saw the Island of Cerralvo and the Bahía de la Ventana to the east. To the west we saw the cloud line above the Pacific Ocean. El Dátil and Santa Ana ranches were also visible down toward the northeast.

A small, roughly circular area, nearly seven meters in diameter, was clear from trees and bushes. Since the rest of the mountain was completely covered with short bushes and trees, we ventured to speculate that Velázquez de León himself may have ordered the clearing of vegetation in order to install his observatory in 1769. Today, because the clearing is used by cattle as a resting place, and because the extreme dryness of the region has kept it from being repopulated by vegetation, we could still see the clearing. The altitude of the hill is 912 meters and our GPS device marked the location at 23h 42m 28s, 110° 02′40.5′′ W. The location of three microwave antennae in the vicinity allowed us to have good reception for cell phones. We called our colleagues in San José del Cabo to let them know we had reached the place: we were standing in the very same place where Velázquez de León observed the transit of Venus 243 years before in 1769.

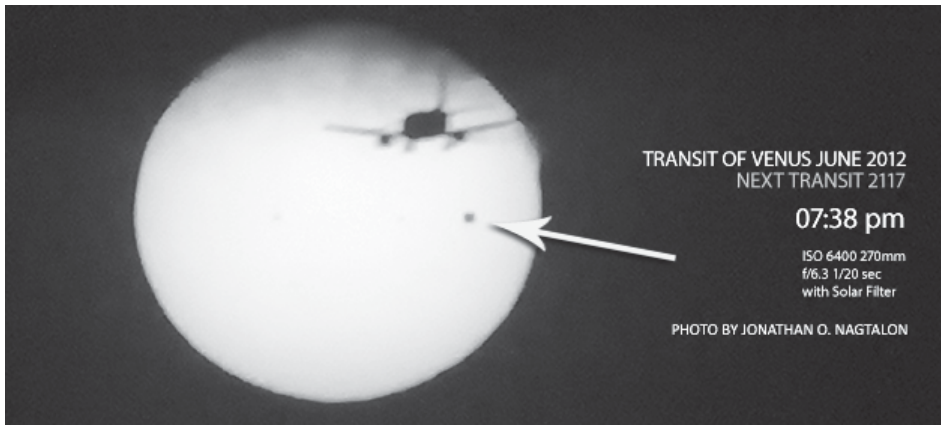
Observations of the Transit of Venus 2012

Former warehouse at the Real de Minas de Santa Ana, currently the house of Manuela Cota and Francisco Salvatierra, owners of Rancho El Dátil.


Immediatamente noté este punto, con toda brevedad,
y vine despues á contar los segundos, me puse á el
Telescopio, en el qual
A las 12h 15' 12" Todavia Venus no acababa de
entrar en el Sol
12h 16m 11s. Contacto interior de los dos lim-
bos exactamente
12h 17' 28" Ya se percibia muy sensible
un filete de luz entre los bor-
des de ambos Planetas

Observations of Joaquin Velázquez de Leon from Real de Santa Ana, June 3, 1769. Museo Naval, Ministerio de Marina, Madrid, Spain.

According to previous estimations, the first contact of Venus with the Sun was to occur at 16:02:24 local time. We set a Meade ETX-70 portable telescope with a 70 mm aperture and a 350 mm focal distance. On this instrument we mounted a homemade "solar funnel" in order to project the disc of the Sun over a high contrast plastic screen. The plastic material slightly reduced the sharpness of the image when projected over the screen. It allowed, however, a comfortable observation of the Sun without having to constantly look through an ocular. This device was similar to others used in observations by the public in Baja California. We also filmed the observation with a video camera. The video did not allow a clear recognition of the first contact at the estimated time, but we noticed the start of the immersion at 16:03:02, when a small notch was visible in the disc of the Sun. The second contact was affected by the "drop effect" described by the eighteenth-century observers, and we had to wait to observe a "slice of light" between the edges of the disks of Venus and the Sun, as described by Velázquez in his journal. We registered complete immersion of Venus at 16:20:20, less than half a minute after the estimated hour for the contact at 16:19:55. Even though our instrumentation was not optimal, it was a very



Photograph of the transit of Venus from San Diego, June 5, 2012. Courtesy Rueben H. Fleet Science Center.

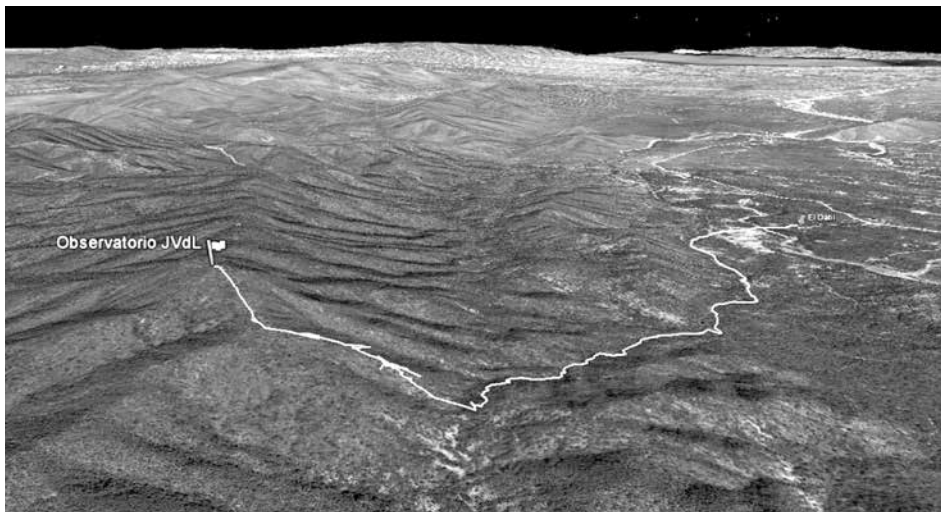
Photographs by Carlos Román and Xavier López atop the 912m observatory hill showing (above), on the horizon, the Bahía de la Ventana and Isla de Cerralvo, towards Northwest; and (below) cloud profile over the Pacific Ocean towards West.

reasonable option given the complicated access route to the site. Moreover, our setting was probably not much different than the one used in 1769. It allowed us to mark the ephemeris by eye, as Velázquez did, with similar precision of less than a minute. The main goal of our expedition was not to measure the transit precisely, but to locate the observatory and to witness the same phenomenon 243 years after Velázquez. Once that mission was accomplished, we packed up the equipment and returned to El Dátil sometime after 16:45.

Discussion

There is a significant difference between the coordinates of the Velázquez de León observatory cited by Higgins, Engstrand and Westfall, and those recorded by our GPS on the summit of the highest hill west of El Dátil. We consider that the confusion resulted from a slight misread of Velázquez de León´s original manuscripts: the Mexican astronomer did not reference the coordinates of his observatory with respect to the *Isla de Hierro* meridian. On page 16 of his manuscript, he reports it with respect to the Royal Observatory in Paris, as described above. To use the meridian at Hierro would make sense, as it was the one used by the Spaniards in the colonial territories. The observations of the transit of Venus reported by Velázquez de León are referred to Paris, however, because they were to be reported to the French Academy and added to the list of measurements taken in 1769 across the globe.

The letter from Velázquez to Viceroy Marques de Croix states a longitude of



A photograph indicating the path we followed to the 912m western hill, which we believe to be the location at which Joaquín Velázquez de León made his observations of the transit of Venus.

Ruins at Real de Santa Ana, c. 1973. Photograph by Harry W. Crosby, courtesy of Mandeville Special Collections Library, UC San Diego.

"7 hours 29 minutes 33 seconds west." This measurement made by Velázquez is equivalent to 112° 23′13.2′′ W from Greenwich, and if we consider that the current longitude of the Royal Observatory in Paris is 02° 20′ 11.42′′ W, then the difference is 110° 03′01.7′′. Our GPS recorded a longitude of 110° 02′ 40.5″ W from Greenwich atop the hill west of El Dátil, which represents a difference of 21.2,′′ giving an uncertainty of 300 to 700 lineal meters, which is perfectly reasonable within the typical error in determining a meridian on land with a gnomon.

We conclude therefore, that we succeeded in our mission of observing the transit of Venus of 2012 at the same site where Mexican astronomer Joaquín Velázquez de León completed his observations of the same phenomenon in 1769. History can, indeed, repeat itself.

NOTES

1. The Transit of Venus was observed by many in San Diego on June 5, 2012, through personal telescopes and by those provided by the Reuben H. Fleet Science Center in Balboa Park. The transit was observed from various other areas throughout San Diego County.
2. His complete surname is sometimes written as Velázquez Cárdenas y León or Velázquez Cárdenas de León (Doyce B. Nunis, editor, *The 1769 Transit of Venus. The Baja California Observations of Jean-Baptiste Chappe d´Auteroche, Vicente de Doz and Joaquín Velázquez Cárdenas de León*. Translations by James Donahue, Maynard J. Geiger and Iris Wilson Engstrand. Natural History Museum of Los Angeles County (Los Angeles: Dawson's Book Shop, 1982). The scientist

signed his own manuscript as Velázquez de León. He is listed as having descended from Diego de Velázquez (1599-1660), Governor of Cuba during the early period of the conquest.

3. A gnomon is the part of a sundial that casts a shadow.
4. Iris Wilson (Engstrand), *The 1769 Transit of Venus observed by Velázquez from Lower California*. (San Francisco: Astronomical Society of the Pacific, 1964): 419, l 1964, Iris Wilson Engstrand, *Royal Officer in Baja California 1768-1770: Joaquín Velázquez de León* (Los Angeles: Dawson's Book Shop), 1976; J.E. Westfall, *The 1769 Transit of Venus Expedition to San José del Cabo* (San Francisco: Astronomical Society of the Pacific, 1992); Santiago Ramírez, *Estudio biográfico del señor don Joaquín Velázquez Cárdenas y León, primer Director General de Minería*. (México. Imprenta del Gobierno, 1888).
5. Joaquin Velázquez de León, Letter to Viceroy Marques de Croix, December 25, 1770, Manuscript 314, Museo Naval, Ministerio de Marina, Madrid, Spain, p. 26.
6. Kepler published his prediction and called up the attention of observers in his *admonitio ad astronomos,* included in his document *De raris mirisque* Anni 1631; see Albert van Helden, "The Importance of the Transit of Mercury of 1631," *Science History Publications,* 1976, pp. 3-6.
7. Kollestroom, *William Crabtree's Venus Transit Observation,* pp. 2-3.
8. James D. Hudon, "A (Not So) Brief History of the Transits of Venus," *Journal of the Royal Astronomical Society of Canada* (2004): 98, 6.
9. San José del Cabo was one of seventy-seven observation stations around the world. See Iris H. W. Engstrand, "The Transit of Venus in 1769: Launching Pad for European Exploration in the Pacific during the Late Eighteenth Century." *Boletin: The Journal of the California Mission Studies Association*, vol. 21, No. 2 (2004), 36-48. Captain James Cook observed the 1769 transit of Venus from the island of Tahiti.
10. Hudon, "A (Not So) Brief History," p. 9.
11. Thomas Hornsby, a British astronomer and mathematician, was a fellow of Corpus Christi College, Oxford; see Westfall, *The 1769 Transit of Venus*, p. 238.
12. Nunis, et al, *The 1769 Transit of Venus*; Abbot Chappe d'Auteroche, *Viaje a Baja California para la observación del tránsito de Venus sobre el disco del sol el 3 de junio de 1769 : conteniendo las observaciones de este fenómeno y la descripción histórica de la ruta a través de México,* 1772. (Colección: Astronomía y su Historia, Ensenada B.C., 1st edition, 2010). Translation by M. Alvarez, H. G. Albert.
13. Chappe d´Auteroche, *Viaje a Baja California para la observación del tránsito de Venus,* 1772.
14. Engstrand, *Royal Officer in Baja California,* 20-22; Roberto Moreno, *Joaquín Velázquez de León y sus trabajos científicos sobre el Valle de México* (Mexico: Universidad Nacional Autónoma de México, 1977), 407.
15. Marco A. Moreno, 1986, "Telescopios utilizados en México (Siglos XVII, XVIII y XIX)." *Elementos* 1(6), 23-30.
16. Joaquin Velázquez de León, Letter to Viceroy Marques de Croix, December 25, 1770, Manuscript 314, Museo Naval, Ministerio de Marina, Madrid, Spain.
17. Wilson, *Transit of Venus*, 1964; Westfall, *The 1769 Transit of Venus*, 1992; Salvador Bernabéu Albert, *Una mirada Científica a la Frontera: California en la Centuria Ilustrada* (Brocar, 2010): 30, 15.
18. Joaquin Velázquez de León, Letter to Viceroy Marques de Croix, December 25, 1770.
19. Engstrand, *Royal Officer in Baja California*, 1976.