Paolo Mentasti

Sundials for the US-Mexico border

"It would be a mistake to suppose that… sundials… had the primary utilitarian purpose of telling time."[1]

Derek J. de Solla Price

A considerable portion of the US-Mexico border fence is made up of 30 foot tall steel slats which cast impressive zebra-esque shadows on either side of the border. For the most part, sundials tend to be a shadow casting objects (gnomon) protruding out of an otherwise uninterrupted planes (dial plate). For the most part, the fence which stands at the US-Mexico border is a tall shadow casting object in an otherwise undeveloped landscape. It was while thinking about these relationships that it occured to me to make sundials for the US-Mexico border. *Sundials: Their Theory and Construction* by Albert E. Waugh was the book which guided me through the conception, planning and building of the sundials. In the book Albert E. Waugh writes about the different types of sundials that have been made, he writes about how they function and provides instructions and data tables for their construction. Out of the many that he presents the two that stood out to me were the horizontal dial and the polar dial. I imagined how these could be applied at the US-Mexico border

Architect and artist Ronald Rael protests the US-border wall by reimagining it as a social, environmental, humanitarian and economic asset. In his book, *Borderwall as Architecture*, Ronald Rael proposes a border wall that serves as a library, a seesaw, a reserve for endemic organ cactuses, a giant xylophone, amongst other things. All of his proposals take the form of drawings, mock ups, models and snow globes. The sundials I am making are propositions of the same kind. They are scale models for objects which in size relate to the US-Mexico border fence and the landscape in which it exists.

It is Earth's rotation around its axis from west to east (counter-clockwise if looking down onto the north pole) that causes the daily appearance of the sun in the eastern horizon and disappearance in the western horizon. The sundial in its most basic form traces with its swinging shadow the apparent motion of the sun in the sky. It was around the 1st century CE that it was discovered that by tilting the shadow casting object of the sundial, which from this point on will be referred to as the gnomon, to be pointing exactly in the direction of the celestial pole, which is Earth's polar axis outwards extension in either direction, that the dial would be able to keep track of time during daylight everyday of the year.[2] Pointing the gnomon to the celestial pole positions the gnomon parallel to the Earth's axis, the sun's motion, which is parallel to the celestial equator, will appear to revolve around the gnomon.[3] Three other inventions or discoveries had to

---

[1] Waugh, 5
[2] Mayall, 15
[3] Mayall, 14

come together to push sundials into their 'certain state of perfection.'[4] These three bodies of knowledge are: the development of trigonometry which is attributed to Al-Battani (850-929 CE) who lived and worked in present day Syria[5]; the introduction of equal hours in the 13th Century by Abul-Hassan; and lastly, Copernicus' heliocentric theory which places the sun in the center of the universe with the Earth rotating around it. Curiously enough a sundial designed to tell time on a heliocentric Earth would be identical in every way to a sundial designed to tell time on a geocentric Earth[6]--it is our understanding of the idiosyncrasies of the sundial that we have Copernicus to thank for.

A sundial measures time differently from our watches and clocks in our phones and computers. A sundial measures what is called Local Apparent Time. No two sundials, unless they lie upon the exact same meridian, that is one directly south of the other will tell the same time. It is called local apparent time because it is localized to a specific longitude and because it is determined by the apparent motion of the sun. Even two sundials 110m away from each other in the same latitude on Earth will have a difference of one quarter of a second.[7] When days are measured by the motion of the sun they end up being of different lengths throughout the year. In late December the days are about half a minute longer than the average and in mid-september they are 20 seconds shorter. By mid-February the sun is at the meridian, its highest point in the sky during the day, almost 14 and a half minutes later than it would if all the days were equal in length.[8] The slowing and speeding up of the sun are partly due to the fact that the sun does not move precisely on the celestial equator. Instead it moves along the ecliptic which is north of the equator in the summer and south in the winter.[9] The variations also arise because the Earth moves faster in its orbit when it is closer to the sun and slower when it is further way. This change in velocity is explained by Kepler's second law of planetary motion which states that "a line joining a planet and the Sun sweeps out equal areas during equal intervals of time."[10]

Due to the sun's irregular motion across the Earth's sky throughout the year, it has been decided that time should be kept by an imagined mean sun which travels in the celestial equator at a constant speed. In a race between the real sun and the mean sun they would both start together, one would speed up, the other would catch up but they would reach the finish line, which in this case is a year, at the same time[11]. This time kept by the mean sun in the clock of our phones is called Local Mean Time.

The shadow casting edge of the gnomon, from this point on called the style, must always be parallel to the Earth's axis. What this means is that the gnomon as well as the 12 o'clock line

---

[4] Mayall, 17
[5] Wikipedia contributors. "Al-Battani."
[6] Waugh, 6
[7] Waugh, 9
[8] Waugh, 9
[9] Mayall, 32
[10] Wikipedia contributors, 'Kepler's laws of planetary motion'
[11] Waugh, 9

always are in a true north south orientation regardless of what type of sundial it is. This happens, of course, to be the case with the horizontal sundial and polar sundial you see on this table next to this text. Formally the polar sundial and horizontal sundial are quite different. The horizontal sundial is an isolated sail in an otherwise empty landscape whereas the polar sundial is a wall dividing the landscape in two. It was while considering these different formal qualities that I began using Google Earth to scope out and study locations and extract latitudes and longitudes for the making of the sundials.

Horizontal sundials are the most common type of sundials.[12] Horizontal sundials have to be made or calibrated for a specific latitude in order for them to work properly. Most of these sundials are often solely ornamental given that they are mass produced with zero regard for the latitudes of the buyers (just like the border fence, their primary function is to visually communicate a function without actually having to perform it correctly). Horizontal sundials typically are made up of a horizontal plane called the dial plate and a vertical triangular plate which is the gnomon. During the day the gnomon casts a shadow onto the dial plate which has hour lines drawn or etched onto the plate. One can tell the time by looking at where the edge shadow of the style, falls relative to the hour lines.

It has been well documented that many immigrants die crossing the border. So far this year 348 deaths on the border have been documented.[13] Many of these deaths happen in the Sonoran desert which extends into the state of Arizona. The Arizona based organization Humane Borders places water barrels around the desert for migrants to drink from as they cross the desert. They have also created the Arizona OpenGIS Initiative for Deceased Migrants, which is a searchable map. Viewers may see the exact location where each migrant body has been found, along other information, such as the name and gender of the deceased (if known and if the family has been notified), date of discovery, and cause of death. When searched, the southern edge of Arizona becomes stricken by red dots, one for every person. Exposure, heat stroke and hypothermia are the most common causes of death amongst the recorded data. The map also shows the water stations that Humane Borders maintains. Using the information provided by the map, I was able to determine a useful location for my horizontal sundial. 32.184560, -112.804102. Pima County, Arizona. I chose this place given its closeness to the border, its position relative to a dirt road and highway, its distance from any nearby settlement or water station and the concentration of nearby recorded deaths.

I decided to implement features into the horizontal sundial which will allow it to serve and aid migrants crossing the border. One feature is in the curving of the edges of the dial plate in order for it to act as a basin directing the rain water towards a reservoir. The Sonoran desert receives an unusually high amount of rain for a desert. It has two rainy seasons, one from December to January and one from July to August. It averages 75 to 380 mm of rain, the driest

---

[12] Waugh, 35

[13] Missing migrants website : https://missingmigrants.iom.int/region/americas?region=1422

parts receiving less than 75mm of rain per year.[14] It is for this reason that I decided that the sundial should take advantage of this situation and collect as much rainwater as possible. The curvature of the dial plate has been made mostly outside the edges of the dial plate so as to not disturb the hour lines and have the sundial give out inaccurate readings. Another feature of the sundial is that the gnomon is a fog fence, a vertical mesh onto which water condenses and rolls down the sides of the mesh to be collected. Ordinary fog fences can capture 2% of the moisture in the air while specialized fences can capture up to 10% of the moisture.[15] Fog fences have most notably been deployed in the Chilean and Peruvian desert where heavy fog rolls in from the adjacent Pacific Ocean. The Sonoran desert air is quite drier than the Atacama desert,but it does experience moments of heavy fog. The fog doesn't come from a nearby body of water, given that there is none; instead, fog occurs during winter mornings after rain, when the temperature drops below the dewpoint of 13 degrees celsius. When it is foggy and there is moisture in the air, the mesh gnomon will catch the moisture and deposit it into the reservoir for migrants to drink from and cool down with during drier and hotter times. The 12 o'clock line on the dial plate is also marked with an N for the north cardinal direction which can orient migrants on their journey out of the desert. The gnomon could also have a map of the surrounding area on one side and a text in Spanish on migrant rights on the other. Lastly, a sundial isn't complete without a motto. Most mottos are in latin such as *A lumine motus*.(I am moved by the light.)[16] For this sundial I have chosen: *Amigo, bebe y hállate de mi sombra*.[17] Which translates from Spanish to: friend, drink and find yourself from my shadow.

Photograph of heavy fog near Phoenix, Arizona[18]

[14] The Editors of Encyclopaedia Britannica
[15] Wikipedia contributors. "Fog Collector."
[16] "Sundial mottos." *Wikiquote*
[17] I have done some volunteer work as a Spanish-English translator for the New Sanctuary Coalition pro se clinic in NYC. As a volunteer I helped people who didn't cross the border through an official port of entry fill out asylum applications. The New Sanctuary Coalition calls the people they work with 'friends'. It struck me how powerful that gesture is in this day an age, to call the people which the media and the president are villifing as 'illegal' 'rapists' 'murderers' amongst other dehumanizing things as friends. This is why I chose for the motto to start off the with word amigo - to embrace the migrant with a warm word rather than the racist, cold and xenophobic holding cells of ICE.
[18] Hedding

Table for horizontal sundial

time	*t (degrees and sec of arc)*	*t (degrees)*	*t (rad)*	tan *t*	sin θ	tan *D*	*D (rad)*	D *(degrees)*
11:30 or 12:30	7°30'	7.50	0.131	0.132	0.533	0.070	0.070	4.011
11:00 or 1:00	15°00'	15.00	0.262	0.268	0.533	0.143	0.142	8.123
10:30 or 1:30	22°30'	22.50	0.393	0.414	0.533	0.221	0.217	12.442
10:00 or 2:00	30°00'	30.00	0.524	0.577	0.533	0.308	0.298	17.094
9:30 or 2:30	37°30'	37.50	0.654	0.767	0.533	0.409	0.388	22.231
9:00 or 3:00	45°00'	45.00	0.785	1.000	0.533	0.533	0.489	28.042
8:30 or 3:30	52°30'	52.50	0.916	1.303	0.533	0.694	0.607	34.767
8:00 or 4:00	60°00'	60.00	1.047	1.732	0.533	0.923	0.745	42.694
7:30 or 4:30	67°30'	67.50	1.178	2.414	0.533	1.286	0.910	52.130
7:00 or 5:00	75°00'	75.00	1.309	3.732	0.533	1.988	1.105	63.295
6:30 or 5:30	82°30'	82.50	1.440	7.596	0.533	4.046	1.328	76.117
6:00 or 6:00	90°00'	90.00	1.571	3732053 9.634	0.533	1987871 8.911	1.571	90.000

Given the exactitude of the location of the horizontal sundial and the fact that I made the dial plate out of clay, I decided to lay out the hour lines not by a graphic method, which would make the construction lines finicky to erase on the clay slab or with tabulated angles which would be imprecise. Instead layed out the hourlines by computation. I followed the formula:

$$\tan D = (\sin t)(\sin \theta)$$

In this formula D is the angle as measured from the noon mark; t is time measured from noon in degrees and minutes of arc, where 1 hour is equal to 15 degrees; θ is the latitude of the sundial, which in this case was 32.18456. To format the data I decided to round it to a thousandth degree given that I wasn't going to approximate more than a hundredth of a degree using my needle tool and plastic protractor. The angle of the gnomon, as measured from the style to the dial plate will be of 32.18456 degrees.

There are two places in the US-Mexico Border where the fence runs parallel to the medians. It was key to identify these locations for my polar sundial to be capable of being enacted. These two places are in Gadsen, Arizona and Cameron County, Texas (near Brownville). I decided on the latter given that the horizontal sundial was already made for Arizona but most importantly, the part of the fence in Texas I was looking at lies much closer to Mexico than in Arizona. Surprisingly, the fence is not made on the border but rather quite a distance from it! The coordinates are 25.878031, -97.377061. The difference between the polar

dial and the horizontal dial is that the dial plate is not level with the ground, instead it lies parallel the Earth's axis. As mentioned earlier in sundials the style is parallel with the Earth's axis as well, this makes for the dial plate in the polar dial to be parallel to its style. As a result a polar sundial looks a bit like a tennis court with a wedge running underneath one of its long sides. Depending on the scale of the dial plate that tennis net could easily turn into an imposing wall which is what I am proposing, for the polar sundial to replace a section of the US-Mexico border fence. The fence-gnomon and the surrounding US-Mexico fence would functionally split the sundial in two. In the US side of the border fence one can only tell time using the sundial from sunrise to noon, then, on the Mexico side of the border fence one can only tell time from the sundial from noon to sunset.

I chose to construct the polar sundial by calculation as well. I started out by rolling a rectangular clay slab and slicing it in half horizontally so I could place the gnomon in between the parted slabs. I measured the half slab to be 20.45 after firing it to cone 06 and so I based all of the calculations on that measurement. The way the calculations work is that the hour lines are drawn relative to the height of the gnomon so we take that height to be 1 unit. In his book *Sundials: Their Theory and Construction*, Albert E. Waugh lays out a table in which all hourlines are measured from the gnomon in this unit. The 7 o'clock line lies 3.732 units from the 12 o'clock line (or the gnomon) the 5 o'clock line lies 3.732 units from the 12 o'clock line on the opposite side of the dial plate which means that there are 7.464 units between them. Because a sundial only works during daylight hours, we can take the 7 am line and 5 pm line to be our limiting hour lines. If 3.732 units covers the 20.45cm dial plate then 1 unit equals 20.45/3.732, or 5.48cm. I etched the hourlines on the unfired dial plate following the same procedure but using the measurements of the unfired slab. For this sundial I came up with the motto: *Like day: como la Tierra.* (like day: like Earth.) The first part in English is written on the Mexico side of the fence-gnomon while the second part in Spanish is written on the US side of the fence-gnomon.

Using a rolling pin I rolled up two clay slabs. I cut long wooden square prisms to use as guiding rails as I constructed my slabs. I placed the wooden rails parallel to each other a distance of just short the width of my rolling pin. I placed the clay between the rails and began rolling. The rails ensured that the slab I produced would be of an even thickness throughout. In order for the sundials to dry flat I sandwich the slabs between layers of canvas and cement board. The canvas was to protect the slabs from the cement board and to help with the removal of water from the slab. The cement board was there to make sure the slabs dried flat. Having made my dial plates out of clay I waited until after the plates are fired before I made the gnomon. When clay dries and gets fired it shrinks. The gnomons I want to use are made of metal and nylon which do not shrink when fired in a kiln. Given that in the case of the polar sundial the height of the gnomon and the size of the dial plate are in relation to one another it makes sense for me to have made the gnomon following post-firing measurements. The dial plate for the horizontal sundial is placed on a wedge so that the plate is at an angle of 25.878031 degrees to the horizontal.

Table for Polar sundial

hour line	hour angle (degrees)	tangent of hour angle (sundial units)	distance on dial face of 42 cm (cm)
noon	0.00	0.000	0.000
11:30 and 12:30	7.50	0.132	0.743
11:00 and 1:00	15.00	0.268	1.508
10:30 and 1:30	22.50	0.414	2.330
10:00 and 2:00	30.00	0.577	3.247
9:30 and 2:30	37.50	0.767	4.316
9:00 and 3:00	45.00	1.000	5.627
8:30 and 3:30	52.50	1.303	7.332
8:00 and 4:00	60.00	1.732	9.746
7:30 and 4:30	67.50	2.414	13.584
7:00 and 5:00	75.00	3.732	21.000
6:30 and 5:30	82.50	7.596	42.743

Sundials are sensitive to the structures of the natural world, so it made sense to make them sensitive to the structures of mankind's political world. When I started reading Waugh's book I quickly came upon this quote near the end of the first chapter: "Sundials had become so common in Rome by 200 B.C. that the comic dramatist Plautus condemned in verse 'the wretch who first… set a sundial in the market place to chop my day to pieces.'"[19] Up until that point I had never considered the division of my day into hours as anything other than natural, I realized then the violence of chopping the day into pieces by the hour lines in the sundial. Equal hours and equal days are as imagined and contrived as geopolitical boundaries on Earth. And yet, sundials are powerful tools. It's empowering to be able to know the length of daylight, to know when to expect noon and sunset, to be able to orient yourself geographically. I have made two model sundials so that each can take on a set of qualities that sundials at a scale relevant to the environment they are made for can embody. The polar sundial at the border divides, crushes and alienates while the horizontal sundial in the desert quenches, orients, informs, aids and empowers.

[19] Waugh, 4

Bibliography

Britannica, The Editors of Encyclopaedia. “Sonoran Desert.” Encyclopædia Britannica, Encyclopædia Britannica, Inc., 19 Sept. 2017, www.britannica.com/place/Sonoran-Desert.

Hedding, Judy. “Does Phoenix Ever Get Foggy?” TripSavvy, TripSavvy, 23 July 2017, www.tripsavvy.com/fog-in-phoenix-2683742.

Mayall, R N, and Margaret W. Mayall. Sundials: Their Construction and Use. Newburyport: Dover Publications, 2012. Internet resource.

"Sundial mottos." Wikiquote, . 23 Feb 2017, 16:37 UTC. 25 Apr 2019, 19:11 <https://en.wikiquote.org/w/index.php?title=Sundial_mottos&oldid=2227097>.

Waugh, Albert. Sundials: Their Theory and Construction. Dover Publications, 2012. Internet resource.

Wikipedia contributors. "Al-Battani." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 13 Feb. 2019. Web. 25 Apr. 2019.

Wikipedia contributors. "Fog Collector." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 14 Mar. 2019. Web. 25 Apr. 2019.

Wikipedia contributors, 'Kepler's laws of planetary motion', Wikipedia, The Free Encyclopedia, 4 April 2019, 07:47 UTC, <https://en.wikipedia.org/w/index.php?title=Kepler%27s_laws_of_planetary_motion&oldid=890894477> [accessed 25 April 2019]