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SAVED BY A SHADOW

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"SAVED BY A SHADOW"

BY WILLIAM F. RIGGE

IN an Omaha criminal court a short time ago, the fate of an accused man hung upon a shadow, that is to say, it depended upon the accuracy with which the time of exposure of a certain photograph could be deduced from the position of a shadow. The circumstances were as follows:

On Sunday, May 22, 1910, a suit-case containing dynamite was found on D's porch at 2.50 o'clock in the afternoon. E was arrested and accused of having placed it there with criminal intent. The state produced only two witnesses, girls 17 and 11 years of age, who said that while walking in the neighborhood shortly before three o'clock they had seen a man answering E's description carrying such a suit-case. The attorney for the defense, John O. Yeiser, found that the girls had just come from a church a mile away. They had attended services there, and had posed for their photographs twice in front of the building. A prominent shadow in one of the pictures gave the attorney the idea of consulting an astronomer in the hope of finding from the position of the shadow the time at which the plate had been exposed. Should this prove to be after 2.50 o'clock, the testimony of the witnesses would be invalid.

His friends directed him to me. With the help of a surveyor, we measured the distances the shadow had fallen down, eastward and northward. The data obtained furnished four different methods of computation. The principle is a very simple one to those that understand the elements of trigonometry and astronomy. "It is briefly this" and here I am quoting from the *Scientific American*, of February 4, 1911:

"It is briefly this, that in measuring the distance that a shadow is cast down, north or south, and east or west, we can find the sun's place in the sky at the moment, and thence deduce the time of the day and the day of the year. For this purpose we make use of the astronomical triangle whose vertices are the zenith, the pole, and the sun. The side extending from the zenith to the pole is the complement of the latitude of the place. The side from the pole to the sun is the complement of the sun's declination. The third side, from the sun to the zenith, is the sun's zenith distance, the complement of its altitude. The angle at the zenith is the sun's azimuth counted from the north. The angle at the pole is the sun's hour angle, the local apparent solar time. The angle at the sun is called the parallactic angle.

"Of these six parts, three sides and three angles, three must be given in order to enable us to compute the rest. In the present instance, the sun's azimuth was known from the ratio of the distances that the shadow was cast eastward and northward. The sun's altitude also was known from the ratio of the vertical and horizontal distances. The latitude and longitude were obtained from the city map with reference to our observatory. And finally the sun's declination was known, because the day was given and the hour was about 3 p.m.

"There were thus four out of the six parts of the triangle given, one part more than was needed. As the angles at the pole and at the sun were the only unknowns, each of the four known parts was in turn taken as the third unknown. This furnished four methods of solving the problem, in which, along with the time and the parallactic angle, the sun's altitude, azimuth, and declination, and the latitude of the place were successively taken as unknowns. The results were :

3 o'clock 21 minutes 12 seconds.
3 o'clock 21 minutes 31 seconds.
3 o'clock 21 minutes 29 seconds.
3 o'clock 21 minutes 33 seconds.

The mean of which was 3 o'clock 21 minutes 26 seconds, and the residuals, or differences from the mean, 14, 5, 3, 7 seconds, the extremes being 21 seconds apart.

"The close agreement, of the four methods showed that no appreciable error had been made in any of them. In the first method the azimuth of the sun had been obtained by assuming the curb line of the street to be correctly in the meridian. The second method made no use of the azimuth at all. The third method used no other data than the latitude and longitude of the place and the measures made upon the building, and found from them the time of the day as well as the day of the year. The error in the computed declination of the sun was about one-fourth of its daily variation at the time, so that there could be no doubt whatever of the day. The date, as far as the shadow was concerned, might also have been July 22nd as well as May 22nd, because on both of these days the sun's declination is the same. But besides being altogether out of the question, the later date was negatived by the immature condition of the foliage shown in the photograph.

"In the fourth method the latitude, which had been taken as unknown, differed only 4⅔ miles from the truth. If the time had been given, the longitude would have been found within about the same range.

"The data used in the problem were that the shadow had fallen 14·22 feet down, 13·10 feet eastward, and 3·43 feet northward. The horizontal distance was found to be 13·52 by measurement and 13·54 by computation. An error of one-tenth of a foot in the shortest horizontal side would have changed the time 1 minute 54 seconds. The same error in the altitude would have caused a difference of 1 minute 15 seconds. The omission of the correction for refraction would have produced a difference of 2 or 3 seconds. The latitude was 41 deg. 16m. 42s. N. and the longitude 6h. 23m. 48s. W. The sun was 3 minutes 33 seconds fast, and the time used central time."

In order not to claim too great an accuracy for the results I thought I would leave a reasonable margin of uncertainty by maintaining the time 3·21½ to be within a minute of the truth.

But even the close agreement of the four methods would probably never have induced me to bear testimony in court, had I not had the experience of a similar problem about seven years

PLATE VI.

A SHADOW IN THIS PICTURE PROVED AN ALIBI

The shadow is seen at the right, on the building. The object casting it was easily identified, and from measurements was found to be 19·62 feet from it at this time. From the position of the shadow it was computed that the photograph was taken within one minute of 3.21½ p.m., May 22, (1910).

3.20½ p.m. 3.21½ p.m. 3.22½ p.m.

THREE PHOTOGRAPHS OF THE SHADOW TAKEN JUST TWO YEARS LATER, MAY 22, 1912

The width of a weatherboard is 0·37 feet, and the shadow passed over one in 4m. 37s.

before, in which I found the time of the day, the day of the year, and even the year itself, from a shadow in a photograph of our Observatory. Further particulars in regard to both pictures may be found in the *Scientific American* of September 24, 1904; February 4, 1911, and July 20, 1912.

The scientific testimony split the jury in the first trial. At the second trial the attorney for the prosecution, an expert criminal lawyer, realized that his only hope of success lay in overthrowing, or at last weakening, the astronomical evidence advanced by the defence. He therefore belittled the calculations and positive assurance of scientific men generally, and by his sarcasm and witticisms kept the jury in continuous laughter. The result was a tribute to his skill in handling a jury, an unanimous verdict of "Guilty," which drew a sentence of fifteen years in the penitentiary.

The defence then appealed to the Supreme Court. While its decision was pending, the first anniversary, May 22, 1911, of the taking of the photograph occurred. The day was partly cloudy, and pressing business made it impossible for me to go to the place of the shadow. The next day, however, was bright, and I was free to go. I then had the supreme satisfaction to see with my own eyes that the shadow must have been on the previous day so close to its place on the photograph, that my probable error of a whole minute could not have been an actual one greater than a quarter of that amount.

If the close agreement of my four methods of computation had given me such a degree of certainty that I could declare upon my honor I was not in error by more than a minute, the actual sight of the shadow increased my certainty a thousandfold and made me feel that I could safely defy the world, that anyone differing from me by more than a minute must be decidedly in error, and that I could challenge him and everybody to come and see the shadow at any anniversary. And if a third trial of the same case should ever become necessary, I knew I had an argument in my possession that must convince any jury and must outweigh in their minds all the mathematics in the world.

"Some months later" — to quote from the *Scientific American*, of July 20, 1912, "the Supreme Court decided that the accused had been convicted upon insufficient evidence. In preparing for a third trial, the prosecution called upon G. D. Swezey, Professor of Astronomy at the University of Nebraska, to remeasure the position of the shadow and recompute the time. Professor Swezey, narrating the event at a public meeting of the Nebraska Academy of Science, held in Lincoln, on May 3rd last, said that he studiously refrained from consulting or even referring to any of the former measurements or findings until he had completed his own calculations. The outcome was that he obtained a difference of only twenty-nine seconds, thus falling decidedly within the one minute that the defence had allowed as a probable error. The State then abandoned the prosecution."

A still more convincing proof of the accuracy of the first calculations was to come. I felt all along that the only way to dispel the doubts still lingering in the minds of some people, to whom astronomical and mathematical methods were unintelligible, was to make a public appeal to a fact, which anyone who wished to might verify for himself.

Three days before the second anniversary drew nigh, that is, on Sunday, May 19, 1912, I published a short article in the the *World-Herald*, of Omaha, under the headlines, "Shadow will be there, says Father Rigge. Scientist invites critics to sift the evidence by observation." It reproduced the original photograph with its shadow, and concluded with these words: "Next Wednesday, May 22, will be the second anniversary of the taking of the photograph. Within one minute of twenty-one and a half minutes after three o'clock the shadow will be in exactly the same position it occupied at the time the photograph was taken. It was there last year at that time, and it will be there each anniversary as long as the church stands. Anyone interested in the matter may go to Twenty-eighth and Parker Streets and verify the fact for himself."

When the appointed hour arrived, the Omaha *Daily News* sent its photographer to take the picture of the shadow and compare it with the original. Three exposures were made: The first at 3.20½, a minute before the computed time; the second at 3.21½, exactly on time; and the third at 3.22½, a minute after the computed moment. How closely the middle picture reproduced the exact position of the shadow as it appears on the original photograph of two years before, can be seen at any time by actual comparison. In both the lower left hand corner of the shadow is exactly in the middle of the same weatherboard. It is somewhat below this spot in the picture taken a minute before, and as much above it in the one taken a minute later. The computed time was therefore certainly correct to the minute, and probably so even within a few seconds.

NOTE.—The objection may occur to some astronomers that, as the day and the tropical year are incommensurable, the sun can never on any anniversary reach the same declination at the same time of the day, and that consequently a shadow can never again fall on the same spot. In theory the objection is well taken, but in practice it is of no consequence.

If we plot upon the wall of the church the path of the shadow, of which there is question in the present instance, we shall find that at the time being it moved at the rate of 1·14 inches or 0·096 feet a minute, and that the paths of the preceding and following days were at a distance of very nearly three-quarters of an inch on either side, the change in the sun's declination in one day being very close to 12 minutes of arc. From this it follows that, because the calendar year was one-fourth of a day shorter than the tropical year, the sun's declination on the first anniversary at the same hour was less by one-fourth of 12 minutes, that is, by 3 minutes of arc, and the path of the shadow was one-fourth of three-quarters of an inch, that is, three-sixteenths of an inch, above its former one of the preceding year.

The second anniversary, May 22, 1912, occurred in a leap year. If the year had been an ordinary one, the sun's declination would have been 3 minutes of arc less than in the preceding year and 6 minutes less than it was on May 22, 1910, and the shadow path would have been three-eighths of an inch higher. This was, of course, the fact on May 21, 1912. By the following day, May 22, 1912, the sun's declination had increased 12 minutes. It was, therefore, 6 minutes more than it had been on May 22, 1910, and the shadow path was three-eighths of an inch lower than on that day.

As the two paths of May 21 and 22, 1912, were at the same distance on either side of the original one of May 22, 1910, I might have taken either date, but I judged it best to select the latter and to adhere to the ordinary meaning of the word anniversary in order not to give rise to this very difficulty.

The difference of 6 minutes of arc in the sun's declination on May 22, 1910 and May 22, 1912, displaced the shadow path laterally, as I have said, three-eighths of an inch. This entailed a much smaller longitudinal displacement in hour angle, in which, however, my probable error of a whole minute allowed me a range of over an inch, or three times as much, in either direction. If we take into consideration the additional facts that a shadow is always bordered by a penumbra which makes it difficult to locate it with precision, and that the original photograph is on a scale less than one-fiftieth of the reality, I think that not even an expert astronomer would hesitate to pronounce the two photographs of the shadow on May 22, 1910, and on May 22, 1912, as perfectly identical as would be necessary to convince any jury. He would also, I am sure, endorse the assertion that within one minute of twenty-one and a half minutes after three o'clock on May 22 of any year, the shadow would be as accurately in the identical spot as any eye could see by comparing the original photograph with the reality. Future verifications are, however, no longer possible, because the building was entirely demolished by the tornado of Easter Sunday, March 23, 1913.

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