THE UNIVERSITY OF ARIZONA ECLIPSE EXPEDITION, PORT LIBERTAD, SONORA, MEXICO, SEPTEMBER 10, 1923

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By A. E. Douglass

Plans for the eclipse took shape the previous year when President Marvin arranged an eclipse budget of $500. Occasionally some details were thought out and jotted down. These depended of course on a compromise between interest on the one side and budget on the other. I had observed the eclipse of April 16, 1893, in Chile, with Professor W. H. Pickering, and had obtained photographs of the corona in a 5-inch visual telescope. (Professor Pickering, by the way, got a spectrum of the "reversing layer" at that eclipse). In the eclipse of May 28, 1900, at Washington, Georgia, I attempted to trace a zodiacal light. I saw the eclipse of June 8, 1918, from Arlington, Oregon, having reached Portland the day before and consulted the local Weather Bureau Observer as to a probable break in the pall of clouds. He advised central Oregon. I have regretted not visiting Goldendale at that time, which would have been a liberal education in eclipse apparatus, and would have insured the arrival of the break in the clouds noted by Campbell, a little before totality instead of at its very instant of beginning, as at Arlington. For the present eclipse I felt that it was impossible to get an outfit suitable for making the Einstein tests even if there had been time for its construction. So plans confined themselves to straight photography of the corona and a study of its relationships to the Sun's surface on the one side and to space in general, and the Earth in particular on the other.

Captain McDougall, Superintendent of the U. S. Naval Observatory, kindly loaned us a 5-inch achromatic photographic lens of 12 meters focal length. This was safely received at Tucson several months ahead of time. The advantage of mounting this in a tube pointed directly at the Sun was evident enough, but, on investigation, the expense of a tower to hold the upper end was greater than seemed advisable; whereas a hori-

series planned was satisfactory, yet in doing it again, I would be inclined to emphasize the exposures between 1 and 4 seconds and 32 to 64 seconds. In a 3-inch visual lens of 52 inches focus, with light color screen, on an orthonon plate, one second was much longer than needed for the prominences and that region was greatly overexposed. In the same instrument a 64-second exposure gave more of the outer corona, some two diameters of the Sun away from the limb, than a 16-second. Probably a little was gained in that instrument by exposing beyond 30 seconds.

The eclipse of September 10, 1923, had for years seemed secure in the matter of weather. I had told my classes about it for ten years in advance with no real doubt that the weather conditions would be favorable. Arizona has winter and summer rainy seasons, more marked at high altitudes. The California coast has winter rains with clear summers, but during summers a strong ocean-and-land breeze develops, blowing on to the land in the afternoons and off-shore at night. The cold off-shore breeze meeting the dampness near the shore-line frequently produces fog in the night and early morning. The warmth of the day dissipates the fog giving midday and afternoon almost invariably clear. The eclipse was due at one or two o'clock. At that hour there seemed no danger of fog. The only risk in Northwestern Mexico was the lateness in the rainy season. Thus there seemed a 95 per cent prospect of clear weather in all the eclipse line from its entry point on our northwest coast to the cloudy east coast of Mexico. It seemed best for us to go to some point in northern Mexico, south of Tucson. This not merely spread the observers out over greater length of the eclipse line, but was more in accordance with our budget. In May, Dr. D. T. MacDougal of the Carnegie Institution was making a 225-mile trip to Port Libertad on the Gulf of California, and very kindly included me in his party. We spent three very interesting days there but the roads for automobiles were very bad, being filled with ruts, washes, sand and encroaching trees. So I planned to go to Hermosillo or its vicinity. Hermosillo is a town of 12,000 people, about 240 miles south of

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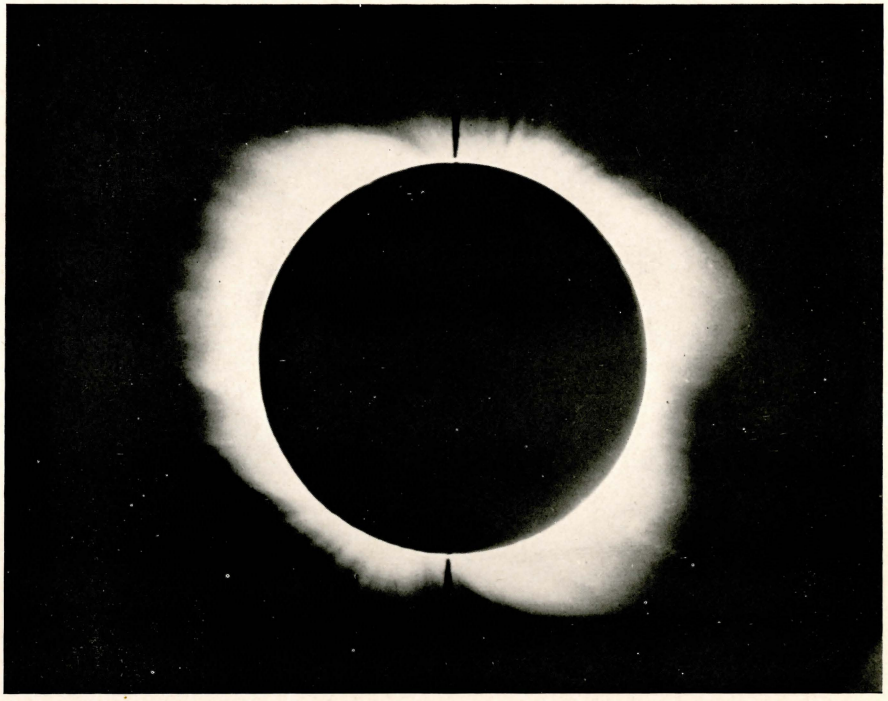

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Plate XI. The Solar Corona, September 10, 1923, Port Libertad, Mexico. Taken with the 5-inch lens, focal length 40 feet, exposure 32 seconds.

A disk slightly larger than Moon's image was used in printing from negative.

Tucson on the railroad, and therefore very accessible. The railroad authorities, however, could not give any assurance of help in transportation.

In returning from California in mid-July, the summer rainy season seemed unusually in earnest. During August it showed no signs of ceasing as it usually did, and the entire question of location changed. Under ordinary conditions, there was a 95 per cent expectation of clear weather at all points and we could choose some place convenient to reach. Now it appeared that there was a 75 to 90 per cent expectation of clouds and we really must figure out a least cloudy spot. Perhaps this could be done. Our summer rains come on southerly winds which blow more or less continually in July and August. They are laden with moisture and when they are forced up into cooler altitudes by mountain slopes, they produce storms and rain. Mountains therefore must be avoided. Hermosillo has mountains to the south between it and the Gulf. It was evident that the least cloudy spot would be found on the coast of the Gulf itself. Guaymas had such a situation and was on the railroad but the expense would be greater. (The central line of totality passed half way between Guaymas and Hermosillo). Port Libertad on the Gulf was only 18 miles north of the central line and nearer than Hermosillo itself. As the end of August approached, and the rains did not diminish, Port Libertad was evidently the place for our station. The only change required was a new calculation of the position of the eclipsed Sun in the sky in order to give proper direction to the instruments and some slight changes in the instruments themselves. The lens and mirror of the 40-foot camera had a range of 20° or 30° in adjustment, and the inclination of the track at the plate end only needed to be altered 3° to allow for the different longitude and latitude. This merely meant tipping the framework which carried the track. The change shows in the inclination of the plumbline to the side of the plate. The "combination" instrument to be described later, merely required the south end to be set a few inches into the ground.

Port Libertad is an open roadstead in a curving shore be-

tween two fine headlands nine miles apart. It is merely a locality where drinking water may be obtained—no one lives there. It is some 60 miles north of Tiburon Island and 120 miles from Guaymas. Angel Island on the other side of the Gulf is usually visible. On the east, the land slopes gently up for twenty miles to the first mountain range whose passes are about 1400 feet in altitude. Drinking water may be obtained from a well close to the shore or from springs laid bare at low tide. In May the winds were gentle, the water was usually calm, and at lowering tide hundreds of birds gathered on the rocks and drank at the brackish springs as soon as they were uncovered. In September with the summer rains still continuing the winds were strong and from the south and very few birds appeared though the water was full of fish. The longitude and latitude of the place were determined by sextant observations in May as 7 hrs. 30 min. 44 sec. west and 29° 55′N. This is close to the position on Dewey's map but the longitude is not to be considered as very exact.

From the very start, the interest and help from the members of the Carnegie Institution were of the first importance. The inspection trip in May, the loan of flat mirrors, and the telephoto lens and especially the assistance of Mr. Godfrey Sykes and his two sons, Glenton and Gilbert, were all of first value. Mr. Sykes had secured an 8-inch lens of a single piece of glass with a focus of 46 feet. For this he made an excellent mounting of the horizontal type. He used a stationary plate, and a moving mirror mounted at the level of the ground in front of the horizontal tube. The motion was supplied by a long sector arm whose outer end was attached to a weighted piston working in a cylinder filled with oil. The oil passed out of the cylinder through a long tube reaching within the shelter at the plate end of the instrument, and through a valve under control of the observer's hand. Three days' delay in reaching the station by reason of bad roads and the dense clouds on the day and evening before the eclipse unfortunately prevented necessary adjustments and final tests; so that in the actual eclipse, the image was too much displaced for satisfactory

printing. All details of his mechanism had been very carefully worked out and I hope that he will have another chance to use it.

During August a combination wooden mounting was prepared to carry two photographic cameras and a guiding telescope as part of the University equipment. The polar axis was a long wooden box with short bits of steel shafting projecting at the ends. The "pier-heads" were upright posts with V's made of crossed screws. Each had three slanting braces. The sector arm held to the axis by clamps was five feet long and carried a bit of brass at the outer end which caught a nut, working upward on a 5-inch screw. This screw was rotated by a Victrola motor, supplied with a reduction gear taken from a common alarm clock. The regulator on the Victrola supplied full adjustment for getting the correct speed. A long handle attached to the regulator was held by Mr. William Doan who was at the 3-inch guiding telescope. When the instrument was correctly pointed and without vibration, Mr. Doan gave the word to expose and Mr. Ed Bayless held a large black screen away from in front of the cameras. Mr. Duane A. Hawkins kept the Victrola wound and timed the exposures, giving the word to close the exposure. Mr. Philips Brooks attended to the plateholders on the 52-inch focus camera and Mr. Edwin Knagge did the same for the "telephoto." The former instrument was a 3-inch visual lens with a light color screen (x3) about 6 inches from the plate. It gave very good results especially on the outer corona. The telephoto was a 4-inch portrait lens reduced to 3 inches by a diaphragm (loaned by Mr. A. R. Buehman of Tucson), with a Zeiss telephoto attachment giving an equivalent focus of 15 feet. Its results were slightly reduced because it did not get sufficiently adjusted owing to clouds on the day before the eclipse. The four-by-five plate was too small; the plates should have been eight-by-ten inches. Mr. Doan, failing to find *Venus* readily due to error in focus, correctly turned to the Moon's edge and guided by it. Thus the image of the eclipse was moved too near one edge of the plate. For short focus telescopes, the Moon's edge serves

very well for guiding. For long focus instruments like the 40-foot camera, *Venus* was especially favorable for guiding because its motion relative to the Sun was extremely small, much less than that of any star.

The lens of the 40-foot camera in its metal cell was fitted in a tubular cube of wood 12 inches on a side. This was in turn clamped at the proper angle in the open top of a heavy box whose sides were doors and whose end below the lens was open. Within the box was a loose but heavy wooden base with an upright and a slanting hinged piece to which the flat mirror was fastened. This hinged piece rested on a long screw which served to adjust its slant. The mirror thus could be altered quickly in direction or altitude in the few minutes before totality. The azimuth of the eclipsed Sun was computed as 40° 08′ 20″ south of west and the line of the tube was laid off as near that direction as possible. At the lens end the tube was 18 inches square, enlarging to 4 feet as it entered the shelter which protected the plate. At this point a 42-degree inclined track and carriage were arranged with a motion of two inches per minute, controlled by clockwork. The plate was supported in a movable square frame resting on a horizontal shelf attached to the carriage. In the triangle between the shelf and the slanting carriage was clamped an eye-piece so placed as to be near the expected position of *Venus*. The eye-piece was three-quarters of an inch in focus and thus gave a very high power, 630. Of course it was much too high but it was the only available one at hand with micrometer threads. At eight minutes before totality there was no trace of *Venus* in the eye-piece but it showed plainly on a piece of ground glass and after the loss of some valuable seconds of totality, the eye-piece was adjusted upon it.

In order to pass the border into Mexico, proper facilities had been offered to astronomers by the Mexican Government through Señor Gallo, Director of the Observatorio Nacional of Tacubaya. As I had no direct assurance that word had been sent to Sásabe, our place of entry, I first wired to Señor Gallo, who, however, was already off on his eclipse expedition. Re-

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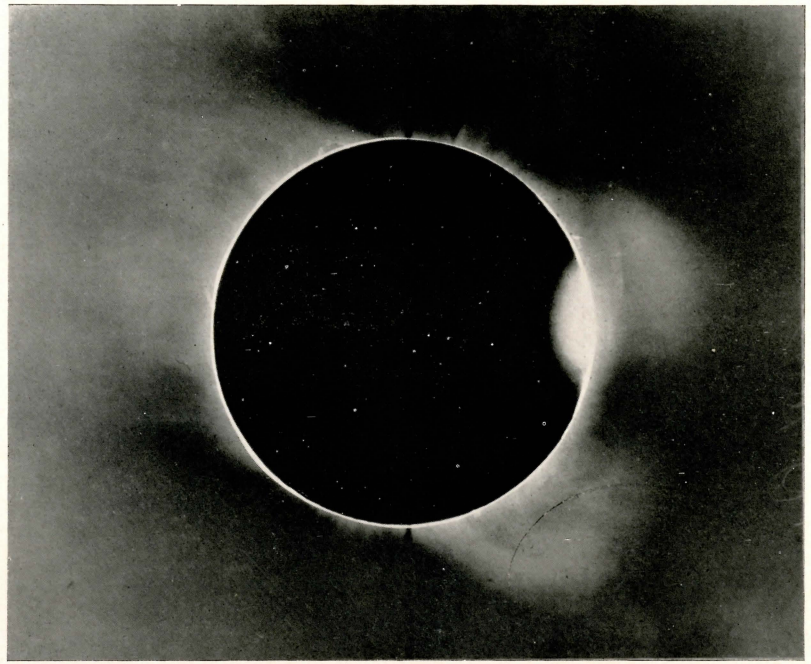

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Plate XII. Inner Corona, September 10, 1923, Port Libertad, Mexico. Taken with the 5-inch lens, focal length 40 feet, exposure 64 seconds.

A disk slightly larger than Moon's image was used in printing, which caused the apparent narrow white edge about the Moon.

ceiving no reply, I wired to the Secretario de Hacienda and received reply on Saturday, September 1st. Our four-ton truck had gone the day before and passed the border without delay. Four of us left in a Ford touring car and a "stripped" Ford on Sunday, September 2. We reached Sásabe in the middle of the afternoon and were given every aid. In the midst of a heavy rain, just beyond the border, in the late afternoon, we got on the wrong road because we took the road that did not go through a gate into apparently private property. As a matter of fact we were already on private property and should have gone through the gate to public land. So we went a mile through water and crossed a wash and then were sent back by a happily-met cowboy. We returned through the wash and part of the flood until we were completely bogged in its mud. Fortunately at that time of need, a Mexican farmer appeared in a wagon with two good horses. He pulled us out and set us through a barbed wire fence and faced us in the right direction with a readiness and facility born of long experience. For hours after dark, we traveled through rain and water. We extinguished some blazing insulation close to the starting motor and went on with defective headlights. But by ten o'clock, we reached the ranch houses of San Rafael, backed our cars right under the stone porch, and had supper.

The truck had been out three days but we caught up with it early the next morning and helped it out of a sand wash. It spent most of the morning in a bog hole. I rode a horse for the first time in fifteen years and telephoned to Altar, 30 miles away, without expense, for it was a government line. We prepared an elaborate camp dinner at Señor Frederico's ranch at the end of which Sykes' party of three caught up with us, having left Tucson early that morning. We camped that night outside Altar, 130 miles from Tucson.

Tuesday was clear and hot. We passed through Altar, traversed an indifferent road for 15 miles to Pitiquito, and promptly got badly caught in the Altar river just beyond that town. Messrs. Fowler and Harrison, who were erecting the cotton gin there, generously sent a six-mule team which skilfully

have been mistaken. However, a visitor on the evening after the eclipse showed us that a small shallow pit at low tide in the beach sand at exactly the right spot, gave absolutely pure water. The place was marked with an iron stake and after that we had no trouble. Of course, the rainfall on that west coast of the mainland is extremely small, but there is some underground flow of water. At the camping point a small dry wash comes down right over a ledge of rock. This buried rock brings the fresh water to the surface of the ground above low tide level. When a strong southerly wind is blowing, the tide may fail to go low enough to uncover the springs.

Right after lunch on the first day, Thursday, I began to get together parts of the instruments soon to be needed and found that a necessary part had been left behind. On studying the matter, I recalled exactly where and why it had failed to come. It was delicate and I had left it slightly apart fro- the rest of the boxes in order to protect it from being stepped on, and the young men who loaded the car thought that the box was to be left behind. We were three days late and had only four days to the eclipse and needed all hands for erection of the instruments, but Mr. Doan and Mr. Glenton Sykes left in the stripped Ford at 3 P. M. A tremendous thunderstorm came up at dark and we thought of the two messengers racing back through it in an unfamiliar country with misleading roads and in danger of bogging or even of losing the car in a mountain torrent. They got beyond Pitiquito that night, some 85 miles. The next morning from Altar, they wired to Tucson and the missing box was forwarded and met them at the border at 5 P. M. They turned back immediately and reached the Port at 5 P. M. on Saturday—a fine trip.

In the meantime, though short-handed, we erected the instruments and made all adjustments possible. On Thursday the 40-foot camera was not ready for trial. On Friday and Saturday at the eclipse hour, it could not be fully tested owing to the mishap above mentioned. On Saturday night, however, it was focussed visually on *Altair* in the eclipse azimuth and the distance from plate to lens set at 39 feet 3 inches. On Sunday

Figure 1. Eclipse Camp, Port Libertad, Mexico. Looking south over the Gulf.

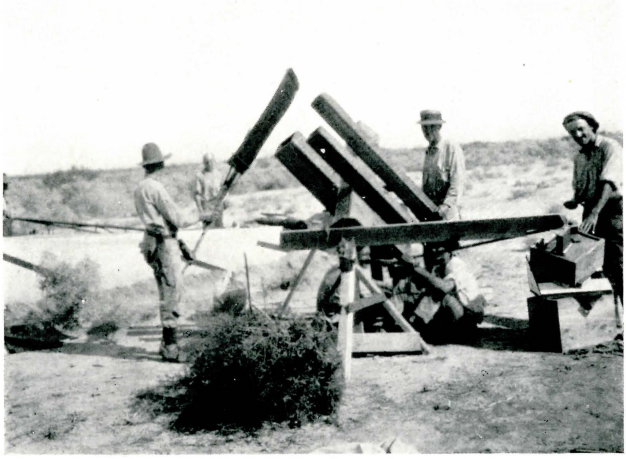

Figure 2. The "Combination" instrument with the crew at their places. This included a 15-foot equivalent focus, a 52-inch focus and a guiding telescope. The sector arm was driven by a Victrola motor.

we had another extraordinary thunderstorm lasting from noon to 9 P. M. in which we were drenched to the skin and thoroughly chilled. It cut out the "dress rehearsals." We had to dismount the combination instrument and tie it in canvas. We shoveled earth on and about the horizontal telescopes and tied them with ropes to prevent the gale from blowing them away, and it was long after dark when we could begin to put things together again. Clouds interfered too much while trying to adjust the combination instruments but they did not prevent the exposure of a focussing plate on *Altair* between 10 and 11 in the 40-foot camera. This was developed at once and a needed extension of two inches found in the focal distance.

This kept the writer up until 2:30 A. M. A blanket had been loaned to another and sleeping outside was too cold, so the folding cot was set up in the horizontal tube itself and four hours' sleep obtained. On going to sleep, the sky was nearly clear, but at 6:30 A. M. it was again partly cloudy. It soon showed signs of clearing and after a brief breakfast things became very active, without thought of meals till late afternoon. After the corrections of the 40-foot focus, Mr. Doan adjusted the alignment and focus of each smaller instrument on neighboring mountains. I reset their polar axis with transit readings. Mr. Bayless made a fan-like shutter on a long pole and we had a careful rehearsal or two. After this, a final rehearsal was held during the partial phase.

I had brought a complete equipment for photographing the entire partial and total eclipse on a small scale every 15 seconds but had no one to run it. Also I had full equipment for photographing shadow bands as worked out and used on artificial shadow bands twenty years ago, but there was no one for that either. Nor could we spare anyone to act as timekeeper. I had made the mistake of not making a rigorous calculation of the eclipse for that locality but trusted to the published maps. Totality began 1½ minutes before it was expected. That was disconcerting although, in fact, not especially harmful, for we had no timekeeper to announce it. Mr. Sykes and I were each inside pitch dark shelters, looking after big plates. At the last

seconds before totality, I had to cut off the image of the Sun and wait for word from outside. All those outside had never seen a total eclipse before, and were fascinated. Finally, I could hear some one call, "Say, fellows, it's begun; let's get busy," and I began counting the beats of a metronome beside me. Between 10 and 20 seconds must have been lost in this way; but perhaps it was worth it in the impression on those who saw that remarkable sight for the first time.

Little things sometimes cost a good deal—the only real budget is made up after the event. I had bought in Tucson some colored paper because there was no colored glass to fit the small dark-room lantern. At Port Libertad, I put that paper away so carefully that it could not be found until after the eclipse. The result was that Mr. Sykes and I worked in complete darkness. So, with darkness and delay in finding the guide-star, it is not surprising that I was at count 40 when the first exposure started. It seemed time for long exposures and I gave 32 seconds. The plate handling went very slowly in the dark and it was about count 116 when the second exposure began. It was stopped at 176 when the Sun reappeared. This slowness in handling the plates was almost wholly due to lack of light.

And connected with the handling of plates appeared other kindnesses of providence. In lack of full opportunity to make separate plate-holders for some nine 14x17 plates, I had two large light-tight boxes made, one for unexposed and the other for exposed plates. Nine plates were placed in readiness in the unexposed box. The method was to open that box, take out a plate, put it in the exposing frame, then after exposing, to remove it to the other box and take a fresh plate. Doing this by touch in absolute darkness was painfully slow. Time was better spent in exposing than in making many such changes, but I regret not having a single short exposure. As the Sun appeared at the end of the second exposure, I hastily dropped the shutter which was suspended from the top of the shelter. A knot in the rope slipped through an eye which was supposed to catch it and would have made a double exposure of the in-

Figure 3. The 40-foot (12 meter) camera.

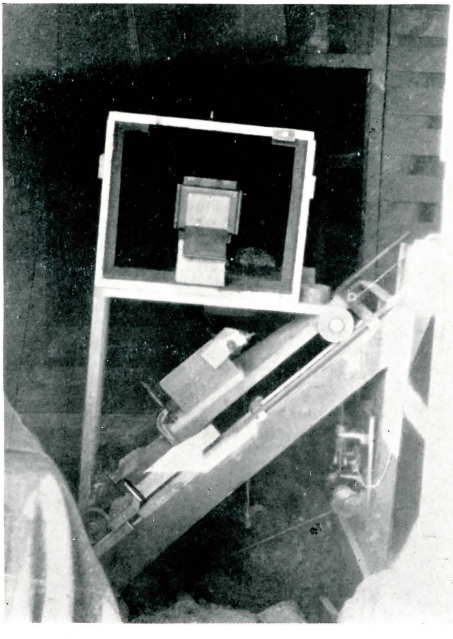

Figure 4. Plate end of 40-foot camera, showing inclined track and carriage for 14x17 inch plate, clock, guiding eyepiece, plumb-line, ground glass, etc.

creasing Sun if a second screw-eye had not caught it just in time. As it was, it left a faint shadow across the plate. As it happened, this plate did receive too much light and development was cut shorter than with the 32 second plate. It, therefore, shows the prominences very readily. But the real good fortune occurred in regard to the boxes. The temperature and humidity inside the shelter were very high at eclipse time, so fearing to repack the plates at once in their own boxes owing to the danger of perspiration falling on them, they were left until night in the light-tight box with a blanket thrown about it. On developing the large negatives each one showed a large black spot on each end just entirely out of reach of the corona. These spots were caused by nail-holes in the boards, completely overlooked in preparing the boxes. It was providential that they were not central on the plates.

The five men in charge of the smaller instruments performed their parts like clock-work, without a hitch. They gave exposures of 1, 4, 16, 64, and 32 seconds, being caught on the last one by the returning Sun. On the final exposure in each instrument there is a ray tangent to the returning solar crescent, which is not yet accounted for. In the 52-inch focus camera it extends across the shadow of the color screen. So it must be an instrumental effect close to the plate. The reddish ring of the chromosphere was noted with the naked eye. Eight stars—including planets—were counted. It was just not too dark to tell time by a watch. Shadow bands were not noted. The wind fell decidedly near totality and the temperature recorded on a thermograph dropped 3° F. Several cars of visitors came nearly 100 miles to observe the eclipse with us. They had a splendid view. If I could have followed my own inclination, I would have started everyone else at work, and then gone off by myself, without any cares, to watch the eclipse. As it was, I only saw it through an extra thick photographic film.

The selection of the locality was fortunate in the matter of weather. Of the seven days of our stay, only two were cloudy in the region of the Sun near the eclipse hour, giving a 70 per cent probability of clear sky. Hermosillo was cloudy.

While most of the sky was clearing for us in the early morning of the 10th, clouds began to gather over the mountains 20 miles east. These got heavier and thunder storms raged in the distance much of the day. Once during the partial phase, a very thin cirrus haze swept over the Sun, but it lasted only a few minutes and except for that the sky was perfectly clear the entire day, except below an elevation of 40° to the east and south. The seeing conditions were good, also, as evident on *Venus* with a power of 630. The 40-foot instrument worked exceedingly well with its stationary lens and mirror and moving plate, even though I had silvered the mirror myself and, years ago, designed the clock. By care in orientation, and in starting the clock, the eclipse exposures were made immediately about the optical axis. The mirror showed no perceptible temperature effect perhaps because it had been kept for a day or two exposed to the air in the box in which it was to be used. The lens was protected from exposure to the Sun, and in actual tests was covered by a piece of cheese cloth to prevent the Sun's heat from reaching the mirror.

Late Monday afternoon we had a dinner of fresh fish, plum pudding and other delicacies. Tuesday we packed, Wednesday we rested, fished and otherwise enjoyed life, and on Thursday, my own group of four started back. It was 75 miles away at Pitiquito that we first had news from the outer world and learned that the weather had been unfavorable in California. Friday evening we reached Tucson, and Saturday and Sunday were given over wholly to developing plates. The weather was so warm that ice had to be used continually as the running water in the dark room registered 84°. The developer used was elon-hydrochinon at temperature 65° to 67° F. In catching the midnight train, Sunday, for Los Angeles, I did not have time to develop the slides made of the two big negatives, and so at more risk than was justified, carried one negative along with me. We, the slides, negative and myself, arrived just in time to take part in the eclipse report at the scientific meetings.