The Rebun Island solar eclipse of May 9, 1948

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Abstract

An annular solar eclipse was observed on May 9, 1948 from the small island called Rebun Island in Hokkaido, Japan. Three different center lines were predicted for the eclipse. Observations of the eclipse were reported to have been successful because they were made at a location near the center line that had been predicted on the basis of Japanese lunar occultation observation results. This paper clarifies that the original report did not reflect a correct conclusion about the eclipse observations because of lunar limb irregularities.

1. Introduction

The solar eclipse of May 9, 1948 was predicted to be annular, and calculations at that time showed that an annular solar eclipse would be visible in a narrow zone that passed through Rebun Island, Hokkaido, the northernmost part of Japan. The width of this zone was predicted to be only about 1,200 m. Although it was known that Japanese geodetic coordinates were shifted from world geodetic coordinates, the size of this shift was not precisely known. Hirose (1948) estimated the size of the shift to be about 600 m, based on his analysis of lunar occultation observations made in Japan and elsewhere. Following the solar eclipse observations on Rebun Island, it was reported that the annular eclipse had been successfully observed because the observation site was chosen on the basis of Hirose's recommendation.

The lunar limb has irregularities of up to several kilometers due to geographical features on the Moon. This fact casts doubt on the report that a 600 m shift in the annular zone's position could be detected by observations. This paper clarifies the original report by taking into account the irregularities of the lunar limb.

2. Predictions and observations of the annular eclipse

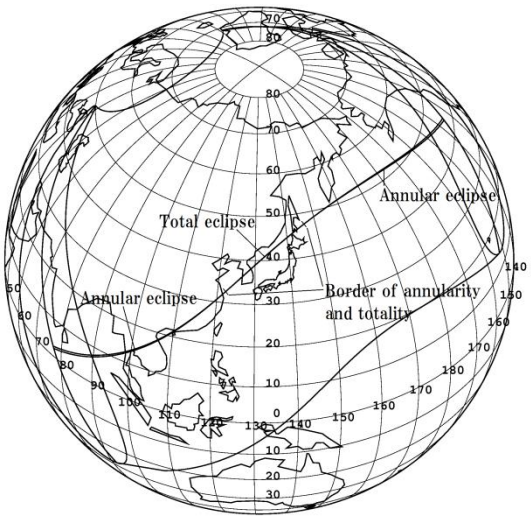


Figure 1. Predicted path of the annular- total eclipse of May 9, 1948.

A predicted eclipse map for the solar eclipse of May 9, 1948 is shown in Figure 1, and the predicted annular-total zone near Hokkaido is shown in Figure 2. The path of the eclipse in these figures is calculated using modern astronomical constants and ephemerides. In particular, the radius k of the Moon in units of the Earth's equatorial radius is 0.2725076. As shown in the figures, the eclipse is predicted to be annular-total and a total solar eclipse is predicted to be seen near Hokkaido. At the time, however, a k value of 0.272274 was used for the radius of the Moon (about 1.4 km smaller than the modern value), therefore the eclipse was predicted to be annular.

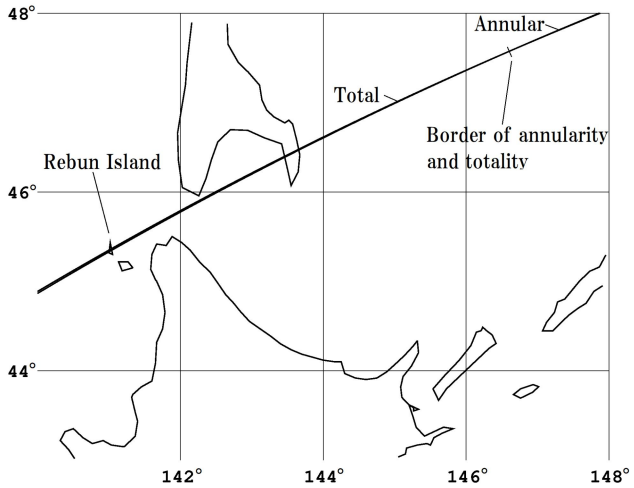
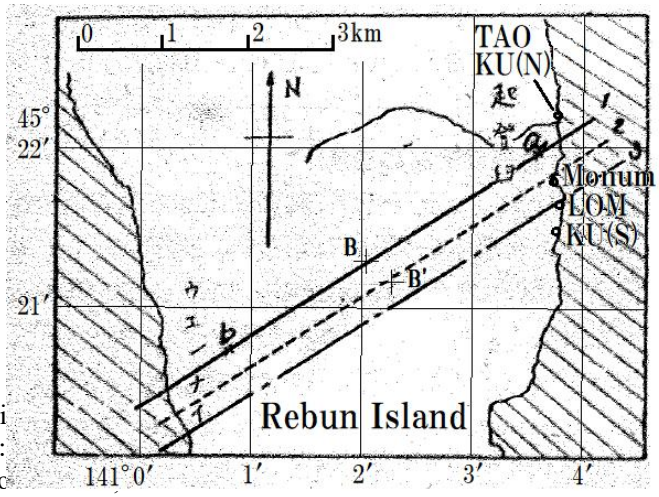


Figure 2. Predicted path of the annular-total eclipse near Hokkaido.



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deflection by Kawabata (1940), 3: based on the analysis of lunar occultations by Hirose (1948). The geodetic coordinates shown are those of the Tokyo Datum. Points *b* and *a* are the shadow centers at 11h 50.5m and 11h 50.6m JST calculated by Satô (1948). Point B is the shadow center at 11h 50.5m calculated by the present author using the precise modern ephemerides and astronomical constants. The shift in the Tokyo Datum is now precisely known. Using the known shift the correct position of the shadow center at 11h 50.5m JST is shown by point B'. Observation stations from universities and observatories are indicated as follows: TAO: Tokyo Astronomical Observatory, LOM: Latitude Observatory of Mizusawa, KU(N): Northern Station of Kyoto University, KU(S): Southern Station of Kyoto University. The location of the Monument of the Solar Eclipse Observations is indicated by Monum.

Japanese geodetic coordinates were known to be shifted from world geodetic coordinates. Hirose (1948) analyzed lunar occultation observations and found systematic differences between results based only on Japanese observations and those worldwide. He correctly attributed these differences to the shift in the Japanese geodetic coordinates. Conversely, Kawabata (1940) estimated the amount of the shift in the Japanese geodetic coordinates using measurements of vertical deflection from all over Japan.

The predicted center lines on Rebun Island calculated prior to the 1948 eclipse are shown in Figure 3. This figure is based on the map in the paper by Satô (1948). Line 1 was drawn using the calculated geodetic longitudes and latitudes. Line 2 is a corrected center line using Kawabata's estimates of the shift in the Japanese geodetic coordinates. Line 3 is the center line based on Hirose's analysis of lunar occultations. The distance between lines 1 and 3 is about 600 m. The path width of the annular eclipse was calculated to be about 1.2 km on Rebun Island, so the difference in the center lines was of practical significance.

Observers were sent to Rebun Island from the Tokyo Astronomical Observatory, the Latitude Observatory of Mizusawa, and Kyoto University. To prepare for observations of the eclipse from Rebun Island, an Eclipse Committee was organized (Hiei & Sôma, 2020) with Prof. Y. Hagihara of the University of Tokyo as its chairperson. He observed the eclipse from a site very close to line 3 in Figure 3 and reported that Hirose's predictions had been verified (Hagihara, 1948; Tokyo Astronomical Observatory, 1969; The University of Tokyo, 1987).

3. Examination of the prediction

The shadow center at 11h 50.5m JST (Japan Standard Time) was predicted to be at point *b* in Figure 3 by Satô (1948). Using precise modern ephemerides for the Moon and Sun and modern astronomical constants, the shadow center at 11h 50.5m JST can be corrected to point B in Figure 3. This is close to line 1 but the time differs by about 2 s, a

difference that reflects errors in the positions of the Moon and Sun then used. The shift between the Tokyo Datum and the World Geodetic System is now precisely known. Taking this shift into account, the shadow center at 11h 50.5m JST can be revised to point B' in Figure 3. Thus, the center line calculated using modern ephemerides and astronomical constants is one that passes point B' and is parallel to line 1 in Figure 3, lying close to line 2 but slightly shifted toward line 3.

Lunar limb irregularities play a very important role in eclipse observations. The Japanese lunar explorer Kaguya (Selene) was launched by Japan Aerospace Exploration Agency (JAXA) on September 14, 2007 and made observations of the Moon for about two years. An accurate and precise global topographic map of the Moon was constructed from the data obtained by laser altimeter (LALT), one of the instruments on board Kaguya. NASA's LOLA (Lunar Orbiter Laser Altimeter) on the Lunar Reconnaissance Orbiter (LRO, launched June 18, 2009) also provides a high-resolution global topographic model. Lunar limb profiles can now be precisely predicted from these lunar topographic data, and predictions based on data from Kaguya and LOLA agree very well. Using these data, eclipse predictions can now be made very accurately.

The eclipse of 1948 on Rebun Island was filmed by the Japan Movie Company. The film clearly shows Baily's beads all around the solar limb during the annular/total eclipse. It is publicly available on a website of NHK (Japan Broadcasting Corporation) with the label "Japan News No. 123." Unfortunately, the precise time and place of filming are not known. Nonetheless, the images of Baily's beads recorded on the film can be compared with those inferred from lunar limb irregularities predicted by the lunar topographic data obtained by Kaguya. These results showed that the film was made at a location close to the point denoted by "TAO" and "KU(N)" in Figure 3, about 900m northwest of line 3. A comparison of Baily's beads in one frame is shown in Figure 4. The time of this frame was found to be 11:50:33.0 JST. The lunar limb irregularities drawn using the Kaguya data in Figure 4 are radially exaggerated by a factor of about 50, and the location of the solar limb relative to the lunar limb irregularities is also drawn. As is readily apparent, the luminous points on the video are in almost perfect agreement with those predicted from lunar limb irregularities based on Kaguya data. Photos of Baily's beads were also taken at the northern station of Kyoto University (Fujinami, 1952). It can also be seen that the luminous points in these photos agree well with those predicted from the Kaguya data.

This film and photographs indicate that Baily's beads were visible all around the Sun from anywhere near lines 1–3 in Figure 3, because the lunar limb has irregularities of up to several kilometers due to geographical features on the Moon. Therefore, although Hagihara (1948) reported that his eclipse observations had been successful because he had observed from a place close to line 3 in Figure 3, he would have met with similar successful if he had observed from anywhere close to lines 1–3. In fact, Hirose et al. (1950) mention nothing about the differences between the center lines in their analysis of the eclipse.

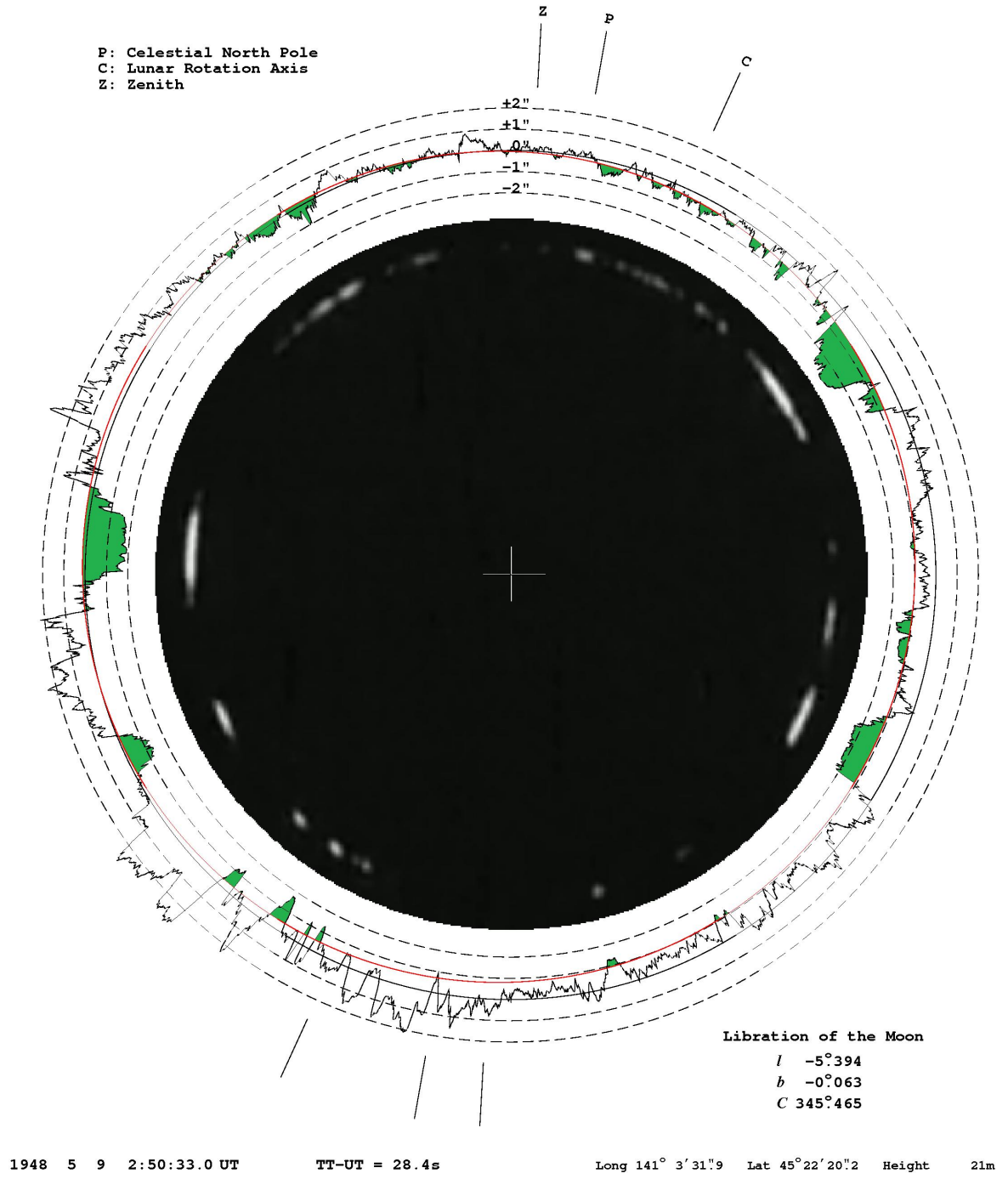

Figure 4. Comparison of Baily's beads recorded on film with those inferred from lunar limb irregularities predicted by lunar topographic data obtained by Kaguya.

4. Conclusion

The annular solar eclipse of May 9, 1948 was predicted to be visible in a narrow zone on Rebun Island, Hokkaido. Three different center lines were predicted for the annular eclipse, each separated by about 300 m, while the overall width of the zone was calculated to be 1,200 m. Observations were reported to have been successful because they had been made near the center line predicted on the basis of Hirose's (1948) analysis of Japanese lunar occultation observations. Due to lunar limb irregularities, however, the report did not reflect the true nature of the eclipse observations. In fact, Baily's beads should have been

observable all around the solar limb from any location where close to any of the central lines then predicted.

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