New discoveries on astronomical orientation of Inca site in Ollantaytambo, Peru

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Abstract

This paper deals with astronomical orientation of Incas objects at Ollantaytambo, which is located about 35 km southeast from Machu Picchu, about 40 km northwest from Cusco, and lies in the Urubamba valley. Protzen [7] devoted his monograph to description and interpretation of that locality. Book of Salazar and Salazar [8] deals, among others, with the orientation of objects in Ollantaytambo with respect to the cardinal direction. Zawaski and Malville [9] documented astronomical context of major monuments of nine sites in Peru, including Ollantaytambo. We tested astronomical orientation in these places and confirm or disprove hypothesis about purpose of Incas objects. For assessment orientation of objects we used our measurements and also satellite images from Google Earth and digital elevation model from ASTER. The satellite images were used to estimate the astronomical-solar-solstice orientation, together with terrestrial images from Salazar and Salazar [8]. The digital elevation model is useful in the mountains, where we need the actual horizon for a calculation of sunset and sunrise on specific days (solstices), which were for Inca very important. We tested which astronomical phenomenon is connected with objects in Ollantaytambo. First, we focused on Temple of the Sun, also known as the Wall of six monoliths. We tested winter solstice sunrise and the rides of the Pleiades for the epochs 2000, 1500 and 1000 A.D. According with our results the Temple isn´t connected neither with winter solstice sunrise nor with the Pleiades. Then we tested also winter solstice sunset. We tried to use the line from an observation point near ruins of the Temple of Sun, to west-north, in direction to sunset. The astronomical azimuth from this point was about 5° less then we need. From this results we found, that is possible to find another observation point. By Salazar and Salazar [8] we found observation point at the corner (east rectangle) of the pyramid by Pacaritanpu, down by the riverside. There is a line connecting the east rectangular "platform" at the river, going along the Inca road up to vicinity of the Temple of the Sun and then in the direction to the Inca face. Using a digital elevation model we found the astronomical azimuth, which is needed for confirm astronomical orientation of the Temple. So, finally we are able to demonstrate a possibility of the solar-solstice orientation in Ollantaytambo.

1. Introduction

Determination of astronomical azimuth of sunrise or sunset at solstice of important objects in north-eastern Peru was studied by many authors [8, 9, 4, 1, 6]. Figures 1 shows the astronomical azimuths of the Sun for the geographic latitude of Cusco area, for sunrise and sunset at solstices, June 21 or 22 is the day of the winter solstice in the southern hemisphere. The Sun rises at the astronomical azimuth 66 degrees, provided that we can observe the Sun at ideal horizon (elevation 0 degrees or zenith distance 90 degrees). December 21st or 22nd is the day of their summer solstice. The Sun rises at 114 degrees East of North. The azimuths of sunsets are symmetrical along the cardinal North-South line (local meridian) to the azimuths of sunrises because we are close to the equator. The azimuths of sunrise/sunset at the equinoxes are, of course, 90 and 270 degrees.

In the mountains, we probably will not see sunrise/sunset at the theoretical zero horizon, but at some elevation angle (height) dictated by the local topography. We can compute the difference in the azimuth of such sunrise/sunset due to various elevations. For a model of local topography we make use of online digital terrain model Earth Remote Sensing Data Analysis Center [2].

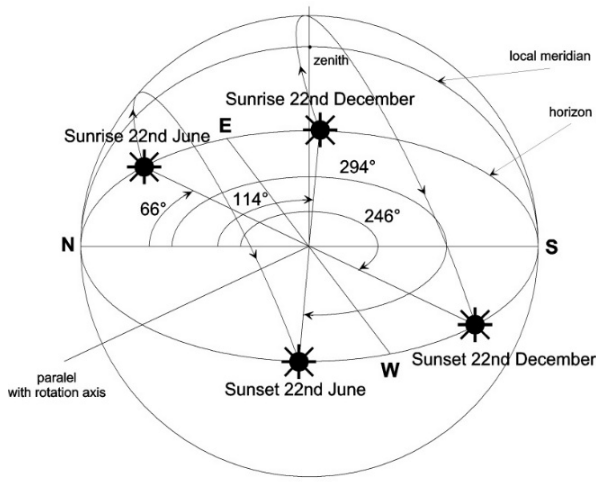

Figure 1: Astronomical azimuth of sunrise and sunset at the winter and summer solstice

2. Ollantaytambo

Ollantaytambo ($\varphi = 13°15´$S; $\lambda = 72°16$'W) is a small town with an archaeological area from the Inca period by Urubamba river near Aquas Calientes, which is a starting point to Machu Picchu. By Protzen [7], Zawaski and Malville [9] or Salazar and Salazar [8], we know some interesting information about orientation of Inca object in this area. Inticcahuarina (Incamisama) also Altar represents a sundial which is not an exception in this area.

We tested many objects in Ollantaytambo. Namely the Temple of the Sun, also known as Wall of six monoliths, ruins up the Temple of the Sun, Temple of the water, a big stone in the valley and the pyramid of Pacaritanpu. Temple of the Sun is a relatively large object with bright protrusions in the front. The ruins were surveyed during expedition in Peru 2012.

Figure 2: Ollantaytambo, the upper part: the Temple of the Sun, also known as the Wall of six monoliths. © Hanzalová 2012

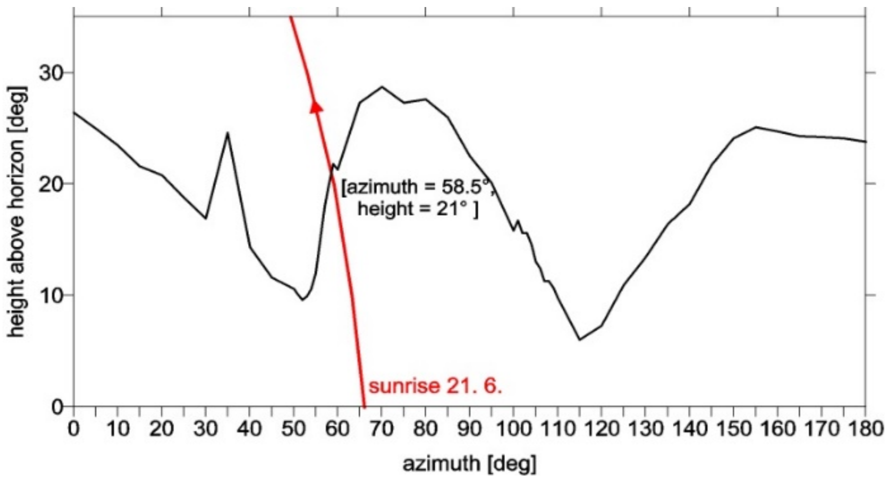

Figure 3: Altitude profile was created from DTM in direction from north to east. Observing point is Temple of the Sun. The line with arrow shows sunrise at the winter solstice.

These projections suggest a solar orientation. We have investigated, which astronomical phenomenon can be connected with the Temple.

3. Methods and results

We have astronomical azimuth of the wall of the Temple of the Sun 53°. We used the global digital elevation model ASTER GDEM as above to create terrain profiles. The observation point was in the middle of the wall. It were created 19 profiles from north to east with the constant interval. On the basis of profiles was calculated the astronomical azimuth of sunrise on June solstice, 58–59° or 32–31° north of east.

We compared the astronomical azimuth of the Temple of the Sun and the astronomical azimuth of sunrise. We can conclude that the Temple of the Sun is not observation point in conjunction with sunrise on June solstice.

We tested also the rise of the Pleiades, which have a similar declination as the Sun in June at the winter solstice. In the case of any stellar object, excluding the Sun, we have to account for the effect of precession. We computed sunrises of the Pleiades for the epochs 2000, 1500 and 1000 A.D. The astronomical azimuth is decreasing with time (see figure 5). The astronomical azimuth of the rise of Pleiades was about 62–64° some 500–1000 years ago, but for proving the astronomical orientation the azimuth should be about 50°. Also we cannot prove the astronomical orientation of the Temple of Sun.

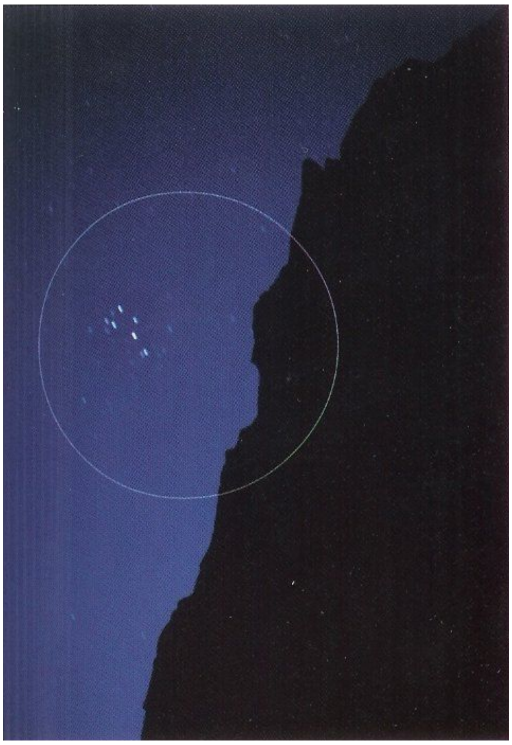

Figure 4: The rise of Pleiades at Ollantaytambo behind the Face of Inca.
© Salazar and Salazar [8]

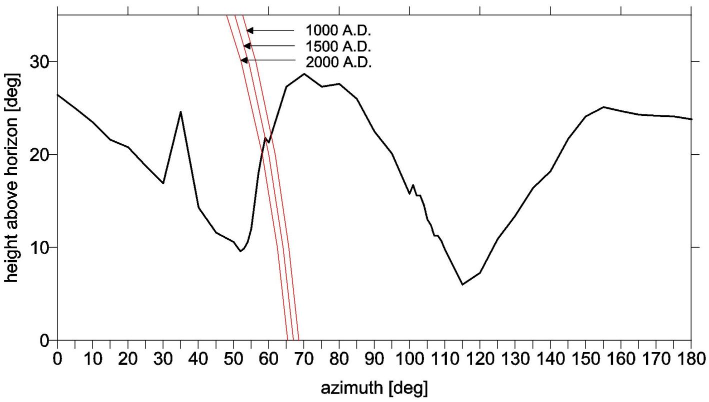

Figure 5: The rise of Pleiades in epochs 1000, 1500 and 2000 A.D.

We tested directions west-north from an observation point near ruins of the Temple of the Sun, in the direction to sunset at the winter solstice. We computed the profile for the surrounding mountains in direction west-north. According to sunset at the winter solstice, the astronomical azimuth for height about 26°, is 305° (see figure 6). Again, the result was unsuccessful.

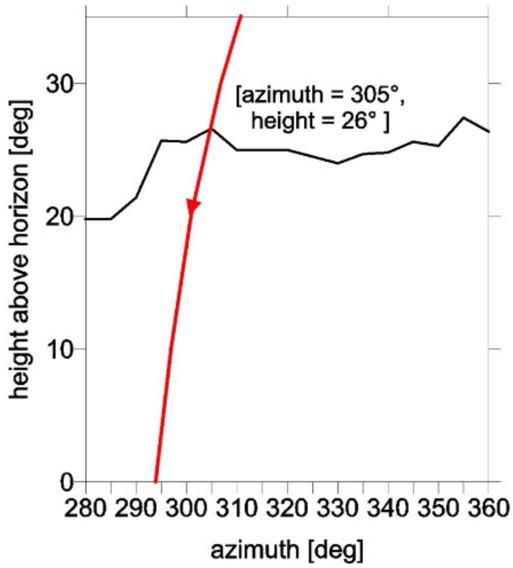

Figure 6: Altitude profile in direction from west to north for sunset.

We tried a possibility of another observation point. In 2012, we were in Ollantaytambo and founded interesting ruins, which are up the hill 100 m over the Temple of the Sun (see figure 7). We tried to calculate the profile with observation point in this place, but also without any success.

By Salazar and Salazar [8], near the Temple of the Sun, down by the riverside there is a pyramid (see figure 8). We considered point P, as observation point, at the corner (east rectangle) of the pyramid. There is a line connecting the east rectangular "platform" at the Urubamba river, going along the Inca road up to vicinity of the Temple of the Sun and then over the valley north of terraces and storehouses and the bearded man face in the direction to the Inca face (see figure 9).

The astronomical azimuth of this slant line is 620. It was compared with the azimuth from the profile. The astronomical azimuth was calculated about 62–63°. Accounting for possible inaccuracy of both approaches, the conformity is excellent. It seems that we founded a possible solution.

By Salazar and Salazar [8] the ray of sunlight falls in winter solstice to a corner of the pyramid. The chronicler Guamana Poma (1613) wrote that by means of sunshine falling on some windows the dates of sowing and harvest were estimated. Is it an accidental choice? After Salazar and Salazar [8], we also try to calculate the western slope of the pyramid and sunrise at their summer solstice. The astronomical azimuth of this slant is 112° derived by means of Google Earth tools (see figure 13). It was compared with the profile, which shows the azimuth about 1120. This results is also excellent. Now, we can confirm the astronomical-solar-solstice orientation in Ollantaytambo.

4. Conclusion

We tested astronomical, solar orientation in Ollantaytambo, Peru. For determination of the astronomical azimuth of an object in mountains we need the digital elevation model, because the azimuth of the sunrise/sunset is not in theoretical zero horizon. For this work we used the online digital terrain model Earth Remote Sensing Data Analysis Centre [2]. First, we focused on Temple of the Sun, also known as Wall of six monoliths. We tested astronomical azimuth of sunrise and sunset with observation point by the Temple of the Sun. The wall of Temple is directed roughly to the rise of Sun and has astronomical azimuth about 50°. But the astronomical solar orientation was not confirmed, because the astronomical azimuth of

Figure 7: Ollantaytambo, ruins 100 meter above the Temple of the Sun, view in east direction, © Hanzalová 2012

Figure 8: Ollantaytambo at the Urubamba river. The pyramid at the valley. © Salazar and Salazar [8]

Figure 9: The line connecting the pyramid, the Temple of the Sun and the Inca face; the situation for sunrise at their winter solstice. © Google Earth

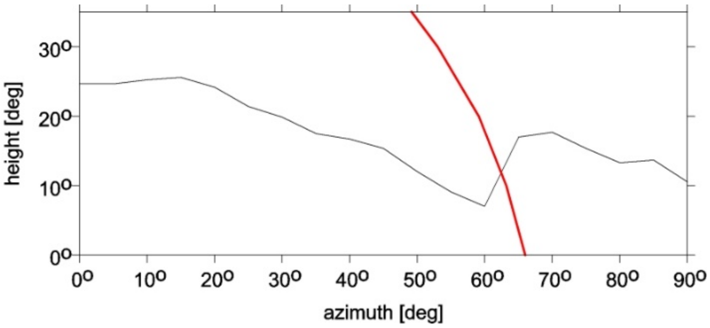

Figure 10: The terrain profile with observation point on the pyramid (point P — see fig. 9) in direction north to east for sunrise at winter solstice.

sunrise at their winter solstice is about 60°. Then, we tested the rise of Pleiades in epochs 1000, 1500 and 2000 A.D. Again, the result does not confirm the hypothesis of astronomical orientation of the Temple of Sun. We tested also the astronomical orientation of the ruins, located 100 m above the Temple. Neither the ruins are connected with solar orientation. Then, by Salazar and Salazar [8] we focused on the pyramid located near the Temple of the Sun, down by the riverside. We founded the line that connects the pyramid, Temple of the Sun and Incas face. In this direction the sun rises. The astronomical azimuth of sunrise at winter solstice in real horizon is about 62–63°. In comparison with the astronomical azimuth of the slant line, which is 62°, it is an excellent agreement. After that, we also tried to calculate the astronomical azimuth of western slope of the pyramid at summer solstice. There is also

Figure 11: View on pyramid during the sunrise their summer solstice. © Salazar and Salazar [8]

Figure 12: The western slope of pyramid. The line shows a direction to sunrise at summer solstice. © Google Earth

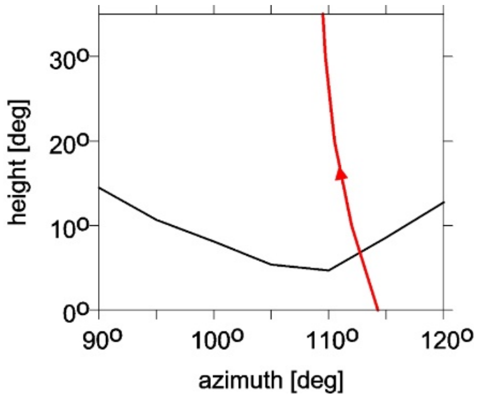

Figure 13: Terrain profile in direction west-south from pyramid. The line with arrow shows the sunrise at summer solstice.

excellent agreement. Both of the azimuths are 112°. Finally, we prove the astronomical solar orientation in Ollantaytambo. The main object which is connected with Sun is the pyramid. Our results mean a new information about astronomical orientation of the Inca object in Ollantaytambo, Peru. It is a very good example showing that the remote sensing has very important role in archaeoastronomy.

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