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LOOKING THROUGH A TELESCOPE WITH AN OBSIDIAN MIRROR. COULD SPECIALISTS OF ANCIENT CULTURES HAVE BEEN ABLE TO VIEW THE NIGHT SKY USING SUCH AN INSTRUMENT?

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ABSTRACT

Convex cut mirrors manufactured from the volcanic glass obsidian had been known since Neolithic time (7400/7100 to about 6200 BCE) in Çatalhöyük, Turkey. A Herschel type telescope made with an obsidian mirror (Ø 12 cm) allowed to see the Moon's craters sharp and distinct, the phases of Venus as well as the discs of Venus and Jupiter. The moons of Jupiter however are not visible due to the low degree of reflection of the used obsidian mirror. A specimen with a much better reflection or a bigger one would result in improved views of celestial objects. The paper reports on the making of the telescope and its potential application. Moreover, as a general basis, the study addresses the prehistory and symbolism of mirrors, with special focus on a possible assignment for skywatching.

KEYWORDS: Obsidian mirrors, prehistory of reflecting telescopes, symbolism of mirrors, Çatalhöyük, Neolithic optics

1. INTRODUCTION

In the 17th c. different types of reflecting telescopes had been developed and sometimes practical used (Wilson 2007, 1-15): ca. 1616 by Niccolò Zucchi (1586-1670), using a Herschelian design (see below); before 1626 by Cesare Caravaggi (died before 1626); 1632 by Bonaventura Francesco Cavalieri (1598-1647); and 1636 by Marin Mersenne (1588-1648) (Wilson 2007). The most advanced constructions had been developed 1663 by James Gregory (1638-1675) – the Gregorian, 1668-1672 by Sir Isaac Newton (1643-1727) – the Newtonian, and 1672 by Laurent Cassegrain (ca. 1629-1693) – the Cassegrain. The brothers John Hadley (1682-1744), Henry Hadley (1697 – 1771) and George Hadley (1685-1768), in 1721 constructed an improved reflecting telescope type 1721 using a parabolic mirror as primary.

Some (Atalay 2006; Buys 2007; Atalay and Wamsley 2009, 163-164) consider Leonardo da Vinci (1452-1519) to be the first describing the theory and the use of concave mirrors for stargazing purposes (Leonardo da Vinci, Codex Arundul, 1513). It is discussed that he might have constructed and used a reflecting telescope of the Herschelian type.

The history of polished concave and convex mirrors however is much older, being backtracked fifth or even ninth millennia (Albenda 1985; Vedder and Swogger 2005; Badisches Landesmuseum Karlsruhe 2007; Anderson 2007; Enoch 2006, 2007).

That raises the question of whether a few specialists of archaic cultures in principle would have been able to construct and manufacture a kind of reflecting telescope albeit without having an ocular, which they could have used for valid observations of the night sky phenomena. This paper reports on a kind of experimental archaeoastronomy, done by Josef Vit (Oberbettingen, Germany), who grinded the obsidian mirror and used it as a Herschelian type telescope. Michael A. Rappenglück added research on the cultural background of mirrors, in particular of specimens, which might have been used for sky watching, all over the world and through epochs back to the Neolithic time (ca. 7500 BCE; Enoch 2006, 775-776).

2. THE EARLIEST MIRRORS

Earliest mirrors had been made of different matter (Nordenskiöld 1926; Albenda 1985, 2; Taube 1992a, 169, 1992b, 33; Schechner 2005, 141-145; Saunders, 2003, 19; Calvo 2003, 5, 10-11; Matsumoto 2013, 103): Obsidian, jet, copper, gold, silver, bronze, selenite, slate, haematite, magnetite, anthracite, pyrite, and later glass. Hitherto obsidian is the oldest known material used for producing mirrors, as it is attested by specimens from the 6th millennium BC in Anato-

lia, Syro-Mesopotamia, and the Levant (Albenda 1985; Vedder and Swogger 2005; Enoch 2006, 2007; Badisches Landesmuseum Karlsruhe 2007).

Usually the mirrors are hand-sized (9-16 cm) and have a round or oval shape (Nordenskiöld 1926; Albenda 1985; Enoch 2006, 775, 777-778; Matsumoto 2013, 103). Their handles are long. The artisans apparently designed most of the mirrors for feeling good in the hand. Nevertheless, there are also bigger specimens, Ø up to 30 cm, and smaller ones, Ø down to 4 cm (Matsumoto 2013, 103; Enoch 2006, 778).

The curvatures of earliest mirrors typically are flat, but a few had been grinded convex or concave (Nordenskiöld 1926; Albenda 1985; Enoch 2006): At Çatalhöyük, Turkey, 7,400/7,100-6,200 BC, the hitherto found obsidian mirrors are convex (Vedder and Swogger 2005; Enoch 2006, 775-776, 778; Badisches Landesmuseum Karlsruhe 2007). In ancient Egypt, starting with ca. 2,900 BC, mirrors, made of different matter, have a convex or concave curvature (Enoch 2006, 776). Since approximately the first millennium BC, the Olmec (Mesoamerica) manufactured concave and some convex mirrors (Drucker, Heizer and Squier 1959, 176-184 and plate 43a; Lunazzi 1995, 1996; Enoch 2006, 778; Mexicon 2011, 36-37). Surprisingly a few are slightly shaped parabolic (Gullberg 1959, 280-283, and pl. 62). They have diameters up to 10 cm and focal lengths between 5 and 80 cm (Enoch 2006, 778). The mirrors are well polished. They still have excellent optical imaging and enlarging abilities.

Ancient people had been well aware of different types for mounting and holding a mirror: cells, cords, handles or tangs made of different materials (Albenda 1985; Juliano 1985, 36; Lerner 1996, 11; Enoch 2006, 775-776, 778, and Table 1/2).

Since at least the ninth millennium BCE advanced and more than sufficient technologies had been available for shaping (pecking and flaking), grinding and polishing surfaces (Enoch 2006, 780-781; Astruc et al. 2011, 3415-3424, 3418, fig. 5), which could be used for producing excellent mirrors. There are evidences for the usage of certain kinds of mechanical devices supporting the manufacturing process of very smooth and well-shaped surfaces (Astruc et al. 2011, 3421-3422).

Finally it is noteworthy that Mesoamerican people produced liquid mirrors using water and in a few cases probably mercury (Matsumoto 2013, 105).

3. SYMBOLISM AND USAGE

Studying cultures across the world and through time gives evidence for multiple profane and sacral use of flat and curved mirrors (Lerner 1996, 11; Moyer 2012). They helped providing self-perception (Juliano 1985, 37; Lerner 1996, 11, 31; Pendergras

2003; Mexicon 2011, 36-37; Moyer 2012; Matsumotu 2013, 104-105): They served as toiletry for personal preparation of the body. They permitted self-observation putting on cloths. They had been used as fashion accessories. People often associated the mirror, just as e.g. the spindle and the distaff, with woman's activity (Lerner 1996, 31). Mirrors figured into entertainment (Lerner 1996, 11). Moreover they had been a practical but also a ritual aid for the illumination of dark interiors (Russell 1988, 672 and fn. 45) by directing sunlight into them. People used them for medical purposes (Lunazzi 1996, 412).

Moreover mirrors were important figuratively: In general they symbolized the possibility of self-awareness and self-contemplation embodied by the power of reflection (Lunazzi 1995; Moyer 2012; Matsumotu 2013, 104-105). People believed that mirrors, especially if they are curved, allow seeing deeper into the everyday world. Moreover they open insight and give access into the normally hidden otherworld (Coqueugniot 1998, 358; Cauvin 1998; Moyer 2012). They reveal benevolent or malevolent power beings disguised in the shape of a human being or other creatures. Hence in the opinion of people mirrors served for getting knowledge.

The Latin word for 'mirror' is *speculum* (Pokorny 1959, 984). The word is rooted in the Indo-European *spek-* meaning "to watch". Derivations refer to the activities of observation, exploration, spying, and scrying (Pokorny 1959, 984). Similar the Yucatec (Maya language) word for (obsidian) mirror means "considering, contemplating, foretelling" (Taube 1992b, 34; Matsumotu 2013, 113-114). The Warau in South America used one term for denoting a shadow, the image in a mirror and the spiritual being of a decedent (Goeje 1930, 62 [415]). These linguistic examples are complement to the traditions of past and present cultures according to those mirrors served for catoptronic and scrying purposes, using reflecting surfaces, e.g. water, crystals, crystal balls, and other material (Taube 1992b, 33-34; Lunazzi 1995; Chevalier and Gheerbrant 1996, 657-661; Saunders 2001, 224; Maillet 2004, 49-55; Schechner 2005, 141; Blainey 2007; Moyer 2012; Matsumoto 2013, 105).

According to archaic conceptions mirrors allowed spiritual specialists gazing into the divine real. They worked as 'openings', which enabled communication and encounter with 'other worlds', wherein deities, ancestors, certain powers or other entities exist. They specifically played an important role during the passage between life and death, and for the renewal of life (Kano 1979, 9-10; Moyer 2012; Matsumoto 2013, 104-105, 109-110). They therefore were important in rituals dealing with those topics, e.g. funerary customs (Lerner 1996, 11, 31; Moyer 2012).

Because mirrors offered access to other realms of the world they had been associated figuratively to doorways, caves, wells and pools of water (e.g. Mesoamerican and other cultures) (Moyer 2012). Mirrors, functioning as 'gates', were protected and used by supernatural beings (Waterbury 1952, 117-136; Bulling 1960; Strätz 1996; Moyer 2012). These ideas often were related to archaic cosmologies.

Moreover ancient people considered mirrors to be a kind of 'eyes' and interrelated them with vision and contemplation (Schele and Miller 1986; Lunazzi 1996, 416; Blainey 2007; Matsumotu 2013, 104, 112-113). Cosmovisions in particular are often linked with both 'tools' for 'viewing': the eye and the mirror. That explains why some animal species (often carnivores), who have a superior night vision, caused by a layer of tissue behind the eye's retina (tapetum lucidum; Ollivier 2004), which reflects the visible light back through it whereby increasing the light for the receptors, had been correlated to shamans or rulers: Like for example a felidae, who uses the 'eye shine' ('mirror like eyes') in the night, shamans and rulers probably wanted to see into 'other worlds' (Matsumotu 2013, 104).

The above-mentioned ideas led to the view that mirrors have magical, apotropaic, protective, destructive, political and divine power (e.g. Juliano 1985, 36; Witzel 2005; Blainey 2007; Moyer 2012; Matsumotu 2013, 106-107).

4. SKYGAZING AND ANCIENT MIRRORS

Ancient Traditions passed down the concept of the mirror as a tool for viewing far away objects (Laufer 1928).

Mirrors in the underworld are dark (Roe 1982, 135). They are complemented by bright mirrors, e. g. embodied by the sun, who reflected and focused the light onto the Earth (Roe 1982, 228). Obsidian 'dark' mirrors are thought to be opposed to 'bright' pyrite ones (Taube 1992b, 33; Cauvin 1998). Mirrors collect cosmic energy (Saunders 2003, 25).

All over the world archaic cultures associated mirrors with fire and sun (Kano 1979, 9-10; Carlson 1981, 128; McCrickard 1990, 64, 65, 67, 69, 91, 97, 102, 122, 124, 125, 126, 170, 194, 210, 214, 225, 242, 251; Taube 1992a, 192-195; Milbrath 1999, 92, 88-89, 102, 226; Matsumotu 2013, 104). The mirror symbolized the Japanese Sun-goddess Amaterasu-Omi-Kami. It was an imperial implement in Shinto shrines (Witzel 2005, 15, 16, 19, 21, 24, 26).

The Maya Moon Goddess Ixchel is giving birth to a rabbit, a symbol of the moon, onto (or in front of) a mirror situated directly where the cosmic World Tree grows (Miller and Taube 1993: 127. 142; Schele and Miller 1986: 143-144).

Amerindians considered the Moon as a mirror and the stars as tiny mirrors (Roe 1982, 249; Milbrath 1999, 133 Fig. 410, 198, 283; Matsumoto 2013, 112). In ancient China the 'Broken Mirror', was related to the Moon's phases, except Full Moon, which was regarded as a whole mirror (Gheerbrant 1996, 658).

The Aztec and Toltec god Tezcatlipoca ('smoking mirror') is equipped with a round obsidian mirror and linked to the Big Dipper asterism and lightning (Lehmann-Nitsche 1938, 73-76, 79; Taube 1992b, 34, 75; Saunders 2001). Mirrors coming from ancient China show animals of the cosmic cardinal quarters, Sun, Moon, the five planets, the Big Dipper asterism and Polaris, the zodiacal signs and the stems (Schaffer 1978-79; Juliano 1985, 36; Von Falkenhausen 1989, 222-223). They have apotropaic functions collecting light from the heaven, e.g. rays from the stars (Schaffer 1978-79, 58).

In ancient China during the New Fire ceremony in spring fire was kindled with the aid of a mirror (Frazer 1919, 166). In the Roman Empire the Vestals produced sacred fire collecting the sun rays by a mirror (Frazer 1919, 168, fn. 347). Mirrors may have served for fire making in Olmec rituals, too (Lunazzi 1995; but Mexican 2011, 36-37). In the Late Han-Dynasty (23/25-220 AD), during a special ceremony the "Director of Sun Fire" a concave Bronze mirror facing the Sun at noon used to focus solar fire (Seidel and Kalinowski 1982; Needham 1996, 87). In addition it was used to collect dew, being exposed to the Full Moon's light. Mirrors were associated to fire, Sun, water and Moon (Moyer 2012, 285, 291, 292).

According to the traditions of shamans in the Altai region Sun and Moon act as the two heavenly mirrors, displaying events on Earth (Holmberg 1927: 419). From both the images are reflected again into the magic mirrors, which a shaman uses. They are accessories of his costume (Holmberg 1964, 419, 437). These magical mirrors symbolize Sun and Moon (Rappenglück 2016, 22). Often ancient cultures considered the Moon to be a mirror reflecting the Sun's light (Chevalier and Gheerbrant 1996, 658; Moyer 2012, 304). They sometimes are decorated with the animals of the zodiac (Holmberg 1964, 437). Orphism (6th to 5th c. BCE) handed down a very similar idea about the Sun mirroring the primeval light and the Moon reflecting the Sun's rays (Eisler 1910, 656-657, 687). A comparable concept is delivered by Pythagoreanism, 6th c. BCE (Eisler 1910, 687, 724 fn. 4). Later Empedocles (c. 490 - c. 430 BCE) regarded the celestial luminaries as reflections of the primeval cosmic light (Eisler 1910, 692). In the Old Testament, Job 37.18 (English Standard Version), the complete sky was considered to be a cast metal mirror. Even today Nahua Natives regard the dome of the sky as

a living (crystal) mirror filled with the sparkle of the sun and stars (Saunders 2003, 20).

The Polynesians had concave polished mirrors (Kelley and Milone 2005, 346). It remains unclear whether they used them for sky watching. The Kogi people in South America used obsidian mirrors for magical purposes related to the sun, shining vertical through a hole in the temple (Reichel-Dolmatoff 1982, 177-178; Kelley and Milone 2005, 433).

Modern indigenous Maya people still use liquid water surfaces for indirect watching reflections of eclipses (Matsumoto 2013, 105). Some researchers assume that ancient Maya observed these and perhaps also other astronomical phenomena alike (Milbrath, 1999: 27; Matsumoto 2013, 105). Moreover some scientists speculated that the Maya applied obsidian mirrors for astronomical observations possibly in relation to shamanistic practices (Schagunn 1975; Milbrath 1999, 27; Kelley and Milone 2005, 353, 354 fig. 12.2, 433; Blainey 2007, 26; Matsumoto 2013, 105). The Olmec, too, seemed to have used mirrors for astronomical purposes (Lunazzi 1995).

It is not clear what the few representations of persons (rulers, shamans) viewing into a mirror or into a ceramic bowl, which sometimes is equipped with a mirror placed at the bottom, really show (Kelley and Milone 2005, 353, 354 fig. 12.2, 433; Matsumoto 2013, 105-106). Is an act of self-reflection, of meditating, or of sky gazing (Kelley and Milone 2005, 353, 354 fig. 12.2, 433) depicted?

5. OLDEST OBSIDIAN MIRRORS

During Mesolithic and Neolithic time Aşıklıhöyük (ϕ : 38° 20' 57" N, λ : 34° 13' 47" E, 1119.5 m.a.s.l.) and Çatalhöyük (ϕ : 37° 40' 3" N, λ : 32° 49' 42" E; 903 m.a.s.l.), both in Anatolia (Turkey), were important centres of obsidian trade close to the volcanic glass resources at the volcano of Hasan Dağ (Turkey).

A highly polished obsidian bracelet from Aşıklı Höyük, Central Anatolia 8,300-7,500 cal. BC. (Astruc et al. 2011, 3415-3424, 3418, fig. 5), reveals that the artisans in those days had been able to search and select obsidian of high quality as well as applying an excellent drilling and abrasive technology. It seems that certain complex polishing techniques for obtaining a surface quality down to nanometres had been at their disposal. That precision is in the same scale as needed by telescope lenses today.

From Wadi Rabah Culture, Kabri's Area A (Israel) comes an obsidian mirror, which is dated to ca. 6th/5th millennium BCE (Ben-Tor 1992, 39; Gopher, Marder, and Barkai 2011). The source for the raw material was ancient Anatolia. Because of having a handle, that beautiful worked specimen probably served for cosmetic purposes.

Some centuries older and much more impressive are the convex spherical obsidian mirrors, perfectly smoothed, from Çatalhöyük, Turkey, 6,520-6,220 cal. BC (Museum of Anatolian Civilizations, Ankara, Turkey; Enoch 2006, 775-776).

6. ÇATALHÖYÜK, 6,520-6,220 CAL BC

Eight totally preserved mirrors made of obsidian had been dug up in Çatalhöyük, Turkey. A few more were found broken (Vetter 2005; Badisches Landesmuseum Karlsruhe 2007, #336; Haddow 2014, 39, 217-218). Some of them still show perfect optical imaging quality (Vedder 2001; Enoch 2006, 775-776, and Figure 2). The smallest mirror (Ø 4 cm, H: 2 cm; found in space 226) has not been finished.

Most of them had been found in graves of levels VI-IV, c. 6,520-6,220 cal BC (Mellaart 1967, 79, 80 table 13, 156, 208, 209, and plate XII; Badisches Landesmuseum Karlsruhe 2007, #336). Several burials, mostly of women, yielded circular, hand-sized objects, about 9 cm in diameter, made of highly polished obsidian (Enoch 2006, 775-776). Some of the obsidian still show an excellent image (Hodder 2012, 9). The finest of these was set into lime plaster. Archaeologists left open the question whether these mirrors had been used for ritual or for another purpose. Some but not all obsidian 'mirrors' seemed to be related with skulls, azurite and ochre, beads, and hackberries. A solely relation of the mirrors to female gender is not allocable.

A kind of serial production is evident, showing that the craftsmen of that time controlled the technology (Badisches Landesmuseum Karlsruhe 2007, #336; Astruc 2011). Experiments showed: First the surface for the mirror was squared. Then followed repeated working steps of cutting, grinding, and polishing using raw and fine whetstones, sand, clay, and water (Badisches Landesmuseum Karlsruhe 2007, #336; Vit, pers. communication). The production of one mirror took about 7-8 hours (Badisches Landesmuseum Karlsruhe 2007, #336; Astruc 2011, 3421-3422).

A photograph (Fig. 1), taken from the object during the exhibition showed the reflection of a fluorescent lamp, which allowed to determine the corresponding concave mirror's focal length. That served as a template for making an obsidian mirror telescope. The surface of the mirror is polished spherical and is slightly convex. The backside is conical and only a bit carved.

Answering the question whether an obsidian mirror telescope could work, required an experimental assembly, which for a 12 cm obsidian mirror was done by Josef Vit (see below).



Figure 1: 8,500 years old example of a spherical convex obsidian mirror (Ø: 9.5 cm, H: 5.1 cm); exhibition "Anatolian Monuments", Karlsruhe, Germany, 2007. Photo: Josef vit.

7. MAKING THE OBSIDIAN MIRROR

Obsidian (Ericson et al. 1975) is a deep black or blackish green translucent glass (70–75% SiO₂, MgO, Fe₃O₄) of volcanic origin. Its properties are similar to quartz, but it is softer, having Mohs values of 5.0-6.0. Obsidian is an amorphous material with a density of 2.3-2.6 g/cm³. As a special characteristic obsidian shows a conchoidal surface fracture.

Though its reflectance (R%) is only 4-5%, which is quite low compared with other material (e.g. silver [Ag]: 93.3%; copper [Cu]: 64.4%; pyrite [FeS₂]: 51.7%; hematite [Fe₂O₃]: 26.4-29.9%; magnetite [Fe²⁺(Fe³⁺)₂O₄]: 21%; (Craig and Vaughan 1994, Table A2.1, 405-410; Lunazzi 1995, 4), it can serve as material for the production of flat or curved mirrors (Lunazzi 1995;). Obsidian mirrors can be etched and polished up to the limit allowed by properties of the material.

Sphericity results from the grinding process, which also gives a pair of concave-convex surfaces. First experiments (Vedder 2001; Vedder and Swogger, 2005) lead to a largest mirror surface of ca. 4 by 6 cm. Grinding and polishing was done by granite, sand, sandstone, fine-grained stone, and clay. The mirrors were slightly convex and had a good imaging.

Resuming Vedder's construction of the past, Vit started making a mirror of obsidian. Raw obsidian material coming from different source worldwide was carefully proven with the unaided eye concerning purity, homogeneity, frictions, and cracks. Then a piece of Mexican obsidian was cut for preparing a round disk. Subsequent the specimen was grinded

and polished. It turned out that grinding an obsidian mirror results more quickly in a deep curvature than grinding quartz glass, because of a lesser Mohs value (obsidian: 5.5-6.0 / quartz: 7). Finally the proof of quality was done using a modern method: a Bath-Interferometer (Bath 1973).

The theoretical base for making the mirror followed Bath (2007), though ancient experts doubtless will have applied the trial and error method. The computations depend on standard values for near and far point, visual acuity, exit pupil, reflectivity of obsidian, myopia, and some other parameters etc. The finished mirror is characterized as follows: $\varnothing = 12$ cm, focal length $f = 213.5$ cm, ratio = 1:17.8, theoretical limiting magnitude: 9.0 mag, magnification: 20x, true field of view: 3.4° . The degree of reflection however was about 3%, less than the expected 5%.

The secondary mirror in a Newtonian design, if manufactured as an obsidian reflector, too, would consume another 5% of the incoming light, resulting in only 0.25% degree of reflection for the complete telescope. That would make the instrument useless. With regard to the used material obsidian and the modern variants of telescope designs, only one telescope design seems to be sufficient: *the Herschelian type*, named after William Herschel (1738-1822), who applied that type of construction for his reflecting telescopes (Hoskin 2011). For reducing errors caused by the Herschelian design – observing off the optical axis – the mirror must have a long focal ratio.



Figure 2: The Herschelian telescope with the obsidian mirror, ready for observing; Full Moon observed with the obsidian mirror. Still image taken from a film. Photos: Josef Vit.

The 12 cm Herschelian reflector ($f = 213.5$ cm, based on a mirror made of obsidian, was set in a wooden mounting, which allowed aligning and a bit reposition of certain astronomical targets by the observer or / and an assistant. The abilities for carpentering and woodturning of such a bracket had been excellent at the time and place of Çatalhöyük (Mellaart 1967, 213-215, and Fig. 55; Asouti 2013).

The Herschelian telescope with its obsidian mirror shows a brilliant, sharp and detailed image of the Moon (Figure 3), with lunar maria, craters, lunar rays, and mountains. The observer can recognize the phases of Venus, the disk of Jupiter, and also some other celestial objects (e.g. Open Clusters, Orion Nebula). The Galilean moons of Jupiter or the Orion Nebula (M42) however are not visible due to the low degree of reflection of the used obsidian mirror. A specimen with a much better reflection or a bigger mirror (e.g. $\varnothing = 16$ cm or 19 cm) for sure would result in improved views and an extension of the range of celestial objects: If the obsidian has 5% reflectivity and the diameter of the obsidian mirror is 19 cm, the limiting magnitude would reach about 10 mag (Bath 2007).

8. CONCLUSION

An obsidian mirror could have been both a catoptronic and a proto-scientific tool, comparable to the ancient Chinese geomantic compass (Needham 1996: 254-273). There is some evidence for sky gazing and astronomical referenced time-reckoning at Çatalhöyük (Matossian 1980): People observed the annual cycles of bees and barley. Counting days they correlated them with the star phases of the Pleiades and perhaps asterisms in the area of today's Bull and Ram, which they recognized there. Whether the interest in sky gazing and the experimentally verified ability of producing high quality obsidian mirrors actually resulted in the development and use of a Herschelian type obsidian based reflector is not proven. At present there is no evidence for or against that the society at the time of Çatalhöyük would have required an astronomical telescope. This article however demonstrates that the technical abilities of constructing a Herschelian type obsidian basically have been existing in the Neolithic epoch.

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