INTRODUCTION TO THE HISTORY OF LENSES AND VISUAL CORRECTIONS: A REFERENCE TO SPAIN AND THE SPANISH COLONIES IN THE NEW WORLD (XV-XVI C.)

María Luisa Calvo*, Departamento de Óptica, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Madrid, España
Jay M. Enoch**, School of Optometry, University of California, Berkeley, USA

ABSTRACT
Archaeological optics is a branch of science studying the early history of lenses, optical devices and introduction of visual corrections from ancient civilizations up to our modern world. The first known lenses were located in Egypt, (ca 2600 BC). There are well documented studies of discoveries adressing the early use of corrective lenses. However, little information exists relative to discoveries relating to early lens and mirror use in the American continent. We address early use of corrective lenses in Spain and in the Spanish Colonies in the New World, emphasizing the XV-XVI centuries. We report documents obtained from the Archives of the Indias, (Seville, Spain) indicating presence of limited optical technologies in Cuba, Mexico and Peru. Also, we refer the discovery of a copy of a portrait of an early Viceroy of New Spain, Luis de Velasco (the Son), located in the Pecos National Monument, Santa Fe, New Mexico. It has been confirmed that the original portrait is located at the Museum of the Castle of Chapultepec, Mexico City, Mexico. We have pursued inquires searching for a link between this discovery and the early use of lenses in Spain *per se* and also in relation to the personal history of this Viceroy. Studies at the Archives of the Indias indicate the introduction of various technologies on the American continent, but the link is missing relative to contributions of ancient American civilizations (e.g., in Mexico and Peru). They had knowledge about astronomy and optical technology.

RESUMEN
La óptica arqueológica es una rama de la ciencia que estudia la historia de las lentes, de los instrumentos ópticos y de las correcciones visuales, desde una perspectiva del desarrollo de las antiguas civilizaciones hasta la época actual. Las primeras lentes de que se tenga constancia estarían localizadas en Egipto (2.600 años AC). Existen estudios bien documentados que refieren el descubrimiento de lentes para correcciones visuales. Sin embargo, no se dispone de información suficiente relacionada con el uso de lentes correctoras y de espejos, para ciertas aplicaciones, en el continente americano. Nos referimos en este trabajo al uso de lentes correctoras en España y en las colonias del Nuevo Mundo con especial énfasis en los siglos XV y XVI. Se presentan documentos consultados en el Archivo General de Indias (Sevilla, España) que indican la presencia de ciertas tecnológias ópticas en Cuba, México y Perú. Igualmente, los autores refieren el descubrimiento de una copia de un retrato del Virrey de Nueva España, Luis de Velasco (hijo), localizada en el Museo de Pecos, Santa Fé, Nuevo México. Se ha confirmado que el retrato original estaría emplazado en el museo del Castillo de Chapultepec, Ciudad de México. Los autores han proseguido investigaciones con objeto de encontrar un vínculo entre este descubrimiento y el uso de lentes correctoras en la España del s.XV *per se* así como en relación con la historia personal de este Vicerrey. Los estudios llevados a cabo en el Archivo General de Indias indican las introducción de varias tecnologías en el continente americano, pero hay un "eslabón perdido" relativo a las contribuciones que pudieron proporcionar las antiguas civilizaciones americanas (por ejemplo, en México y Perú). Es sabido que poseian vastos conocimientos en astronomía y algunas técnicas ópticas.

1. INTRODUCTION

Archaeological optics is branch of science dedicated to the study of the early history of lenses, optical devices, and to the introduction of visual corrections from ancient civilizations to modern times [1].

The first known lenses have been located in Egypt (ca 4630 BP: Before the Present time); later lenses were encountered at other sites in the Middle East and the Greek Islands [2]. Mirror use can be traced back 8000 BP in Anatolia (located in south-central modern Turkey). Mirrors latter appeared in Egypt and Mesopotamia.

Early optical discoveries on the American continent occurred remarkably early and are only poorly documented. By about the year 4000 BP (2000 BC) mirrors appeared broadly throughout the Middle East, Greece and Etruria, Asia and China, and surprisingly in the New World. Mirrors in Western Asia, Egypt and in Eastern Mediterranean areas

E-mail: *<mlcalvo@fis.ucm.es>
**<jmenoch@berkeley.edu>

were different in design from later Siberian and Chinese structural models. After first discoveries of mirrors in the New World, mirrors were found in Peru during the Chavin culture, then the Moche culture, and in Mexico to the North (the Olmec civilization in Central America). Rock crystal ground lenses were apparently in use during the Moche culture (Peru) and later were also known in Mexico. Grinding and polishing skills were key elements in mirror and lens evolution. These technologies emerged early, and probably were associated with modification of "hard rock" materials.

Limited early discoveries of lenses used for corrective lenses have been reported in Spain and in the Spanish Colonies in the New World (XV-XVI C). Our main objective has been to investigate the links between the early development of corrective lenses in Spain and their later introduction into the New World. The latter analysis has centered upon lenses worn by an early representative of Spain in the New World, the Viceroy of New Spain, Luis de Velasco (the younger). In order to clarify events occurring, we sought to determine his personal history as well.

And to place matters in context, we searched the Archives for links related to ancient Native American civilizations (e.g., in Mexico and Peru), but the latter are missing. In this preliminary study, we found important ties to astronomical instruments and glass technology, and learned about the presence of rather astonishing optical technologies in very early stages of the pre-Columbian civilizations.

2. OPTICS IN ANTIQUITY: SOME OVERVIEW

The origins of archaeological optics are unknown and linked to the study of the first *known* lenses and mirrors. We can quote here the sentences of the philosopher Seneca, a Roman citizen who was born in the city of Cordoba (ca 2000 BP-2061 BP): *"I have already said there are mirrors which increase every object they reflect. I will add that everything is much larger when you look at it through water. Letters, however tiny and obscure, are seen larger and clearer through a glass ball filled with water"* .

At an earlier time, we need to consider some important factors: Miniaturization in art and written letters has existed from ca 5300 BP. Micro-cuneiform text written on clay tablets in Mesopotamia can be observed in quite a number of Museums. As added examples, the Egyptians created figures with details less than 1mm in height. Miniaturized Hebrew texts have been found in phalacteries located near the Dead Sea (Princeton Theological Seminary).

The first *known* mirrors were manufactured *and* polished by 8000BP, earlier human civilizations created/employed natural water mirrors. The first known fabricated mirrors were found in graves in Anatolia in the region of the Neolithic settlement of Çatal Hüyük. They are polished obsidian mirrors, c.a. 9 cm in diameter. One is mounted on a stand and the formed reflected images are recognizable, and in some instances they are outstanding.

As noted, first *known* lenses were located in Egypt (ca 4630 BP) and were superb. They were made from rock crystal, had a convex front surface, and a flat posterior surface with a centered ground small-radius concave curve located at its center.

Visual corrections (lenses and mirrors, mainly the latter) were used before the time of Christ. The use of mirrors and a water-filled lens by Seneca (he lived from ca 4-65 AD), cited just above, were used by him as a visual correction for presbyopia and magnification. Spectacles date from ca 1280 (XIII C) in Nothern Italy.

3. THE PRE-COLUMBIAN AMERICAN CIVILIZATIONS: SOME AVAILABLE DATA

Here, we consider representative pre-Columbian civilizations where evidence of utilization of optical technologies has been identified. As examples, in Mexico and Central America there were the Olmec civilization which was located near modern Villahermosa, elegant Mayan centers such as in Chichén Itzá in the Yucatán peninsula, evidence of lens and mirror use in Chiapas State. In Chichén Itzá there was an astronomical site which was constructed with additional elements for inspecting the sky. The latter were stone columns with water located on at the top of columns. These which were used to create water mirrors (see Figurs. 1a and 1b).

The Azteczs and Olmecs were also developing and manufacturing mirrors. Olmec mirrors, made of obsidian, range in dates from 3125-2130 BP, had remarkable quality and the appearance of mirrors continued up to at least the Teotihuacan civilization a few centuries before Spanish colonization which occurred in ca 500 BP [3]. These mirrors had very interesting properties:

i) Greatly advanced techniques were used for forming these mirrors. ii) The artisans apparently had knowledge of the properties of various minerals and mineral-related substances such as obsidian (SiO_2) which has properties similar to quartz, with the exception that obsidian is an amorphous material. It is softer than quartz, with Mohs values (a scale for measuring hardness) of 5.0-5.5. Obsidian also exhibits a form of conchoidal surface fracture. iii)

The color of an obsidian rock can be black, grey, brown, dark green or white transparent.

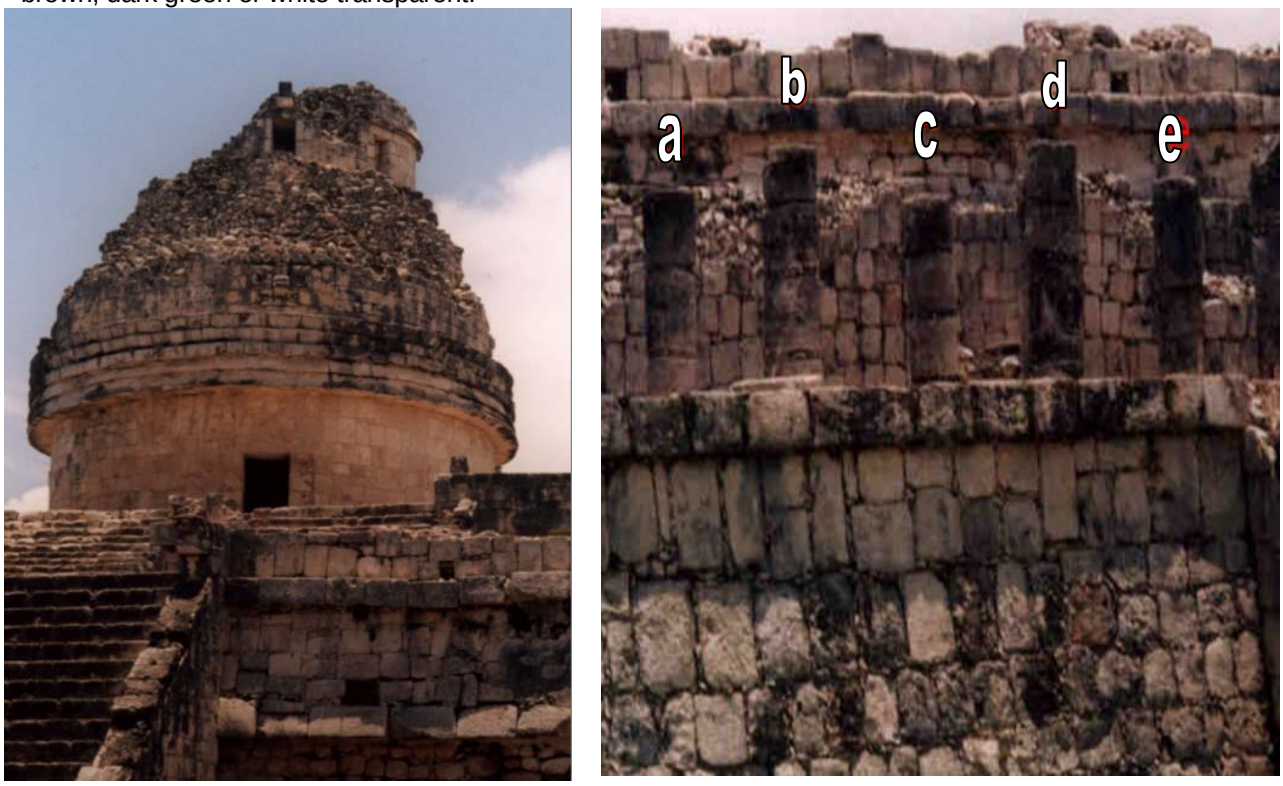


Figure 1. a) An astronomical site at Chichén Itzá. b) Red letters indicated the locations of water mirrors.

South-American civilizations also utilized optical technologies. Additionally, they developed valuable techniques for polishing, melting of metals, and for sculpting precious or semi-precious rocks. For obvious reasons, we cannot enter here into deeper consideration of possible connections between Meso-American and South-American pre-Columbian civilizations. Certain facts indicate that similarities were found in types of mirrors developed and techniques applied. Many ancient cultures in this continent have been studied. We only mention here aspects that help to clarify optical developments occurring among Chavin, La Tolita, and Moche peoples (see Figure 2).

An ancient South-American civilization is the Chavin culture (c.a. 2900 BP - 2200 BP). The Chavin people settled in the North-Eastern part of Peru. They were located North of the region where the center of the Inca civilization developed. The Chavin people constituted an original Andean culture. They constructed impressive sites and religious centers. Evidence was found for utilization of optical techniques for polishing remarkable quality mirrors made from anthracite (Figure 3). See Appendix I for a more extended, and to our knowledge, original study of technical aspects of these mirrors.

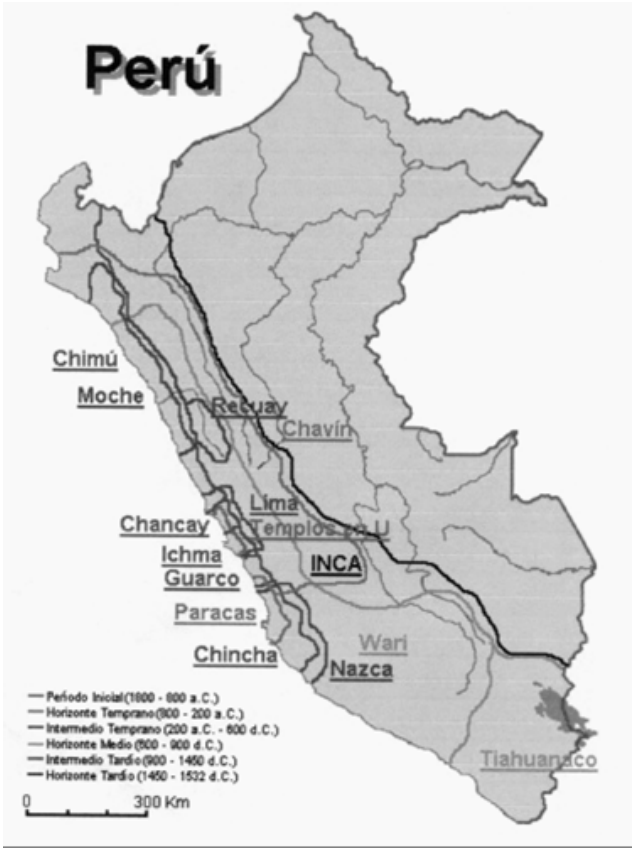


Figure 2. A map showing the location of ancient civilizations in Peru.

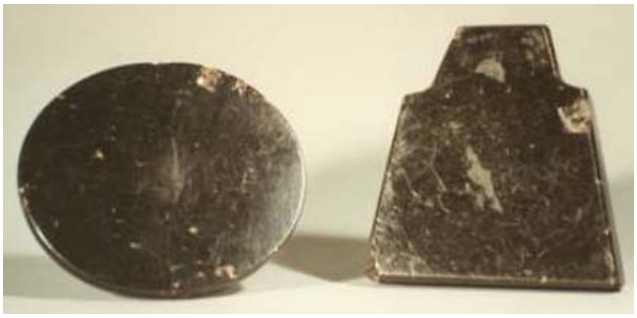


Figure 3. Reproduction of two Chavin mirrors from the private David Bernstein's collection, New York.

The so called La Tolita culture (c.a. 2600 BP - 2300 BP) was developed in Southern Colombia-Northern Ecuador. These people settled near the Santiago river. La Tolita Island was predominantly a necropolis. At archeological sites evidence is provided for remarkable burial ceremonies and grave contents, e.g., masks. Refined manufacturing techniques for working gold and polishing precious stones were clearly introduced by these people.

The Moche culture dated from 2200 BP to 1200 BP. These people settled in river valleys along the Northern Peruvian coastline. Moche art became predominant in the region. This civilization lasted almost five centuries and underwent five phases of development. There are fine examples of elegant rock crystal and glass necklaces and pendants, lenses, jewelry (with lens-like polishing elements), and mirrors made of copper (Figure 4).

4. POST-COLUMBIAN DEVELOPMENTS: THE TECHNOLOGIES IN THE SO-CALLED NEW SPAIN (XV AND XVI C)

Pre-Columbian and Post-Columbian civilizations developed in parallel for a certain period of time. Both benefitted from sharing knowledge. Over the course of centuries, a number of historians from both sides of the Atlantic have studied the importation and export of many products. Some examples of technical and economical data obtained in the XVI C focus upon:

Figure 4. Reproduction of a Moche mirror. Metropolitan Museum of Art, New York City. Jan Mitchell Treasury for Pre-Columbian Works of Art in Gold, New York.

a) **Agriculture**: production of cereals, tropical products (e.g., sugar cane), dye substances for the textile industry, exploitation of silk.

b) **Civil construction**: As an example, irrigation systems.

c) **Mines**: Gold and silver exploitation [4]: This was an important factor serving to stimulate increased internal and external commerce. One of these was the introduction of new chemical techniques utilizing quicksilver ("azogue"). This is an amalgam formed using mercury and salt. It was later used for manufacturing mirrors and introduced by B. Medina, in the years 1550-1560 in Mexico.

d) **Navigation and scientific travel**: Cristobal Columbus was not only an experienced navigator but he was also very interested in many aspects of the scientific instrumentation used for observation of various phenomena. He discovered a magnetic line without declination in the Atlantic. Another important example was Father A. De Urdaneta who wrote a number of volumes addressing fundamentals of meteorology, the analysis of winds, and the origin of cyclones.

e) **Medicine, pharmaceuticals and botanicals**: An enormous number of scientific and technical publications were produced by many researchers of that époque. Quite a number of these were developed in the Americas [5].

5. EARLY VISUAL CORRECTIONS AND OPTICS IN SPAIN: EARLY APPROACH

Even today, there are only limited archival references available to the optical sciences and technologies in Spain for dates prior to the XVth C. One must consider several historical facts: Periods of great unrest occurred in the Iberian Peninsula due to multiple invasions from the North and the South. The most valuable sources are artistic representations researchers found in paintings, sculptures, religious monuments, and on medals[6]. Other facts that can create some difficulties are the availability of the historical archives. Many of them are located at religious sites and on some occasions are not accessible. Civil archives are also of great importance, we can mention the General Archive of the Indias (Sevilla, Spain), the Archives of the Mexican Nation (Mexico City, Mexico), the Biblioteca Nacional, (Madrid, Spain), and the numerous Archives located also in Ibero-American countries. But it is evident that the great dispersion creates a hard task when one tries to recuperate different époque elements. Other sources have origin in literary works and documentation from Spanish historians (mainly outside of the technical world).

The earliest and first known technical book edited in Spanish is the one from Benito Daza de Valdés (XVII C.), edited and printed in Sevilla in 1622, a reproduction of the front page is shown in Figure 5. One can read: *On the use of spectacles (*antoios or "antojos" in old Spanish*) for all kinds of vision. In which one teaches how to know the gradations each person is missing in his vision, and (properties of) those who already have spectacles. Licenciate Benito DaÇa de Valdés. From the Sainted Official of the City of Sevilla. Dedicated to Our Lady of Fuensanta, City of Cordoba.* We may notice that B. Daza de Valdés was a clerical belonging to the Inquisition movement. Inquisition played a determinant role all over Europe, during the middle XVI and XVII centuries, avoiding the spreading of new scientific theories which were considered heretical. Other European or World sources related to the then current technical works appearing in Spain during this period of time are very limited and not always as objective as desired, due to the so-called Black Legende, creating the vision of a dark and tyrannical time.

Figure 5. The front page of the first known book writen in Spanish on visual corrections (Sevilla, 1622).

6. OUR FINDINGS: PORTRAIT OF VICEROY LUIS DE VELASCO (THE YOUNGER)

In Figure 6 we display a reproduction of a portrait of the Viceroy of New Spain, Luis de Velasco y Castilla, also named “The Younger” or “The Son”, in order to prevent confusion with his father, also Viceroy and having the same first and family names. This painting was created during his first term as the eighth Viceroy of New Spain (1590-1595). He also served as the eleventh Viceroy in 1607-1611.

Figure 6. A portrait of Viceroy Luis de Velasco. He is wearing spectacles.

We are giving here some available data on this painting:

1. A photographic copy (B&W) was found by one of the authors (JME) at the Museum of the Pecos National Historical Monument, near Santa Fe, New Mexico, United States of America.

2. The original painting (in color) was previously located at the Viceroy Gallery, Chapultepec Castle, Mexico City, Mexico. Currently it is located at Museo Nacional del Virreinato, Mexico City.

3. A similar painting, but with a white beard, exists representing his second term as Viceroy. In other previous works [7-8] we studied the possibility as to whether the spectacles were obtained in Mexico City, or alternatively in Spain or other European regions. There are still uncertainties today relative to this question. The main reason is the mixing and sometimes controversial data that we have obtained from various sources in archives and publications in Spain. At the moment of writing this article the authors are convinced that inspection of archives in places as Mexico City, Lima and other Ibero-American cities are compulsory. Therefore, the subject needs added time for it’s resolutionan. It is clear that the spectacles would have had to be maintained in Mexico for periods of time.

To have an idea of the most important aspects of his life and the historical context we provide some relevant data in Table I.

Table I. Chronological data of Luis de Velasco.

Chronology based on documentation from the Archivo de Indias, Sevilla (Spain)	
1532	Luis de Velasco (Son) Born in Carrión de los Condes (Palencia, Castile, Spain).
1550	(he was 18 years old) Leaves Spain for Mexico.
1550 - 1585	in Mexico (he resided in the New World for 35 continuous years).
1585 - 1590	Resided in Spain and Italy (largely serving as Ambassador to Florence).
1590 - 1595	Returns to Mexico. His first period as Viceroy of New Spain.
1595 - 1602	Peru (Lima), served as Viceroy of Peru.
1602 - 1607	Peru? Mexico? No data.
1607 - 1611	Mexico, Second Period as Viceroy of New Spain.
1611	Leaves Mexico for Spain.
1611 - 1617	Served in Spain as President of the Council of the Indias.
1617	Died in Seville, Spain (age ca 85).
Other relevant data	
1534	Bishop Juan de Zumarraga established the first New World printing press in Mexico City. The press was transported from Seville.
1553	The University of Mexico was founded. (In Spain: University of Salamanca, Pérez de Oliva, Chair of Light and Magnetism).
1577	F. Alonso de Veracruz founded Saint Paul College, (Mexico), containing an important library. Use of maps, terriestrial globes and scientific instrumentation. Author of *Physica Speculatio*.

7. SOME FINDINGS LOCATED AT THE *"GENERAL ARCHIVE OF THE INDIAS"* IN SEVILLE, SPAIN

In the visit performed by one of the authors (MLC) to the General Archive of Indias, in the city of Sevilla (Spain), there were investigations on the number of archives related to the *èpoque* of the Viceroys (father (2nd Viceroy) and son). These Archives are digitized and one can find more than 10,000 entries alluding to the time of Viceroys Luis de Velasco. Many of the entries relate to commercial activities, export-import matters, mining aids and other needs for local development of industries. In this aspect we have to admit that a more refined and detailed search is required.

The so-called section for "Maps, Charts, Engines and Samples" was dedicated to catalogues of devices for various technical purposes. We have selected those that to our appreciation are related with optical technologies:

1. Series of astronomical moon observations (Puerto Rico, 1561-1600 AD).
2. Design for a grid system and "spy glass" dated 1633 (unknown location).
3. A number of military patents, objects for sailing, and a magnifier used to inspect fabrics were also found at the Archive in our search.
4. Designs for the basement of the installation of a telescope located on the jutting rock of "*El Morro*", Port of Havana (archive entry in 1809, but plans may be older). This design is shown in Figure 7. It was probably done by pencil, since the quality of the original reproduction was very low, and an additional digital treatment of the image was applied in order to enhance the contrast. The author or authors is/are unknown.
5. There is an interesting and curious hand drawing design for a "*hydroandric machine* for wear under water" (for scuba diving activities). The design is signed by Alejandro Durand, and it was originally dated in Lima, Peru, in 1720, see Figure 8. The text indicating the points F.F. (for the eyes) reads: *"Eye spectacles made in glass for the vision of the scuba diving"*.

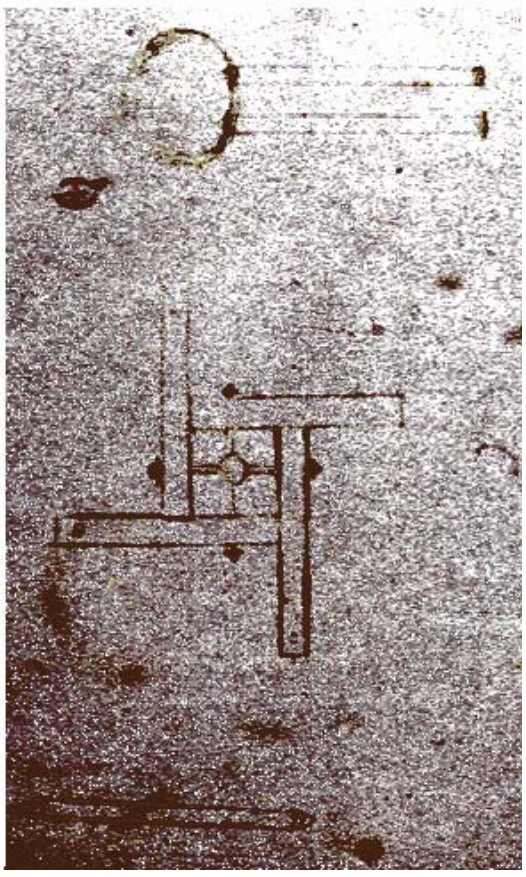


Figure 7. Design for the installation of a telescope in "El Morro", La Havana Port, Cuba.

Figure 8. A curious design for scuba diving, Lima, Peru, 1720.

8. CONCLUSIONS

From the previous results and findings several conclusions are drawn: 1. The lens technology necessary for visual corrections, and provision and maintenance of spectacles could have been available in the New World Spanish Colonies during the time of Luis de Velasco (the Son) as Viceroy. 2. The Viceroy would have had access to information regarding this technology. His spectacles could have been obtained in Spain, the Netherlands, or in Italy. 3. One has to distinguish between first spectacle use and first known use of visual corrections devices in the Americas, New Spain and in the future United States. 4. We cannot state whether any sea captains or crews of exploration vessels wore visual corrections (it would not be surprising). Other questions relating the existence of optical technologies in the Pre-Columbian civilizations also require deeper analysis. The search for connections is always a difficult task. Nevertheless, the authors are now pursuing additional studies.

ACKNOWLEDGMENTS

Partial results of this work were presented at "Optics, Life and Heritage", La Havana, Cuba, 26-30 September 2004. We thank the Spanish Ministry of Science (Grant TIC 2002-01846) and the Rectorate of the Complutense University of Madrid for financial support. The results of Appendix I were obtained with the technical and scientific assistance of Oscar Martínez Matos and José A. Rodrigo. The anthracite samples were provided to us by Ana Manzanares, from GreenLight Solutions. The assistance of the documentalists of the Archive of Indias are also acknowledged.

APPENDIX I

Optical properties of anthracite surfaces[1]

We have studied the optical properties of anthracite. It is a bituminous organic coal, a metamorphic rock, with black color. It presents a high luster. The Mohs hardness is 2.5–4.0. The refractive index values are: 1.64-1.68 (for 589 nm), there were high reflectivity properties. Pleochroism was not noted. The mirror appearance can be that of crystal or stone, and it can have massive size. As to other properties, when the surface is rubbed it can become electrically charged.

Peru has one of the World's largest minefields for charcoal. It has been exploited from the very early days of the pre-Columbian civilizations. These mines are located all along the Andes mountains with very important mine locations at Chacamarca [4] (not far from the earlier settlement of the Chavin civilization!).

We have obtained two samples of anthracite from Northern Spain charcoal mines (see Figure A1). The two blocks were cut under two different directions, namely, parallel and perpendicular to the plane of exfoliation. These planes define layers with easy mechanical cleavage. After obtaining the samples a standard polishing procedure was applied (with water and fabric on metallic surface). A laser source (a solid state laser emitting in green: 552 nm) was used to illuminate the surfaces. A CCD camera captured light reflected from the surfaces (see Figures A2a)-A2b)). The corresponding line profile of the images (obtained from a digital treatment [9]) has information on the reflectivity efficiency. Figure A2g) displays the image of the beam.

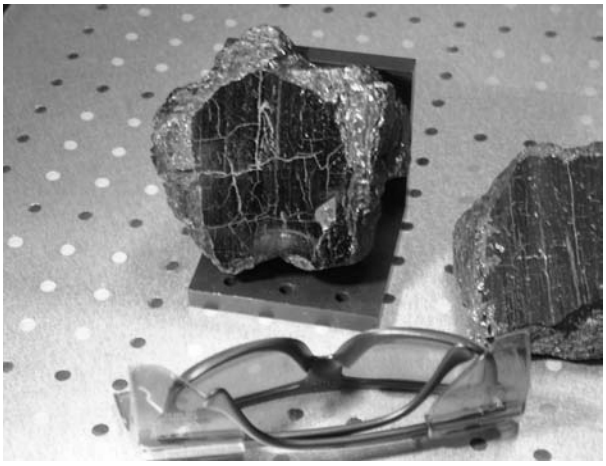


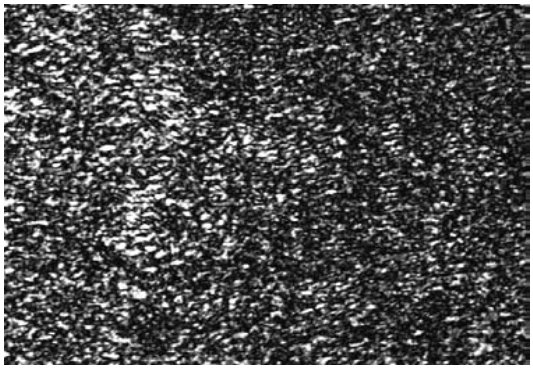
Figure A1. Two anthracite mirrors obtained in our laboratory. The right one was cut parallel to the exfoliation planes, and the left one was cut perpendicular to the same planes. See the reflections of the goggles.

Figurs A2c) - A2d) show the corresponding line profiles. In order to have a more accurate data we have applied the Fast Fourier Transform (FFT) to the images (Figures A2e) - A2f)). It gives us the two spectra associated to reflected light of the two surfaces, respectively, and in 3-D. One can state that the reflectivity depends on the form of the preparation of the sample. The cut perpendicular to the plane of exfoliation shows a higher efficiency, may be also due to the state of its partial polarization. This is due to the presence of micro layers. These are same are highly reflective as can be seen when observed directly with the naked eye. The use of

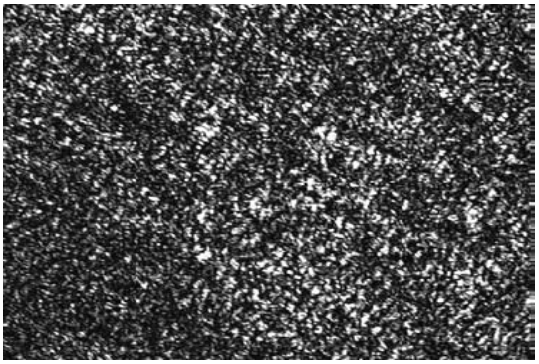
[1]The results of this Appendix have been obtained with the collaboration of Oscar Martínez Matos and José A. Rodrigo, from the Department of Optics (UCM) and Ana Manzanares, from GreenLight Solutions.

direct exfoliation planes would allow the Chavin artisans to obtain the desired reflective surfaces, and then probably a simple polish was applied. Nevertheless, when observing the reproduction of old Chavin mirrors it is not clear how best to appreciate the quality of the surfaces, and we cannot conclude if polishing techniques were applied as well.

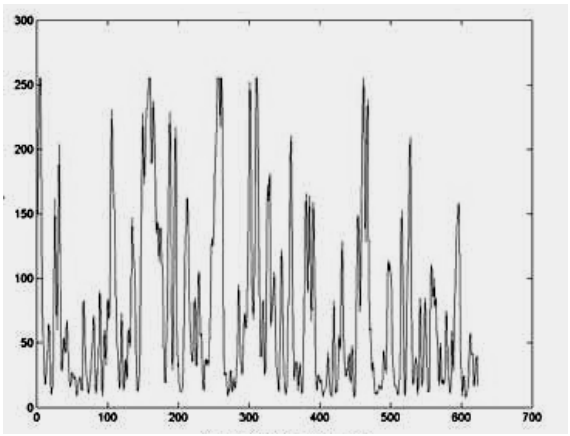
These aspects are now under current study by the authors.



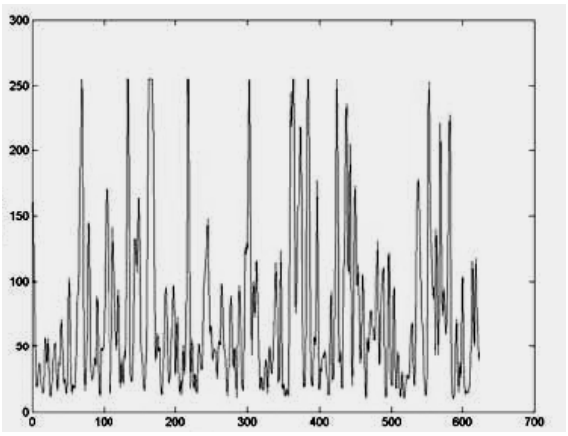
(a)



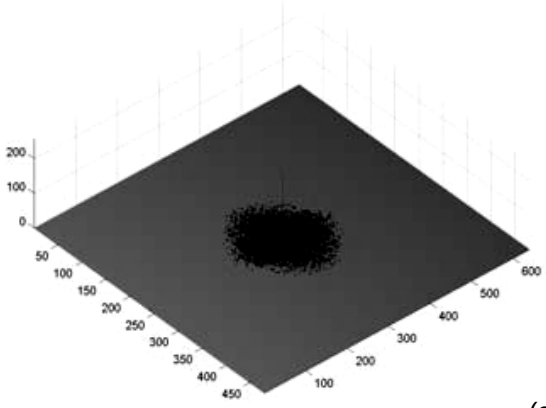
(b)



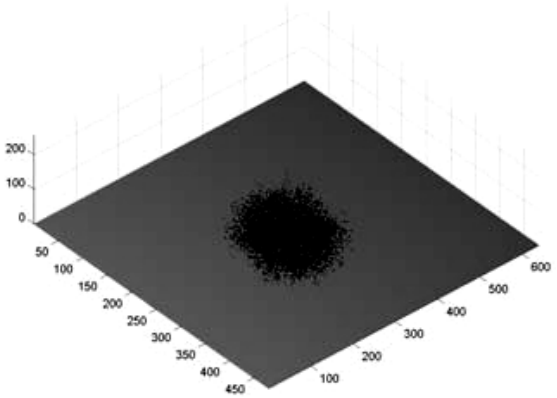
(c)



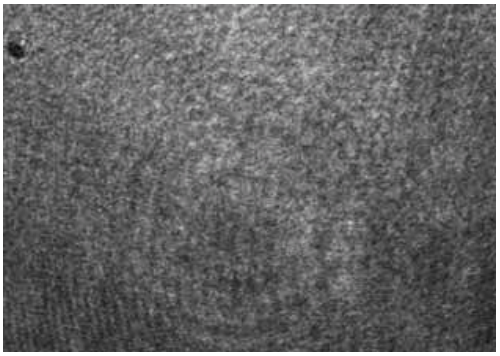
(d)



(e)



(f)



(g)

Figure A2.

a) Image of reflecting light from anthracite surface cut perpendicular to the planes of exfoliation.

b) Image of reflecting light from anthracite surface cut parallel to the planes of exfoliation.

c) and d) the respective line profiles.

e) and f) the respective Fourier spectra represented in 3-D.

g) Image of the incident beam light prior to suffer from reflection of the surfaces.

REFERENCES

1. ENOC, J.M. (2002): “Archaeological Optics”, In: **International Trends in Applied Optics***,* 5, International Commission for Optics - ICO, Ed. A.H. Guenther, SPIE Press, chapter 27.

2. _____ (2002): “Introducción a la historia de las lentes y correcciones visuales: una referencia a España y a los territorios del nuevo mundo”, in: **Óptica Avanzada** (M.L. Calvo, coord.), Chapter 1, Ed. Ariel, Barcelona (contains many references).

3. LUNAZZI, J.J. (1996): “Olmec Mirrors: an Example of archaeological American mirror”, In: **International Trends in Optics**, 3, International Commission for Optics - ICO, Ed. Anna Consortini, Ac. Press., chapter 22, p.p. 411-421, including a color picture.

4. ESPÍ, J.A. (2001): (Ed.), *El Libro de la Mineria del Oro en Iberoamérica*, CYTED-Comité Aurífero del Perú, Madrid.

5. BARREIRO, A.J. (1928): “La ciencia española en s. XVI”, en: *Reivindicación histórica del s. XVI*, Curso de conferencias en la Real Academia de Jurisprudencia y Legislación, Madrid.

6. ENOCH, J.M. y M.L. CALVO (1998): “Una evidencia del uso de lentes correctoras en la España del s. XV”, **Ref. Esp. Fis**. 12(2), 55-57.

7. CALVO, M.L. y J.M. ENOCH (2002): “Acerca del uso de lentes correctoras en las colonias españolas del nuevo mundo: una referencia al Virrey Luis de Velasco y la tecnología de su época (s.XVI)”, **Óptica Pura y Aplicada**, **33**, p.p. 1-6.

8. _____ (2003): “Early use of corrective lenses in Spanish Colonies of Americas including parts of the future United States: Reference to Viceroy Luis de Velasco (the Son)”, **Optometry and Vision Scienc**e, 80(1), (October).

9. CALVO, M.L.; T. ALIEVA; J. RODRIGO; D. RODRÍGUEZ y T. ALIEV (2004): **Laboratorio virtual de óptica***.* **Guía práctica***.* Delta Publicaciones. Madrid.