Comparative study of pre-Hispanic and colonial adobes in Mexico. Preliminary inferences on the effects of the granulometric distribution and used recycled materials in the state conservation of earth architecture

Estudio comparativo de adobes prehispánicos y coloniales en México. Inferencias preliminares sobre los efectos de la distribución granulométrica y materiales reciclados en el estado de conservación de la arquitectura de tierra

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How to cite this article:
Puy-Alquiza, M.J., Ordaz-Zubia, V.Y., Cruces-Cervantes, O., Bello-Sandoval, A., Miranda-Avilés, R., Salazar-Hernández, M.C., Carreño-Aguilera, G., Zanor, G.A., Li, Y., 2022, Comparative study of pre-Hispanic and colonial adobes in Mexico. Preliminary inferences on the effects of the granulometric distribution and used recycled materials in the state conservation of earth architecture: Boletín de la Sociedad Geológica Mexicana, 74 (3), A010422. http://dx.doi.org/10.18268/BSGM2022v74n3a010422

Manuscript received: December 7, 2021.
Corrected manuscript received: February 20, 2022.
Manuscript accepted: March 29, 2022.

Peer Reviewing under the responsibility of Universidad Nacional Autónoma de México.

ABSTRACT

The characterization of the pre-Hispanic and colonial adobes used in the construction of buildings in Mexico was carried out to know the differences between their processes and manufactures. The eight samples obtained correspond to adobe blocks 0.45 m long x 0.35 m wide and 0.12 m thick, which were part of the interiors of houses, the structure of fences, and hacienda galleys. These samples were investigated using X-ray Diffraction, X-ray Fluorescence, and Scanning Electron Microscopy techniques to determine the morphometry of the material and its chemical and mineralogical composition. Likewise, some analyzes were performed to determine their mechanical properties (simple compressive strength), physical properties (granulometry, solid density, cohesion, plasticity index, porosity, and moisture content), and biological (organic matter content). The results obtained in terms of the granulometric distribution indicate that pre-Hispanic adobe has a higher content of sand than silt-clay and gravel, while the colonial adobes present a low or null content of gravel with a higher content of silt-clays. Regarding the organic matter content, the colonial adobe presents the highest percentages compared to those of the pre-Hispanic adobes. Taking into account the above the pre-Hispanic adobes have better resistance and durability than colonial adobes due to their granulometric distribution, low organic matter content, good cohesion, high plasticity index, and the use of materials found in their natural environment, while the colonial used recycled materials, coming from the economic activity to which the hacienda was dedicated, for example, agriculture, mining, livestock, this has given rise to different manufacturing techniques and construction styles that reflect the state of conservation of buildings throughout the pre-Hispanic and colonial times. The granulometric distribution that pre-Hispanic adobe provides favorable physical and mechanical qualities for any construction technique, so it is recommended to use this formula to manufacture resistant and durable adobe.

Keywords: pre-Hispanic period, colonial period, adobes, manufacture, technical, conservation.

RESUMEN

Se realizó la caracterización de los adobes prehispánicos y coloniales utilizados en la construcción de edificaciones en México para conocer las diferencias entre sus procesos y manufacturas. Las ocho muestras obtenidas corresponden a bloques de adobe de 0.45 m de largo x 0.35 m de ancho y 0.12 m de espesor, que formaban parte de los interiores de las casas, estructura de cercos y galeras de hacienda. Estas muestras se investigaron utilizando técnicas de difracción de rayos X, fluorescencia de rayos X y microscopía electrónica de barrido, para determinar la morfometría del material y su composición química y mineralógica. Asimismo, se realizaron algunos análisis para determinar sus propiedades mecánicas (resistencia a la compresión simple), propiedades físicas (granulometría, densidad sólida, cohesión, índice de plasticidad, porosidad y contenido de humedad) y biológico (contenido de materia orgánica). Los resultados obtenidos en cuanto a la distribución granulométrica indican que el adobe prehispánico tiene un mayor contenido de arena, limo-arcillas y gravas, mientras que los adobes coloniales presentan un bajo o nulo contenido de gravas con un mayor contenido de limo-arcillas. En cuanto al contenido de materia orgánica, el adobe colonial presenta los porcentajes más altos en comparación con los de los adobes prehispánicos. Teniendo en cuenta lo anterior los adobes prehispánicos tienen mejor resistencia y durabilidad que los adobes coloniales debido a su distribución granulométrica, al bajo contenido de materia orgánica, a la buena cohesión, al alto índice de plasticidad y al uso de materiales que se encuentran en su medio natural, mientras que los adobes coloniales, su materia prima deriva de materiales reciclados, provenientes de la actividad económica a la que se dedicaba la hacienda, por ejemplo agrícola, minera, ganadera, esto ha dado lugar a diferentes técnicas de manufactura y estilos constructivos que reflejan el estado de conservación de las edificaciones a lo largo de la época prehispánica y colonial. La distribución granulométrica que presenta el adobe prehispánico brinda cualidades físicas y mecánicas favorables para cualquier técnica constructiva, por lo que se recomienda utilizar esta fórmula para fabricar adobes resistentes y duraderos.

Palabras clave: época prehispánica, época colonial, adobes, manufactura, técnica, conservación.

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1. Introduction

Throughout the history of Mexico, the soil has been used as the construction material for public buildings and foundations by pre-Hispanic cultures (Chevalier, 1963; Perez *et al.*, 2016). The Maya of Mexico and Central America developed adobe bricks before the arrival of the Spanish in the early XVI century (Punzo-Díaz, 2005; Daneels and Guerrero, 2012; Daneels, 2015; Mateu *et al.*, 2022), while the native Americans of the southwestern United States did not use adobe until the Spanish introduced it in the seventeenth century. The adobe technique used in pre-Hispanic times consisted of making a solid block of mud which was obtained by mixing clay soil, sand, gravel, and often vegetable matter. The adobe architecture was associated with alluvial soils, clay-rich soils, or sandy-clayey soils with a domain of sand composition and regular granulometry (Yuste, 2016). The addition to the mixture of vegetable matter depended on the type of soil; if it was very clayey, the plasticity increased, which is why the addition of vegetable fibers was necessary. The size of the blocks varied from region to region, so there was a wide diversity in terms of shape, composition, color, and texture (Barbeta, 2002; Guillaud *et al.*, 2008). The Olmeca, Mixteca, Zapotec, Maya, Teotihuacan, Tolteca, and Mexica-Azteca groups, to name a few, developed different construction systems; for example, the larger buildings were raised on top of solid foundations using structured fillings, adobe fillings, while the walls were built with adobes, poured mud (formwork), or blocks of moist earth (Gama-Castro *et al.*, 2012; Daneels, 2013). As for public buildings, the most used material was adobe in walls, columns, and stairways, before the arrival of the Spanish, at the beginning

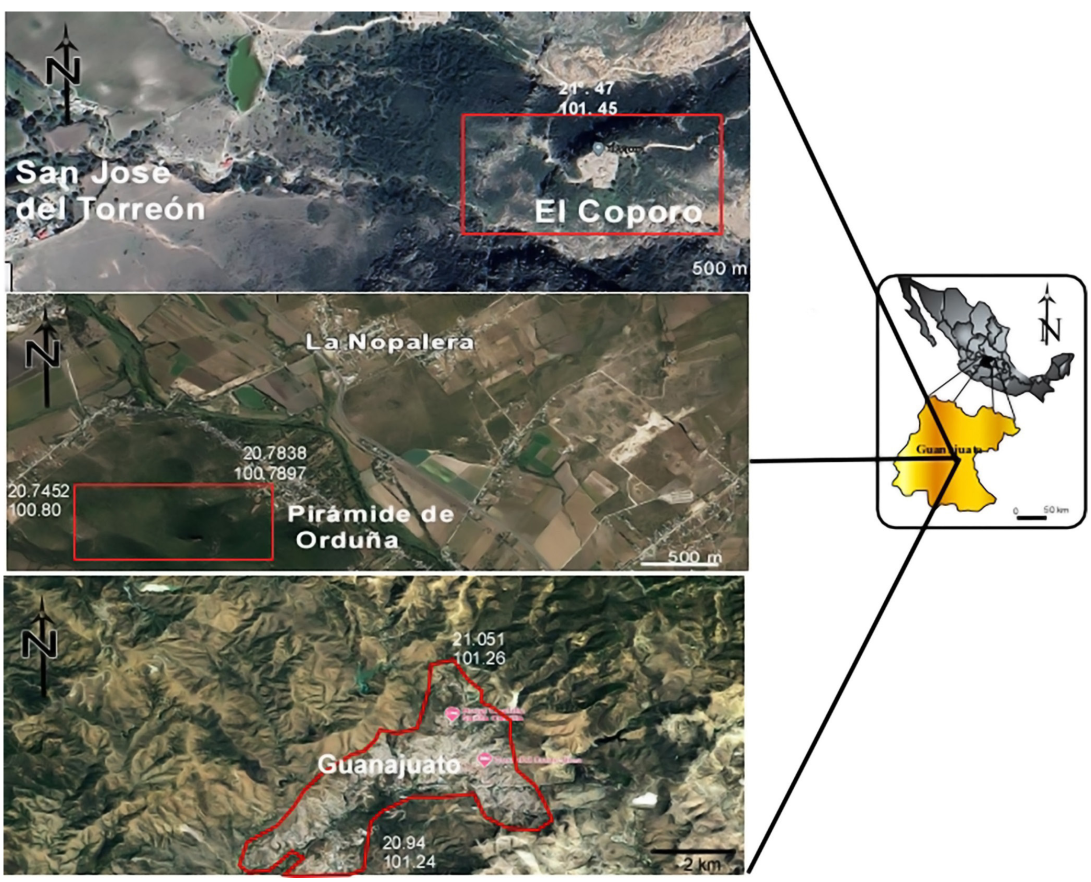

Figure 1 Location of study area.

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of the 16th century. Whereas, during the Spanish colonial period, most of the adobe buildings erected were used for domestic purposes, combining mixed technologies such as block technique (adobe) and formwork technique (Tapia). The adobe architecture was associated with sandy soils, adding vegetable matter in most cases. Most of the buildings raised corresponded to mixed technologies where stone, adobe, wood, and masonry were used for development or exploitation purposes, as is the case of the farms where agriculture, mining, and livestock were developed (Wolf and Mintz, 1957; Van Young, 1983; Jarquin, 1990; Fournier-García and Mondragón, 2003).

The construction techniques have been changing during each period modifying manufacturing processes to give rise to different architectural elements (Morner, 1973). The construction techniques and the ways of materializing architectural elements have been subject to different changes throughout history and this is largely due to the needs and possibilities of each epoch (Ledesma, 2014). Due to cultural change and the loss of indigenous traditions, much of the manufacturing knowledge was lost. Based on this, the objective of this research work was to compare the different physical, mechanical, chemical, and biological (organic matter content) properties of two periods of earthen construction (pre-Hispanic and Colonial), to understand the evolution of construction systems over time, and to be able to select adequate strategies for its conservation, contributing at the same time to the knowledge of manufacturing techniques.

2. Study area

A set of eight samples of different types of adobe construction was selected: two belonging to the pre-Hispanic and Middle Classic period and the rest from the colonial period (17th and 18th centuries). The pre-Hispanic adobes were collected in the state of Guanajuato, while the colonial adobes were

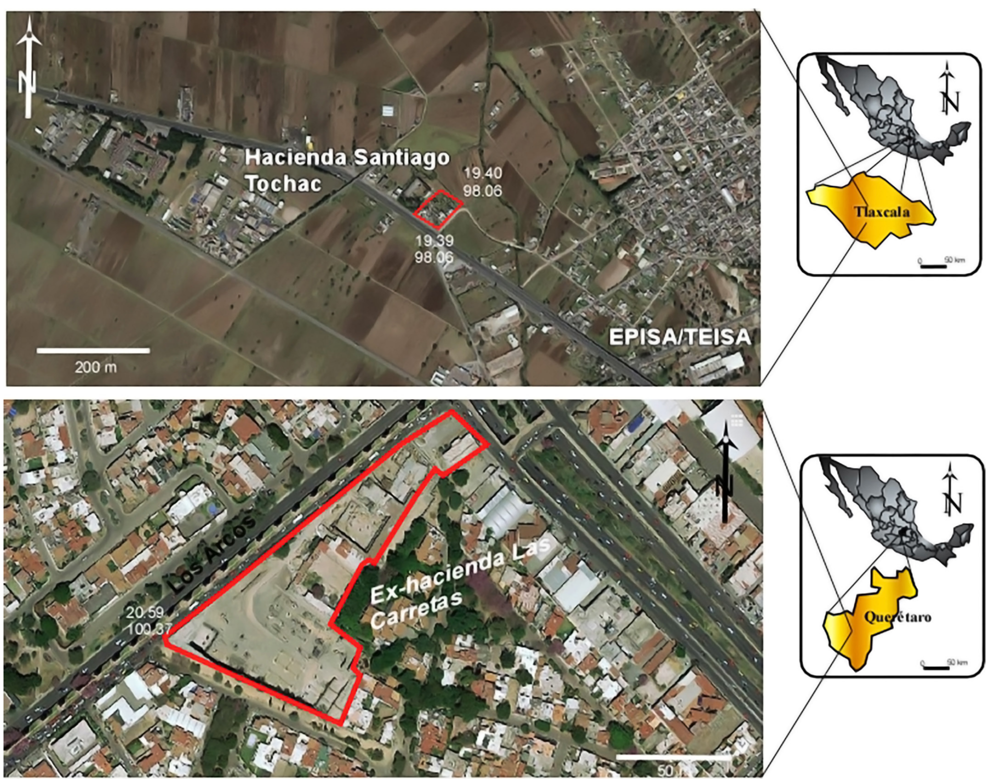

Figure 2 Location of study area.

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collected in the states of Queretaro, Tlaxcala, and Guanajuato. Based on this, two representatives to the pre-Hispanic adobe from the archaeological sites of Coporo (municipality of Ocampo), and La Nopalera (municipality Comonfort), from the Classic period in the state of Guanajuato, two adobes from an agricultural estate, coming from the Hacienda de Santiago Tochac in the state of Tlaxcala and Las Carretas in the state of Querétaro of the 17th and 18th centuries and finally four miners adobe, two of the 17th century (Durán and San Clemente) and two of the 18th century (Dolores de Barrera and El Patrocinio) of the state of Guanajuato (Figures 1, and 2). The adobe blocks studied have dimensions of 0.45 m long x 0.35 m wide x 0.12 m thick, they belong to fences, interiors of houses, and hacienda galleys.

2.1. GEOLOGICAL SETTING

The states of Queretaro, Tlaxcala, and Guanajuato are located within the Cenozoic Trans-Mexican Volcanic Belt (TMVB) and the Mesa Central provinces (Raisz, 1964). The municipalities of Comonfort and Ocampo are located in the state of Guanajuato, in the physiographic province of the Mesa Central, on its border with the province of the Trans-Mexican Volcanic Belt. In these municipalities outcrop rocks are of marine origin covered by volcanic rocks (tuff, ignimbrite), domes of rhyolitic to rhyodacitic composition, with intercalated andesite. As for the types of soils, Phaeozems type soils predominate, they are porous, dark soils rich in organic matter, they are used for agriculture. The Phaeozems are distributed in lacustrine and fluvial-alluvial plains or on volcanoclastic. and alluvial-colluvial deposits in temperate and humid zones (Garrido-Pérez *et al.*, 2006). The state of Querétaro is among the physiographic provinces of the Mesa Central, Sierra Madre Oriental, and the Trans-Mexican Volcanic Belt. The rocks that outcrop in the state are metamorphic, igneous, and sedimentary, predominantly Leptosol-type soils. These soils are characterized by a dark color since they contain a good percentage of organic matter (more than 1%), and a content of Ca, Mg, Na, and K (FAO, 1998). The state of Tlaxcala is included within the physiographic province of the Trans-Mexican Volcanic Belt, dominated by outcrops of volcanic rocks such as andesites, rhyolites, basalts, tuffs, and volcanic breccias, characterized by Cambisol-type soils, which have little clay content, organic matter, aluminum, and iron compounds. They mostly come from colluvial, alluvial, and aeolian deposits. Their use is mainly agricultural (FAO, 1998).

2.2. DESCRIPTION OF THE PRE-HISPANIC BUILDINGS (CLASSIC AND MIDDLE CLASSIC PERIODS)

2.2.1. THE ARCHAEOLOGICAL ZONE OF COPORO

The archaeological zone of Coporo is in the municipality of Ocampo, northwest of the state of Guanajuato, on the foothills of the Sierra de Santa Barbara and next to the community of San Jose del Torreon. The predominant type of climate is temperate semi-dry, with maximum temperatures of up to 40°C, with minimum temperatures of 8°C. The average annual temperature is 17 °C. The rainfall is 433 millimeters on average per year. Coporo is a ceremonial center with housing units. Its architecture is mixed of earth and stone, highlighting the stone and adobe walls, the latter being the most abundant. Its extension is great, conserving hundreds of houses with the religious civic part at the base of the hill and the religious part at the top of the hill. The occupation in this archeological zone was during the classic Mesoamerican period (400 to 600 dc). It is an ancient city made up of three neighborhoods: Coporo neighborhood (at the top of the hill), Gotas neighborhood (lower part of the northwest slope), and Montes neighborhood (lower and southwest part of the hill). The Coporo can be considered as a civic and ceremonial site. The lower part was occupied by individuals associated with administrative activities as indicated by the different housing units, while the Coporo neighborhood located on the top/summit of the hill can be a ceremonial space due to its proximity to divine beings (Castañeda-Lopez *et al.*, 2007). Remains of ancient housing units are located between the northwest slope and the valley, from which adobe samples were

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obtained. The adobe samples correspond to the floors of the houses. Structural pathologies such as minor cracks and loss of material are observed. The adobes are exposed to the environment since their excavation in 2006, have an orange-brown color, are rectangular, and do not have any type of coating. Lichens grew on the adobe bricks, presenting orange and grayish colorations on the surface, in the same way, black scabs are observed. No mineralogical alterations nor internal degradation conditions due to bioturbation are observed.

2.2.2. THE ARCHAEOLOGICAL ZONE LA NOPALERA

La Nopalera archaeological site is located at the foot of the Orduña hill in the municipality of Comonfort Guanajuato, near the community of La Nopalera. The climate is temperate, with a maximum temperature of 38.0ºC and a minimum of 10ºC. The average annual precipitation is 776.8 mm. The first data of population settlements in that area, according to data from Kirchhoff (1946, 1960), establish the presence of humans in the valleys of the Lerma, Laja, Turbio, and Guanajuato rivers, since times as remote as 350 years before Christ. A study by Howell (2002), proposes that there was a gradual depopulation between the years 900 and 1150, possibly due to two reasons environmental problems, which led to food shortages since other tribal groups attacked the settlements and stole their belongings. It is difficult to specify when the first Pames tribes arrived in this region, what is already known is that they have already found a territory populated by primitive agricultural, gatherer, and hunter tribes, a region rich in natural resources and a climate pleasant enough to live. The Nopalera archaeological site corresponds to small sites with a marked presence of mounds as main elements, there are references to burials in flat areas. It is represented by stone walls, earth fills, and adobe foundations. The adobe sample corresponds to the walls of a basement. They have a brown color. Structural

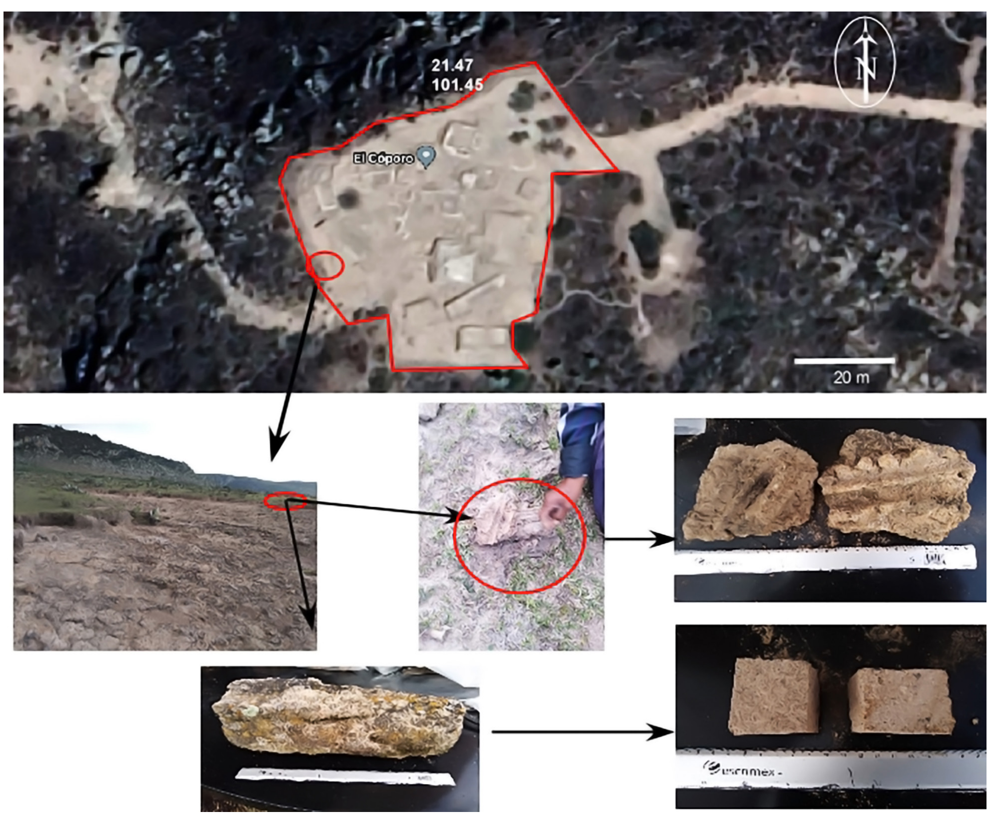

Figure 3 Description of the pre-Hispanic buildings (Classical and medium classical period). The archaeological zone of Coporo.

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pathologies such as vertical cracks, inclined walls, minor cracks, detachment, or loss of material are not observed. The adobe block is exposed to environmental factors since 2019, covered with vegetation roots being observed on the surface. No mineralogical alterations or internal conditions of degradation due to bioturbation are observed.

2.3. DESCRIPTION OF THE COLONIAL PERIOD: AGRICULTURAL HACIENDA (17TH AND 18TH CENTURIES)

2.3.1. SANTIAGO TOCHAC HACIENDA

The Santiago Tochac hacienda located in the municipality of Xaloztoc, Tlaxcala, was founded in December 1533 and it is unknown who its first owners were. The climate is temperate sub-humid. the maximum temperature is 25.1°C, the minimum being 4.0°C. The average annual precipitation is 758.5 mm. The peasants dedicated themselves to working the lands that belonged to the town, which initially formed a whole; then they were divided into three parts called Santiago Tochac, San José Piedras Negras, and the Concepción Zacazontetla. In later years, due to abuses, the lands came into the power of the caciques without income, donations, or any form of legal alienation, and the peasants, therefore, became part of their labor force, in the cultivation of wheat and maguey, to extract pulque. In January 1869, the Santiago Tochac hacienda, located in the Huamantla was put up for sale, the property was put in the auction and announced to the public so that people who wanted to make a posture would attend the Fifth court Civil to receive instructions (Santibañez-Tijerina, 2010). The adobe block was obtained from the wall of the main house corresponding to the room, built-in 1800. The color of the adobe is dark brown. The wall is covered with lime mortar. It is not exposed to environmental factors or humidity. Structural pathologies such as minor cracks or loss of material are not observed.

2.3.2. CARRETAS HACIENDA

The Carretas hacienda corresponds to the historic center of the city of Queretaro, located next to

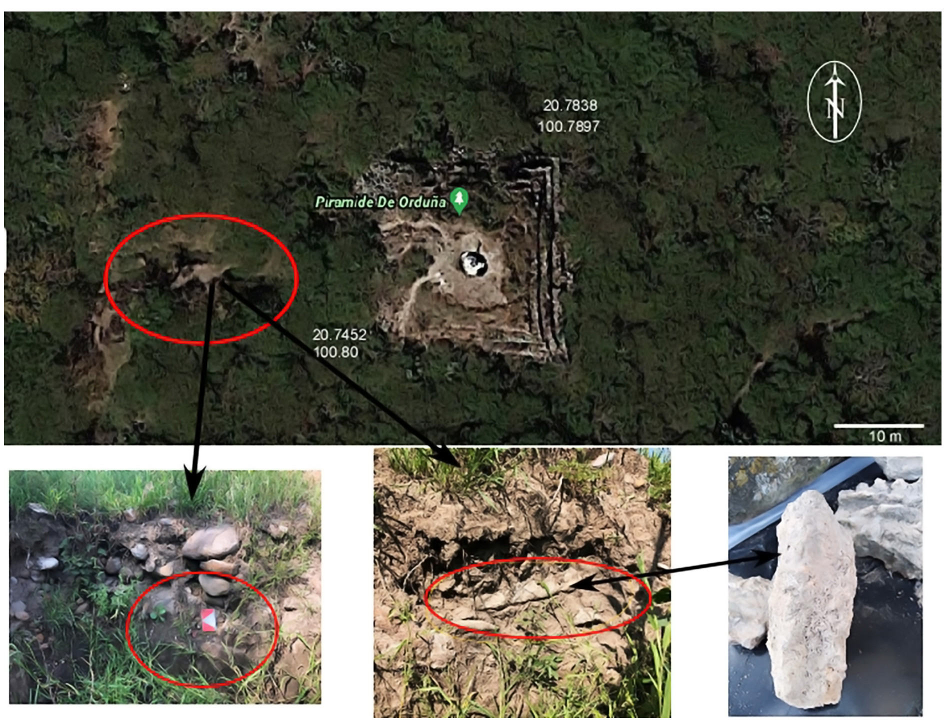

Figure 4 Description of the pre-Hispanic buildings (Classical and medium classical period). The archaeological zone La Nopalera.

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Los Arcos. The climate is dry to semi-dry. The maximum temperature is 35°C and the minimum 5°C. The average annual precipitation is 600 to 700 mm. By 1531 the place where the Carretas hacienda exists today was a lagoon. Before the property was considered as Heritage, it functioned as intermediate whereabouts established by Blessed Sebastian de Aparicio in the year 1547, for his oxcart carts in which he transported the silver of Zacatecas minerals to be melted and minted in Mexico. Later in the year 1562, Don Diego de Saldívar built accommodation for travelers with dumps, pens, and everything necessary to service the carts. Later in that place and with nearby lands the "Hacienda de Carretas" was founded. The Carretas hacienda estate is in front of the Arches, at a height with Avenida Bernardo Quintana. Approximately by the years 1588 and 1604 the owner of carts (García Urbano) was dedicated to moving large volumes of wool, from Querétaro to the cities of Mexico and Texcoco. This indicates that the Carretas hacienda was dedicated to cattle-raising the raising of sheep, sheep, rams, mares, donkeys, and cows, among others (Garcia-Ugarte, 2015). The adobe block was obtained from the main facade of the house, built in 1860. The color of the adobe is dark brown. The wall is covered with lime mortar. It is not exposed to environmental factors or humidity. Structural pathologies such as minor cracks or loss of material are not observed.

2.4. DESCRIPTION OF THE COLONIAL PERIOD: MINER´S HACIENDA (17TH AND 18TH CENTURIES)

The miner's haciendas are localized in the center and south of the city of Guanajuato. The climate of the city of Guanajuato is dry to semi-dry. The maximum temperature is 30°C, and the minimum is 5.2°C. The average annual precipitation is 650 mm. The discovery in the sixteenth century of the silver vein in the Mineral de la Luz initiates the exploitation of the mineral wealth in the Mining District of Guanajuato (Antúnez, 1964). This discovery led to the formation of haciendas built for the sole purpose of mining, smelting, or amal-

Figure 5 Description of the Colonial period: agricultural hacienda (seventeenth and eighteenth century). Santiago Tochac hacienda.

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gamation of silver. These haciendas were in fact the first buildings in various parts of New Spain. In Guanajuato, the morphology of the settlement was determined by the route that followed both the main river and other currents that in times of rain became important. The haciendas then emerged in the sixteenth century, promoting the development of local mining by means of silver amalgamation. The haciendas in their beginnings occupied what nowadays is the center of the city; by the eighteenth century, they had moved them outside of the city being located on the banks of the main river. The Bourbon reforms (1765-1808) caused the proliferation of haciendas throughout the mining district of Guanajuato, concentrating mainly in an industrial corridor that began towards the north of the city and continuing towards the east with the hacienda of Duran, Dolores de Barrera, El Patrocinio, and San Clemente (Puy-Alquiza *et al.*, 2019). The adobe blocks were obtained from fences, workmen's galleys, and hacienda facades. The color of the adobe is gray. The adobe blocks were covered with lime mortar. There was no moisture or degradation in the material. The adobe blocks were covered with lime mortar.

3. Methodology

To carry out this investigation, the following activities were carried out: physics characterization, physics, (granulometry, cohesion, solid density, porosity, moisture content, plasticity index); biological characterization (organic matter content,), and mechanical characterization (resistance to simple compression) of the sampled materials. Subsequently, the chemical characterization and morphological analysis were carried out using the techniques of X-ray Diffraction (XRD), X-ray

Figure 6 Description of the Colonial period: agricultural hacienda (seventeenth and eighteenth century). Carretas hacienda.

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Fluorescence (XRF), and Scanning Electron Microscopy (SEM-EDS). Macroscopically, the degree of conservation of the adobes was determined highlighting structural pathologies such as vertical cracks, inclined walls, minor fissures, detachment or loss of material, and alteration of the form.

4. Laboratory tests

4.1. MECHANICAL AND PHYSICAL CHARACTERIZATION

4.1.1. PHYSICAL TEST

The physical tests consisted of determining the granulometry, cohesion, solid density, porosity, moisture content and plasticity index. The granulometry consisted in the determination of the distribution of the size of the particles applying the sieving method. Sieve analysis was carried out according to ASTM D2487-11. The samples were classified considering the Unified Soil Classification System (USCS). Another of the parameters studied was the cohesion tests where it was applied the European Standard Norm UNE-EN 13880-10:2004. Solid density test was carried out, applying the ISO 17828:2015. Porosity test was carried out on eight specimens, applying the European Standard Norm UNE-EN 1936:2006. Total porosity was calculated using the relationship between the volume of the pores (open and closed) and the apparent volume of the specimen (Equation 1).

$$p = (1 - pb / pr) \times 100 \qquad \text{(Equation 1)}$$

Where (pb) is apparent density and (pr) real density. To determine the moisture content, a piece of adobe was cut and weighed. Subsequently, the cut piece was placed into the oven at a constant temperature of 105 ± 5°C for 24 hours. After

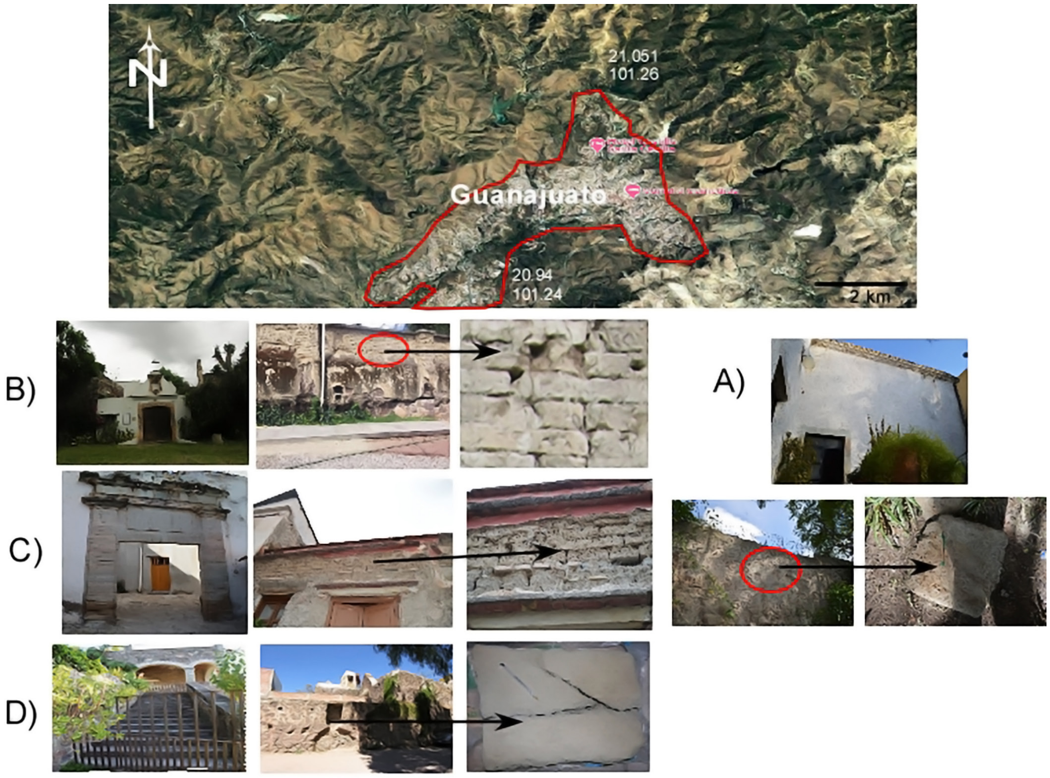

Figure 7 Description of the Colonial period: miner's hacienda (seventeenth and eighteenth century). a) Duran Hacienda; b) Dolores de Barrera Hacienda; c) El Parocinio Hacienda; d) San Clemente Hacienda.

this time, the sample was removed from the oven, allowed to cool, and weighed. The moisture content was calculated considering the relative weight change between the initial weight and the dry weight of the sample. The plasticity index test was carried out on eight species, applying the Atterberg method. This method determines the humidity range in which a clay mass is moldable, defining a plasticity index, IP, as the difference of humidity between the liquid limit, LL, or humidity above of which a mass does not have enough consistency to be moldable, and the plastic limit, LP, or minimum percentage of water to make a dough moldable.

4.2. TOTAL ORGANIC MATTER

The total organic matter content was carried out applying the Mexican Standard Norm NMX-AA-21-1985, which makes a relationship between the volume of potassium dichromate, the ferrous sulfate, and the sample weight (Equation 2).

Organic matter (%) = (V_1. N_1- VNF) K /P (Equation 2)

Where V_1 = Volume of potassium dichromate solution used in the sample cm^3. N_1 = Normality of the solution of potassium dichromate. V = volume of ferrous sulfate solution used in the titration of the sample in cm^3. N = Normality of the solution of ferrous sulfate. P = weight of sample. K= 0.003.

4.3. MECHANICAL TEST

Simple compressive strength (UCS) tests were carried out on eight specimens, applying the European Standard Norm UNE-EN1926:2006. The cubic samples (8 cm x 8 cm x 8 cm) were parallelly and perpendicularly cut to the sediment bedding in order to obtain information about mechanical isotropy. The testing device (Universal Press Forney apparatus) allowed a maximum axial load of 1471 kN. The axial load was increased continuously at a rate within the limits of rupture (1367 kN). Load and strain were continuously registered; sampling time interval was between 2 and 6 min.

4.4. CHEMICAL CHARACTERIZATION AND MORPHOLOGY ANALYSIS

The samples studied were analyzed using XRD model Rigaku, ULTIMA IV diffractometer at mineral research and characterization laboratory (LICAMM), laboratory of the Guanajuato University, with CuKα radiation. A first fraction of eight powder samples of 0.0625 mm was obtained by sieving, which allowed the partial removal of the quartz. Subsequently, a fine fraction of 0.044 mm (Wentworth-Udden particle scale) was obtained, as described above. Both fractions were investigated by X-ray diffraction between 3° and 90° 2θ, with a step width of 0.02 and 2 s data collection per step. To determine the composition chemical, the samples studied were analyzed using X-ray fluorescence (XRF) Spectrometer Rigaku NEX CG, using energy dispersion (EDXRF). The spectrometer has a Pd anode X-ray tube, maximum power of 50W with maximum voltage of 50KV-2mA, and in He atmosphere. The samples studied were ground using an agate mortar and then passed through a 230-mesh screen to have a homogeneous particle size. The morphological aspects of the adobe bricks were investigated by SEM observation without any metal coating. The SEM instrument (JEOL, JSM- 6010 PLUS/LA) was operated at 15 kV in a low vacuum, while the energy dispersion scanner spectrometer (EDS), attached to the SEM, was used for semi-quantitative chemical analysis. The SEM-EDS analyses were carried out in the laboratory LICAMM of the Guanajuato University.

5. Results

5.1. PHYSICAL CHARACTERIZATION OF PRE-HISPANIC AND COLONIAL ADOBES

The granulometry (grain size) is an essential aspect to be considered when characterizing adobe since it provides insight into the type of raw material originally used to make the adobes. The pre-Hispanic produced adobe contains 9 to 13 wt% gravel-size grains, 21 to 73 wt% sand-size grains, and 16 to 65wt% silt-clay size grains. For the adobes agricultural hacienda there are no gravel-size grains (0 wt%), but 18 to 40 wt% sand-size grains and 59 to 81wt% silt-clay size grains. While the miner's adobe contains 0.20 to 2 wt% gravel-size grains, 5 to 17 wt% sand-size grains, and 81 to 94 wt% silt-clay size grains. Table 1 shows the size distribution of the particles that make up the adobe's matrix studied. According to the USCS, the adobes studied correspond to the three types of soil: Pre-Hispanic adobe (SM: poorly graded, sands and gravelly sands, little or no fines, and ML: Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity); agricultural adobe (ML: Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity), and miner adobe (CL: Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays), (Table 1).

The cohesion soils according to Mitchell and Soga (2005), are fine-grained, low-strength, and easily deformable soils that have a tendency for particles to adhere. The soil is classified as cohesive if the number of fines (silt and clay-sized material) exceeds 50% by weight. Considering the above, the pre-Hispanic adobe El Coporo presents a better cohesion followed by La Nopalera, later the agricultural adobe Las Carretas, Santiago Tochac, and finally the adobe miners (Table 2).

Regarding the density and porosity data of the solids, these are shown in Table 2. The pre-Hispanic adobe samples showed similar density and porosity values in terms of bulk density, the range of values shown by the bricks studied is 2.2 g/cm^3 to 2.7 g/cm^3. Porosity is an important parameter due to its influence on properties, such as chemical reactivity, mechanical strength, durability, and the overall quality of the brick. The porosity of the pre-Hispanic adobe bricks studied varies from 31% to 40%. The same is not the case with agricultural adobes where the solid density varies from 2.6 g/cm^3 to 2.8 g/cm^3 and the porosity is 47% to 48%. The miner's adobe has a density that varies from 2.5 g/cm^3 to 2.7 g/cm^3 and the porosity varies from 49% to 62%. The moisture and organic matter content are shown in Table 2. Of all the adobes studied the moisture content varies (0.97% to 10.61%) as well as the organic matter content (0% to 8.90%). Considering the plasticity index, the Coporo pre-Hispanic adobe presents higher plasticity index (34.42) than that of La Nopalera (11.33), while the Carretas agricultural adobe shows the highest plasticity index (39.38) with respect to the adobe of Santiago Tochac (5.51). The mining adobes show a plasticity index that varies from 12.66 to 17.23, (Table 2).

5.2. TOTAL ORGANIC MATTER CONTAINED IN ADOBES

The highest percentage of organic matter is presented in agricultural and miners adobes, which vary from 4.09% to 8.90%, (Table 2).

5.3. MECHANICAL CHARACTERIZATION OF ADOBES

The results of the mechanical tests are given in Table 2. These tests were conducted on specimens using perpendicular orientations. The results showed that the eight bricks samples exhibited different behavior. Pre-Hispanic adobes: Coporo (66.05kg/cm^2) and La Nopalera (4.73kg/cm^2). Agricultural adobes: Santiago Tochac (3.28kg/cm^2) and Carretas (6.09 kg/cm^2). Miners adobes: Dolores de Barrera (1.18 kg/cm^2), El Patrocinio (1.1 kg/cm^2), Duran (5.48 kg/cm^2) and San Clemente (7.11 kg/cm^2). Where the pre-Hispanic adobe the Coporo presents greater resistance to uniaxial compression.

5.4. MINERALOGICAL AND CHEMICAL CHARACTERIZATION

The analyzed samples contain different types of crystalline minerals (Table 3). Pre-Hispanic adobes present the following mineral phases which have been grouped into silicates (quartz, albite, anorthite, sanidine, microcline, lazurite), phyllosilicates

Table 1. Granulometry of adobe bricks samples.

			Granulometry			
Adobe bricks samples			Gravel (wt%)	Sand (wt%)	Silt-Clay (wt%)	Classification (USCS)
Pre-Hispanic	CLASSICAL PERIOD	Coporo	9.54	73.76	16.70	SM: poorly graded, sands and gravelly sands, little or no fines
	MIDDLE CLASSIC PERIOD	La Nopalera	13.33	21.49	65.19	ML: Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
Agricultural	XVII century	Santiago Tochac	0.00	40.33	59.67	ML: Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
	XVIII century	Carretas	0.00	18.21	81.79	ML: Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
Miners	XVIII Century	Dolores de Barrera	1.41	12.02	86.56	CL: Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		El Patrocinio	0.20	5.73	94.07	Cl: Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
	XVII century	Durán	0.25	17.87	81.87	Cl: Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		San Clemente	2.05	10.01	87.94	CL: Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.

(halloysite and montmorillonite), zeolites (gismondine), and secondary minerals (calcite). Agricultural adobes present silicates (quartz, albite, anorthite, obertiite, kyanite, magnesium-hornblende, cristobalite), phyllosilicates (montmorillonite), and zeolites (epistilbite). Miner's adobes present silicates (quartz, anorthite, albite), phyllosilicates (montmorillonite, vermiculite, volkonskoite), chlorite group (clinochlore- chromian), mercury sulfate (schuetteite), sulfides (fizelyite, zinkenite), phosphates (brushite), zeolites (erionite, faujasite), and sulfates (parnauite, gypsum).

The pre-Hispanic adobes as well as the Colonial agricultural ones present high concentrations of Si, Al, Na, K, Ba, Ca, and Fe, observing absence in elements such as P, As, Se, Sb, Hg, and Ag. While mining adobes show high concentrations in Pb, As, Se, Ag, Sb, and Hg, (Table 4). As for the oxides present in pre-Hispanic and agricultural adobes, we can mention that SiO_2, Al_2O_3, Na_2O, K_2O, Fe_2O_3, and CaO present high concentrations in percentages, unlike P_20_5, which is common in mining adobes apart from those already mentioned (Table 5).

5.5. SEM-EDS ANALYSIS

In pre-Hispanic, agricultural, and miners' adobes, the SEM examination revealed silicon/aluminum (Si/Al)-rich particles (silicates), clay minerals (phyllosilicates), and zeolites in all adobe bricks. Phosphates, mercury sulfates, and sulfides are only observed in mining adobes. The presences of spores, dry grass, and vegetal fibers are common in agricultural, and mining adobes. As for the metals, it can be observed that most of the adobes of the miner's haciendas studied have Fe, Cu, As, Hg, Pb, Sn, Zn, S, and Se (Figure 8).

6. Discussion

6.1. PHYSICAL, MECHANICAL, AND ORGANIC MATTER CONTENT CHARACTERIZATION OF PRE-HISPANIC AND COLONIAL ADOBES

Adobe bricks are one of the oldest and most commonly used materials in construction. The use of

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Table 2. Simple compressive Strength, Cohesion, Solid density, Porosity Moisture content, Plastic index, and Organic material content of adobe bricks samples.

Adobe bricks samples			Mechanical Properties	Physical Properties						Samples
			Simple compressive Strength (Kg/cm^2)	Cohesion (kg/cm^2)	Solid Density g/cm^3	Porosity (%)	Moisture content (%)	Plasticity index	Organic material content (%)	
Pre-Hispanic	CLASSICAL PERIOD	Coporo	66.05	33.02	2.7	40	1.73	34.42	0.00	
	MIDDLE CLASSIC PERIOD	La Nopalera	4.73	2.37	2.2	31	10.61	11.33	2.18	
Agricultural	XVII century	Santiago Tochac	3.28	1.38	2.6	47	1.59	5.51	4.09	
	XVIII century	Carretas	6.09	2.19	2.8	48	4.55	39.38	8.90	
Miner	XVIII century	Dolores de Barrera	1.18	0.60	2.5	60	1.73	15.01	7.26	
		El Patrocinio	1.1	0.55	2.6	62	0.97	12.66	2.27	
	XVII century	Durán	5.48	0.75	2.5	49	1.9	17.23	5.21	
		San Clemente	7.11	0.65	2.7	54	2.18	14.86	7.18	

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Table 3. Mineralogical phases (XRD) of adobe samples.

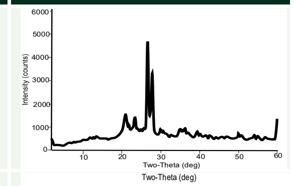
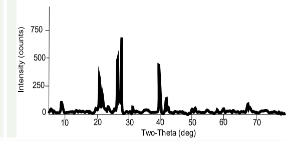
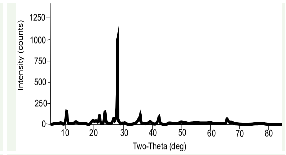
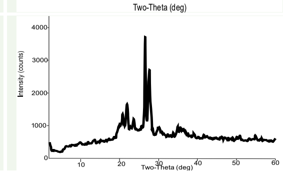
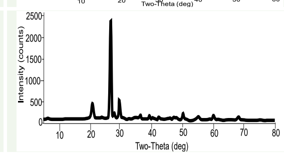
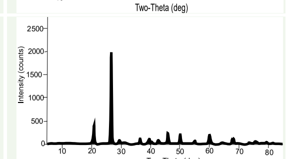
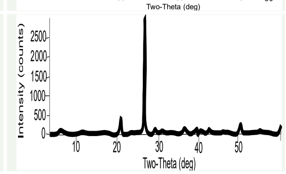
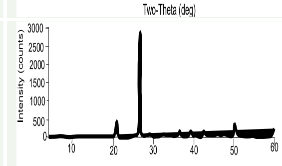
Adobe samples			Tectosilicates	Phyllosilicates	Aluminosilicates	Inosilicates	Carbonates	Chlorite	Sulfates	Sulfides	Phosphates	XRD-DIFFRACTOGRAM
Pre-Hispanic	CLASSICAL PERIOD	Coporo	Quartz Albite	Halloysite Montmorillonite	Anorthite	----	----	----	----	----	----	
	MIDDLE CLASSIC PERIOD	La Nopalera	Quartz Sanidine Gismondine Lazurite	Montmorillonite	Microcline	----	Calcite	----	----	----	----	
Agricultural	XVII century	Santiago Tochac	Albite Kyanite Cristobalite	----	Anorthite	Obertiite Magnesio-hornblend-, ferroan	----	----	----	----	----	
	XVIII century	Carretas	Quartz Cristobalite Epistilbite	Montmorillonite	Anorthite Epistilbite	----	----	----	----	----	----	
Miner	XVIII century	Dolores de Barrera	Quartz Albite	Volkonskoite Montmorillonite Vermiculite	Anorthite	----	Calcite	Clinochlore chromian	Parnauite -	----	----	
		El Patrocinio	Quartz Albite Sanidine-	----	Anorthite	----	Calcite	----	----	----	----	
	XVII century	Durán	Quartz, Faujasite-K, Faujasite-Na, Erionite-K	Dickite	----	----	----	----	Gypsum Schuetteite	Fizelyite	Brushite	
		San Clemente	Quartz Faujasite-Na	----	----	----	Calcite	----	Gypsum Schuetteite	Zinkenite	----	

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Table 4. Chemical compositions (FRX) of adobe samples.

CHEMICAL ELEMENTS (ppm)	PRE-HISPANIC ADOBES		AGRICULTURAL ADOBES		MINER´S ADOBES			
	Classical period	Middle Classic period	XVII century	XVIII century	XVIII century	XVIII century	XVII century	XVII century
	COPORO	LA NOPALERA	HACIENDA SANTIAGO TOCHAC	CARRETAS	DOLORES DE BARRERA	EL PATROCINIO	DURAN	SAN CLEMENTE
Si	294000	224000	265000	24400	215000	267000	251000	231000
Al	80400	67400	72400	71500	34600	23700	22200	59400
Ba	109	548	353	531	170	178	128	206
Na	6820	3390	15700	7020	----	9880	----	8180
P	----	----	----	----	1200	----	162	----
Mg	----	5380	3760	4260	12500	8800	12600	5220
S	149	469	436	715	6690	10300	10600	528
Cl	69.4	80.7	245	268	2570	296	1450	216
K	24900	17400	9660	16900	18500	13100	13200	16400
Ca	3840	19900	19100	16100	36700	33400	33300	15100
Mn	517	592	829	599	1120	1030	1180	352
Cr	16.2	33.5	67.6	40.7	36.8	17	25.5	34.2
Fe	17000	25700	28500	25000	21000	16300	13600	20500
Ni	----	16.6	33.7	12.7	19.6	12.4	----	----
Cu	11.5	15.4	21.4	17.2	1190	2420	1450	32
Zn	68.7	71.3	63.9	58.4	317	714	635	82.6
As	----	----	----	----	36.3	28	47.6	4.19
Sn	17.9	22.7	17.4	16.3	----	18.1	----	7.12
Pb	21.9	19.4	25.7	13.3	231	557	406	25.9
Sr	36.5	147	317	210	71	47.1	34.2	186
Se	----	----	----	----	35.1	65.8	34	----
Ag	----	----	----	----	56.2	98.6	90.4	----
Sb	----	----	----	----	23.8	52.5	22.8	----
Hg	----	----	----	----	819	1460	1000	17
Ti	2060	3350	3550	4210	1660	899	----	4200
V	31.4	82.4	96.1	66.9	74.1	42.5	----	65.2

adobe is very common in Latin America, Africa, the Indian subcontinent and other parts of Asia, the Middle East, and Southern Europe (Sharma *et al.*, 2015; Rincon *et al.*, 2019; Vega *et al.*, 2011; Costa *et al.*, 2021; Mauricio *et al.*, 2021). The results of this study indicate that pre-Hispanic adobe has a better granulometric distribution than colonial adobes since it contains low gravel-sand content, and high clay-silt content, which makes it more resistant to the passage of time. The percentage of clay-silt and its plasticity index indicate that the manufacture of the adobe could be exposed to the environment (Morales, 2007). The lack of addition of vegetable matter indicates that the material and manufacturing technique of pre-Hispanic adobe provided solid physical and mechanical qualities. According to Jiménez Delgado and Caña Guerrero (2007), a good adobe soil must have a very low percentage of gravel-sand and a high content of silt-clay. With this relationship, the adobe does not need to be stabilized with any binder or element such as gravel, sand, or vegetable matter due to its natural cohesion. Taking into account the climatic conditions of the place, the pre-Hispanic areas studied have a temperate to semi-dry climate, which favors the resistance to erosion of the earthen walls since they have been protected by remaining buried under a collapse layer for a long time. The pre-Hispanic adobes have different mechanical properties in terms of resistance, this is due to the different manufacturing techniques used, derived from the different periods of occupation in said archaeological zones (Liberotti and Daneels, 2012). On the other hand, the agricultural adobe of the 17^{th} and 18^{th} centuries buildings in Guanajuato city present physical, mechanical, and organic

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Table 5. Oxides compositions (FRX) of adobe samples.

OXIDES (%)	PRE-HISPANIC ADOBES		AGRICULTURAL ADOBES		MINER´S ADOBES			
	Classical period	Middle Classic period	XVII century	XVIII century	XVIII century	XVIII century	XVII century	XVII century
	COPORO	LA NOPALERA	SANTIAGO TOCHAC	CARRETAS	DOLORES DE BARRERA	EL PATROCINIO	DURAN	SAN CLEMENTE
SiO^2	72.3	67.9	69.6	68.7	71.7	78	77.1	70
Al_2O_3	15.4	14.4	13	16	9.85	7.21	5.78	6.29
MnO	0.0655	0.0797	0.105	0.0799	0.166	0.159	0.273	0.369
Na_2O	5.04	4.83	6.97	3.77	----	----	----	3.45
MgO	----	1.98	0.923	1.56	3.1	2.15	3.04	3.19
K_2O	3.65	2.52	1.28	2.35	2.77	1.98	1.88	1.99
CaO	0.576	3.36	2.96	2.61	6.35	4.78	5.6	3.51
P_2O_5	0.0664	0.0325	0.128	0.0872	0.417	0.144	0.133	0.082
SO_3	0.0365	0.0601	0.102	0.145	2.35	2.53	3.43	3.74
Fe_2O_3	2.52	4.07	4.29	3.86	3.55	2.85	2.6	3.38
TiO_2	0.385	0.73	0.687	0.873	0.342	0.186	0.206	0.2

material content properties similar, indicating that manufacturing techniques did not change much between the 17th and 18th centuries. The analysis of particle size indicates that sizes, silt, and clay are the predominant component in the matrix of the adobes studied, the percentages of silt-clay are high, exceeding 59.67%, sand (40.33%), and have no gravel. Have a higher content of vegetable matter compared to pre-Hispanic adobes (Tables 1 and 2). The addition of vegetable matter in this type of adobes was to achieve the stabilization of the adobe and increase its resistance (Sharma *et al.*, 2015) since based on the data obtained, agricultural adobes have very slight plasticity, low cohesion, and low resistance to compression. They are adobes that show a greater deterioration over time. For the case of mining adobes, the particle size analysis indicates that the sizes, silt, and clay are the predominant components in the matrix of said adobes, the silt-clay percentages are high, exceeding 81.87% (Table 1); the fact that fine, very fine and silty sand fractions predominate, with a moderate amount of organic matter (Table 2), which gives these materials a high erodibility and a potential risk of being eroded by water, especially in the rainier areas. The similarity of these materials in their distribution and particle size, suggests that there was a careful selection of raw materials to produce adobes and control in production. Similarly, we can see that the buildings of the 17th and 18th centuries have greater particle size diversity, and according to the USCS, they correspond to CL types of soil (Table 1). The different values of compression are explained by the different percentage content in clays and silts (Table 2).

All samples contain a greater amount of aluminum and silicon, have a higher content of silty- clays. Porosity results are related to the use of vegetable fibers as a supplement in the mixture of soil and water. Organic matter plays an important role in the above variables (porosity and density); as in a sample with high content of organic matter, it increases the porosity and aeration capacity of clayey soils, better tolerating the mechanical effects caused by time (Sharma *et al.*, 2015). Based on this, the adobes of 17th and 18th centuries haciendas (Dolores de Barrera and San Clemente) have a higher content of organic matter, which explains its percentage of porosity and resistance to uniaxial compression. Mixing dry grass with clay allows proper agglutination, great weather ability and prevents the blocks once solidified from cracking. The presence of these elements provides insight into the construction history of the building.

6.2. XRD, XRF, AND SEM-EDS ANALYSIS

The morphological observation by SEM-EDS and results obtained from the X-ray diffraction in pre-Hispanic adobe show the presence of eight

http://dx.doi.org/10.18268/BSGM2022v74n3a010422

major minerals grouped in silicates (quartz, albite, anorthite, sanidine microcline), phyllosilicates (halloysite, montmorillonite), and zeolites (gismondine). From a geological point of view, these groups of minerals derive mainly from existing volcanic rocks in the area. X-ray fluorescence analysis shows that the elemental composition of pre-Hispanic adobes is different from that of colonial adobes, with variations in the percentage of element content (Si, Al, P, Fe, Pb, As), and in the concentrations mainly related to iron oxide (Fe_20_3) and phosphorus (P_20_5). These variations may explain the dissimilarity in color, ranging from orange-brown, brown, dark brown, and gray, especially in the colonial period (Acevedo-Sandoval *et al.*, 2004; Avrami *et al.*, 2008). Differences are observed with the colonial period in terms of the type of phyllosilicates and zeolites present. Pre-Hispanic adobes present phyllosilicates of the montmorillonite and halloysite type, while in the colonial period the phyllosilicates are of various types between montmorillonite, volkonskoite, vermiculite, and dickite. The presence of phyllosilicates marks a secondary origin, which derives from the alteration of primary minerals or other silicates from volcanic rocks. From the point of view of the deterioration in buildings, montmorillonite could cause deterioration in buildings because it allows water ingress, has high absorption, and high susceptibility to contraction and expansion. Regard-

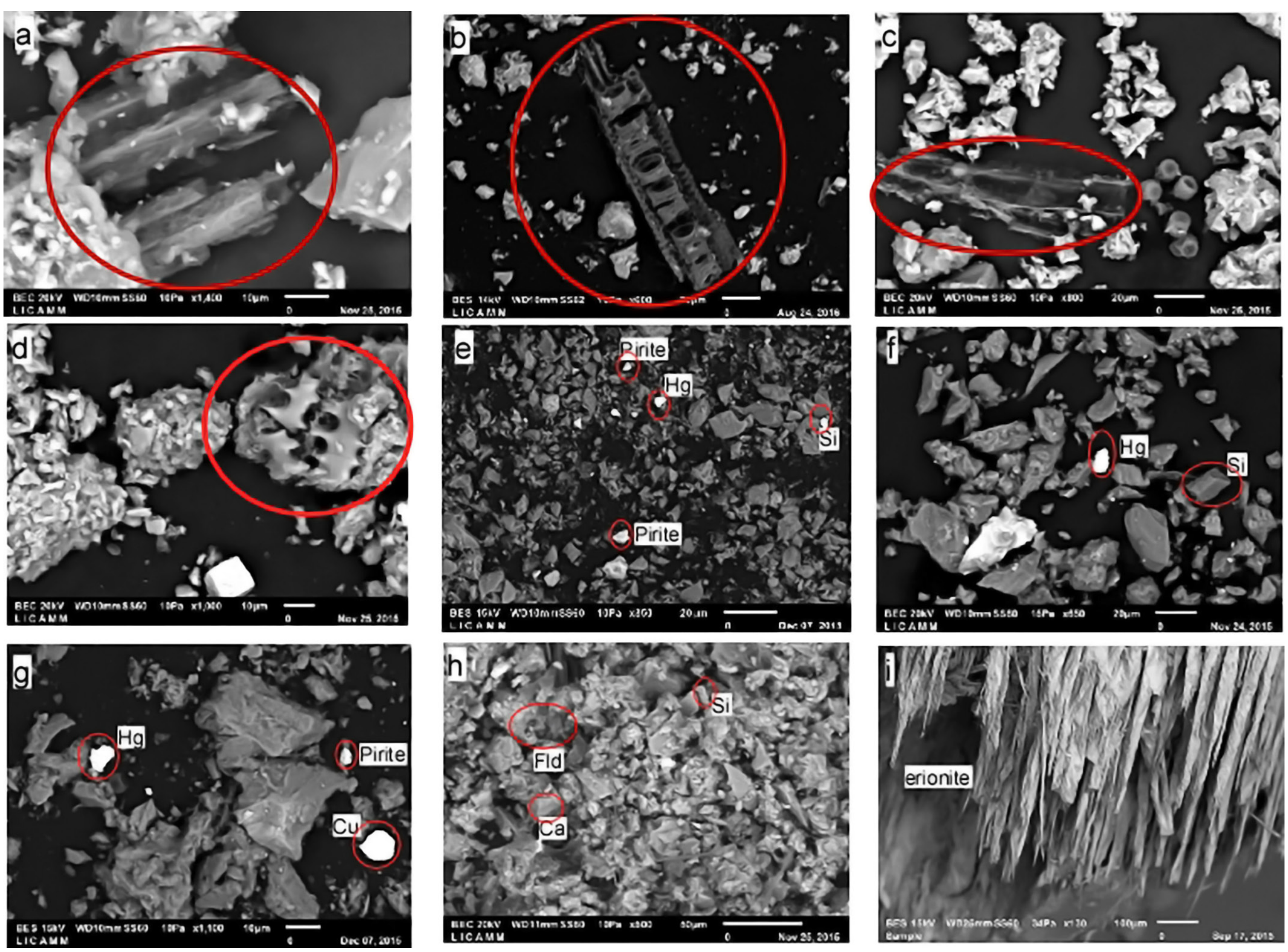

Figure 8 Images obtained with the scanning electron microscope in the samples of the adobes studied. a), b), c), d) presence of spores and vegetal fibers are common in agricultural and miners adobes; e), f), g) metals observed in miners adobes; h) silicates mineral observed in all adobes; i) erionite in miners adobes.

ing the presence of zeolites, pre-Hispanic adobes present gismondine as a mineral, while colonial adobes present several types among them faujasite, erionite, and epistilbite, these are formed by the transformation of the volcanic glass contained in the tuffs of intermediate to acid composition, and ignimbrites, they are also usually the product of secondary alteration in cavities and vesicles of igneous rocks. In the case of gismondine, this is usually the product of hydrothermal alteration. According to Avrami *et al* (2008), zeolites indicate the existence of high silica activity in aqueous solutions, affecting the crystallization of the silicate. From the point of view of the deterioration in buildings, zeolites can hydrate and dehydrate, when dehydrated the crystal develops a porous structure, forming cavities that can be occupied by ions and water molecules, allowing ion exchange and dehydration, thus causing the deterioration of the building.

Another disparity between pre-Hispanic and colonial adobe is that in colonial adobe, specifically in agricultural haciendas, amorphous phases such as cristobalite associated with volcanic glass and opal have been observed. According to Pérez *et al* (2016), the content of amorphous phases influences the resistance, plasticity, contraction, and expansion behavior of adobes. Although we did not quantify the content of amorphous phases in this study, we could think, according to the existing geology in the area, the existence of these in the composition of the soil. Another difference between pre-Hispanic and colonial adobe is that pre-Hispanic adobe has a concentration of Si, Al, Na, K, Ba, Ca, and Fe, which indicates a domain of silicates and aluminosilicates, these elements correspond to the essential constituents of the soils (Perez *et al.*, 2016), this indicates that the materials used for the manufacture of the pre-Hispanic adobe derive from the soil generated by the weathering of the volcanic rocks that outcrop in the surroundings of the archaeological sites studied, while the colonial adobes present elements such as Ni, Cu, Co, Zn, Cr, Pb, As, Se, Ag, Sb, V, and Hg, which indicates that the origin of the raw materials used for the manufacture of adobe is local, derived from the type of soil in the area and the method of benefit applied at the time for the extraction of gold and silver, derived from the mining of the time (Orozco, 1921; Antunez, 1964; Echegoyen-Sánchez *et al.*,1970; Puy-Alquiza *et al.*, 2019). An important element within the colonial adobes is the presence of erionite-K. The erionite-K is a natural fibrous zeolite found in certain volcanic tuffs (*e.g.* rhyolite tuff) and a wide range of geological settings. Erionite-K has been used as a noble metal-doping catalyst in a hydrocarbon cracking process and studied for its use in agricultural applications (*i.e.* in fertilizers and odor control in livestock production), (IARC, 1987; NTP, 2004). The characteristics that define these bricks units are variable. This may be due to the presence of the materials used; manufacturing processes; and dominant conditions (Rivera-Torres and Muñoz-Díaz, 2005).

6.3. CONSTRUCTIVE TYPOLOGIES, AND STRATEGIES FOR ITS CONSERVATION

The architecture of the pre-Hispanic sites studied is characterized by its simple aesthetics related to the environment and the available resources. Adobe represents the important manufacturing element at both sites (Coporo, La Nopalera) where the most common dimensions found are 10 cm x 15 cm x 35 cm and 10 cm x 32 cm x 20 cm. The reason for this heterogeneity is probably related to traditions, natural resources, and the type of soil, influencing the size of the blocks that vary according to the place, the type of use, and the historical period of construction (Ferrada and Segovia, 2007; Baudouin, 2021). On the other hand, the colonial haciendas represent industrial complexes whose dimensions were directly related to their economic activity, the wealth, and the capital of their owners. The hacienda is made up of a set of buildings interrelated in their functions so that generally the layout of the buildings was related to an architectural patio, with which the other buildings were built, contemplating the link that existed with the other spaces. The Haciendas housed within their territorial extensions various architectural elements such as the main house, where the patron and the administrative staff lived, the processing patios, the galleys, the laundries, ovens, stables, sheds, water wells, and troughs. The most used materials were wood, stone, brick, adobe inside as well as outside. The size of the adobes and their composition was a function of the type of soil, the natural resources, and the economic activity of the hacienda. Based on this, the colonial adobes present a great variety of dimensions: 10 cm x 27 cm x 30 cm, 10 cm x 30 cm x 37 cm, and 15 cm x 35 cm x 45 cm, indicating that each owner of the hacienda had his own technique for the preparation of bricks and this was subject to the type of soil and the contribution of organic matter content in the case of agricultural bricks, and for mining bricks, the raw material represented the waste product of the metallurgical process. One of the problems with the use of adobe in construction is the presence of pathologies (alteration and degradation) derived from the abandonment of the construction system and exposure to the elements (Gomez-Patrocinio *et al.*, 2020). Various techniques have been proposed to avoid accelerated degradation of the material (healing, ochratization, stapling, injection of epoxy resin, injection with cement pastes and micro-concrete, post-tensioning systems, sealing of cracks or fissures, among others). (Monjo-Carrió and Maldonado-Ramos, 2001). In recent years, the use of consolidants has been proposed to prevent the deterioration of adobe (Salazar-Hernández *et al.*, 2021).

7. Conclusions

Construction techniques have changed over time to make better use of existing natural and anthropogenic materials. This has led to changes in the manufacturing and manufacturing processes that have characterized each period. The adobes from the different periods studied showed that the chosen materials and techniques were determined by the environmental conditions, the available resources, and technical and cultural reasons. The geological characteristics of the studied areas represent an extraordinarily favorable scenario for the exploitation of raw materials such as clay, for the manufacture of adobes. Clay is mined close to settlement and/or production sites to reduce the time and cost of acquisition and transportation. Proof of this is that the pre-Hispanic adobe presents a good granulometric distribution between the content of gravel, sand, silt, and clay, in addition to this it presents a low or null amount of organic matter, and high plasticity index, making it one of the most durable adobes studied. The quality of the material and the percentages used show a wide knowledge of the selection of materials and masonry. During the colonial period, the materials used linked to soils with little clay content and sandier caused low plasticity and cohesion, for which the addition of organic matter was necessary. The clay soils caused too much shrinkage and fractures, while the sandy soils did not have enough interaction between the particles, so the adobes crumble, on the other hand, soils with excessive content of organic matter had low resistance and short duration against humidity. It is considered that an adequate mix of the four granulometric components (gravels, sands, silt, and clay) and the material origin are the keys for the manufacture of resistant and durable adobes over time, as is the case of pre-Hispanic adobes compared to colonial adobes. Two sources of materials used for the manufacture of adobes can be identified in this study, one related to the geological materials and the type of soil which is characteristic of pre-Hispanic adobes and another material related to the use of waste materials from the economic activity of agricultural and mining haciendas. The changes in manufacturing techniques can be caused by the presence of new groups with different cultural and technical backgrounds. Similarly, this change could also be explained from the perspective of an exchange of ideas between different communities, over time.

The biggest problem for the repair, maintenance, and correct execution of adobe buildings is the loss of an ancient tradition, passed down from generation to generation, creating a gap in the construction culture, losing know-how, and generating problems that can be fatal., especially in the case of seismic countries with ancestral heritage. Knowing the manufacturing techniques and processes will help to apply more effectively the conservation and restoration strategies of buildings from different times.

Acknowledgments

Our thanks to the laboratory LICAMM for its support in the realization of the analysis of X-ray diffraction, and Scanning Electron Microscopy. Also, acknowledge Cristina Daniela Moncada Sánchez and Jesús René Báez Espinoza for their technical support in this work. The samples from the archaeological sites were obtained with the permission of the director of the archaeological sites, co-author Omar Cruces, an archaeologist from Centro Guanajuato of the National Institute of Anthropology and History (INAH), who in 2006 was in charge of the El Cóporo restoration project, and in 2019 of the collection campaign at La Nopalera. The characterization of materials, carried out by the Department of Geology of the University of Guanajuato, was done in collaboration with INAH.

Contributions of authors

(1) conceptualización: MJPA, (2) análisis o adquisición de datos: MJPA, (3) desarrollo metodológico/técnico: MJPA, (4) redacción del manuscrito original: MJPA, (5) redacción del manuscrito corregido y editado: VYOZ, RMA, GAZ, MCSH, (6) diseño gráfico: GAZ, MCSH, GCA, YL, (7) trabajo de campo: MJPA, VYOZ; OCC, ABS, (8) interpretación: MJPA; RMA; GAZ, GCA; MCSH, YL.

Financing

This research work was carried out without funding.

Conflicts of interest

The authors declare that there is no conflict of interest.

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