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Geology, art and mysticism of Tezontle (volcanic scoria) of the Basin of Anáhuac, the newest designated Heritage Stone from Mexico

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Tezontle from the Anáhuac Basin became Mexico's second IUGS Heritage Stone in August 2024. This volcanic scoria of basaltic to basaltic-andesitic composition, once considered a 'providential gift' or a 'divine material', has been used for over twenty centuries in countless architectural monuments, many of which are included in UNESCO's World Heritage List. The abundant availability of tezontle in central Mexico, combined with its exceptional physical properties of lightness, hardness, and durability, made it the preferred material for building the massive structures of the monumental Pre-Hispanic City of Teotihuacan (1st-7th centuries). Centuries later, the Mexica utilized tezontle to build the island-city of Tenochtitlan (14th-16th centuries), adapting to the challenging lacustrine soil conditions by using it for foundations and masonry. The use of tezontle continued after the conquest of Mexico, adorning numerous New Spain Baroque style buildings (17th-18th centuries) of the center of Mexico City. Both in these buildings, as well as in the later, Neoclassical and functionalist styles structures of the 19th-20th centuries, tezontle was prominently used in façades. Its characteristic dark-reddish hue and rough appearance created a striking aesthetic contrast with the decorative elements of white or gray tufts, contributing to the development of a distinctive architectural identity for Mexico City. Despite the abundance of volcanic cinder cones (source of tezontle) in central Mexico, extensive mining of aggregates around Mexico City has significantly depleted the supply of high-quality stone for producing blocks and tiles. Furthermore, the tradition of artisanal tezontle work has become uncommon.

Introduction

The International Union of Geosciences (IUGS), through the International Commission on Geoheritage, awards the *IUGS Heritage Stone* designation —hereinafter referred to as HS— to "natural stone that has been used in significant architecture and monuments, recognized as integral aspects of human culture" (ToR-SHS, 2022). In this way, HS recognizes those stones that enhance cultural heritage contributing to our understanding of the use of building materials and the evolution of art and techniques from antiquity to the present (*cf.* IGC-IUGS, 2024). Therefore, this designation offers us a unique opportunity to celebrate, appreciate, and understand the confluence of geoheritage (stones and quarries) and cultural heritage (buildings and monuments, traditional artisanal practices).

It is worth mentioning that the stones' global cultural significance was first acknowledged by IUGS in 2010, and the inaugural designation protocol of what at the time was called "Global Heritage Stone Resource" was launched in 2013 (*cf.* Cooper, 2010; Cooper *et al*., 2013; Marker, 2015).

Under the revised criteria approved in 2022 (ToR-SHS, 2022), the IUGS recognizes to date (as of November 2024) a total of 55 HS (Ehling *et al*., 2024). Among these, the first from Mexico to receive the designation was the *Tezoantla White Tuff*, in 2022 (González-León *et al*., 2024). This HS not only added a new country to the list but also highlights the underrepresented volcanic tuff, a type of rock with remarkable historical and current use due to good workability, aesthetic value and insulating properties (Pötzl *et al*., 2022).

In this context, the *Tezontle from the Anáhuac Basin* becomes the second HS in Mexico —and the fourth in Latin America—, distinguished by unique technical properties (high porosity, low density) and significant influence on architectural styles and construction solutions (Canet *et al*., 2024). Nevertheless, Mexican Tezontle is not the only volcanic scoria that the IUGS recognizes for its imprint on cultural heritage; the Ethiopian *Lalibela Basaltic Scoria* was also designated as an HS in 2024 (Taye, 2024). These two HS show highly specialized, adaptive constructive uses of porous, light volcanic stones in totally different cultural and geographical contexts.

Following the same layout and organization used by González-León *et al*. (2024) for the first Mexican HS (Tezoantla White Tuff), this article presents the comprehensive documentation that underpinned the HS candidacy of *Tezontle of the Basin of Anáhuac* (volcanic scoria).

Overview of the Heritage Stone

The "Criteria and Procedure for designation of HS" (ToR-HS, 2022) outlines the essential information that must be included in any HS proposal. The following provides the general data included in the «Tezontle of the Basin of Anáhuac (volcanic scoria)» nomination, submitted in December 2023 to the HSS, endorsed in April 2024, and approved by the IUGS in August 2024.

Formal Name «Tezontle of the Basin of Anáhuac»

«Tezontle» is a term of Mexican Spanish that comes from the Nahuatl word '*tetzontli*', composed of '*tetl*' (stone) and '*tzontli*' (hair)

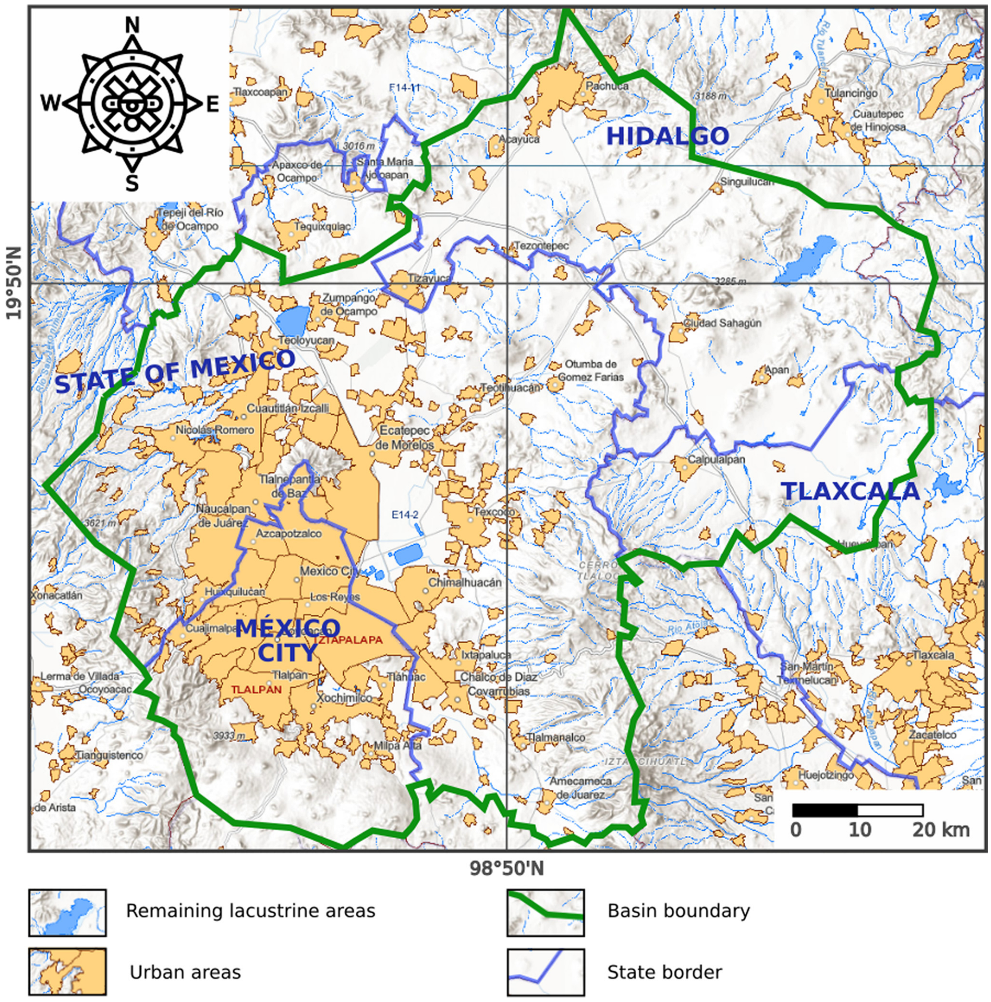

Figure 1. Map or the Basin of Anáhuac, a large lacustrine and volcanic basin in the central highlands of Mexico. Very characteristic of the built cultural heritage of this area is tezontle, a volcanic scoria whose source can be found at the numerous monogenetic volcanoes (cinder or scoria cones) scattered throughout the basin. This unique stone was essential in the construction of Tenochtitlan, ancient 'Aztec' capital, as well as later, in many colonial buildings of what became Mexico City. The Basin of Anáhuac includes Mexico City in its whole and extends over parts of three neighboring states (State of Mexico, Hidalgo, and Tlaxcala), encompassing the Metropolitan Area of the Valley of Mexico, with over 22 million inhabitants. (Drawn from a GeoInfoMex, 2023 base map).

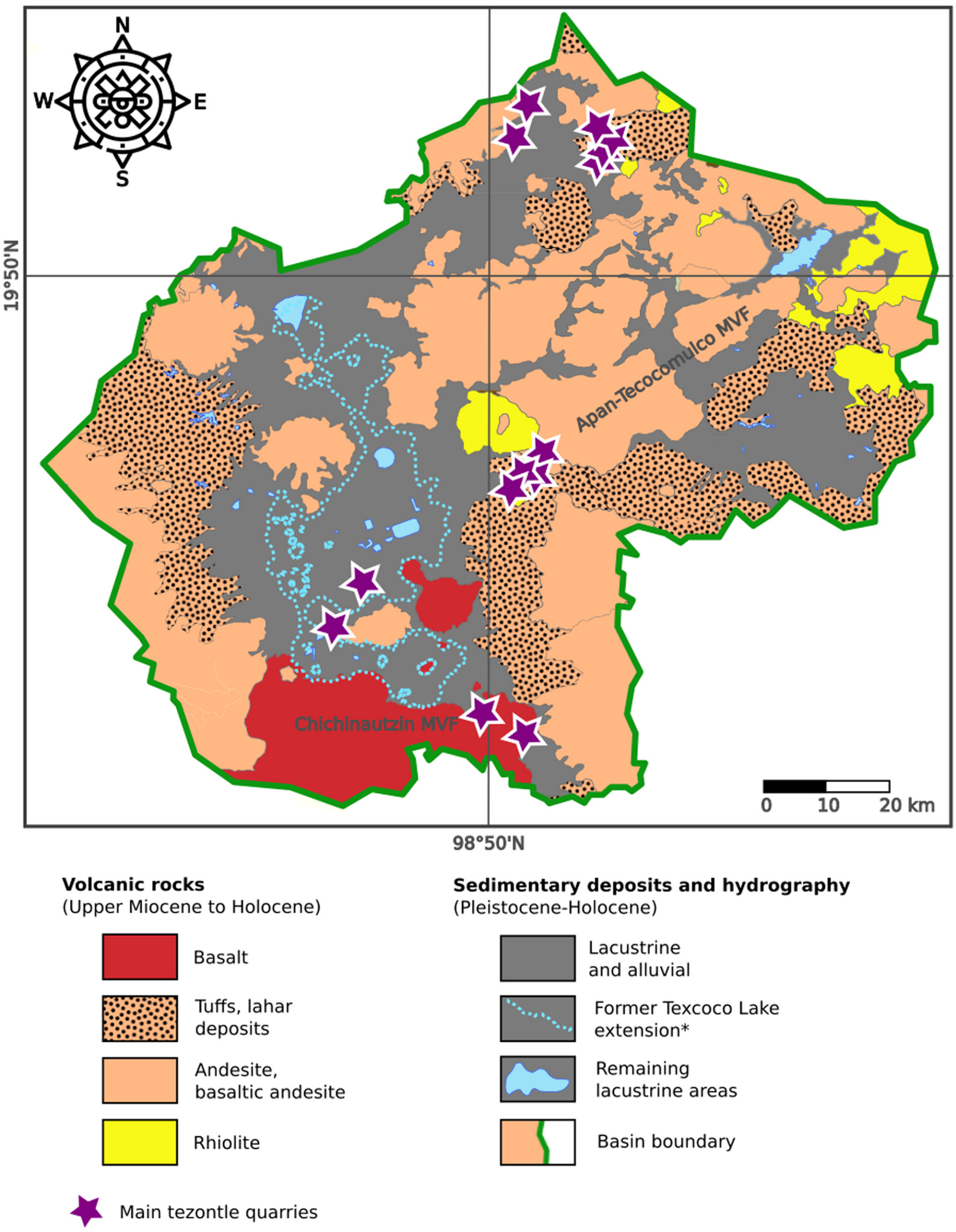

Figure 2. Simplified geological map of the Basin of Anáhuac (geology data obtained from SGM, 2017), showing the extension of the former Texcoco Lake at the arrival of the conquistadors (as delineated by Carranza-Edwards, 2018). Also shown are the locations of the main tezontle quarries. The two main monogenetic volcanic fields (MVF) —Chichinautzin and Apan-Tecocomulco— are marked on the map.

(RAE, 2023). Its use is widespread in Mexico to refer to the reddish-dark volcanic scoria that is used in construction, landscaping (‘*xeriscaping*’, in particular), and as aggregate.

The «Basin of Anáhuac» —also known as Basin of Mexico— is an elevated plateau, at an average altitude of ~2200 m above the sea level, surrounded of large stratovolcanoes and massive volcanic reliefs (over 5000 m high), constituting a former lacustrine basin dotted with monogenetic volcanoes (Figs. 1, 2 and 4). The native Nahuatl name of the region, ‘*Anáhuac*’, which literally means ‘close to water’, refers to this.

Geological Name

Oxidized volcanic scorias of basaltic to basaltic-andesitic (or rarely andesitic) compositions, from cinder cones of the Apan-Tecocomulco and Chichinautzin monogenetic volcanic fields (Pliocene-Holocene), at the eastern part of the Trans-Mexican Volcanic Belt (TMVB).

Other Names

«Tezontle» is the only generalized denomination in Mexico, both as a commercial term and in the popular or even the cultured registers (the obsolete and erroneous forms ‘*tesontle*’ or ‘*tezoncle*’ may be eventually found). However, according to Rodríguez Morales (2011), the first Spanish chroniclers (beginning of the 17th century) referred to this rock as *piedra rufa* or *piedra colorada* (both in reference to its reddish appearance) and, erroneously, as *piedra pómez* (pumice) or *pómez* *colorada* (reddish pumice).

Commercial Designations

By far the most common commercial designation is simply «tezontle». Despite this, the rock is advertised by a few dimension stone suppliers as '*cantera roja tezontle*' (tezontle red tuff).

On the other hand, the expression '*tezontle laminado*' (laminated tezontle) is used in the specialized market to refer specifically to the slabs of tezontle (*e.g.* Medina, 2017), thus differentiating such product from other that is much more in demand today: '*piedra tezontle*' (tezontle stone), a granulated material (natural or crushed) widely used in landscaping and cactus gardening.

Area of Occurrence

Tezontle is a valued raw material found in all monogenetic volcanic fields throughout Mexico and, in fact, it is quite homogeneous among the different regions in terms of constructive properties and appearance. However, the present application focuses on the Basin of Anáhuac (Figs. 1 and 2), where tezontle was used to build the ancient Tenochtitlan —capital of the Mexicas[1]— (14th and 16th centuries) and, later, in numerous monumental New Spain buildings (17th and 18th centuries). This unique stone is therefore a distinctive architectural element of the cultural built heritage of Mexico's capital city and its surroundings.

In this regional context, tezontle can be considered a product of proximity, close at hand and easy to extract around what it was and still is the largest urban area in the country. Thus, tezontle has been exploited in historical times and continues to be exploited today from the numerous cinder cones that dot the former lacustrine basin of Anáhuac. Many of these volcanic structures have vanished in recent years, causing social and environmental concerns (Robichaux *et al*., 2023).

Covering almost 10,000 km^2, the lacustrine and volcanic region of Anáhuac, once the heart of Mesoamerica and a privileged location of the island-city of Tenochtitlan, is today the most populated area of the country, with approximately 22 million inhabitants in the metropolitan area (which includes Mexico City, with over nine million inhabitants) (INEGI, 2023).

In addition to including Mexico City in its whole, the Basin of Anáhuac extends through part of three current states of the center of the country, namely: (*a*) State of Mexico (municipalities of Acolman, Axapusco, Chalco, Cuautitlán Izcalli, Ecatepec, Otumba, Papalotla, San Martín de las Pirámides, Tecámac, Temascalapa, Teoloyucan, Teotihuacán, Tepetlaoxtoc, Texcoco, Tezoyuca, Tlalmanalco, and Zumpango, among others); (*b*) Hidalgo (municipalities: Almoloya, Apan, Epazoyucan, Pachuca de Soto, Singuilucan, Tepeapulco, Tizayuca, Tlanalapa, Villa de Tezontepec, and Zempoala, among others); and (*c*) Tlaxcala (municipalities: Calpulalpan and Tlaxco, primarily) (Fig. 1).

Location of Quarries

In the Basin of Anáhuac tezontle has been exploited since time immemorial, so the total number of quarries is difficult to determine. According to SGM (2017) there are only seven registered tezontle mining sites, of which six are inactive, all of them located towards the north of the basin (municipalities of Pachuca de Soto, Mineral de la Reforma, and Epazoyucan, in Hidalgo) (Fig. 2). Two additional quarries are registered to the southeast of the basin, in the municipalities of Chalco and Tlalmanalco, State of Mexico (SGM, 2021a).

On the other hand, in the research that Robichaux *et al*. (2023) did to unmask the mining devastation derived from the construction of a new airport for Mexico City in 2016, it is mentioned that about 150 quarries operated in the east of the State of Mexico, particularly in the municipalities of Tezoyuca, Papalotla, Tepetlaoxtoc, and Texcoco. These quarries mined tezontle from scoria cones to satiate the huge demand of raw material for the runway pavements.

As for Mexico City, there is no official mining information available, unlike what happens in the neighboring states. However, many former quarries are well-known conspicuous elements of today's urban landscape, and several of them are mentioned in the bibliography on historical architectural practices and heritage (*e.g.* Rodríguez Morales, 2011); for instance, Peñón de Los Baños, Peñón Viejo or Del Marqués, Cerro de la Estrella, or the striking Yuhualixqui volcano (Fig. 4), which at the time were islands of the now disappeared Texcoco Lake.

According to official data provided by SGM (2021b), Mexico's total production of tezontle was in 2018 approximately of 25 Mt, of which ~3 Mt correspond to State of Mexico and ~1 Mt to Hidalgo, being Michoacan (>100 km W of the Basin of Anáhuac) the leading national producer, with ~6 Mt. The cancellation of the new airport in 2019 resulted in a substantial decline in tezontle demand, leading to a decrease by 75% to ~6 Mt; in spite of that, production subsequently rebounded to ~16 Mt in 2020 (SGM, 2021b).

Figure 3. Photographs of decorative tezontle showing variations in color and porosity. Slabs of tezontle: (A) brownish-red tezontle, and (B) black tezontle; view of tezontle ashlar walls —a display of the chromatic variability of the stone: (C) regular ashlars (sillares, in Spanish), and (D) smaller, irregular ashlars (sillarejos, in Spanish). (Photographs courtesy of Manuel Medina, https://disenoyartemexicano.blogspot.com/2017/05/tezontle-laminado.html)

[1]The term *Mexica* will be used throughout the text to refer to the Nahuatl-speaking peoples who ruled the Triple Alliance (15th and 16th centuries), a powerful pre-Columbian state popularly known as the 'Aztec Empire'.

Aesthetics and Primary Colors

Tezontle usually comes in two colors, both appreciated for decorative purposes in Mexico (Fig. 3): (*a*) brownish-red or *terracotta*, and (*b*) black (Prado Nuñez, 2000; Rodríguez Morales, 2011). In addition, there are variations and shades in between, including a less appreciated gray variety. Sometimes, the different exposure of the façades to weathering and natural lighting gives the sensation of chromatic and aesthetic variability.

In addition to its typical dark-red (and black) color, an aesthetic particularity of tezontle is its matte, rough appearance (it cannot be polished); these two properties together completely prevent tezontle from shining in the sunlight as light-colored tuffs[2] do. Thus, seeking a decorative effect based on contrast, tezontle was often combined in intricate Baroque-style ornamentations with gray or white tuffs (Piña Dreinhofer, 2013). Tezontle was therefore considered to aesthetically enhance the nearby stones, especially the aforementioned tuffs, which were also appreciated (Kubler, 2009; González-León *et al*., 2024). To be able to use, tezontle was cut in the quarries into ashlars, used in the facings. Tuffs, on the other hand, were reserved for the production of jambs, columns, frames and decorative details.

Natural Variability

Because cinder cones are very abundant in central Mexico, particularly along the TMVB, tezontle resources in general are still plentiful and readily available. However, most of this stone resource occurs naturally granulated (unwelded lapilli-scoria tuff) —suitable for use as aggregate—, while that which can be laminated and used for decorative architectural works is much scarcer. The latter must have a high degree of welding, reflecting particular eruptive and depositional conditions (higher temperature; *e.g*. Fisher & Schmincke, 1984). Besides, since the aesthetic attributes are essential in its valuation, several features visible to the naked eye, such as color (degree of oxidation), the abundance and size of vesicles, and weathering degree are also taken into account in the selection of quality dimension stone. All these properties may vary from one volcano to another, as well as within the same cinder cone.

However, none of the aforementioned physical and aesthetic properties significantly affect aggregate mining, which is an increasingly aggressive activity that consumes entire volcanoes (Robichaux *et al*., 2023). This, together with the fact that both the work in the quarry and on-site façade cladding require a lot of expertise, the dimensional tezontle is currently a limited material, whose demand is mainly for remodeling and restoration of the built heritage (Medina, 2017).

Geological Framework

This section presents a comprehensive overview of the geological properties of tezontle, including its geological setting, petrological features, and composition (geochemistry and mineralogy), as outlined in the HS application.

Regional Geology and Age

The Basin of Anáhuac is a highland (~2200 m asl) lacustrine depression placed at the eastern sector of the TMVB (Martínez-Abarca *et al*., 2021). The TMVB is a Neogene continental arc that runs ~1000 km through central Mexico —dissecting the country from coast to coast—, to which most of the country's active and hazardous volcanoes are associated (Gómez-Tuena *et al*., 2007). The arc is built on the North American plate continental crust that is underneath by the subducting Cocos and Rivera oceanic plates (Pardo & Suárez, 1993). Active since the Miocene (Pasquaré *et al*., 1991), the volcanism in this arc is calc-alkaline for the most part, although intraplate (alkaline), K-rich and adakite lavas also formed (Ferrari, *et al*., 2012).

The eastern sector of the TMVB is characterized by huge andesitic-

Figure 4. Panoramic views of the Yuhualixqui volcano (~2400 m asl at the top; 19°18'57.9"N / 99°3'9.8"W), currently a mine of tezontle producing construction aggregate. The remains of this monogenetic volcano, associated with the Chichinautzin monogenetic volcanic field, stand out in the urban landscape of Tlahuac and Iztapalapa, in southeastern Mexico City. In the distance (to the right of the Yuhualixqui) the snow-capped summit of Iztaccihuatl (~5230 m asl) can be seen. (Photo taken on December 1, 2023)

[2]Referred to as canteras, in Mexican Spanish.

dacitic stratovolcanoes of calc-alkaline geochemical signature (*e.g.* Popocatépetl and Citlaltépetl volcanoes) juxtaposed with large calderas and dome complexes (*e.g.* Los Humeros caldera; Las Derrumbadas dome complex) (García-Palomo *et al*., 2002; Ferrari *et al.*, 2012). In this sector of the TMVB, the volcanic units (total thickness: ~1000 to 3000 m; SGM, 2002) unconformably overlie a Mesozoic marine sedimentary sequence that is related to the opening and evolution of the Gulf of Mexico. Although the nature of the pre-Mesozoic basement is unknown, seismic data allowed us to infer that the continental crust beneath this zone is 45-50 km in thickness (Pérez-Campos *et al*., 2008).

In addition to dozens of large volcanic edifices such as stratovolcanoes and calderas (Ferrari *et al*., 2018), in the TMVB there are a huge number of cinder (scoria) cones, the geological source of tezontle (Fig. 4). In fact, from recent work (Macias & Arce, 2019) a number of about 8000 of them can be estimated. These small, short-lived volcanoes occur clustered in monogenetic volcanic fields, being the largest that of Michoacán-Guanajuato, in the central sector of the TMVB. In the Basin of Anáhuac cinder cones are also abundant, clustering in two monogenetic volcanic fields (Fig. 2), namely: (*a*) Chichinautzin, to the south and east of Mexico City, and (*b*) Apan-Tecocomulco, extended between northwestern Tlaxcala and southeastern Hidalgo. The former consists of more than 25 volcanoes, including those that stand out from the surrounding urban landscape of the densely-populated *colonias* (districts) of southeast Mexico City (*e.g.* Chimalhuacán, Peñón del Marqués, Cerro de la Estrella and Sierra de Santa Catarina) which, for that reason, were intensely mined for tezontle. The oldest monogenetic activity in this volcanic field dates back to ~1.3 Ma, whereas the youngest volcano erupted 1675 ±40 yr B.P. (*i.e.* the Xitle volcano, well known to archaeologists because of the volcanic crisis that affected the Cuicuilco pre-Columbian settlement; Jaimes-Viera *et al*., 2018). On the other hand, the Apan-Tecocomulco monogenetic volcanic field encompasses 27 cinder cones, with ages ranging between 2.0 to 0.19 Ma (García-Tovar *et a*l., 2015). In both cases, volcanic products associated with cinder cones range in composition from basaltic to basaltic-andesitic.

The Basin of Anáhuac was closed —thus becoming endorheic— during the Pleistocene, as a result of the volcanic activity whose products (mostly andesites) blocked the fluvial drainage southwards (Mooser, 1963). Since then and until the conquest of Mexico, this basin hosted a single, large brackish lake, known as Lake Texcoco, which had an extension of about 2000 km^2 during the flourishing of the island-city of Tenochtitlan (Fig. 2).

The earliest anthropic transformation of the lake was carried out by the Mexicas, who arrived in the area in *ca*. 1250 AD and constructed many dykes, notably the one known as 'Albarradón de Nezahualcóyotl', 16 km long and 20 m wide (García & Romero, 1978). However, the most drastic changes began in the 17th century, during Spanish rule, when it was decided that the lake complex should be completely dried up to allow urban growth and avoid flooding. For this purpose, five drainage canals were excavated during four centuries, the first of which was the 'Tajo de Nochistongo', whose works began in 1609 and lasted

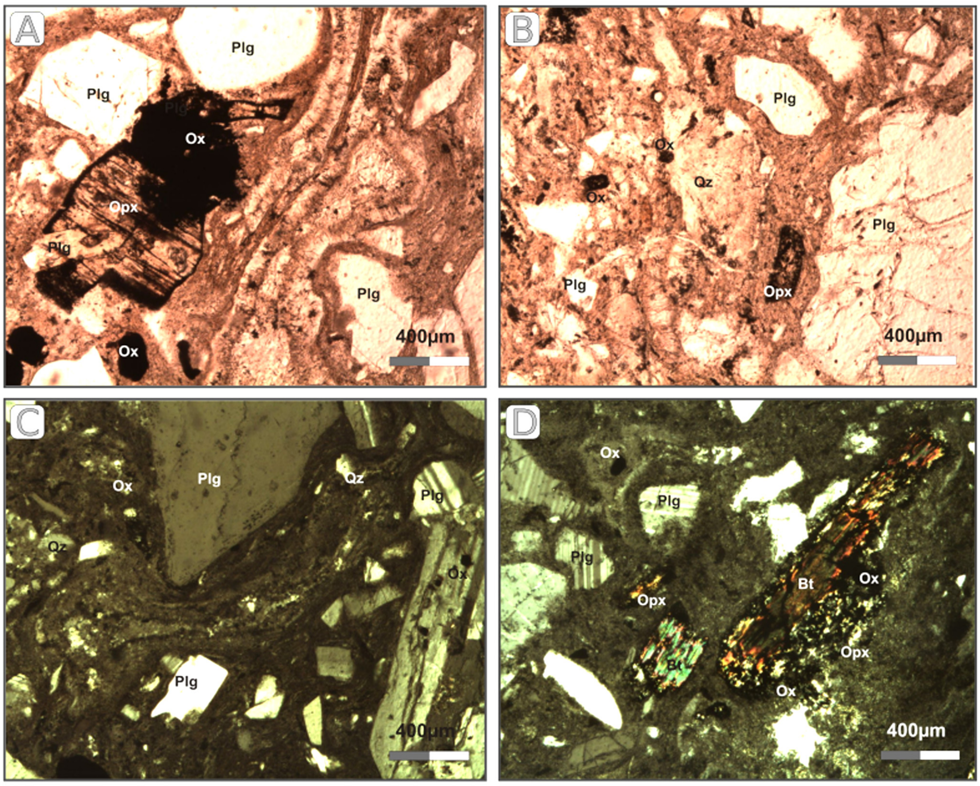

Figure 5. Photomicrographs of tezontle of the Basin of Anáhuac, oxidized volcanic scorias of basaltic to basaltic andesitic composition. Samples from Iztapalapa, southeastern Mexico City, corresponding to the Chichinautzin monogenetic volcanic field. Phenocrysts of plagioclase (Plg) and orthopyroxene (Opx) in a glassy groundmass. Biotite (Bt) also occurs, possibly being xenocrysts; secondary iron oxides (Ox), responsible for the reddish color of the stone, are abundant. (A-B-C-D) Transmitted, plane polarized light; (C-D) using crossed Nicols.

for 25 years (Alcocer & Williams, 1996). Because of these transformations, only a few relictual lacustrine areas remain in the basin (Figs. 1 and 2), whose drainage discharge currently gets to the Gulf of Mexico through the Pánuco River.

Petrology

Basaltic to basaltic-andesitic (and less commonly andesitic) volcanic scoria, *i.e.* glassy, highly vesicular solidified mafic (to intermediate) lava, formed from explosive Strombolian eruptions, usually occurring in cinder cones —also known as *scoria cones*—. The characteristic reddish color is acquired by oxidation of the iron contained in the melt during the eruption, by contact of the still-hot pyroclastic material with air.

Under the petrographic microscope, tezontle shows typical porphyritic textures, with phenocrysts (less than 20% modal) within a glassy groundmass (Fig. 5). Phenocrysts, mostly of plagioclase and pyroxenes (ortho- and clinopyroxene), are up to 3 mm across and usually occur randomly oriented. However, in some cases flow textures can be macroscopically observed and so the orientation of smaller crystals. Other recognizable phases, generally in subordinate amounts, are biotite, hornblende, quartz and olivine; these minerals can be interpreted as xenocrystals. Iron oxides are abundant, conferring the characteristic reddish coloration that is observed macroscopically.

Composition

Consistent with compositions of volcanic scoria from TMVB and elsewhere, tezontle of the Basin of Anáhuac chemically ranges from basalt to basaltic andesite (and rarely andesite) (Table 1), with SiO_2 between ~50% and ~60% (García-Tovar *et al*., 2015; Jaimes-Viera *et al*., 2018). As in any basaltic or akin rock, alkalis (K_2O+NaO) do not exceed 5%, remaining below CaO (7-10%), while Fe_2O_3 and MgO together are around 15% (Table 1).

The essential minerals (phenocrysts) rarely exceed 20% (modal) of the rock, in which glassy-microlithic groundmass and vacuoles predominate. These minerals are, in order of abundance: plagioclase (andesine-labradorite members), clinopyroxene (augite-diopside members), olivine, and orthopyroxene; in addition, hornblende occurs as accessory phase in the more silica-rich lavas (García-Tovar *et al*., 2015).

Constructive Properties

The tezontle has unique constructive properties, which influenced architectural styles and provided construction solutions to the specific problems of building on the soft, lacustrine soils of the Basin of Anáhuac. This section describes these properties within the historical and physiographic context of architectural application.

Geotechnical Properties

A highly praised property of tezontle —that gives it a great advantage for architectural uses— is 'lightness', of which there are numerous references in chronicles and technical documents of the XVI and XVII centuries, even mentioning that some tezontle stones 'can float on water' (*cf.* Kubler, 2009; Rodríguez Morales, 2011). Indeed, density of tezontle is low, being reported as 1.2-1.6 g/cm^3 by some specialized suppliers, and as 1.3 g/cm^3 by González-Avellaneda *et al*. (1988). Technically accurate measurements of tezontle samples (from a particular scoria cone in Hidalgo) are reported by Ponce Lira *et al*. (2013), who differentiate: (*a*) the dry bulk density —the significant parameter for historical uses—, ranging between 0.87 g/cm^3 and 1.33 g/cm^3,

Table 1. Chemical composition (major elements, in wt.%) of representative samples of Tezontle (volcanic scoria) Heritage Stone (X-ray fluorescence analyses). Analyses #1 to #4 correspond to scoria cones of the Apan-Tecocomulco monogenetic volcanic field, reported in García-Tovar et al. (2015). Analyses #5 and #6 correspond to the Chimalhuacán and Peñón de los Baños scoria cones of the Chichinautzin monogenetic volcanic field, reported in Jaimes-Viera et al. (2018)

Sample	#1	#2	#3	#4	#5	#6
key	*CAL-10*	*CAL-26*	*CAL-56*	*CAL-58*	*CH-2*	*CH-3*
SiO_2	55.73	52.40	50.75	55.25	54.93	54.42
TiO_2	1.00	1.46	1.61	1.49	1.12	1.34
Al_2O_3	18.21	17.00	16.29	16.63	18.83	17.13
Fe_2O_3	6.69	8.23	9.99	7.95	7.23	8.18
MnO	0.11	0.13	0.15	0.11	0.11	0.11
MgO	4.90	6.92	6.90	5.07	4.53	5.42
CaO	7.94	8.99	8.44	7.05	7.24	7.72
Na_2O	3.78	3.41	3.53	4.00	3.54	3.75
K_2O	1.19	0.79	0.86	1.56	1.44	1.33
P_2O_6	0.18	0.36	0.55	0.45	0.35	0.41
LOI*	0.21	0.05	0.63	0.45	n.r.	n.r.
Total	99.93	99.73	99.70	100.02	-	-

*LOI – loss on ignition
n.r. – not reported
Silica contents < 53% correspond to basalt (analyses #2 and #3)
Silica contents ≥ 53% correspond to basaltic andesite (analyses #1, #4, #5 and #6)

and (*b*) the particle density, obviously higher, between 2.37 g/cm^3 and 2.83 g/cm^3. Density is related to another distinctive property of tezontle: porosity. This parameter, although variable, is always high in tezontle, making this stone attractive as an agricultural substrate (Trejo-Téllez *et al*., 2013), with values as 53-64% (total pore space) (Ponce Lira *et al*., 2013).

Another important petrophysical parameter is compressive strength, which in the case of tezontle ranges between 45 kg/cm^2 and 75 kg/cm^2 according to González-Avellaneda *et al.* (1988); the same authors also mention as relevant constructive properties of this stone the adherence to mortars and stucco, as well as its resistance to saltpeter and atmospheric agents.

The constructive properties of tezontle had already been described in 1895 by the architect Torres Torija, who in his study on construction practices described this stone as the best construction material because its porous texture facilitates a perfect adherence with the mortar, forming over time a single block of high resistance, and also results in very light works (Torres Torija, 2001).

Modern and updated information on the physical-mechanical properties of tezontle (*e.g*., density, porosity, compressive strength) will be provided in a subsequent study.

Suitability and Architectonic Uses

Tezontle was an irreplaceable building material in central Mexico during pre-Columbian times, and its architectural use continued into the colonial period (Prado Nuñez, 2000) and later. The widespread utilization of tezontle was not only because it was the most readily available and easy-to-extract stone in the area; beyond that, its constructive properties made it suitable to build on the unfavorable, sinking ground of the lacustrine basin. In particular, its lightness (low density) is an advantage from a constructive point of view (it does not add excessive load), therefore, tezontle was used as a filler material and as covers or finishes on façades and vault masonry. It was also used in foundations.

In the 16th century, the most important religious buildings had roofs built with wood and lead frames, which were expensive, heavy and easily flammable. During the 17th and 18th centuries, many of these roofs were replaced by barrel vaults, built with tezontle, which were safer and lighter than those made of wood or ashlar (Rodríguez Morales, 2018). This type of vaults were an innovation in Novo-Hispanic architecture. The temples of San Lorenzo Mártir, Santo Domingo, and Santa Teresa la Nueva are some examples of buildings with tezontle vaults (Fig. 6).

On the other hand, tezontle was widely used for decorative purposes. Because it is a porous and fragile material, tezontle is in principle not suitable for elaborate carving; however, the Mexicas knew how to work it with mastery and elaborated innumerable magical-religious pieces of particular beauty (Fig. 7), as well as some reliefs and sculptures such as those found in the Templo Mayor of the ancient city of Tenochtitlan. For the same reasons, tezontle is not appropriate for joining large arches or for exposed corners, for which tuffs were preferably used.

Because of how appreciated its reddish color and rough appearance, tezontle was widely used in colonial buildings as façade cladding for wall embellishment (Kubler, 2009). The careful combination of reddish-dark tezontle and clear tuffs in façades —seeking of an effect of contrast between both stones— provides a particular aesthetic to the historical Mexico City, clearly differentiated from that of other neigh-

Figure 6. Choir vault built with tezontle to achieve a weight-reducing effect —a constructive innovation of the 17th century in Novo-Hispanic architecture—. The ornaments on the cusp are carved in clear tuff. Example from the San Lorenzo Mártir temple, in alcaldía (borough) Cuauhtémoc of Mexico City: (A) detail of the vault and ornaments; (B) street view of the temple; (C) close-up of a façade showing the chromatic diversity of tezontle.

Figure 7. Tepetlacalli Tlaloc. Aztec, ca. 1469-1481. Tezontle with stucco and blue pigment, 68 × 58 × 38 cm. Provenance: Offering 41 of the Templo Mayor, Museo del Templo Mayor 10-168850 0/2, Mexico City. (Taken from El Imperio Azteca. Catalog published on the occasion of the exhibition El Imperio Azteca curated by Felipe Solís. 2005. Guggenheim Museum, Bilbao, Conaculta - INAH)

boring capitals such as Puebla, where monumental buildings, both civil and religious, are dominated by brick and tile (Piña Dreinhofer, 2013).

Historic Use and Heritage Significance

Used in construction for at least 20 centuries, tezontle can be considered the most representative building stone of Mexico. The following is a comprehensive overview of the historical and present use of tezontle, with emphasis on built heritage. Its broader cultural implications are also highlighted.

Historic Use and Geographic Area of Utilization

Tezontle has been widely used in central Mexico, mainly along the TMVB geologic province, where it occurs as a product of monogenetic volcanism. Principally, although not exclusively, tezontle was used in the Basin of Anáhuac.

The first architectural use of tezontle dates back to the first century AD, in the early days of the ancient Mesoamerican city of Teotihuacan, located at the center of the basin (Figs. 1 and 8). According to Margain (1966), tezontle was one of the main constructive materials of Teotihuacan, along with tuff, basalt, adobe, lime, cement(s), and wood. Particularly, tezontle was used as filler material, in masonry (in foundations), and as a component of concrete. Centuries after the fall of Teotihuacan, at the beginning of the 14th century, the Mexica settled in the region and founded the city of Tenochtitlan. Again, tezontle played a key role in urban development, being profusely used in the construction of the island-city (Aguilar Moreno, 2006). If we take into account that tezontle continued to be used in the Baroque-style buildings of the colonial period, especially during 17th and 18th centuries (Figs. 9 and 10), and, although to a lesser extent, in Neoclassical, neo-colonial and even functionalism styles, until mid-20th century (Fig. 11), it can be concluded that this volcanic stone has been used uninterruptedly in construction for at least 20 centuries.

Social and Cultural Impact

Tezontle can be considered the most representative building stone of Mexico (*cf.* Prado Núñez, 2000). In the 14th century, it was used massively by the Mexicas for the construction of temples in the island-city of Tenochtitlan and hydraulic works in the surrounding Lake Texcoco. The architectural use of this volcanic stone continued during the colonial era (16th to 19th century), often reusing it from temples destroyed by the Spanish conquistadors. One of the earliest colonial buildings in which tezontle was used is the mid-16th century Franciscan Chapel or *Visita* of the Sierra de Las Navajas, placed in which is often considered the most important obsidian source of Mesoamerica (Cruz-Pérez *et al*., 2021), currently a geosite of the Comarca Minera UNESCO Global Geopark, at the northern end of Anáhuac Basin (20°05'00.0"N / 98°34'36.8"W). In the obsidian workshops of this archaeological site, small rectangular tezontle blocks have been found and are interpreted as abrasion artifacts used in obsidian carving. Also worth mentioning are those uses of tezontle related to domestic and craft activities of pre-Columbian origin that continue to this day. For instance, tezontle has been used to line the traditional *barbacoa* ovens, small shafts specifically constructed for the culinary technique —still widely used today— for the slow cooking of meat products (nowadays mainly lamb).

Due to its unique constructive properties, which made it suitable for building on the unfavorable lacustrine ground (*i.e.* soft, water-saturated soils), tezontle was considered a gift of providence, and some Novo-Hispanic chroniclers even attributed to this stone a magical character (Kubler, 2009). As recorded in the technical document of the late 18th century entitled «*Architectura mecánica conforme la práctica de esta ciudad de México*» (Mechanical architecture according to the

Figure 8. Pyramid of the Moon (Pirámide de la Luna) in the Mesoamerican city of Teotihuacan, an archaeological site registered in the UNESCO World Heritage List as "Pre-Hispanic City of Teotihuacan" (WHC, 2023). Tezontle is found throughout the structure of the pyramid, in which blocks of mainly tezontle and basalt are combined. Originally, the pyramid was covered with painted stucco and therefore the tezontle was not visible.

Figure 9. Prominent examples of the use of tezontle in monumental architecture in the Basin of Anáhuac, central Mexico: (A) Top of the Guadalupe Aqueduct, built between 1743 and 1751, made with reddish tezontle ashlars combined with gray tuff decoration. (B) Main façade of the Tabernacle of the Catedral Metropolitana (Mexico City Metropolitan Cathedral), built between 1749 and 1768. From the last phase of the Churrigueresque Baroque style, this monument is characterized by the stipite columns framed by walls with tezontle cladding. (C) Palacio de Gobierno (government building) of Mexico City. Its construction began in 1527, being the oldest building for which materials looted from previous Mexica temples were used. In spite of its overlapping of later construction stages, it preserves the Spanish (peninsular) Baroque style, with the particularity of interspersing the gray tuff fine decoration with reddish tezontle rough cladding. (D) South façade of the Colegio de San Ildefonso, former Jesuit college that is currently a science museum. Of baroque style, construction of this building began in 1583. Windows are highlighted with mixtilinear arches and decorated frames done with clear tuff; the delicate decoration is emphasized by contrasting it with the reddish tezontle façade cladding. Locations: (A) Alcaldía (borough) Gustavo A. Madero, Mexico City. (B), (C) and (D) Alcaldía Cuauhtémoc, Mexico City, within the "Historic Centre of Mexico City and Xochimilco" UNESCO World Heritage site (WHC, 2023).

practice of the city of Mexico), tezontle was called «*divino material*» (divine material) (Moreno de Alba, 2007), an epithet that stems from its mystical character and at the same time points to how highly valued this stone was among the architects of the time.

Particularly, the reddish tezontle variety —the most abundant in nature— was the most used historically, becoming a characteristic aesthetic element of the historic Mexico City, in particular of New Spain architecture (17th and 18th centuries) (Romero de Terreros, 1918). In fact, the special appearance of this stone, so different from the stones used in European capitals, particularly in Baroque architecture, is seen as unique and provides identity to Mexico City (Lanzagorta-García, 2020). In this sense, the rare beauty of tezontle, whose color is for many an allegory of blood, is part of the modern imaginary of Mexico City, as reflected in the early poem of Octavio Paz (1990 Nobel Prize in Literature) «*1930: Vistas Fijas*» (1930: Fixed Views), which refers to his youthful impressions of Mexico City, his home town:

(...) «*vegetation of blue domes and white bell towers, walls of the color of dried blood, architectures: feast of forms, petrified dance under the clouds that are made and unmade and never end up being made, always in transit towards their coming form, ochre stones tattooed by a choleric star, stones washed by the water of the moon.*»[3]

[3]Free translation by the authors.

Heritage Utilization

The earliest use of tezontle in monumental structures dates back to the I-VII centuries AD, a long period during which the holy city of Teotihuacan was built (Fig. 8). What today is an outstanding archaeological site of Mesoamerica was inscribed in the World Heritage List as “Pre-Hispanic City of Teotihuacan” in 1987 (WHC, 2023). Much later of the collapse and abandonment of Teotihuacan, with the arrival of the Mexicas to the Basin of Anáhuac (13-14th centuries), tezontle played a fundamental role in the construction of Tenochtitlan. Only few vestiges of the island-city remained after the devastation caused by the Spanish invaders, with the urban archaeological sites of Templo Mayor and Tlatelolco standing out.

The decorative use of tezontle is conspicuous on the façades of countless monuments, mainly, but not only, of New Spain Baroque style (17th and 18th centuries; Fig. 9). Most of these monumental buildings are within the zone of Mexico City that was inscribed on the UNESCO World Heritage List, since 1987, with the denomination “Historic Center of Mexico City and Xochimilco” (WHC, 2023). Prominent examples of these historical buildings are: Palacio Nacional (seat of the Federal Government in Mexico), Colegio de San Ildefonso (Fig. 9D), Monte de Piedad, and the tabernacle of the Metropolitan Cathedral (Fig. 9B). Also included in the World Heritage List, but on the outskirts of Mexico City (on the border between the State of Mexico and Hidalgo) is the “Aqueduct of Padre Tembleque Hydraulic System”, registered in 2015 (WHC, 2023). The construction of this great engineering work of the XVI century was based on tezontle ashlars (Fig. 10).

The Neoclassical style in Mexico succeeded the Baroque since the late 18th century. It is identified with progressive political ideas and with the *Art Nouveau* movement (Schavelzon, 2013). This style is primarily represented in civil buildings, whose typical facades are usually clear —in allegory to art of classical antiquity, imitating the appearance of marble—. Hence, the use of white tuff was favored, such as the Tezoantla White Tuff HS (González-León *et al*., 2024). Nevertheless, tezontle was still being used, as this stone has always been seen as an element of the city’s aesthetic (Piña Dreinhofer, 2013). The most outstanding buildings of Neoclassical style (as well as of the related *eclectic* style) date from the 19th and early 20th centuries and are located in downtown Mexico City, including the Centro Cultural España and the

Figure 10. Acueducto del Padre Tembleque, registered in the UNESCO World Heritage List as “Aqueduct of Padre Tembleque Hydraulic System” (WHC, 2023). Built between 1555 and 1564, it crosses the Tepeyahualco ravine, extending between four municipalities: Axapusco and Otumba (State of Mexico), and Zempoala and Tlanalapa (Hidalgo). The central part of the bridges is built with finely carved tezontle masonry, including pilasters and the profiles of the voussoirs of the arches.

Figure 11. Mural of the University Olympic Stadium, by Diego Rivera, inaugurated in 1952. It is located within the Central University City Campus of the Universidad Nacional Autónoma de México (UNAM), a monumental complex of buildings, green spaces and sport facilities that was inscribed into UNESCO’s World heritage List (WHC, 2023). The central relief is constructed with different stones, especially reddish tezontle, and represents the conjunction of social forces.

Table 2. Non-exhaustive list of relevant monuments, most of them in Mexico City, in whose construction tezontle was used

	Buildings	Location	Architects / Builders	Year	Style	Type	Description (main architectural features)
1	Palacio Nacional (National Palace)	Alcaldía Cuauhtémoc, Ciudad de México	Viceregal authorities	1529-1926	Baroque, eclectic	Residential	From its inception, this building was a massive fortress with embrasures in the corners for the cannons, as well as loopholes in the floor for the riflery. An upper floor was added to this building in 1926, its windows were designed with semicircular arches, while in the center of the façade above the parapet, a clock and a bell were placed. The design of its façade follows the style of the city of that time, mainly using tezontle and Chiluca stone. The last floor is classified as Neocolonial style, but the tezontle finishing is part of the harmony that is achieved with the other construction stages.
2	City Hall Palace / Government of Mexico City	Alcaldía Cuauhtémoc, Ciudad de México	Pedro de Arrieta and José Miguel Álvarez	1527-1714 1941-1948	Peninsular baroque	Residential	This is the oldest building that used stones taken from previous Mexica temples. It was built as a fortress and served the purpose of protecting the inhabitants from those who were prohibited from settling in the area. Currently, only the foundations and some walls remain from the original building. In 1714, the City Hall was rebuilt in the Peninsular Baroque style (defined more closely to European influence) with arches and decorations. This remodeling largely resulted in its current appearance. However, for the centenary of Independence in 1910, a new restoration added a new floor and completely restored the building.
3	Ex convento de San Hipólito (Former convent of San Hipólito)	Alcaldía Cuauhtémoc, Ciudad de México	Unknown	1547	Baroque	Religious and civil	Colonial Patio: Historic patio surrounded by colonial semicircular tuff arches on both levels. It also has a fountain in the center. Upper Floor: First and last level overlooking the main patio. Delimited by a wrought iron railing bounded to the arches. Candiles Room: It is located on the first level of the building, it has natural light, wooden floors and stone walls. Private Room: Located on the upper floor, it has a private bathroom, living room, ventilation and natural light.
4	Acueducto del Padre Tembleque (Padre Tembleque Aqueduct)	Between the State of Mexico and Hidalgo, (Otumba and Zempoala)	Fray Francisco de Tembleque	1555-1564	Industrial-Hydraulic Engineering	Public work	It is a hydraulic construction to convey water from the springs to supply reservoirs. The water is channeled along 36.9 km through ditches with masonry walls covered with stone slabs. Three arch bridges were built to carry the water across three ravines located along the way. The highest is the Tepeyahualco bridge (almost 1 km long). This bridge has a clearing at its highest part (50 m), which is the highest in this type of hydraulic construction. The aqueduct was planned to resist wind, earthquakes, and flooding of the stream that runs below. It was built based on two construction principles: (1) built with tezontle stone, resistant and light in weight, finely carved for the profiles of the pilasters and the interior voussoirs of the arches, and smaller stones in Cyclopean masonry. (2) Use other masonry that can serve as a kind of scaffolding and formwork. As a final addition, it is one of the most important hydraulic works in Mexico, built in the 16th century.
5	Ex Antigua Aduana / Edificio de la SEP (Former Customs Building)	Alcaldía Cuauhtémoc, Ciudad de México		1530-1792	Neoclassic	Public work	This building began its construction in the 16th century. It went through several construction stages, including expansions and adaptations until it reached its current appearance. Its style is more related to the Neoclassic, it shows sobriety in its elements, but it preserves the baroque trend on its façade with the laminated tezontle finishing, black on the first floor and red on the next two floors, in combination with frames of white tuff.
6	Parroquia San Juan de Dios (San Juan de Dios Parish)	Alcaldía Cuauhtémoc, Ciudad de México	Miguel Custodio Durán	1582		Civil work	Main façade. It is one of the few examples of a vestibule with a fluted exterior vault resembling a shell. The entrance is characterized by a molded and richly decorated semicircular arch. On the sides of the door, there are three undulating embedded pillars, fluted and supported on high plinths. A frieze decorated with plant elements and the same type of pillars separates the second floor from the first. The third floor comprises the shelled vault in which the choir opens.
7	Colegio de San Ildefonso (San Ildefonso College)	Alcaldía Cuauhtémoc, Ciudad de México	Unknown	1583	New Spain baroque	Civil work	The Colegio has on its north façade a marble relief of San Ildefonso receiving the chasuble from the hands of the Virgin Mary, as well as the Royal Coat of Arms of Castilla y León. The architectural complex has three levels characterized by two areas: (1) the first one belongs to the Baroque period and is composed of three patios with a masonry construction that has arcades on pilasters and façades covered with tezontle, as well as frames and tuff cornices; (2) the second was built to the south of the previous one (between 1907 and 1931), with two small patios.

Table 2. (continued)

	Buildings	Location	Architects / Builders	Year	Style	Type	Description (main architectural features)
8	Iglesia de Santiago Tlatelolco (Church of Santiago Tlatelolco)	Alcaldía Cuauhtémoc, Ciudad de México	Fray Juan de Torquemada	1609	Medieval	Religious work	It was built on materials such as lime and boulders, with a baroque façade characteristic of the 17th century. The façade is made of tuff and towards the sides, two quadrangular towers can be seen. On the left side façade, two wooden sculptures can also be observed (a flagellated Christ and Saint Francis of Assisi). The atrium is a magnificent esplanade where there are still vestiges of the pre-Hispanic temples. Inside the building, the nave has a cross plan and on the top of the walls, there is a symmetrical series of closed windows adorned with abstract stained glass.
9	Mayorazgo de Guerrero	Alcaldía Cuauhtémoc, Ciudad de México	Francisco Guerrero y Torres	1713	Baroque	Civil	There are two houses, each located on the sidewalks (east and west) of Moneda Street. The houses were built with the typical materials used in the buildings of the Historic Center: tezontle masonry for the walls placed on robust stone blocks, the frames of the doors, windows, and the cornices of the mezzanine are made of Chiluca stone, a material that was also used for the stairs and the arches of the patio. These houses are located in an area whose architectural designs and construction procedures contributed to the development of the history of Novohispanic architecture. They are within the area declared as Historical Monuments of the Center of Mexico City since 1981.
10	Iglesia La Profesa (Temple of La Profesa)	Alcaldía Cuauhtémoc, Ciudad de México	Pedro de Arrieta	1720	Baroque, neoclassical	Religious work	In this building, the most prominent elements are the dome and two side towers. Its exterior is covered with tezontle ashlars and buttresses with decorated rings. The main façade, carved in white stone, has an ogee arch at the entrance and is flanked by two pairs of columns with fluted bodies and Corinthian capitals, with a sculpture between each pair. The arch and columns are decorated with plant motifs. As for its interior, the breadth of the three-nave basilica space and the extraordinary development of the roofs are surprising.
11	Templo de San Lorenzo Mártir (bóvedas) [Temple of San Lorenzo Mártir (vaults)]	Alcaldía Cuauhtémoc, Ciudad de México	José Joaquín García de Torres	1728	Baroque	Religious	The vaults of the temple are barrel-shaped with lunettes or smaller perpendicular vaults beneath which they have openings that allow lighting. They were made from tezontle ashlars, set with lime mortars. The stereotomy is considered an admirable work based on modules where five rows of tezontle joined by lime stand out. Each one has a row of limestone as a construction joint. It is worth highlighting the choir vault, whose complex design was worked in a very detailed manner.
12	Templo de la Santa Veracruz (Temple of Santa Veracruz)	Alcaldía Cuauhtémoc, Ciudad de México	Cristóbal de Medina Vargas Ildefonso de Iniesta Bejarano	1759-1776	Baroque	Religious	The building has façades on the west, south, and east, with the south façade, facing Hidalgo Street, as the main one. In the apse is the Christ of the Seven Veils, which, according to tradition, was given to Charles V by Pope Paul III, subsequently Charles V then gave it to the Brotherhood. Another important image is the Virgen de los Remedios, which is also known as La Gachupina and received its name for being the protector of the Spanish in Mexico.
13	Colegio de Vizcaínas (Vizcainas College)	Alcaldía Cuauhtémoc, Ciudad de México	Started by Pedro Bueno Basori and finished by Miguel José de Rivera	1732	New Spain baroque	Civil work	Its façade is baroque style and its four sides are covered with tezontle stone. The sections of the building construction are divided by pilasters surmounted by pinnacles. It consists of four main patios connected by a monumental staircase. The chapel preserves its Churrigueresque altarpieces.
14	Iglesia de San Fernando (Church of San Fernando)	Alcaldía Cuauhtémoc, Ciudad de México	Jerónimo de Balbás, José Eduardo de Herrera and Manuel Álvarez	1735	New Spain baroque	Public work	The church contains the remains of the viceroys Matías Gálvez and Bernardo de Gálvez. The latter died in 1786 in Tacubaya and was buried shortly after. The cemetery contains many historical figures such as those of Vicente Guerrero.
15	Casa Conde de Heras y Soto (Conde de Heras y Soto House)	Alcaldía Cuauhtémoc, Ciudad de México	Attributed to Lorenzo Rodriguez	1760	New Spain baroque	Civil work	It consists of two floors, two façades, a central patio, main staircase and bays that develop around the patio and backyard. The main façade is made up of a set of openings and masses arranged asymmetrically with the main entrance. The side façade, like the main one, it is made up of massifs covered with tezontle and openings with jambs extended to the cornice and balustraded parapet.
16	Iglesia de San Hipólito (San Judas) [Church of Saint Hippolytus (Saint Jude)]	Alcaldía Cuauhtémoc, Ciudad de México	Unknown	1740	Baroque	Public work	It is a temple that was built in stages. It belonged to a nunnery or convent. It has a side façade that gives access to the parish where the craftsmanship of its tezontle masonry can be seen. The sculpture of San Judas Tadeo was placed on the main altar of the temple in 1980, and since then its parishioners celebrate it every October 28 with pilgrimages in which they usually wear white clothing, in addition to carrying images and figures of the saint to receive a blessing in the church.

Table 2. (continued)

	Buildings	Location	Architects / Builders	Year	Style	Type	Description (main architectural features)
17	Rectoría de Santo Domingo de Guzmán (Rectory of Santo Domingo de Guzmán)	Alcaldía Cuauhtémoc, Ciudad de México	Pedro de Arrieta and Manuel Tolsá	1770	Neoclassical baroque		The temple of Santo Domingo is a baroque construction built with gray tuff and tezontle coverings. The choir, located above the entrance to the temple, is shaped like a horseshoe with tribunes that project over the nave; this is one of the most beautiful parts of the temple due to the balance it shows. The carved wooden stalls are from the 18th century and in the central part of the painting attached to the wall are located, from top to bottom, the Trinity, in the middle the Virgin Mary, and further down Jesus crucified, the geographic center of the complex. The temple has a Latin cross plan and a single longitudinal nave cut in the north by a transept. The vault is barrel-vaulted, it was built with tezontle and is supported by magnificent tuff arches. Both the nave and the transept have semicircular apses at their ends, with enormous altarpieces. The two gilded altarpieces in the transept are baroque works from the 18th century.
18	Colegio San Mateo Valparaíso (Banamex) [San Mateo Valparaíso College (Banamex)]	Alcaldía Cuauhtémoc, Ciudad de México	Francisco Antonio Guerrero y Torres	1772	New Spain baroque	Palace	Corner building with a usual layout for houses of that time. The building is covered in tezontle ashlars. The rest of the decoration consists of chiluca moldings on its slightly mixtilinear façades and great sobriety in the distribution of its decoration, from its cornice, with a luxuriously sculpted convex frieze and gargoyles supported by little angels that rest on corbels with masks, scrolls and flowers . The corner tower contains an angular niche to project the image of the Guadalupana flanked by Solomonic columns.
19	Monte de Piedad	Alcaldía Cuauhtémoc, Ciudad de México	Restoration and readaptation by Armando Chávez	1775	Colonial	Originally palace, later residence and currently commercial use	After the fall of Tenochtitlán, the Mexica temples were demolished and the rocks that formed them were used to build new buildings. The house of Hernán Cortés was built in the same place where the Palace of Moctezuma was located, and for its construction, the same stones from the old palace were used. The remains of both constructions were discovered during the archaeological work that was carried out in this building, along with a restoration and readaptation project of the property undertaken by the Board of Trustees of the National Monte de Piedad, between 2014 and 2018 and headed by the architect Armando Chavez.
20	Museo de la Ciudad de México (Palacio de los Condes de Santiago Calimaya) [Museum of Mexico City (Palace of the Counts of Santiago Calimaya)]	Alcaldía Cuauhtémoc, Ciudad de México	Francisco Antonio Guerrero y Torres	1779	Baroque	Palace and museum	It has a 2-body façade, the first is made up of a door with a low mixtilinear arch with two columns with Ionic capitals on each side, and decoration of pedestals like lion's paws. The second has a balcony with paired columns with Corinthian capitals that support architraves decorated with inscribed capitals. The arches of the patio are part of the Tuscan order, where an effort was made to combine 3 fundamental elements: arches, fountain, and staircase. The façade of the chapel (inside the building) consists of a lowered three-lobed arch. The columns, of Corinthian order, are supported by atlantes in the shape of children, although both are very deteriorated today. The door jambs show exuberant decoration, as does the arch located at the entrance.
21	Capilla del Pocito, Villa de Guadalupe (The little well Chapel, Villa de Guadalupe)	Alcaldía Gustavo A. Madero, Ciudad de México	Francisco Antonio Guerrero y Torres	1791	Baroque	Religious work	The design of the chapel presents a dome, whose zigzag decoration, together with the presence of multiform lines used in the windows, contribute to generating an atmosphere of movement. The plant comprises three main geometric figures: the octagon where the sacristy is located, the oval that makes up the main body, and the circle where the water well is located and which is the vestibule of the enclosure. The lower structure of the chapel is made of cut tezontle, with stone-shaped tuff portals and skylights. For the construction of this chapel, the Chiluca stone was used, a very solid stone commonly used in the enclosure of buildings in Mexico for its resistance to saltpeter.
22	Museo del Colegio Militar (Military College Museum)	Alcaldía Cuauhtémoc, Ciudad de México	Unknown	1823		Civil work	The chapel of the Convent of Bethlemites, also known as the Temple of the Immaculate Conception, was built after the arrival of this religious Order established in 1675. After its closure (in 1820), it housed the Military College between 1828 and 1837 by order of President Guadalupe Victoria. After that, the building has had modifications and different uses, such as a convent for nuns of the new education and/or indigenous ladies.
23	Colegio Nacional (National College)	Alcaldía Cuauhtémoc, Ciudad de México	Unknown	1943	Baroque	Public work	It is a three-level building with a sober appearance, whose style reflects the eclectic style with frames of balconies and entrances, cornices, and gray tuff mantels. The skirting board is made of black tezontle, and the rest of the façade is covered with laminated tezontle where the reddish tone predominates and some black pieces.

Table 2. (continued)

	Buildings	Location	Architects / Builders	Year	Style	Type	Description (main architectural features)
24	Templo de San Francisco (Temple of San Francisco)	Alcaldía Cuauhtémoc, Ciudad de México		1525 and 1716	Churri-guere sque baroque		The currently preserved building is the third of those erected on the site, the first two failed due to the watery terrain. It was started in 1710 on Saint Charles's Day (November 4) and was completed six years later. Attached to this church, the Balvanera chapel was built in 1766, whose façade is the main access to the church of San Francisco since its main façade is walled up.
25	Exconvento de la Encarnación (Former Con-vent of the Incarnation)	Alcaldía Cuauhtémoc, Ciudad de México	Jesuit Luis Benítez	1594-1648	Sober baroque	Public work	It was one of the largest convents of that time, which included homes, chapels, orchards, and the main cloister. It was built by the Dominica order. Like the nunneries, its access door is lat-eral to the apse, it has a single tower. The masonry walls are currently exposed, probably due to the arrangement it was flat-tened, although in the buttresses the intention of the quadraped corners can be seen where the combination of red tezontle can be seen, as in the rest. The building is currently tilted due to the instability of the terrain.
26	Biblioteca General de la Cámara de Diputados (Gen-eral Library of the Chamber of Deputies)	Alcaldía Cuauhtémoc, Ciudad de México	Pedro Ramirez	1601-1661	Novohis-pan ic	Public work	This church was part of a convent, it has two doors that lead to Tacuba Street, which was originally adorned with altarpieces inside. On the corner of Tacuba and Bolívar streets, it has a small chapel. This church preserves its appearance as a baroque-style religious temple with the tezontle masonry of its walls in combination with tuff corners and other decorative elements.
27	Hotel de Cortés (Cortes Hotel)	Alcaldía Cuauhtémoc, Ciudad de México	Unknown	1620	Baroque	Civil	This baroque construction has the characteristics of buildings of the time, mainly in the form of a fortress with a combination of tezontle and tuff decoration on its façades.
28	Palacio de la Santa Inquisición (Palace of the Holy Inquisi-tion)	Alcaldía Cuauhtémoc, Ciudad de México	Pedro de Arrieta	1732 and 1736	New Spain baroque		It was the headquarters of the Inquisition, the building had audience rooms, trial rooms, secret chambers, a prison, and accommodations for two inquisitors. During that time, the building was popularly known as the “Casa chata” (flat corner house), referring to one of its corners located to the southwest. The building represented an architectural innovation for the normally square viceregal palace buildings. On the other hand, the Museum and Palace of the Faculty of Medicine has very curious exhibitions on the history of medicine in Mexico.
29	Acueducto de Guadalupe (Guadalupe Aqueduct)	Ciudad de México	Unknown	1743-1751	New Spain baroque	Civil work	It is a 10 km long stone aqueduct, a section of this aqueduct was underground until it reached the town of Tenayuca. The rest was composed of 2,310 arches, along the way there were many fountains made with stone from Cerro de Guadalupe. This aqueduct channeled water to Mexico City from the Tlal-nepantla River and reached a fountain in the ancient Basilica. In some parts, the aqueduct was interrupted to place finishes where tezontle was also used in apparent ashlars with gray tuff decoration.
30	Catedral Met-ropolitana (Sagrario) [Metropolitan Cathedral (Tab-ernacle)]	Alcaldía Cuauhtémoc, Ciudad de México	Lorenzo Rodriguez	1749 and 1768	Baroque	Religious	The building has decorations such as shelves, niches of various shapes, floating curtains, and a large number of cherubs. The fruit elements stand out, such as bunches of grapes and pome-granates, which symbolize the blood of Christ and the Church. Other floral elements such as roses, daisies, and various types of four-petal flowers are also notable. The interior is built with chiluca and tezontle stones, the chiluca covers the walls and floors, while the tezontle is found in the door and window frames.
31	Palacio de Iturbide (Itur-bide Palace)	Alcaldía Cuauhtémoc, Ciudad de México	Francisco Antonio Guer-rero y Torres. It was later completed by Agustín Durán	1779 and 1785	New Spain baroque	Residential	The style of this building is an example of the interpretation of Spanish baroque in New Spain, which includes distinctive ele-ments of the Mexican indigenous roots in the decorative details. The building has three floors. The first is very high and with a mezzanine, the second follows a conventional way, and the third is made up of two towers joined by a gallery, where the doorway has richly carved pilasters, two atlantes, organic and geometric motives.
32	Ex templo y Convento de Santa Teresa la Antigua (Former Temple and Con-vent of Santa Teresa la Antigua)	Alcaldía Cuauhtémoc, Ciudad de México		Mid 17th-century	New Spain baroque	Public work	This building remains one of the most striking examples of New Spain Baroque architecture. The complex was modified at the end of the 17th century and also in the 18th century. The main entrance has double Solomonic columns. In addition, the majestic dome was erected by the architect Lorenzo de la Hidalga in the mid-19th century.

Table 2. (continued)

	Buildings	Location	Architects / Builders	Year	Style	Type	Description (main architectural features)
33	Buildings in the Historic Center of Mexico City (Examples: Casa Molina, España Cultural Center, Mexico City Hotel, Moneda Hotel, Cathedral Passage, Maurel Passage, among others)	Alcaldía Cuauhtémoc, Ciudad de México	Not specified	Late 19th century, early 20th-century	Neocolonial eclectic, Functiona-lis m	Housing, commerce, among others	The use of tezontle continued in Mexico City until the end of the 19th century and the beginning of the 20th century. The new buildings used to have a base of metal structure and rein-forced concrete which, at first, were covered with stone because it was not acceptable to leave it exposed. The tradition of tezontle laminate covering continued for a long time until it was replaced by industrialized materials. Usually, buildings that reached between 4 and 8 levels in height used tezontle along with gray or white quarry in the frames of the openings. As the 20th century advanced, building façades no longer had the appearance of a neoclassical reminiscence. Then building windows began to have wide openings with little or no carved quarry elements, only leaving the tezontle as a finish that gives identity to the Center of Mexico City.

Hotel de la Ciudad de México. In the mid-twentieth century, in some functionalism-style buildings, up to eight storeys, tezontle continued to be used to embellish the façades.

The most recent use of tezontle in a cultural site of the World heritage List can be seen in the ornamentation of some architectural elements of the property “Central University City Campus of the *Universidad Nacional Autónoma de México*”, built between 1950 and 1952 and inscribed by UNESCO in 2007 (WHC, 2023). This is the case of the mural of the Olympic Stadium, by the Mexican painter Diego Rivera (Fig. 11).

Vulnerability and Maintenance of Supply

Tezontle is a building stone with high resistance to saltpeter and atmospheric agents (González-Avellaneda *et al.*, 1988; Urbina Leonor *et al*., 2023), for which it is very appropriate for use in façades exposed to the subtropical climate of the Basin of Anáhuac.

The mining devastation derived from the (later canceled) construction of a new airport for Mexico City in 2016, denounced by Robichaux *et al*. (2023), has drastically reduced the region’s tezontle reserves, particularly of the dimensional quality stone needed for heritage restoration, in addition to having irreversibly altered an immemorial cultural landscape.

Related Heritage Issues

San Pedro Museo de Arte (former San Pedro and San Pablo Hospital, 16th century) in the “Historic Centre of Puebla” (inscribed in the World Heritage List; WHC, 2023) was built with ashlars of tezontle. On the other hand, another UNESCO-designated site in central-eastern Mexico, the “Pre-Hispanic City of Cantona” (WHC, 2023), which dates back to 600 BC, shows an early use of tezontle in the covering of structures and tombs.

Tezontle (locally sourced) was also used in some notable buildings in western Mexico, for example, the Casa Zuno —or ‘*Casa de Tezontle*’ (Tezontle House), as it is commonly known—, of early 20th century neocolonial style, in Guadalajara, Jalisco state.

[4]https://iugs-geoheritage.org/geoheritage_stones/tezoantla-white-tuff/

Related Dimension Stones

For architectural decorative uses, both in New Spain and post-colonial buildings, tezontle has traditionally been combined with light-colored tuffs (Hernández-Soubervielle, 2021) such as Tezoantla White Tuff HS[4] (white tuff) and the Chiluca stone (gray tuff), both quarried nearby Mexico City. As for other dark stones commonly used, the so-called *recinto* (basaltic lava) stands out.

Conclusions

Used in construction for at least 20 centuries, tezontle (volcanic scoria) is the most representative building stone of Mexico. With its designation in 2024, the *Tezontle from the Anahuac Basin* becomes the second HS in Mexico.

The unique technical characteristics (high porosity, low density) and aesthetic qualities (reddish-dark color, rough appearance) of this stone provided construction solutions and had a profound influence on architectural styles in Central Mexico. The most valued property of tezontle for architectural uses is its low density, which made it suitable for building on the unfavorable lacustrine ground of the Basin of Anáhuac.

Many constructions with tezontle are included in UNESCO’s World Heritage List, such as the Pre-Hispanic City of Teotihuacan (1st-7th centuries) or the New Spain Baroque buildings (17th-18th centuries) of the Historic Center of Mexico City and Xochimilco.

Because cinder cones are very abundant in Mexico, tezontle resources, in general, are still plentiful and readily available. However, the majority of tezontle occurs in a naturally granulated form, making large, high-quality blocks suitable for lamination and decorative architecture relatively scarce.

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