GREEN, GOLDEN AND BLACK OBSIDIAN FROM CERRO DE LAS NAVAJAS, HIDALGO: A POTENTIAL CANDIDATE FOR GLOBAL HERITAGE STONE RESOURCE FROM CENTRAL MEXICO

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Abstract

The «Cerro de Las Navajas Obsidian» is a rock within the Comarca Minera UNESCO Global Geopark, Mexico, possessing archaeological, cultural and scientific importance and is presented here as a potential candidate for the Global Heritage Stone Resource designation. Such designation is aligned and in synergy with UNESCO Global Geoparks sustainable agenda. Furthermore, this designation seeks: (*a*) to put in value the multi-dimensional geoheritage of the obsidian, and (*b*) to require competent authorities to regulate and manage obsidian mining and commercialization, under fair trade terms and compatible with conservation, research and responsible tourism. This is relevant given the lack of legal advisory role of geoparks in geological heritage management in Mexico and implies a cornerstone in advancing sustainable geosciences. The Cerro de Las Navajas Obsidian exhibits a unique green-golden macroscopic color, and was exploited and exported since ~250 a.C., by successive Pre-columbian Mesoamerican cultures (Teotihuacan, Toltec, Aztec), extending to early Colonial times, recording the transition to a steel-based society.

Background of the nomination

The Global Heritage Stone Resource (hereafter GHSR) is an international designation that recognizes 'building stones' widely represented in human culture (Cooper, 2010). At present, there are examples of GHSR nominations around the world reflecting the efforts that, following the outlines of the Heritage Stone Task Group of the International Union of Geological Sciences (Cooper *et al*., 2013), have been made in the management and valorization of stone materials (*e.g*. Hughes *et al*., 2013; Cravero *et al*., 2015; Schouenborg *et al*., 2015).

GHSR is a designation that recognizes particular stones in terms of (*a*) conservation of cultural property, (*b*) sustainability, and (*c*) regional economic development, with a vision of safeguarding and protection (Cooper, 2010; Heritage Stones Subcommission, 2017). The added value of such designation is likely to become a cornerstone of sustainable geoscience (*cf*. Gill, 2017). We consider that social and environmental benefits would be expected specially in a framework of geological heritage conservation and promotion, as in the case of UNESCO Global Geoparks (UGG), which seek local development following a sustainable agenda (*cf*. Eder and Patzak, 2004; Zouros, 2004; Mc Keever and Zouros, 2005; UNESCO, 2006; Burlando *et al*., 2011; Henriques and Brilha, 2017; UNESCO, 2017a; Canet *et al.*, 2017; Han *et al*., 2018; Cruz-Pérez *et al.*, 2018b).

Due to the international importance of their geological heritage, UGGs play a key role in raise awareness of the multiple natural and cultural values of geodiversity (*cf.* Gray, 2004; UNESCO, 2006; Henriques *et al*., 2011). In fact, geoconservation is a pillar of UGGs (*e.g.*, Farsani et al., 2014; Ólafsdóttir and Dowling, 2014). In this context, the Cerro de Las Navajas obsidian is a rock within the Comarca Minera, Hidalgo UGG, in central-eastern Mexico (Canet *et al*., 2017; Cruz-Pérez *et al*., 2018a; Morelos-Rodríguez, 2018; Pastrana *et al*., 2018), whose geological, archaeological, historical and cultural values ―of worldwide significance― could fulfill the aspects addressed by the Heritage Stones Subcommission (2017), and thus it is here presented as a potential candidate for the GHSR designation.

Geological framework

Comarca Minera UGG lies within the northern edge of the eastern sector of the Trans-Mexican Volcanic Belt (TMVB) (Figure 1A), a Neogene continental arc that runs 1000 km E-W through central Mexico, dissecting the country from the Pacific coast to the Gulf of

78 Mexico (*cf*. Demant, 1978; Gómez-Tuena *et al*., 2007; Ferrari *et al*., 2012). The arc is built
79 on the continental crust that overrides the oceanic Cocos and Rivera plates along the Middle
80 America Trench (Pardo and Suárez, 1993, 1995; Yang *et al*., 2009). Although volcanism in
81 the TMVB is for the most part calc-alkaline, intraplate-type, K-rich and adakite lavas also
82 formed (Gómez-Tuena *et al*., 2007; Ferrari *et al*., 2012).

83 Cerro de Las Navajas is a Late Pliocene stratovolcano of about 12 km across and 1000 m
84 high, with an altitude at the summit of 3212 m above sea level, located in the center-east of
85 the geopark (Figures 1B and C) (Canet *et al.*, 2017; Martínez-Serrano, 2018). It represents
86 one of the easternmost expressions of a Late Pliocene peralkaline event within the modern
87 TMVB (*cf.* Cantagrel and Robin, 1979; Nelson and Lighthart, 1997). The Cerro de Las
88 Navajas volcano consists of (Figure 1C): (*a*) rhyolitic lava flows and domes along with
89 pyroclastic deposits, associated to a pre-collapse stage, and (*b*) pyroclastic and debris
90 avalanche deposits, directed mostly northward, associated to a post-collapse stage (Figure
91 2A).

92 Monogenetic volcanism contemporaneous to Cerro de Las Navajas is represented by
93 scoria cones and basalt flows —in some parts with spectacular columnar jointing (Figure
94 Figure 3)—, which cover most of the northwestern and southwestern foothills (Figure 1C)
95 (Nelson and Lighthart, 1997; Ponomarenko, 2004; Martínez-Serrano, 2018).

96 Obsidian flows originated both during the pre- and post-collapse stages; they were
97 fractured and displaced due to landslide processes, so that they occur as fragments (with
98 blocks up to 3 m across), some of which can be found as far as 20 km to the north. Therefore,
99 the typical mode of occurrence of obsidian in Cerro de Las Navajas is as discontinuous layers
100 of mixed blocks, of pumice and rhyolite besides obsidian (Figure 2B). The volumetrically
101 most important of these layers attains kilometers in length and up to 100 m in thickness.
102 Such peculiarities made necessary, in Pre-columbian times, a thorough underground mining

labor (Figure 2C), which accounts for 70-m deep shafts. This implies not only a technically complex and challenging mining development, but also that central Mesoamerican societies were powerful enough to undertake and sustain for centuries such exploitation.

Criteria for GHSR recognition

«Cerro de Las Navajas Obsidian» is proposed here as the formal denomination for the aspiring GHSR new designation, after the modern toponym of the obsidian deposits. Since the Spanish conquest of Mexico-Tenochtitlan in 1521, the obsidian locality has been known by its Spanish translation; back then the Nahuatl word *itztli* turned to the Spanish *navajas* (that means "blades", whereas *cerro* means "hill").

As a commercial appellation, "golden obsidian" is currently used, since archaeological literature generally refers to as "Pachuca obsidian" or to the "Pachuca source", due to its closeness to the state's capital city. It should be noted that in the area several obsidian varieties occur, forming a continuum from black to green; among them, the green with golden hue (Figure 2D) possess great geographical, historical and cultural significance (*cf.* Cobean *et al*., 1991) and has been the object of extensive archaeological research for approximately 40 years (the reader is referred to the works of A. Pastrana and collaborators).

Chemical composition

Chemical composition of the different varieties of obsidian has been the subject of several investigations aiming to address key issues of (*a*) provenance of archaeological artifacts, and (*b*) geochemistry and petrogenesis (*e.g*. Vogt *et al*., 1982; Mosheim and Althaus, 1988; Pastrana, 1998; Glascock *et al.*, 1988; Glascock, 1999; Ponomarenko, 2004; Bellot-Gurlet

128 *et al*., 2005; Argote-Espino *et al*., 2010; Donato *et al*., 2018). Major oxides determined by
129 X-ray fluorescence of green-golden obsidian representative of Cerro de Las Navajas are
130 provided in Table 1.
131
132 ***Physical properties***
133
134 Table 2 shows the most relevant physical properties of the obsidian from Cerro de Las
135 Navajas.
136
137 ***Gemological properties***
138
139 Due to its historical use in jewelry, specially by the ancient Mesoamerican cultures,
140 obsidian, in particular green and golden varieties, will be treated herein as a gem. Besides
141 these highly valued varieties, there are others of lesser interest in Cerro de Las Navajas,
142 namely: dark grey banded; dark amber and black with phenocrysts; black shading to grey;
143 dark brown with black spots; pinkish with black/grey stripes (Donato *et al*., 2018).
144 Obsidian in general has a hardness of 5 on the Mohs scale and exhibits a perfect
145 conchoidal fracture, so that it is suitable for manufacturing sharp objects and durable
146 ornaments (Pastrana, 2018). Microscopic studies pointed to oriented micro-vesicles as the
147 responsible for the golden hue, while greenish color is attributed to high iron contents
148 (Donato *et al*., 2018).
149
150 ***Vulnerability and maintenance of supply***
151
152 In Cerro de Las Navajas the obsidian source is buried and therefore its shape and volume

153 are not well constraint; however, a rough calculation allows us to estimate that reserves of
154 this volcanic glass should be in the order of millions of tons.

155 Because of its beauty and rarity, obsidian from Cerro de Las Navajas (in particular, green
156 and golden varieties) nowadays is still used for jewelry and ornament. Obsidian mining in
157 this deposit is artisanal and small-scale, not following any technical plan. Nor restoration or
158 conservation programs exist, in spite of its global archaeological significance and the
159 outstanding natural heritage that makes this one of the most important geosites of the
160 Comarca Minera UGG (Cruz-Pérez *et al*., 2018a).

161 As a consequence of an incipient devitrification process, obsidian from Cerro de Las
162 Navajas locally develops spherulites that spoil conchoidal fracture making it useless for
163 artifact manufacture.

164

165 ***Archaeological importance***

166

167 The spectacular geo-archaeological sequence of stages of obsidian exploitation at Cerro
168 de Las Navajas is an irreplaceable archive of the technological, cultural and political history
169 of central Mesoamerica (Canet, 2018). The work done on obsidian by different
170 Mesoamerican cultures produced a variety of instruments, jewels, weapons and magic-
171 religious objects (*e.g*. scepters, mirrors and anthropomorphic sculptures, closely related to
172 mythological conceptions of gods and the Universe). Because of its direct link with obsidian,
173 the two Aztec gods *Tezcatlipoca* and *Itzpapálotl* (from Nahuatl language: "smoky obsidian
174 mirror" and "black obsidian butterfly", respectively) are worth of mention. Also related to
175 magic-religious conceptions, animal-like pieces (*e.g*. felines, canids, bird and reptile eyes,
176 feathered and/or flaming serpents, rattlesnakes), human figurines (men, free and captive),
177 and vegetables and celestial elements (bolt of lightning, solar ray, stars, crescent moon) were

178 manufactured of obsidian; in addition, weapons were produced, having been described
179 curved and straight knives, projectile points and spear points (Pastrana and Athie, 2014;
180 Pastrana and Carballo, 2017). Such magnificent pieces have been found in the offerings at
181 the pyramids of the Sun and the Moon in Teotihuacan —the prominent city of central Mexico
182 during the Classic Period (Manzanilla, 2011)—, dedicated to deities associated with water,
183 blood, the Sun, war, and sacrifice (Gamio, 1922; Gugiyama, 2005).

184 At the beginning, Teotihuacan (150 b.C.-700 a.C.) exploited and distributed gray-black
185 obsidian from the Otumba source, located 18 km to the east from Teotihuacan. It was until
186 the Tlamimilolpa phase (~250 a.C.) that exploitation at Cerro de Las Navajas began,
187 developing 70 m-deep shafts, galleries and chambers. In-place manufacturing of weapons as
188 well as of religious, crafting and clothing objects was carried out. In particular, green
189 obsidian became the exclusive and symbolic material of the culture and power of
190 Teotihuacan, and by a strategic distribution it reached the governing elites of the Gulf of
191 Mexico, Oaxaca and the Mayan areas of Mesoamerica (Moholy-Nagy *et al*., 1984; Rice *et*
192 *al.*, 1985; Andrews *et al.*, 1989; Pastrana *et al.*, 2018). Besides of mines and ateliers, vestiges
193 of campsites are distributed in the Cerro de Las Navajas, where miners, carvers, carriers and
194 foremen were sheltered. Furthermore, local pottery production took place using clays
195 extracted from the obsidian mines (Pastrana, 1998; Pastrana and Domínguez, 2009).

196 One-hundred and fifty years after the fall of Teotihuacan, green obsidian exploitation was
197 taken up by the Toltecs (950 a.C.-1150 a.C.). Knapping techniques, however, were
198 significantly different from those of Teotihuacan (Pastrana and Domínguez, 2009). The main
199 obsidian tools were scrappers for the extraction of *aguamiel* (*i.e*. agave syrup) from the
200 *maguey pulquero*, *Agave salmiana* Otto ex Salm-Dyck. In addition, small knives and
201 representations of drops of water or blood were elaborated, which were probably sewn to
202 clothing and headdresses. It should be noted that no weapon production has been traced in

203 the Cerro de Las Navajas during the Toltec stage.

204 The fall of Tula city, in 1150 a.C., marked the end of the Toltec obsidian exploitation.
205 During the next 175 years, obsidian was exploited by locals that reused the abundant
206 knapping remnants left by Teotihuacans and Toltecs.

207 Since the Triple Alliance —the strategic association between Mexico-Tenochtitlan,
208 Texcoco and Tacuba (a.k.a. Aztec Empire; 1325 a.C.-1521 a.C.)—, the Aztec geo-
209 archaeological stage begins in Cerro de Las Navajas, characterized for the massive
210 exploitation of green obsidian. Deep mining was again undertaken, as well as ancient
211 Teotihuacan campsites, yet, leaded by a gremial organization of knappers and carriers. At
212 campsites obsidian preforms were concentrated, to then be sent to specialized ateliers in
213 major towns, where final manufacturing was done followed by its commercial distribution.

214 The Conquest of Mexico-Tenochtitlan (1521) reoriented the economy of what is today
215 the Comarca Minera UGG to precious metal production (of silver and gold), beginning in
216 the first half of XVI century in Tlaulilpan (present-day Pachuca) and in Real del Monte
217 (present-day Mineral del Monte, at the NE of Cerro de Las Navajas) (Oviedo-Gámez and
218 Hernandez-Badillo, 2011; Morelos-Rodríguez, 2018). In 1524 the first Franciscans arrived
219 to New Spain and built a chapel or *visita* in the Aztec atelier sites of Cerro de Las Navajas
220 (Figure 3). As suggested by Pastrana *et al*. (2018), this tiny church building is evidence that
221 the last obsidian knappers and miners were converted to Christianity and then reconverted
222 into the first miners and workers for the exploitation and processing of precious metals of
223 Comarca Minera, which followed a near 500-year precious metal mining history. While the
224 manufacture of obsidian weapons and religious objects stopped after the Conquest, obsidian
225 scrappers for maguey processing and knives production continued for several decades; these
226 objects were still sold in local markets as Coyoacan and Tlatelolco (Sahagún, 1989). A
227 thorough review of Cerro de Las Navajas obsidian exploitation history was provided by

228 Thiemer-Sachse (1994).

229

230 ***Historical scientific contributions***

231

232 During the XIX century several publications were issued dealing explicitly with the Cerro
233 de Las Navajas obsidian, covering different topics. In most cases these studies revisited
234 documents carried out since the XVI century. In Mexico, in 1904, the *Bibliografía geológica*
235 *y minera de la República Mexicana completada hasta el año de 1904* (in English: "Geologic
236 and mining bibliography of the Mexican Republic completed until the year 1904") was
237 published by the Mexican Geological Institute in the Bulletin no. 10, which included 4252
238 fact sheets. Such work was done by Rafael Aguilar y Santillán (1863-1940), a Mexican
239 bibliographer and bibliophile who worked as secretary and librarian of the aforementioned
240 institute. Elaborated after a thoroughly revision of such bibliography, Table 3 presents a
241 summary of the studies done in Cerro de Las Navajas from 1811 to 1903.

242

243 ***Heritage issues***

244

245 Cerro de Las Navajas is an emblematic geosite of the Comarca Minera UGG (Canet *et*
246 *al*., 2017; Pastrana *et al*., 2018), which was fostered by the *Universidad Nacional Autónoma*
247 *de México* (UNAM) since 2014 (Canet and Mora-Chaparro, 2017) and declared by the
248 UNESCO in May 2017 (UNESCO, 2017b). The maintenance of the geosite is undertaken
249 by the local *ejido* Nopalillo (*ejidos* are legally established communal organizations,
250 recognized by the Mexican State, allowed to manage the land), in collaboration with the
251 Mexican National Institute of Anthropology and History (INAH for its Spanish acronym),
252 which keeps a small research station and is responsible of the archaeological excavations.

In collaboration with *ejidos*, the UNAM's counterpart of Comarca Minera UGG has established a geoscientific, educative and international cooperation agenda (*e.g.* Canet and Mora-Chaparro, 2017; Cruz-Pérez *et al*., 2018b), and the activities carried out are reported annually to the Global Geoparks Network. Besides, Comarca Minera UGG has been benefited from active regional UNESCO cooperation for developing a sustainable agenda (UNESCO, 2019). However, geoparks in Mexico still do not have a proper legal advisory role in geologic heritage management, although they received official recognition for its pioneer labor by the Mexican Senate (Mexican Republic Senate, 2017). Thus, Cerro de Las Navajas is devoid of any legal protection status, in spite of its outstanding natural and cultural heritage.

Concluding remarks

Cerro de Las Navajas Obsidian is an internationally significant heritage rock of archaeological, cultural and scientific importance treasured by the Comarca Minera UGG.

This GHSR candidature aims to be a designation in synergy and partnership with the Comarca Minera UGG.

With this double international recognition, we are seeking (*a*) to put in value this multi-dimensional geoheritage, and (*b*) to require competent authorities to regulate and manage obsidian mining and commercialization, under fair trade terms and compatible with conservation, research and responsible tourism (*cf*. Brilha, 2015).

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FIGURE CAPTIONS

Figure 1. (A) Simplified tectonic framework of Mexico and the context of the Trans-Mexican Volcanic Belt (TMVB), depicting in red the location of the Comarca Minera, Hidalgo UNESCO Global Geopark. (B) Map of the geopark (after Canet *et al*., 2017) depicting in black the Cerro de Las Navajas volcano. (C) Digital elevation model of Cerro de Las Navajas, which consists of lava flows, domes and pyroclastic deposits. Contemporaneous monogenetic volcanism is distributed throughout the area. In addition, it is possible to observe a NNE oriented opening caused by the collapse. (D) Obsidian exploitation vestiges of different cultural stages, from Preclassic to mid XVI Century (after Pastrana *et al.*, 1989, 2012).

Figure 2. (A) Pumice quarry showing a type section of Las Navajas volcano. (B) Obsidian and pumice horizon in a large pyroclastic deposit. (C) Underground Aztec mine. (D) Hand specimen of green obsidian exhibiting the characteristic golden hue.

Figure 3. Well-developed columnar jointing in monogenetic-related volcanic basalts, contemporaneous to post-collapse Cerro de Las Navajas volcanism. As Cerro de Las Navajas, these rocks were also described in 1803 by Prussian naturalist Alexander von Humboldt during his explorations through Mexico. Both geological features are geosites of the Comarca Minera, Hidalgo UNESCO Global Geopark.

Figure 4. Mid XVI century Franciscan Chapel or *visita* at Cerro de Las Navajas. It reflects the strategic value of the area and the usage of obsidian still in early Colonial times.

Figure 5. (A) Early Colonial obsidian ateliers in Cerro de Las Navajas. They indicate the mid XVI century usage of obsidian and reflect a transition to later iron-based technology. (B) Knapping debris produced by Aztec manufacturers, distributed throughout a large area and exposed to weathering. (C) Artist piece produced of green obsidian. Notice the

477 golden hue. (D) Replica of *macuahuitl*, the Aztec obsidian sword (Pastrana and Carballo,
478 2016). (E) Obsidian scraper replica.

479 **Figure 6.** Pre-columbian Aztec glyphs in allusion to obsidian (original names in Nahuatl
480 language). (A) *Itztepec* - *Itz* from *itztli* = obsidian instrument, *te* from *tepetl* = hill - the
481 obsidian hill. (B) *Ytzteyocan* - *Ytz* or *Its* from *Itztli* = obsidian instrument, *te* from *tetl* =
482 stone, *yo* = possibly road, *can* = place - the place where obsidian is knapped or where
483 obsidian is shaped or the road to the place where obsidian is knapped or shaped. Redrawn
484 from the Mendoza Codex (1979).