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New enigmatic geoglyphs in the Indian Thar Desert: The largest graphic realizations of mankind?

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ABSTRACT

A meticulous survey of the Indian Thar Desert with Google Earth led us to identify eight sites in the Jaisalmer District, with clear geometrical lines that may resemble geoglyphs. The data collected in the field, together with images taken by a drone, revealed the exceptional character of the graphic patterns near the village of Boha. Two remarkable geometrical figures: a giant spiral adjacent to an atypical serpent shaped drawing, are connected with a cluster of sinuous lines. This triad extends over 20.8 ha and totals more than half of the 48 km of lines observed. Three memorial stones positioned at key points, give evidence that planimetric knowledge has been used to create this elaborate design. These artifacts allow us to envisage hypothetical modalities of edification. We collected indicators of antiquity suggesting that these lines may be at least 150 years old and possibly linked to the Hindu memorial stones surrounding them. The lack of visibility from the ground raises the question of their function and meaning. So far, these geoglyphs, the largest discovered worldwide and for the first time in the Indian subcontinent, are also unique as regards their enigmatic signs.

1. Introduction

Geoglyphs (from the Greek word *gê*, 'earth', and *gluphein*, 'engraving') are anthropogenic features built on the surface of the earth and considered by archaeologists as a type of rock art. These drawings, which are generally abstract and geometrical, more rarely represent anthropomorphic and biomorphic figures. This generic term is used to designate very diverse items with regard to their appearance, construction techniques and function. Their large dimensions, ranging from a few meters to several kilometers, constitute a common criterion that distinguishes them from other types of rock art, such as petroglyphs. According to each case, more specific terms have been utilized to designate them: earthworks, ground drawings, stone arrangements, mounds, geometric ditches, etc.

The oldest ones date back to the Late Upper Paleolithic (Mailland, 2012), while others, such as the Marree Man in Australia, were created during the contemporary era. Recent discoveries in Russia, Kazakhstan and India (this article), indicate that they are found in most regions of the globe. However, the majority are located in America and specifically in South America. They are most numerous in arid environments, where the conditions for their preservation and observation are optimal. Those found in the Nazca Desert (Peru) are by far the most famous and comprehensively studied (Aveni, 1990). Major discoveries have also been made in forest ecosystems in Brazil and Bolivia, where more than 450 earthworks are currently being investigated (Pärssinen et al., 2009; Erickson, 2010; Schaan et al., 2012; Virtanen and Saunaluoma, 2017; Watling et al., 2017).

Two construction techniques, which may be combined, have been generally attested. The most common one in desert environments is the extractive technique. It consists in removing the upper oxidized stone pavement, thereby exposing the bright sandy layer below. The second, known as additive technique, involves the gathering of debris, piled on the soil surface.

Seen from an aesthetic point of view, some geoglyphs, such as ground drawings, are special forms of artistic expression. In addition to this subjective quality, the function and meaning exposed by scholars is extremely diverse. The main interpretations suggest sites for rituals and ceremonies, places of collective memory and rites of passage, defensive structures, landmarks, and astronomical functions (Valenzuela and Clarkson, 2014).

Our study describes a cluster of geometric lines detected in the Thar Desert (Western Rajasthan) in 2014, using Google Earth. This ecosystem, also known as the Great Indian Sand Desert, covers approx. 285,000 km^2 at the eastern end of the Sahara-Arabian arid belt. The

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iconographic and dimensional singularities of these geoglyphs are presented here for the first time, based on a meticulous cartographic reproduction of the lines, completed by data collected in the field. This set of graphic expressions, as unique anthropogenic signs, has very interesting cognitive implications.

2. Documentation and methodology

The screen resolution of our computers, in terms of pixel density and dot pitch, has considerably increased in recent years. At the same time, the development of the Internet and software such as Google Earth have made satellite imagery accessible to researchers, allowing them to observe the earth's surface at resolutions ranging from 15 m to 15 cm. In archaeology, the use of these images has opened up new perspectives for survey, site studies and protection against looting (De Laet et al., 2007; Parcak, 2015; Parcak et al., 2016; Parcak and Tuttle, 2016). In the wake of aerial photography, satellite imagery has become a tool of choice for detecting and studying geoglyphs. Google Earth is at the origin of the discovery of an arrangement of zoomorphic blocks in the south of the Urals (Grigoriev and Menshenin, 2012), 60 monumental geometrical earthworks in Kazakhstan (Motuzaite Matuzeviciute et al., 2015) and around 3000 circular paths in the Jordanian Harrat desert (Kempe and Al-Malabeh, 2012, 2017). The workflow described by Bikoulis et al. (2016) has been adapted to our particular case and is summarized in Fig. 1.

In 2014, we conducted a methodical overflight of the Thar Desert with Google Earth, between 150 and 300 m above sea level, over an area of 280 km^2. This reconnaissance work allowed us to locate several sectors with clear lines of kilometric dimensions, which may resemble geoglyphs (Fig. 2). Dune fields were avoided in order to focus our research on desert pavements. These two deposits are easily distinguishable by their specific texture and color (see Section 3 and Fig. 5). The optimal observation altitude was determined between 700 m and 1850 m above ground level (Google Earth altitudes: 1000–2000 m). This range is a compromise between a fairly large area and a good perception of details. On a 15-in. screen with a 2880-by-1800 resolution, these images cover respectively 850 × 520 m and 2100 × 1300 m. The examination of relevant indications requires descending to 350 m above the ground. At this elevation, 1 cm on the screen equals approx. 12 m, and the use of a UAV becomes essential, because at under 300 m, satellite images are pixelated.

At the beginning of our virtual survey, Google Earth had a high qualitative and quantitative coverage of the Thar Desert, with ten sets of usable satellite images taken between 2004 and 2013. The older views have an insufficient resolution.

Eight clusters, comprising twenty-four sites, were located in the Jaisalmer District (Fig. 2). The field study in December 2016 verified the satellite data for fifteen sites. Those targets were overflown below 300 m with a DJI Phantom 4 UAV, taking photographs at a resolution of 12.4 Megapixel (Mark and Billo, 2016; Pavelka et al., 2018). Extrapolation of the information collected on concentrations 4 and 7 made the exploration of concentrations 1 and 6 unnecessary, as they were similar in appearance. All of them correspond to furrows dug for tree plantations that have generally failed. Clusters 2, 3 and 5 have parallel lines, concentric circles and some spirals, also very similar to plantations. Most of them appear to have been created recently, but no trees have been detected on these enigmatic lines.

Our interest has been focused on the cluster near the village of Boha (concentration No. 8), 41 km north of Jaisalmer as the crow flies (Fig. 2). The two main patterns differ from the figures mentioned above in regard of their originality and monumental size, the absence of many portions of lines as antiquity indicators and lastly, no visible tree plantations. Some remarkable archaeological artifacts (memorial stones and graves) present in the vicinity of the lines were also taken into account.

3. Geographical setting

The geoglyphs of Boha stretch over a small territory of 3.5 by 1.7 km, between the Jaisalmer road and a branch of the Indira Ghandi Canal, built in 1988. The cultivation of the east side of this branch started in the late 1990s. The village of Boha is located 3 km west of the main patterns, (See Nos. 1, 2, 3 and 4, Fig. 3). It had a population of 904 according to the 2011 census. Successions of parallel lines were also found north and south-east of this iconographic complex. Fig. 3b and c also include two-line units that appear to be plantation attempts, according to their design and geometric outlines.

With the exception of an isolated mound reaching 164 m, the relief is flat with small undulations. All the lines of the main units are in the altitudinal range of 153–159 m above sea level, on a desert pavement composed of ferruginous sandstone fragments with a sandy-silty matrix (Kar, 2014; Moharana and Raja, 2016). This sandstone pavement has a purplish or grey color on aerial views, that contrasts sharply with the lighter lines (Figs. 3a, 5). The unsorted clasts originate from a strongly altered substratum, whose small outcrops form microreliefs (Figs. 6b, 7). The third deposit type consists of sand sheets, which have, in some areas, a thin surface layer which is slightly indurated like the pavement matrix. The particle size of this deposit is more suitable for plant life and partially colonized by a steppe (e.g. *Lasiurus sindicus*, *Cenchrus biflorus*, *Panicum* sp.), some bushes and isolated trees (*Prosopis cineraria*, *Capparis decidua*). Its white or light beige tint prevents us from seeing the lines on satellite images, whereas they are sometimes still perceptible on UAV images.

The climate is arid as shown by the annual average precipitation of 134 mm in Ramgarh, over the 1957–2012 period (Singh et al., 2014). 90% occur during the monsoon season, from late June to September, sometimes in the form of heavy rain, followed by the dry season from October to June. Temperatures often exceed 47 °C during the summer, while in winter they can drop below 0 °C. Wind is the main agent of erosion. It reaches its maximum intensity in May and June, with an average of 25 kmph (Kar et al., 1998). This uncultivated territory is utilized for the grazing of goats and sheep, that are responsible for the degradation of the steppe and whose many paths crisscross the geoglyphs.

4. Description of the graphic units

The Boha lines are in the form of stripes ranging from 0 to 10 cm deep and 20 to 50 cm wide, whose surface materials have been removed (Fig. 4).

It may be deduced from these modest dimensions that their visibility on satellite images depends on their kilometric extent, as much as on their light tint. Shape, width, color and texture are the main criteria for the identification of these lines. The tracks of small livestock can be distinguished with the following signatures: presence of crossings, absence of curves, absence of regular spacing, constant width and random routes (Fig. 6).

The first mapping carried out before our field work at the end of 2016, based solely on Google Earth satellite imagery, has been completely updated with the UAV images. For example, the Boha 1 unit interpreted as a series of 12 eccentric ellipses, was revealed to be a huge spiral. The video clips and the 66 shots composing the extremely high resolution orthomosaic image, taken at an altitude of 100 m, revealed many new centimetric scale details.

The DigitalGlobe satellite image of Feb. 24, 2011, taken during the dry season, was chosen for its high clarity in order to draw a replica of the lines, using the tool “Path” of Google Earth. We compared the data in this image with the Oct. 2, 2011 post-monsoon one, which shows other

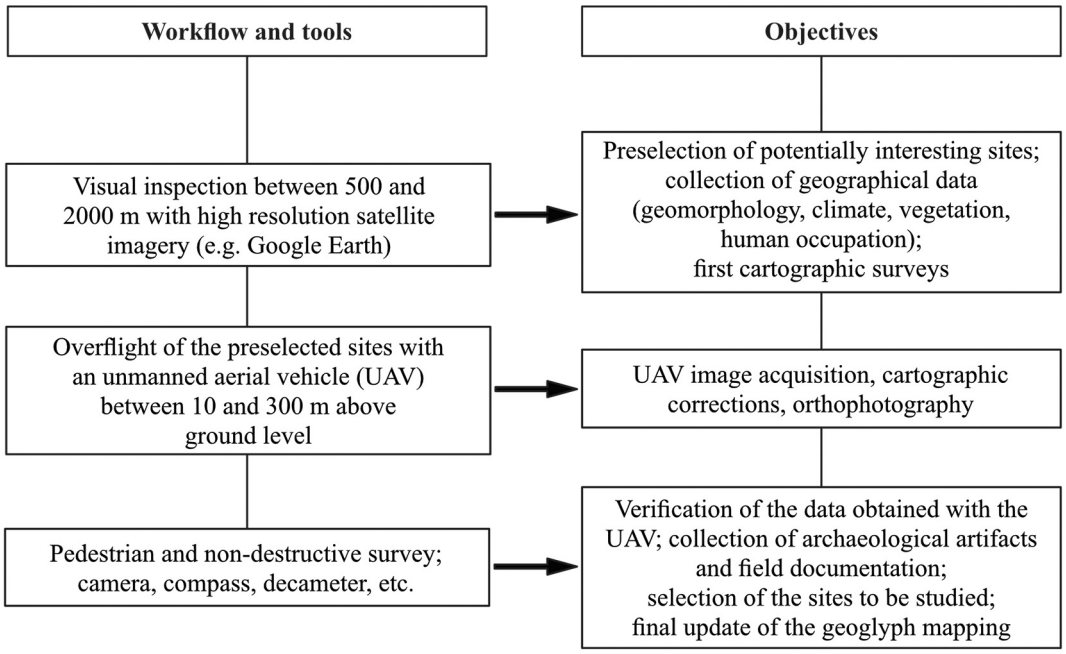

Fig. 1. Three-stage methodological approach.

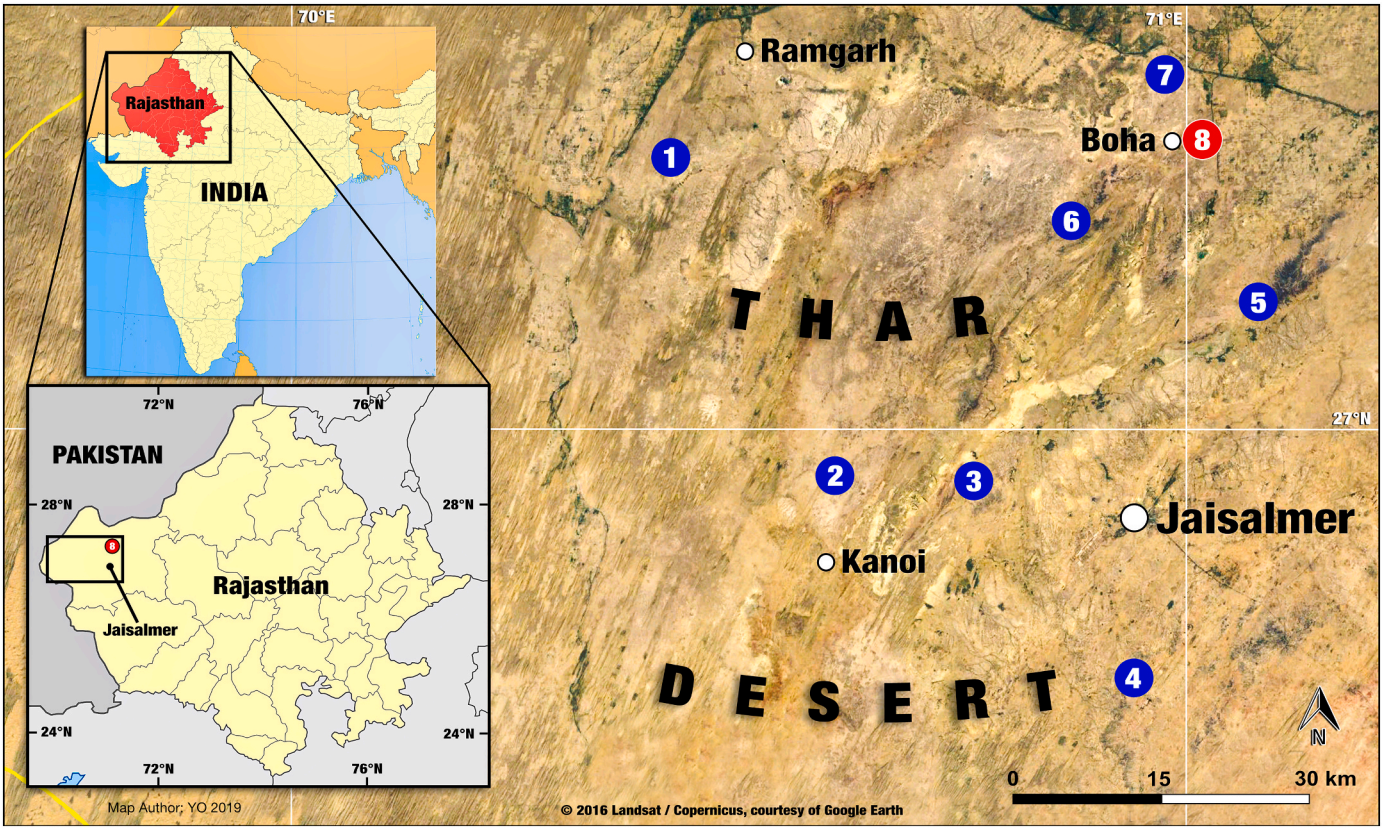

Fig. 2. Surveyed area with satellite imagery. Location of geometric line concentrations and studied area No. 8. Altitude of the photo: 130 km.

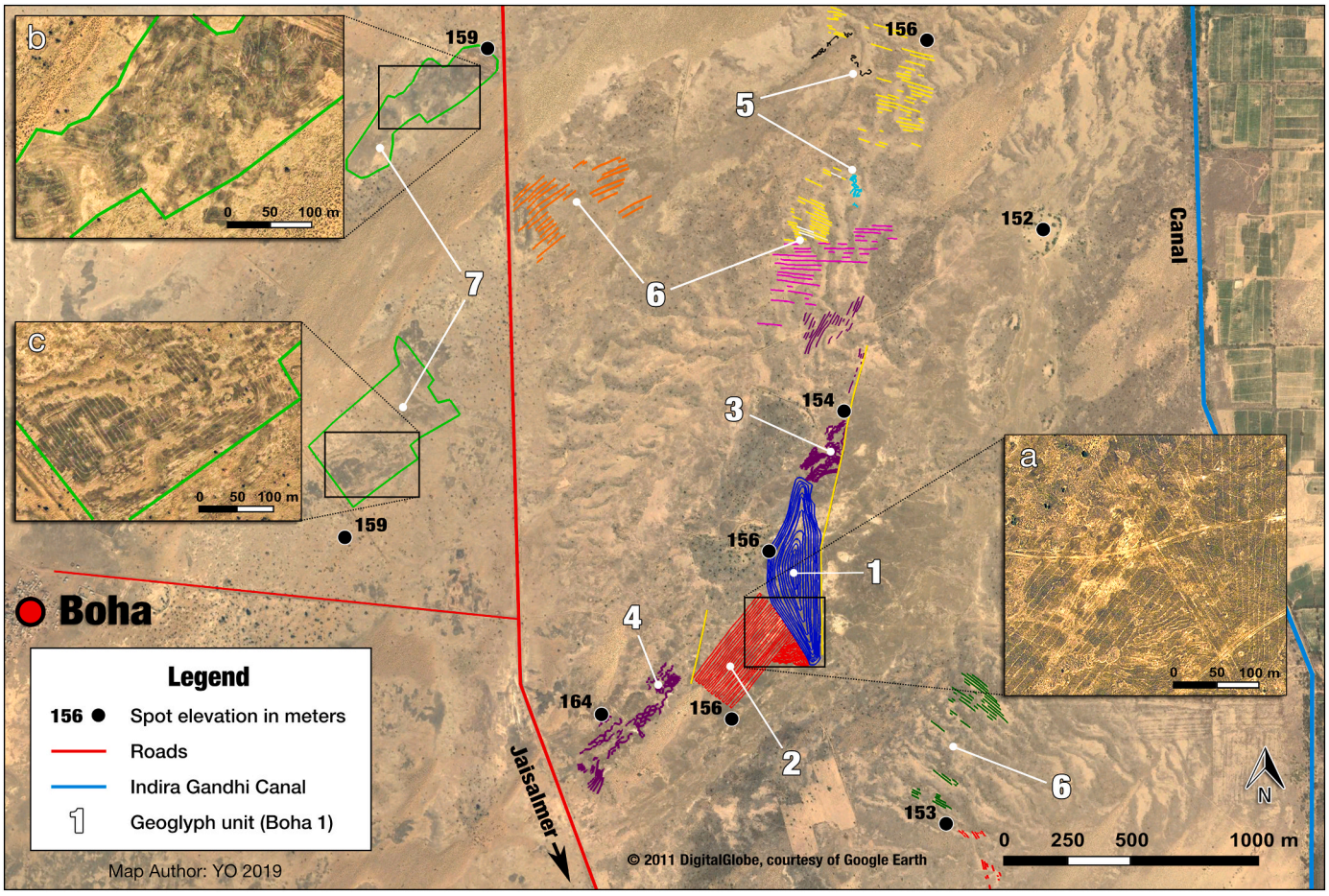

Fig. 3. Geographical environment of the Boha geoglyphs (altitude of the photo: 4.6 km). Nos. 1, 2, 3 and 4: main units. No. 5: other curved lines. No. 6: parallel lines. No. 7: lines excluded from this study.

contrasts. Google's software allowed us to monitor the evolution of the site over 10 year. Its features have been used to define the geographical coordinates, altitudes, lengths and surface area of the geoglyphs.[1] Based on the information collected, we were able to subdivide them into 4 iconographic units.

4.1. *Boha 1: a giant spiral*

The largest geoglyph unit draws a huge asymmetrical spiral of almost 12 km, 724 m long and 201 m wide. Two kilometers of barely visible or absent sections, mainly on sand sheets, have been carefully reconstructed (Table 1, Fig. 5).

Starting from its center, the spiral begins with a NS line slightly convex to the west. It makes a first 180° turn to the north after 132 m, which is barely visible. The following curves reproduce this simple shape with a double orientation change. The figure has a total of almost 12 dextrorotatory windings, gradually metamorphosing. With the ninth turn, the layout becomes more complex. The west side is characterized by a series of twelve arcs equidistant from the center, while to the east, the lines are almost straight and some have a perfect NS orientation. (Fig. 6a, b).

4.2. *Boha 2: a serpent-shaped composite pattern*

This unit is formed by a single line about 11 km long, with a five-sided polygon contour. It covers 8,8 ha and is aligned on the SW flank of the spiral. A total of 2.5 km of eroded or poorly visible sections have been reconstructed (see Table 1). Whether linear, or curved, this line can be broken down into three iconographic subunits of decreasing length (Fig. 5).

4.2.1. *A 9250-m boustrophedon sequence*

Starting from the SW end (milestone M2), this pattern forms a sequence of 23 subparallel straight lines connected by two sets of 11 U-shaped half-turns (Fig. 4c). By analogy these curves replicate a boustrophedon (from the Greek *bous* 'ox' and *strophē* 'turn'). This term refers to primitive writings whose lines can be read from left to right and then from right to left, in the same way a plow travels in a field. The inflection points in the lines generate a gap of 4.7–14 m between them.

4.2.2. *A 1450-m serpent-shaped pattern*

As it continues to move back and forth, the route changes with a short straight line of 47 m, parallel to the boustrophedon. The second 65 m segment follows a slight curve and begins a change of direction. After the fourth curve, the line becomes clearly sinuous and adopts a serpentine shape. At this point, the half-turns are forming hairpin curves with varied bend radius. Although the parallelism is imperfect, the undulations are sometimes replicated from one line to another.

[1] The field test measurements gave identical lengths to those of Google Earth, which is reliable in poorly rugged areas.

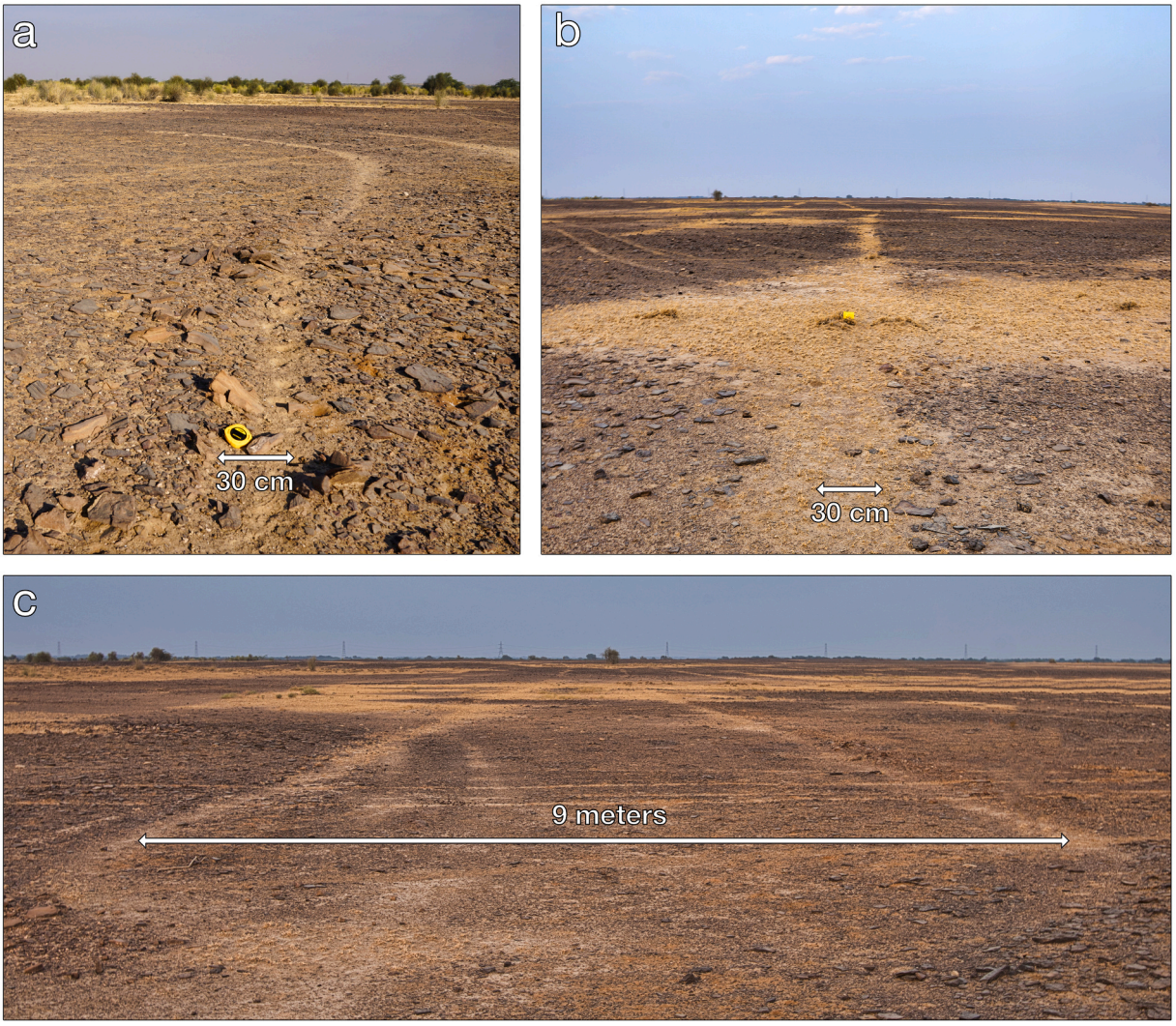

Fig. 4. Close-up views of the lines (see Fig. 5 to locate the photos). (a) Line with a depression on the desert pavement. (b) Vegetated line with sand matrix and silts (aspect during the dry season). (c) U-shaped curve with displaced materials mainly on the convex side.

Table 1
Dimensions of Boha 1 and 2 iconographic units.

Unit name	Coordinates[a] Latitude N / Longitude E	Elevation (m)	Line length (m)	Reconstituted length (m)	Reconstituted length (%)	Geoglyph length[b] (m)	Geoglyph width[c] (m)	Perimetre (m)	Area (m^2) [ha]
Boha 1	27°16′35.17″ 70°59′19.49″	154–158	11,976	1995	16.7%	724	201	1590	99,167 m^2 [9,9]
Boha 2	27°16′24.97″ 70°59′13.18″	159–155	11,000	2552	23.2%	439	335	1343	87,748 m^2 [8,8]
Total	–	–	22,976	4557	–	–	–	–	186,915 m^2 [18,7]

[a] Recorded in the center of the pattern.
[b] Maximum length.
[c] Maximum width.

4.2.3. A 300-m ovoid spiral

The line ends with a small oblong spiral, forming a little more than two complete turns. In its central space, it operates a series of four meandering loops. Its ending has been eroded by vehicles passing through this area. Starting from the center of the spiral, the rotational direction of the line is dextrorotatory, just like Boha 1.

4.3. Boha 3 and 4

These two iconographic units, adjacent to the previous ones, draw about 80 serpentine lines between 40 and 200 m long (Fig. 3, Table 2). Boha 3 forms a cluster of lines oriented towards the NE, immediately at the apex of the giant spiral. Boha 4, on the other hand, is located about fifty meters away, SW of the boustrophedon. We experienced more difficulty achieving a precise mapping because many of these lines are

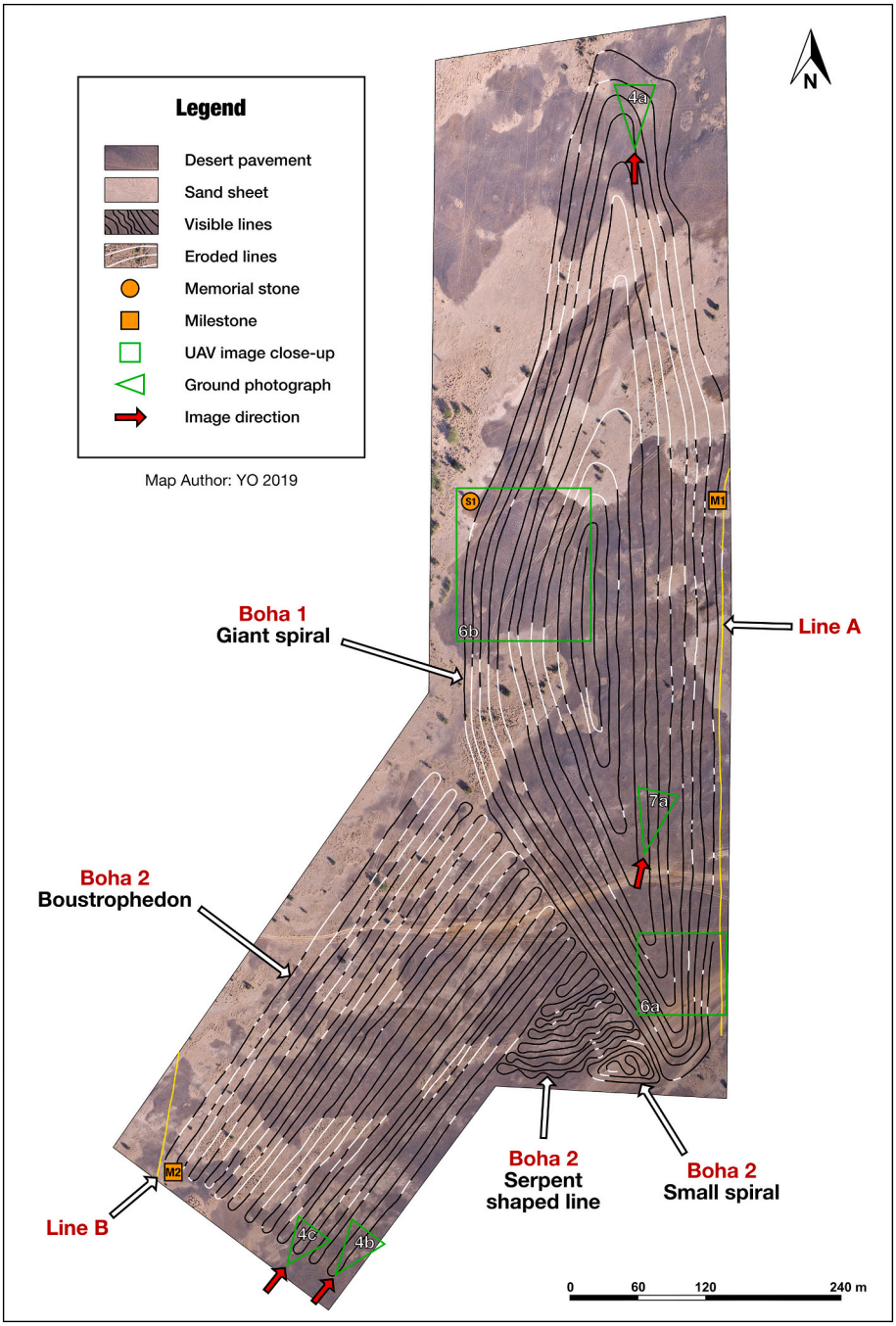

Fig. 5. Orthophoto of Boha 1 and 2 graphic units composed of images taken with the UAV at an elevation of 100 m, with reproduction of visible lines on the desert pavement, reconstituted lines on the sand sheets and location of the close-ups in Figs. 4, 6 and 7.

heavily eroded. They have generally random sinuosities and adopt rhythmic undulations that look like braids in two areas (Fig. 6c).

4.4. Peripheral lines

We discovered a series of short parallel lines with regular spacing and some remains of sinuous sections north and southeast of the main units (see Unit No. 6, Fig. 3). These traces indicate that the Boha lines showed a major extension before being eroded. The presence of U-turns similar to those of the boustrophedon are rare. There was no presence of elaborated pattern in these areas.

Two lines marked A and B deserve special attention (Figs. 3, 5, 8 and Table 2). The first runs along the eastern side of the giant spiral for 420 m, with an almost perfect south-north orientation (azimuth 359.31°). It shifts its course eastward by 13° near the M1 milestone and then joins Boha 3. We noted that several sections of parallel lines run along line A and create a bridge between the four main units and the lines found further north (Fig. 3). Line B shares two characteristics with line A: an almost identical azimuth of 13.13° and the presence of a landmark at its southern end (milestone M2). These significant observations, along with the NS oriented lines of the spiral, reveal that the whole drawing is based on intentionally chosen azimuths.

5. Construction process

The Boha geoglyphs total 48 km of still visible lines, concentrated on

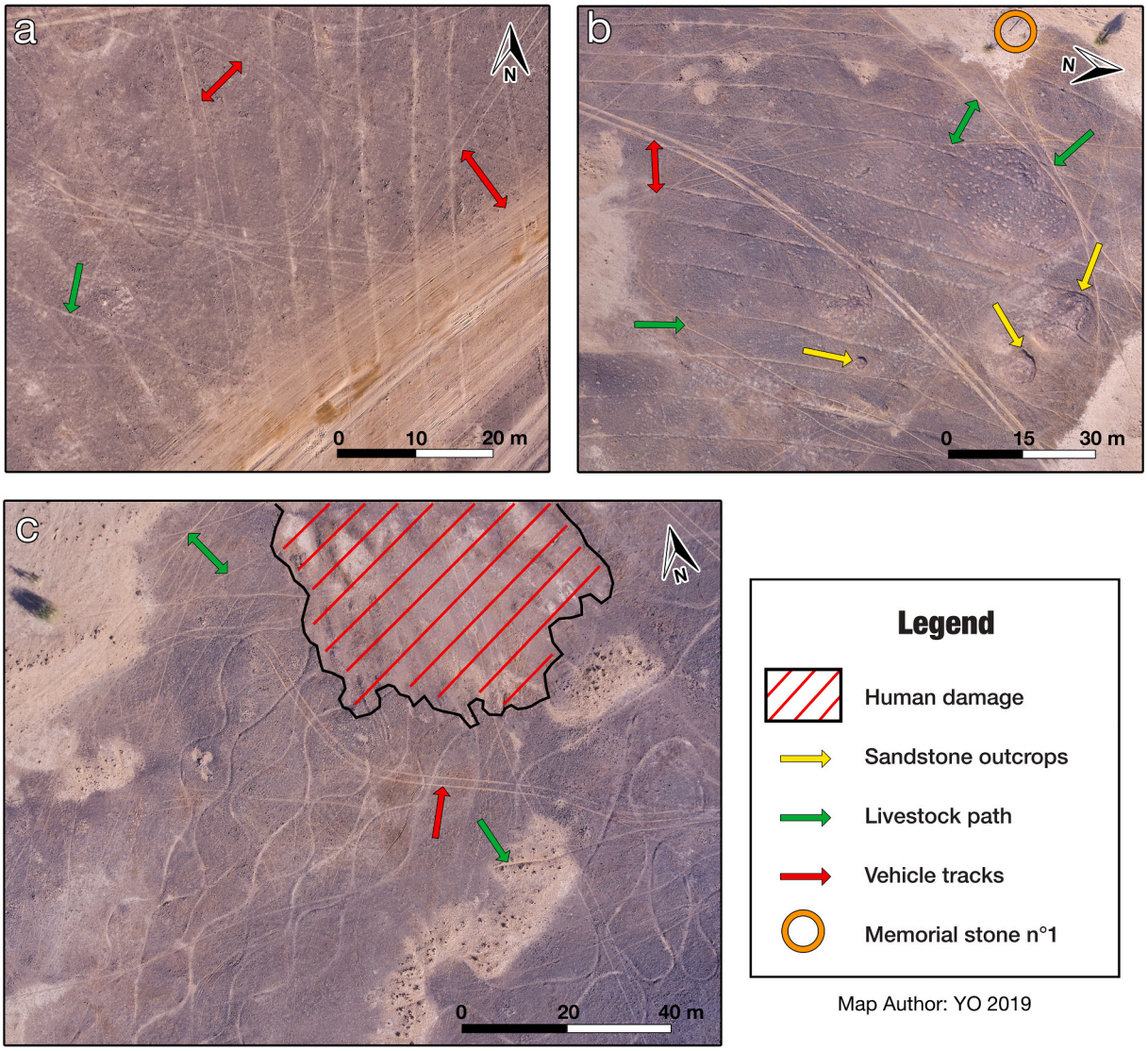

Fig. 6. Close-up UAV photographs shot at 100 m above the ground. (a) South sector of Boha 1. Note that the lines are still visible on the runway, despite vehicle erosion. (b) Central part of Boha 1. (c) Boha 3 meandering shaped lines, partly destroyed by human activity.

Table 2
Lines related to Boha 1 and 2. See Fig. 3 for their location.

Name	Coordinates[a]	Elevation (m)	Total length[b] (m)
Line A Two straight sections	–	153–158	1215 (183)
Straight Line B	–	159–157	290 (117)
Boha No. 3 32 serpentine shaped lines	27°16′50.38″N 70°59′24.06″E	155–154	2796
Boha No. 4 48 serpentine shaped lines	27°16′16.10″N 70°58′55.20″E	163–157	3226
Other serpentine shaped lines (No. 5)	–	154–153	850
Subparallel lines (No. 6)	–	152–155	17,055
Total	–	–	25,432

[a] Coordinates recorded at the center of the pattern.
[b] Reconstituted lengths in parentheses.

a small territory of 2.5 km^2. We estimate that their initial extension reached around 80 km. The giant spiral and serpentine figure are definitely the major points of interest, closely connected to Boha 3, suggesting that all the other geoglyphs were created as a framework for this set. Due to their spatial contiguity, patterns 1, 2 and 3 can be perceived as a sequential project. We still have to identify the semantic relationships binding them. However, we can interpret the construction stages of this triptych, guided by their layout and the principle of simplicity.

The M1 milestone was probably positioned first, at the same latitude as the memorial stone No. 1, which is located only 5 m away from the giant spiral. The latter existed before the geoglyphs or was positioned at the time of their creation to be used as a focal point (see Section 6). The imaginary 201 m-long segment connecting these two monoliths has a perfect EW orientation (azimuth 89.43°). Line A is perpendicular to this segment and may have been built during a second stage. Its azimuth close to 0° could have been used as a reference to build the giant spiral, starting probably from its center. The boustrophedon was then added to its SW flank, starting from the M2 milestone (Fig. 5). Boha 3 completes this main complex to which we can associate unit No. 4, based on its iconographic similarities.

Several observations provide indications of the techniques potentially used to build these geoglyphs. On the desert pavement, rock fragments and sandy matrix have been removed and form small protuberances, on either one side of the furrows, or on both sides (Fig. 4a and c). In addition, the curves often have a regular roundness and the accumulation of debris is mainly on the convex side. Elsewhere, the line is not distinguished as a depression but by a difference in its components

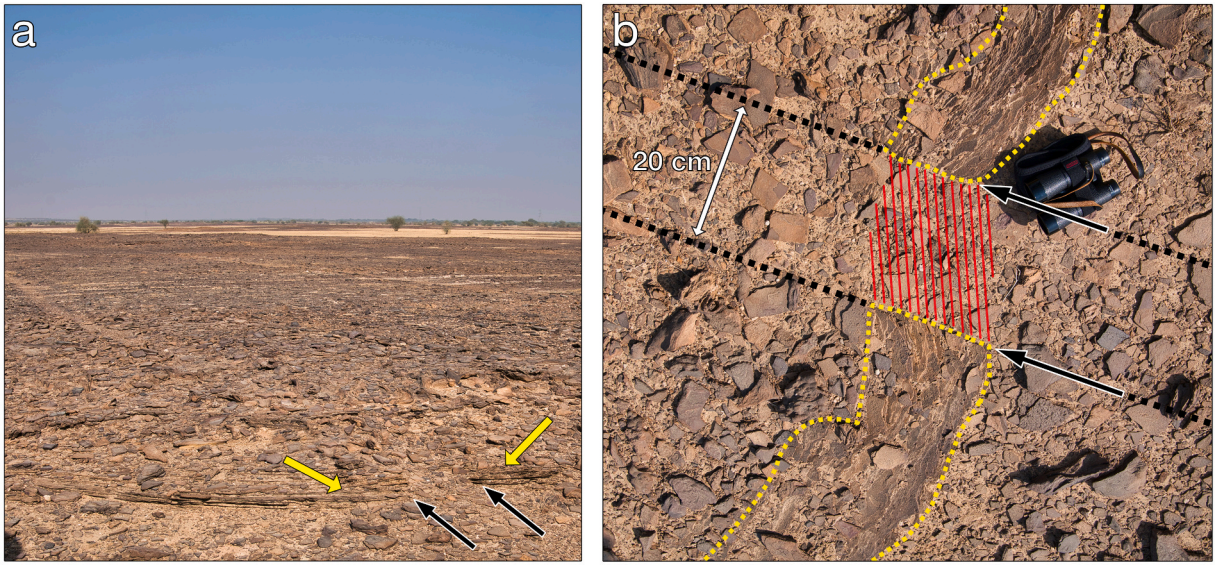

Fig. 7. (a) Carved outcrop: yellow arrows. (b) Vertical close-up view. Outcrop limits: yellow dotted lines. Carved surface: red hatching. Course of the line: black arrows and black dotted lines.

and a chromatic contrast between light sands and the dark rock fragments surrounding them (Fig. 4b). Our observations suggest that a plow-type tool could have been used, possibly pulled by a camel on loose deposits, as commonly practiced by the Thar Desert farmers. This process, which does not exclude manual finishing, would explain the many inflection points in the lines. It should be noted that a small rock outcrop has been carved, indicating a concern to preserve the continuity of the line (Fig. 7). These observations suggest that the creation of the Boha geoglyphs did not represent a considerable labor investment.

6. Relative dating

The Boha geoglyphs do not have any crossings and therefore no overlapping lines, which indicates, with a high degree of probability, that they belong to the same construction sequence. Upon careful examination of several indicators, we may assume that their construction dates back several decades. The herbaceous vegetation, well developed on some portions of the lines, is a first indicator of age. The very slow vegetation conquest in this arid environment is drastically slowed by overgrazing.[2] Furthermore, two scenarios were observed, depending on the type of deposit. On abiotic pavement, the lines have favored the growth of grasses, particularly on certain sections of the boustrophedon.[3] Their construction has temporally improved soil conditions by destroying the surface crust, exporting coarse debris and forming a depression that concentrates the scarce rainfall (Fig. 4b). Conversely, on sand sheets, the vegetation cover shows a similar stage of evolution, both on the lines and on the adjacent areas. About thirty small trees are growing on this territory, but none of them on a line.

A second indicator concerns the crust mentioned above, which has had sufficient time to reform after being destroyed, and since then, has attenuated the erosion of the lines.

The degree of weathering of a surface depends to a certain extent on its exposure time to geomorphic agents. Three observations illustrate this age indicator:

- In general, surface runoff and even more wind erosion have obliterated the lines on sand sheets and greatly reduced their visibility on desert pavements;
- The carving on a sandstone outcrop is now filled with compact debris (Fig. 7b);
- The significant wind erosion of the M2 milestone (Fig. 8c), reveals prolonged sand abrasion.[4]

It remains impossible to date the Boha geoglyphs unambiguously solely on the basis of what we observed in the field. A conservative assumption deduced from the above-mentioned indicators, suggests that they may be at least 150 years old. It is however conceivable that they were built at the beginning of the British colonial period, in the middle of the 19th century. According to this hypothesis, the lines could be contemporary with the neighboring memorial stones.[5]

7. Function and meaning

It is difficult to interpret the purpose of the Boha geoglyphs without a reliable dating and a cultural affiliation. Furthermore, function and meaning are interconnected themes and as long as the latter has not been elucidated, the former will remain questionable. Nevertheless, our observations allow us to suggest various hypotheses and exclude others.

7.1. Visibility

When choosing the location of some of the Palpa geoglyphs, Lambers and Sauerbier showed that good visibility may have been an important criterion. The data collected in the field combined with a statistical analysis, led them to the conclusion that many geoglyphs were stages of gatherings and ceremonies, that could be observed from a distance Lambers and Sauerbier, 2006, 2007). These studies establish a close relationship between location, visibility and function, also stated for the geoglyphs of the Lluta Valley in Northern Chile (Briones, 2006; Ross

[2] The Thar Desert is the most populated of all deserts with 83 inhabitants per km^2. Its population has quadrupled and livestock has doubled in 50 years, generating exponential anthropogenic pressure, especially at the expense of the vegetation (Kar, 2014).

[3] See the after-monsoon Google Earth satellite image from Oct. 2, 2011.

[4] The M1 milestone does not have such a high degree of erosion. This can be explained by the absence of abrasive sand in the vicinity and a higher resistance of its lithofacies (see Fig. 8b).

[5] The memorial stones with images seem to have been erected in the 19th or 20th century, as the figures are very crude which reflect the style of later period (Z. A. Kalhoro, personal communication, July 7, 2019).

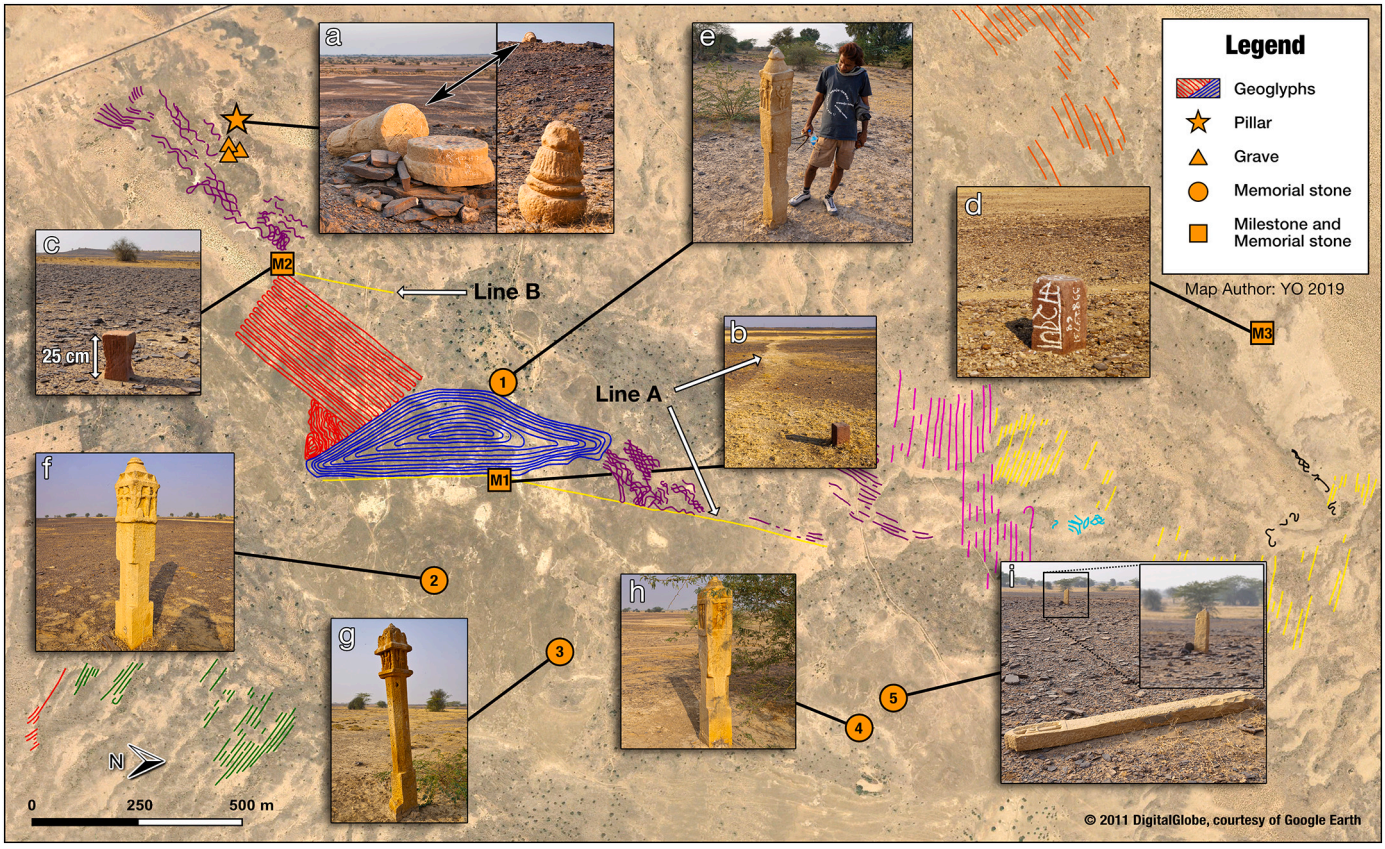

Fig. 8. Archaeological artifacts in the vicinity of geoglyphs and location of the parallel lines A and B.

et al., 2008). However, it is not possible to transpose this hypothesis to the Boha geoglyphs, because of the virtually fat landscape. Only a bird's-eye view 300 m above the ground would lead to the perception of the main complex as a whole. According to this assumption, how could the creators of these ambiguous signs ensure that they were properly seen and interpreted? The question of their meaning can be raised again, with the understanding that "something is a sign only because it is interpreted as a sign of something by some interpreter" (Morris, 1938, p. 4). In any case, the lack of visibility excludes the possibility of artistic expression, intended to be contemplated from the ground and invites us to consider religious, astronomical and/or cosmological meanings. Finally, because of their uniqueness, we can speculate that they could represent a commemoration of an exceptional celestial event observed locally.

7.2. Memorial stones and graves

A variety of archaeological artifacts can be found on the territory of the geoglyphs. During our fieldwork in 2016, we located a total of 9 monoliths with various shapes. The most imposing one is a truncated conical pillar measuring about 1.60 m.[6] It is composed of a base still in place, a massive column and a collapsed top part (Fig. 8a). Roughly carved with geometric drawings, it is covered with inscriptions marked with white paint, that can be found on other monoliths and which shows a still vivid devotion from the locals (Fig. 8d). This pillar was erected on the only topographic prominence, allowing a 360° panoramic view. Three degraded cairn-like structures of loose stones, situated about 40 m below, are similar to graves and indicate possible funeral activities. We also located four memorial stones with sculptures of Hindu deities (e.g. Krishna and Ganesha), two of them being carved with inscriptions whose writing is still to be identified (Fig. 8e–h). A fifth monolith, also with inscriptions and broken at the base (Fig. 8i), is a Sati stone (Settar and Sontheimer, 1982; Kalhoro, 2010, 2015). Finally, we localized three rectangular stones, M1 and M2 already described as landmarks, and M3 considered by Kalhoro as simple memorial stone which might commemorate a common deceased person (Fig. 8b, c, d). The inventory and the study of these archaeological artifacts needs to be completed in order to establish a possible sacred dimension of the lines related to worship activities.

Memorial stones and abandoned cemeteries are common in the Thar Desert. We found similar features within the site No. 3, east of Jaisalmer (Fig. 2). However, without chronological evidence, we cannot contextualize the Boha geoglyphs on a regional scale.

8. Discussion

The geoglyphs of the Thar Desert have a limited number of patterns, drawn over a small area. Nevertheless, their discovery is remarkable for the following reasons. The monumental size of Boha 1 and 2 is particularly impressive and requires a complex way of thinking with regard to their design and implementation. Knowledge of mathematics and planimetry has necessarily been used to realize these figures. Originally, they were probably designed on a large-scale plan. This statement is supported by the position of memorial stone 1 and millstones M1 and M2, probably used as landmarks to build this huge complex (see Section 5). We still need to understand the reasons for this gigantism, a question that is linked to that of their function. The 724 m long spiral consists of a spectacular 12 km line that winds harmoniously over an area of 10 ha. Such dimensions have no equivalent worldwide. For instance, the *Big*

[6] This pillar might have been taken from the abandoned Hindu or Jaina temples and reused as memorial stone (Z. A. Kalhoro, personal communication, March 3, 2019).

Cross of Ashutasty, Turgay's largest pattern, has a maximum length of 436 m (Motuzaite Matuzeviciute et al., 2015; Logvin et al., 2018), all the 15 Nazca spirals we measured on Google Earth have a diameter inferior to 85 m, and the 4405 m long Nazca line, interpreted as a labyrinth, is still 2.7 times smaller (Ruggles and Saunders, 2012). After extensive research, we consider the Boha geoglyphs to be the largest abstract and organically arranged man-made geometric figures discovered so far.

The design and juxtaposition of the spiral and serpentine figure are also unique, considering their complex and singular shapes. We did not find any comparable drawings yet, therefore Boha is an iconographic *unicum* whose signs raise numerous questions including: why do all the lines have a beginning and an end? Why don't they ever cross? How can we interpret the NS orientation of Boha 1 and the 13° azimuth of lines A and B? What is the semantic relationship between the spiral, the serpentine figure and the Boha 3 and 4 line clusters?

These geoglyphs are the first to be discovered throughout the Indian subcontinent and as such contribute to our knowledge of these universal and polymorphic artifacts. This statement should attract the attention of Indian decision-makers and will hopefully urge them to take action to protect this extremely fragile heritage. Raising awareness among the inhabitants passing through this land is a priority, since the damage of the site is mainly of human origin. The construction of a dike has definitively erased 2300 m^2 of lines at the expense of Boha 3 (Fig. 6c); but above all, the vehicles running over the geoglyphs have recently had a disastrous impact (Fig. 6). They were rare to transit before March 14, 2004, as can be seen on the satellite image of that date. The southern runway, which, interestingly, made a detour to avoid the lines, was the busiest at the time.

The last specificity that deserves to be highlighted concerns the impossibility of observing these figures from the ground. For this reason, we do not consider that they have been used for collective ceremonies, nor as landmarks bearing messages. However, before answering the questions of the geoglyph function and meaning, it is necessary to gather a set of convincing evidence to identify the intention of the authors of such an enigmatic work. To this end, an anthropological investigation among the natives and an attempt to date the lines by thermoluminescence are essential. New observations in the field will also allow a symbolic and archaeoastronomical interpretation of the principal signs. Nevertheless, at this stage of the research, we remain convinced that these unique geoglyphs are closely connected to their geographical and cultural context, and possibly contain a universal message linked to the Sacred and the cosmos.

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Credit author statement

Carlo Oetheimer: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data Curation, Writing- Original draft preparation,Writing- Reviewing and Editing, Visualization, Supervision, Project administration.

Yohann Oetheimer: Conceptualization, Investigation, Resources, Data Curation, Writing- Original draft preparation, Writing- Reviewing and Editing, Visualization.

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