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Back to the Ḥawlān: a Geoarchaeological Remote Sensing Analysis of the Yemeni Highland Bronze Age

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Abstract

In 1981, the Italian archaeological Mission in the Republic of Yemen identified sites dating to the Yemeni Bronze Age during their work in the Ḥawlān area of the Yemeni highlands and, in doing so, first displayed the richness of a region that was still totally uncharted. Since then, over 40 years of international research on the 3rd–2nd millennia BCE throughout Yemen has recorded data from both architectonic (settlements and funerary panorama) and material culture points of view. This paper shares new remote sensing data of the Ḥawlān region to evaluate the state of settlements discovered in 1981 by Alessandro de Maigret and his team. Moreover, thanks to the availability of powerful satellite imagery instruments, this paper demonstrates that previously unrecorded information can be collected to enrich the knowledge of the Bronze Age in Yemen further.

Keywords

remote sensing – Yemen – Bronze Age – highland – landscape archaeology

العودة إلى العصر البرونزي اليمني: تحليل جيولوجي أثري بالاستشعار عن بُعد للعصر البرونزي في المرتفعات اليمنية

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الملخص

في العام 1981، قامت البعثة الأثرية الإيطالية في الجمهورية اليمنية بتحديد مواقع تعود إلى العصر البرونزي في المرتفعات اليمنية وذلك خلال عملها في منطقة خولان، وبذلك أبرزت لأول مرة الثراء الأثري لمنطقة كانت لا تزال مجهولة تماماً. ومنذ ذلك الحين، وبعد مرور نحو 40 عامًا من الأبحاث الأثرية الدولية حول الألفية الثالثة والثانية قبل الميلاد في جميع أنحاء اليمن تم توثيق بيانات جديدة عن المستوطنات والمنشآت الجنائزية، وكذلك عن الثقافة المادية. تهدف هذه الدراسة البحثية إلى إعطاء نتائج بيانات الاستشعار عن بعد الحديثة لمنطقة خولان لتقييم حالة أنماط المستوطنات التي اكتشفها أليساندرو دي ميغريت وفريقه في عام 1981. ويضاف إلى ذلك المعلومات المتوفرة بفضل تقنية أدوات التصوير باستخدام الأقمار الصناعية العالية الجودة. توضح هذه الورقة البحثية أنه يمكن الاستفادة من معلومات لم يتم تسجيلها من قبل لإثراء المعرفة بالعصر البرونزي في اليمن بشكل أكبر.

الكلمات المفتاحية

الاستشعار عن بُعد – اليمن – العصر البرونزي – المرتفعات اليمنية – علم آثار المناظر الطبيعية

1 Introduction

1.1 *Back to Ḥawlān*

This paper summarizes the first results obtained by the remote sensing laboratory of the University of Naples L'Orientale concerning the Bronze Age in the southern Arabian Peninsula, with a focus on the highland region of Ḥawlān in Yemen (Cozzolino 2022). It shares remote sensing data for the Ḥawlān region and virtually revisits the archaeological sites discovered in 1981 by Alessandro de Maigret and his team (Italian archaeological Mission in the Yemen Arab Republic). Due to the lack of direct on-the-ground access for foreign archaeologists, remote tools enable researchers to monitor endangered heritage

and conduct further research using a landscape archaeology approach. Powerful leveraging of satellite imagery (Google Earth, Bing Map, and GloVis as open access repositories; Landsat imagery (Loreto 2024), high-resolution PNEO, and Kompsat 3a imagery) offers the possibility of new data collection strategies to advance knowledge of the Bronze Age in Yemen.

Due to the political and humanitarian conditions in Yemen, ground-truthing of remote datasets is not currently possible. Therefore, secure verification of the detected evidence is lacking. Instead, this paper evaluates remote sensing data against the previously collected and published data on the Yemeni Bronze Age, especially the work of de Maigret and his team and, to a lesser extent, the research of the American project in Dhamar. Another important resource for evaluating the remote sensing data collected is the *Ancient Yemen Digital Atlas* (AYDA). Developed by the German Archaeological Institute (DAI), AYDA is a WEbGIS that can be considered a pioneering effort for remotely monitoring Yemeni heritage (Schoeneberg 2018). Ḫawlān is included in AYDA, although without a detailed mapping of the complex and articulated network of Bronze Age villages and hydraulic structures known to be present in the area.

1.2 *"A Bronze Age for Southern Arabia"*

1.2.1 The Discovery

The discovery of the Bronze Age in Yemen dates back to 1981 with the pioneering work of the Italian Archaeological Mission led by Alessandro de Maigret. De Maigret himself stressed the strong effect that the discovery had on the mission at that time, as can be deduced from his own words: "The enthusiasm for the discovery shines through the title of the first news article which I published about *A Bronze Age for Southern Arabia*" (de Maigret 1996: 127). Since then, archaeological projects led by Americans, French, English, Russians, Germans, and Yemeni missions have illuminated a general understanding of the cultural developments that characterized the period before the flourishing of the South Arabian kingdoms (Buffa 2000).

1.2.2 The Ḫawlān Bronze Age

In the Ḫawlān region, Bronze Age sites chronologically extend throughout the 3rd millennium BCE and the first part of the 2nd millennium BCE. The main features of these sites, specifically the architectonic ones visible from space, can be summarized by defining settlements distributed according to the agricultural possibilities of the area. The settlements are divided into two types: minor sites (smaller than 1000 m^2) and major ones (greater than 10.000 m^2). Houses are formed by two oval rooms linked with each other, opening onto a central court. House walls at these sites usually have a thickness of more than 50 cm and thus are identifiable on satellite imagery with a ground resolution of up to 30 to 50 cm (minimum pixel dimension). The socio-economic orientation of these communities was typical of sedentary communities practicing agriculture and breeding (de Maigret 1984, 1990, 1996, 2000). In the Ḫawlān region, initial experimentation with agriculture during the Bronze Age took place, which permitted a subsequent adaptation to the more arid regions surrounding the desert margins of the Ramlat al-Sabʿatyn and coastal environments.

Beyond doubt, the complexity of the South Arabian Bronze Age is not only demonstrated by the various settlement patterns and development of agriculture and hydraulic strategies but also involves traces of contact with the north visible in the circulation of shared iconographies, weaponry production, obsidian exchange, and display of funerary architectural models: features that open further possibilities for research within a Bronze Age horizon. In this complex picture, the bulk of data related to the definition

of settlement strategies is indeed in the highland and Ḥawlān al-Ṭiyāl area, where our work has focused, and the remote sensing verifies its spatial extent.

2 Geoarchaeological Remote Sensing Approach to the Ḥawlān al-Ṭiyāl

2.1 *Methods of Identification, Classification, and Deduction*

This study followed a geomorphological approach to remote sensing. This approach involves utilizing techniques and methods to study environmental objects and phenomena (bio-physical) through radiometric measures recorded by sensors installed on the ground (tripods, lifts), aerial equipment (balloon, airplane), and spacecraft (satellite, shuttle). Remote sensing methods also include the elaboration and interpretation of images based on the study of the spectral properties of the objects seen as entities with uniform morphologic-spectral features inside a complex and diversified visual frame.

The archaeological investigation through satellite imagery, based on the interaction between archaeology, geomorphology, geology, and ancient toponymy within the GIS field, has been tested by the archaeological missions of the University of Naples L'Orientale for over a decade (Loreto and Marcolongo 2023). Starting from the morphologic and morphometric interpretation of surface markers (soil humidity, vegetations, microreliefs), images can be analyzed in four phases: individuation, identification, classification and deduction (Marcolongo 2000).

The methodology employs a predictive model based on the geomorphological key elements of the palaeo-environment that may have attracted people in the past attributable to archaeological sites. Key elements of the landscape to be identified include the palaeo-hydrographic system of a region, ancient traces of water courses, and archaeological sites (Loreto 2020). This methodology of investigation is often used to investigate landscapes prior to fieldwork, and also offers an alternative way to conduct research in inaccessible areas.

Essentially, we adopt an approach based on the archaeology of the landscape, a methodology that contemplates not only the observation of a specific site but also the regional trends that provide context: for example, the chronological development of a site and its continually changing relations with the surrounding area. Thus, the geoarchaeological approach is fundamental not only to the remote detection of archaeological sites but also to understanding their contemporary paleoenvironmental context (Loreto 2020).

2.2 *Methodology Applied to the Ḥawlān al-Ṭiyāl Area*

For our investigation of the Ḥawlān area, we first georeferenced digital maps including site plans from the excavation report published by de Maigret (de Maigret 1990). To do this, we layered the archaeological maps with satellite images (Landsat/Copernicus) available on Google Earth Pro and compared features present on both (fig. 1). These features were of three kinds: elevations, rivers, and modern highways. Working first from more general digital maps, it was possible to correctly position the more detailed maps on which the sites were originally reported. This procedure enabled us to locate previously excavated/surveyed sites on satellite images, and georeference them.

The first two general maps positioned over the satellite images were the Ḥawlān map (de Maigret 1990: 233), (fig. 2) and the hydrographic map of the same region (Edens 1999: 107), (fig. 3). Similar morphological features were identified using the "flickering" technique, a process of activating and deactivating an overlaid image in order to accustom the eyes to observing the common features. Further detailed maps of as-Suhmān region,

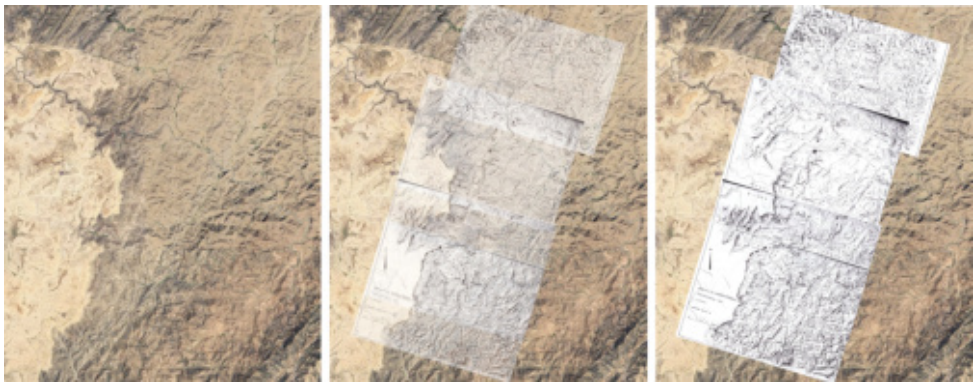

FIGURE 1
Example of the georeferencing process of the whole topographic dataset of sites visited by de Maigret (modified after de Maigret 1990: 233)

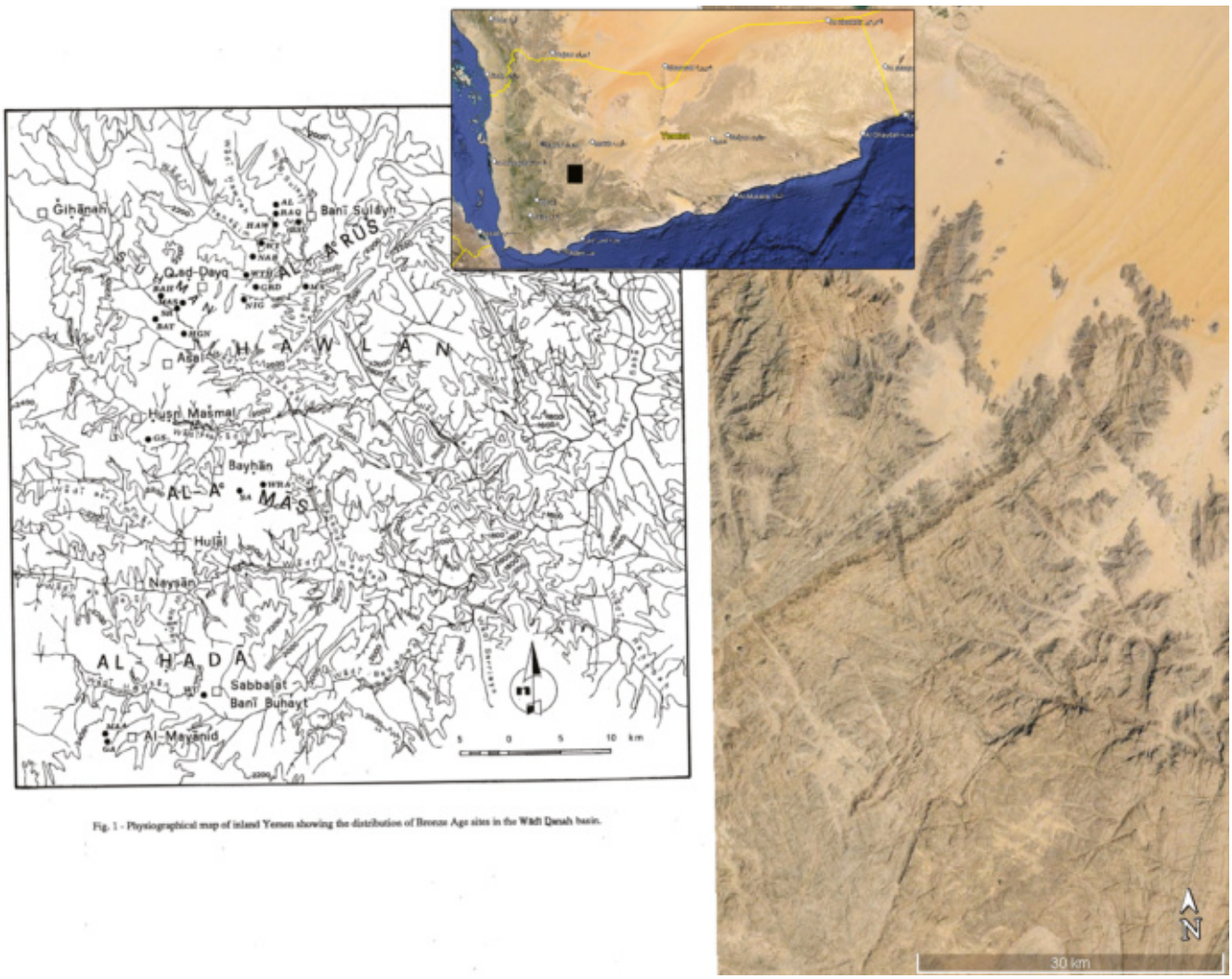

Fig. 1 - Physiographical map of inland Yemen showing the distribution of Bronze Age sites in the Wādī Ḏanah basin.

FIGURE 2
The georeferenced Ḥawlān map produced by de Maigret (the bulk research area of the remote sensing analysis) (modified after de Maigret 1990: 233)

Qarāz region with Ǧabal Hamra and Bani Sulayḥ, were also positioned (de Maigret 1990: 235), (fig. 3).

Once the regional scale maps were georeferenced, we added detailed maps (fig. 1) in which it is possible to identify all the sites for which de Maigret provided an intra-site planimetric relief: site NAB vii, RAQ, WY i and NIG i–iii. The precision that characterizes this detailed topographic mapping enables us to target investigation to specific marked areas of the sites discovered by the Italian Archaeological Mission using satellite

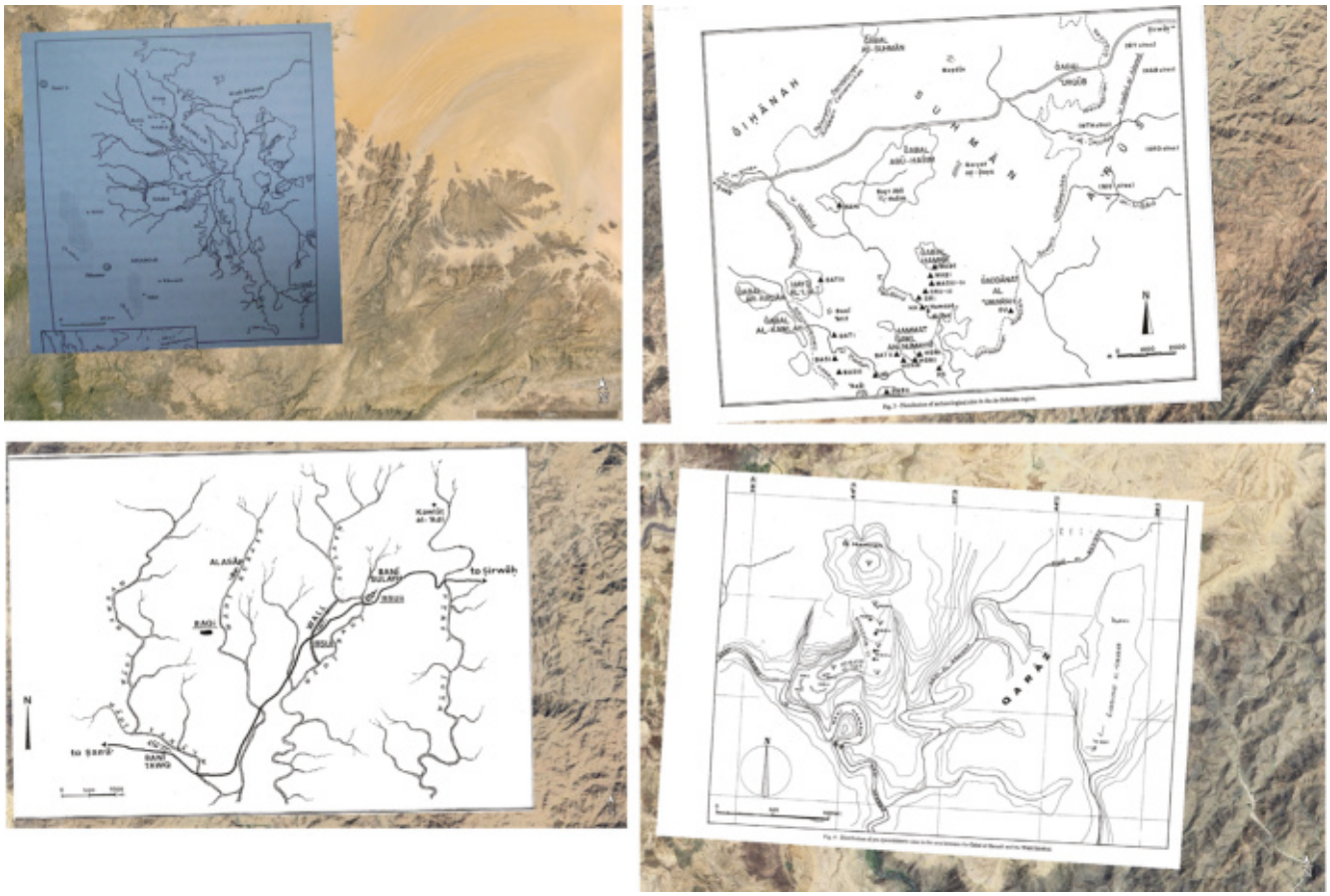

FIGURE 3
Top left: the georeferenced schematic view of the Ḥawlān hydrographic basin (adapted from Edens 1999: 107); top right: as-Suhmān region; bottom right: Qarāz region with Ǧabal Ḥamra; bottom left: Bani Sulayḥ (modified after de Maigret 1990: 235)

imagery. Furthermore, once located on the imagery, we can confirm difficult site identifications simply by overlaying the planimetric sketches produced by de Maigret over the satellite images. Using this technique, we identified the Ḥawlān sites of NAB vii, WY i, RAQ, MAS i, and BAH i based on the strong morphological feature correspondences characterizing both the planimetric reliefs and the sites in question as they appear on satellite images.

2.3 *Reidentified Ḥawlān Sites*

NAB vii (fig. 4).

This is one of the best-preserved sites investigated, disturbed by local shepherds; the Islamic pottery found on the surface suggests that a small settlement was created here for herding (de Maigret 1990: 18). The excavation of the site shows the Bronze Age stratigraphic sequence on a yellow sand layer above a grey clayey layer dating back to the Neolithic (de Maigret 1996: 118). The planimetric relief realized by the mission and the satellite images dated to 2013 correspond perfectly in shape and dimensions.

The latest satellite images of this site date to 2021, at which point the site was still preserved.

WY i (fig. 5)

The original planimetric relief of WY i shows numerous circular and semicircular structures joined together to form an isolated compound. On the north-eastern angle of the site, a structure similar to a turret tomb was detected.

FIGURE 4
NAB vii georeferencing process (modified after de Maigret 1990: portfolio at the end of the volume)

FIGURE 5
WY i georeferencing process (modified after de Maigret 1990: portfolio at the end of the volume)

The individual dwelling units appear to be linked to form arc-shaped complexes, which are, in turn, connected by shared rooms, giving the complex a lace-like appearance typical of settlements of this period. The site was defined as one of the biggest protohistorical agricultural villages in Yemen (de Maigret 1990: 13).

On the satellite images, the position of WY i is certain: the detailed map of the Ḥawlān shows all the geographical features that can be found in the satellite images (mostly rivers and a highway). Nevertheless, the site does not appear in the satellite view except for a few traces of structures. From the images, it is possible to detect some signs on the ground that may be scars from bulldozers or other mechanical equipment. The site has doubtless been destroyed. In his 1990 report, de Maigret underlined the precarious conditions of the site's preservation (1990: 13).

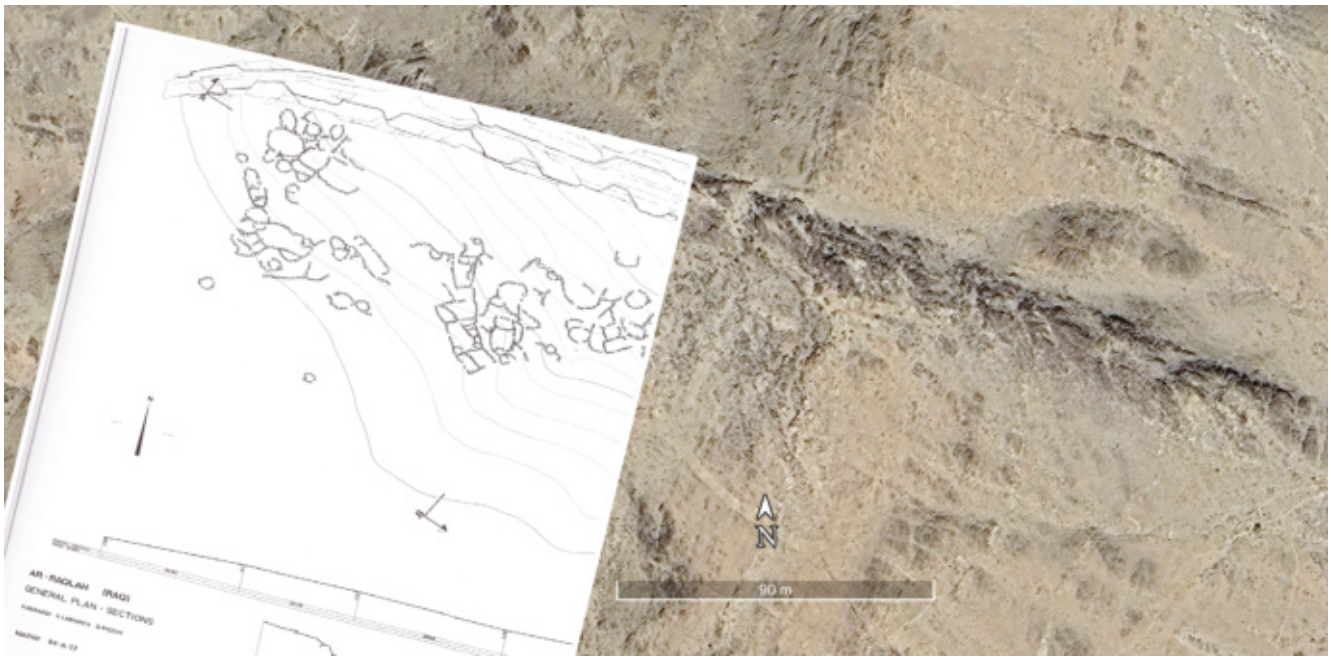

FIGURE 6
RAQ georeferencing process (modified after de Maigret 1990: portfolio at the end of the volume)

RAQ (fig. 6)
The site of RAQ extends 150 m from east to west at the foot of a dike, which protects the site from the north and serves as a quarry for its construction.

The location of this site is secure. The map shows the same geomorphological features present on the satellite image, but the site *per se* is hardly discernible in its shapes, although some features are clear enough to be seen.

MAS i
The map of Ǧabal al-Hamrāʾ and Wādī Habābiḍ serves to identify MAS i (figs. 3, 7). This site seems to match the planimetric sketch made by the Italian Mission of de Maigret. Shifting to the Google Earth Pro repository, the most precise image is dated to 2016 (fig. 8), but most of the anthropogenic features of the site can be detected even in the 2024 images.

BAH i
Owing to the low resolution of available images, this site is among the most difficult to detect using a satellite. Nonetheless, de Maigret's detailed map corresponds to satellite imagery (fig. 7).

After the remote sensing identification of the sites, we positioned all of the available planimetric reliefs produced by the Italian Archaeological Mission during their survey campaign. The correspondence between the planimetric reliefs and the satellite images is quite often astonishing, owing to the amount of detail that is included. However, the Mission did not produce planimetric reliefs for all the sites they investigated.

For the sites listed in Table 1, there is no planimetric relief, but the topographic features of the detailed map produced by the Mission enable an identification. Table 1 summarizes their coordinates, correspondence from satellite images and state of conservation until 2024. For the sites verified using the planimetric reliefs, the state of

FIGURE 7
Detailed map of Ğabal al-Hamrā' after the georeferencing process (modified after de Maigret 1990: 236)

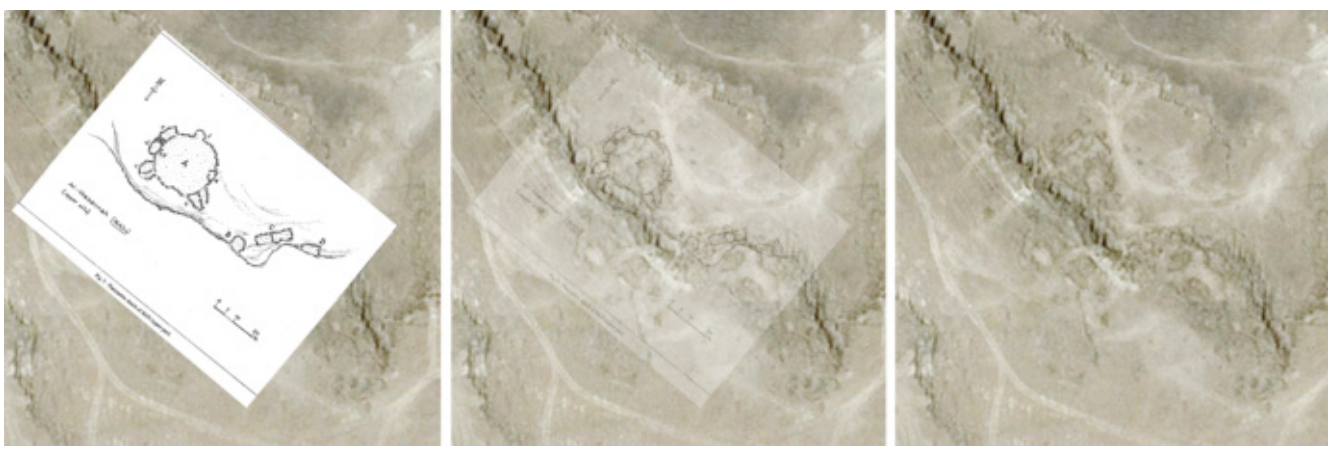

FIGURE 8
MAS i after georeferencing process (modified after de Maigret 1990: 237)

conservation has been reported with the term "intact," while for the sites without a planimetric relief, the term "good" or "bad" has been used according to the case. The term "destroyed" was used when the act of destruction was quite clear in the images. An example of a destroyed site WY i was mentioned above. Another site we determined to be destroyed is WTH iii; the satellite images show this site as surviving until August 2013. After this date, the site disappeared from the images making way for a modern building that seems to have been constructed directly on the site, possibly reutilizing the archaeological material itself (fig. 9).

Here we present a complete list of de Maigret's sites with coordinates, identification status, and state of conservation as per the open access repository of Google Earth Pro (tables 1–3).

FIGURE 9
Identification (left, 2013 imagery) and disappearing (right) of WTH iii

Name	Coordinates	Remotely identified	State of Conservation (Until August 2024)
AL	15°14'7.64"N 44°41'37.93"E	Confirmed	Good
AL i	15°13'34.03"N 44°41'51.73"E	Confirmed	Good
AL ii	15°13'37.14"N 44°41'46.49"E	Confirmed	Good
BAH i	15° 9'21.03"N 44°35'24.03"E	Confirmed	Intact
BAS i	as-Suhmān	Not found	Unknown
BAS ii	15° 5'47.98"N 44°36'2.45"E	Confirmed	Bad
BAS iii	as-Suhmān	Not found	Unknown
BAT i	15° 7'12.36"N 44°35'9.60"E	Confirmed	Damaged
BAT ii	15° 6'56.95"N 44°36'11.64"E	Confirmed	Bad
BAT iii	as-Suhmān	Not found	Unknown
BSU i	bani-Sulayḥ	Not found	Unknown
BSU ii	bani-Sulayḥ	Not found	Unknown
GA	14°45'0.04"N 44°31'38.99"E	Confirmed	Damaged
GRD	Not specified	Confirmed	Good
GS	15° 1'55.51"N 44°34'17.04"E	Confirmed	Good
GU i	15° 7'34.23"N 44°38'9.30"E	Confirmed	Good
GU ii	as-Suhmān	Not found	Unknown
HA i	Ǧabal al-	Not found	Unknown
HA ii	Ǧabal al-	Not found	Unknown
HA iii	Ǧabal al-	Not found	Unknown
HA iv	Ǧabal al-	Not found	Unknown
HAW	15°13'13.11"N 44°41'32.14"E	Confirmed	Good
HAW i	15°12'28.12"N 44°41'17.31"E	Confirmed	Bad
HAW ii	15°12'29.19"N 44°41'24.91"E	Confirmed	Bad

TABLE 1
Summary of the Ḥawlān al-Ṭiyāl sites

Name	Coordinates	Remotely identified	State of Conservation (Until August 2024)
HAW iii	15°12'32.22" 44°41'0.80"E	Confirmed	Good
HD	as-Suhmān	Not found	Unknown
HS	as-Suhmān	Not found	Unknown
HGN i	15° 6'54.93"N 44°36'39.28"E	Confirmed	Bad
HGN ii	15° 6'49.84"N 44°36'32.57"E	Confirmed	Bad
HGN iii	15° 6'47.03"N 44°36'25.88"E	Confirmed	Bad
MA	14°48'32.90" 44°30'27.46"E	Confirmed	Damaged
MAAi	al-Hadā	Not found	Unknown
MAA ii	14°45'4.13"N 44°31'26.52"E	Confirmed	Damaged
MAS i	15° 8'10.63"N 44°36'57.68"E	Confirmed	Intact
MAS ii	as-Suhmān	Not found	Unknown
MAS iii	as-Suhmān	Not found	Unknown
MAS iv	as-Suhmān	Not found	Unknown
MS	al-Aʿrūš	Not found	Unknown
NAB i	15°11'14.11" 44°40'33.13"E	Confirmed	Good
NAB ii/I	15°11'11.47" 44°40'11.57"E	Confirmed	Good
NAB ii/II	15°11'15.22" 44°40'8.27"E	Confirmed	Good
NAB iii	15°11'20.13" 44°40'11.88"E	Confirmed	Good
NAB iv	15°10'43.78" 44°40'5.54"E	Confirmed	Good
NAB v	as-Suhmān Not certain	Not confirmed	Maybe intact
NAB vi	15°10'26.71" 44°39'59.31"E	Confirmed	Good
NAB vii	15°10'57.45" 44°40'33.45"E	Confirmed	Intact

TABLE 2
Summary of the Ḫawlān al-Ṭiyāl sites

Name	Coordinates	Remotely identified	State of Conservation (Until August 2024)
NAB viii	15°10'33.65" 44°40'25.35"	Confirmed	Good
NAB ix	as-Suhmān Unverifiable	Not found	Destroyed
NAB x	as-Suhmān Unverifiable	Not found	Destroyed
NIG i	15° 9'9.44"N 44°40'11.49"	Confirmed	Intact
NIG ii	15° 44°40'26.65"	Confirmed	Intact
NIG iii	15° 44°39'34.52"	Confirmed	Bad
RAQ	15°13'12.44" 44°41'51.11"	Confirmed	Bad
Sa i	al-Aʿmās	Not found	Unknown
SA ii	al-Aʿmās	Not found	Unknown
SA iii	al-Aʿmās	Not found	Unknown
Sr i	as-Suhmān	Not found	Unknown
SR ii	as-Suhmān	Not found	Unknown
SR iii	as-Suhmān	Not found	Unknown
WRA	14°59'16.97" 44°40'38.48"	Confirmed	Good
WTH	al-Aʿrūš	Not found	Unknown
WTH i	al-Aʿrūš	Not found	Unknown
WTH ii	15° 44°40'8.34"E	Confirmed	Bad
WTH iii	15°10'1.55"N 44°39'51.08"	Confirmed	Destroyed
WTH iv	15° 44°40'17.18"	Confirmed	Bad
WTH v	al-Aʿrūš	Not found	Unknown
WU	14°48'8.20"N 44°37'0.69"E	Confirmed	Good
WY i	15°11'49.25" 44°40'45.64"	Confirmed	Destroyed
WY ii	as-Suhmān	Not found	Destroyed

TABLE 3
Summary of the Ḥawlān al-Ṭiyāl sites

2.4 *Limitations*

Despite the high resolution of new satellite imagery, the authors of this paper are well aware of the problems caused by the impossibility of ground truthing the site analyses on location. Some of the sites detected are not clearly defined by the images, and the only way to be certain of their correct identification is to visit the dubious sites directly on the ground. Ground truthing is needed in order to definitively exclude, for example,

tricky rock formations and modern structures erected by the locals such as livestock enclosures and provisional mosques (*muṣallā*).

In some cases, low-resolution satellite images prohibited certain identification of known and previously published sites.

For example, it is difficult to verify what remains of the sites detected around the as-Suhmān region and the more detailed area of Ǧabal al-Hamrāʾ and Wādī Habābiḍ, although the sites are precisely reported on the maps (the sites present in the area of as-Suhmān classified by de Maigret are: BAH i, BAS i–iii, BAT i–iii, GU i–ii, HA i–iv, HGN i–iii, HS, MAS i–iv, and SR i–iii). The poor preservation of the sites, the already-mentioned low resolution of the satellite images available for the zone, and some of the imprecisions within the maps represent the major difficulties found in the investigation of the area. Nonetheless, some were identified for certain, such as BAH i, BAS ii, BAT i and ii, GU i, HGN i–iii and MAS i.

3 *Beyond de Maigret's Research*

3.1 *Identification of Previously Unrecorded Sites*

We did not limit our investigation only to the area surveyed by de Maigret and his team but also applied the same remote sensing techniques to the entire Ḥawlān, an area measuring 4.066 square km (fig. 10).

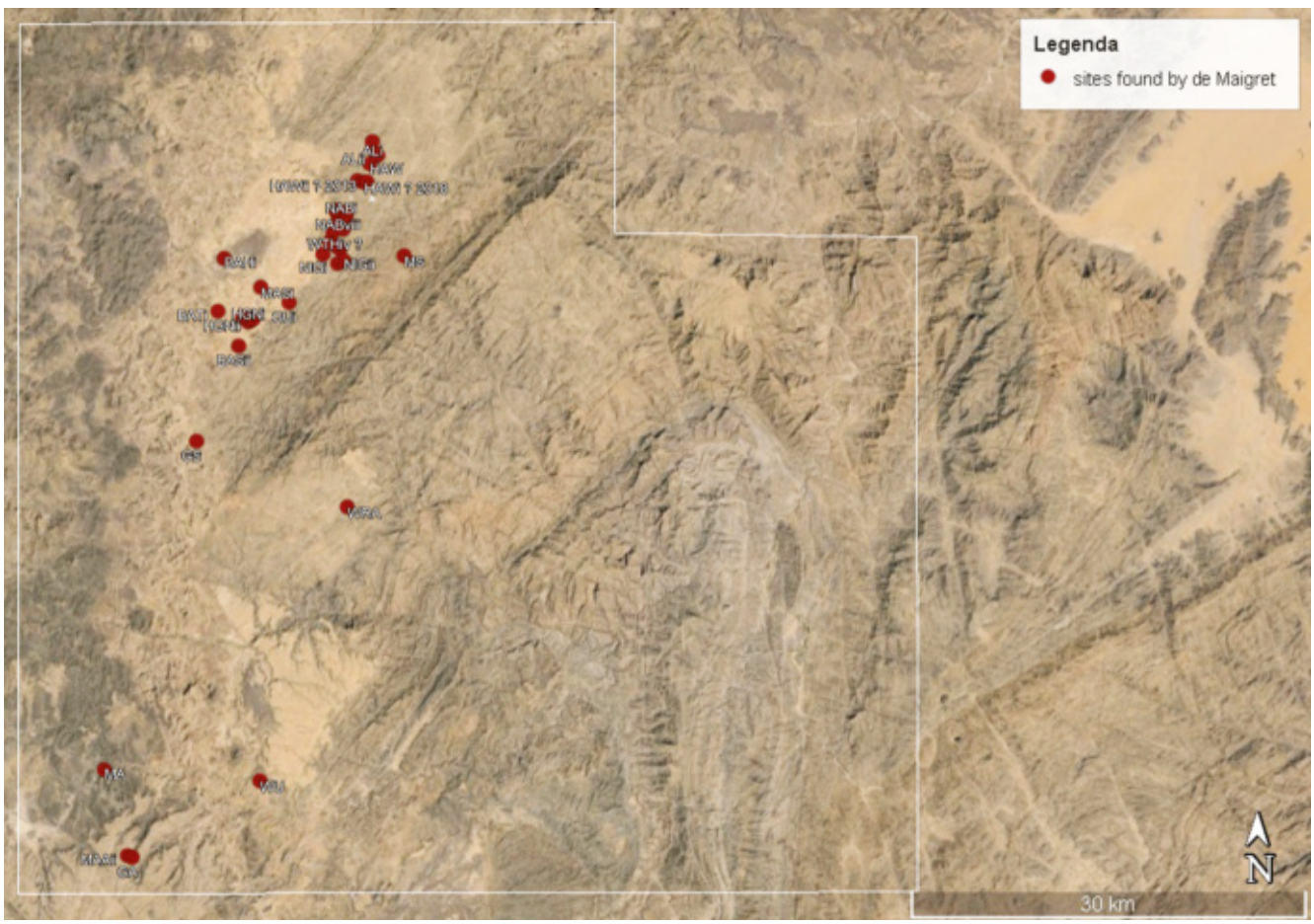

FIGURE 10
Sites detected by de Maigret within the whole area under remote sensing analysis

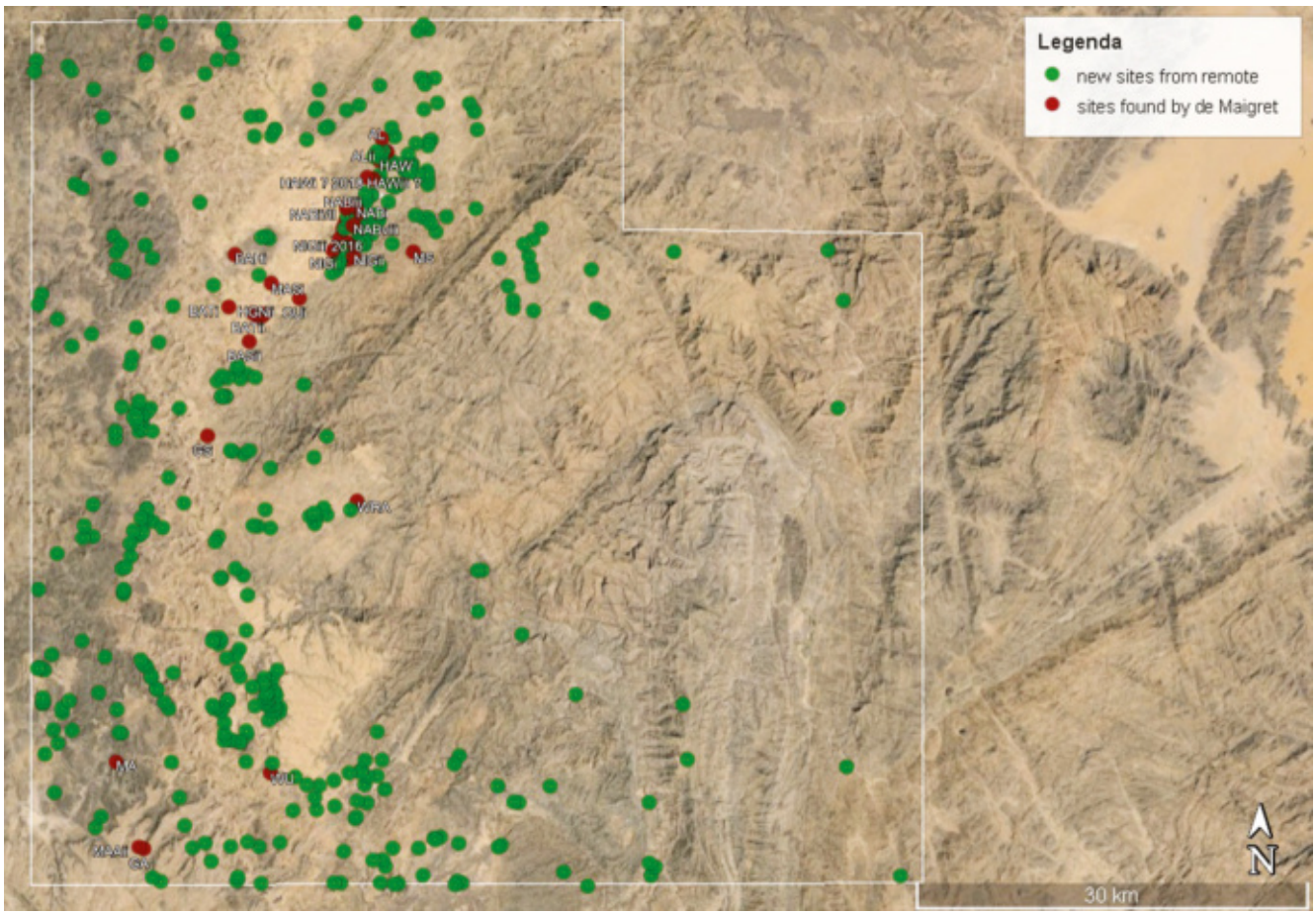

FIGURE 11
General map of the remote sensed data

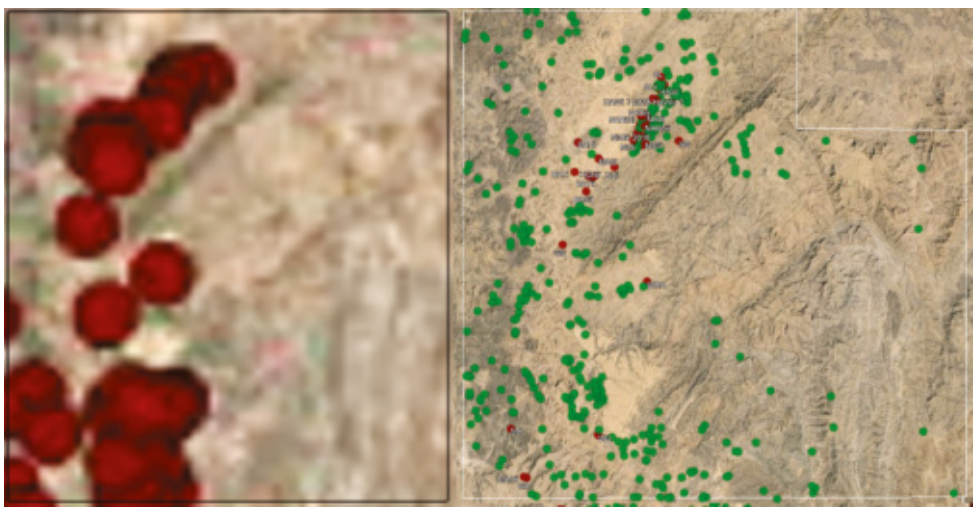

FIGURE 12
Comparison of the Ḥawlān Bronze Age remote sensed data (to the right) with the AYDA repository published by Schoeneberg (2018: fig. 2)

This procedure immediately proved itself valuable when numerous unmarked sites were identified even within the area covered by the detailed maps produced by the Italian Mission.

Several features characterize the distribution of sites detected from satellite images: 1. the majority of the remotely detected new sites lie in the western area of the zone which stretches from north to south, thus avoiding main mountain peaks; 2. most of the sites detected by our project appear to be in the northern part of the investigated zone with the al-Aʿrūš and Bani-Sulayḥ regions having the highest site density.

We compared our results to The *Ancient Yemen Digital Atlas* (AYDA – https://www.archernet.org/en/2020/04/22/ayda-ancient-yemen-digital-atlas/), which includes the results of independent remote sensing efforts in the form of registered sites of different historical periods and types throughout Yemen (Schoeneberg 2018; see also Banks *et al.* 2017) (fig. 12). The overlay of our data with that of AYDA demonstrated that a more detailed analysis of the highland is needed. Although there are matches among the two different datasets – for example, the north-south distribution of sites in Ḫawlān is visible in the AYDA map – there are also many newly detected sites.

3.2 *First Typological Classifications*

The high quality of currently available satellite imagery enables us to correlate new sites to previously identified site types. We place the satellite evidence for newly detected sites in the Ḫawlān in three groups; 1. similar to Ḫawlān sites previously recorded by de Maigret and his team, 2. similar to sites recorded by the American mission to the Dhamar province, and 3. new types of sites unlike any previously recorded in the area.

3.2.1 Type 1: Sites Similar to Those Recorded in Ḫawlān by the Italian Archaeological Mission

The typical domestic structure of the Ḫawlān Bronze Age is characterized by two oval rooms linked with each other and opening onto a central court (fig. 13). This type of arrangement offers the dwellers the possibility to expand the village according to the

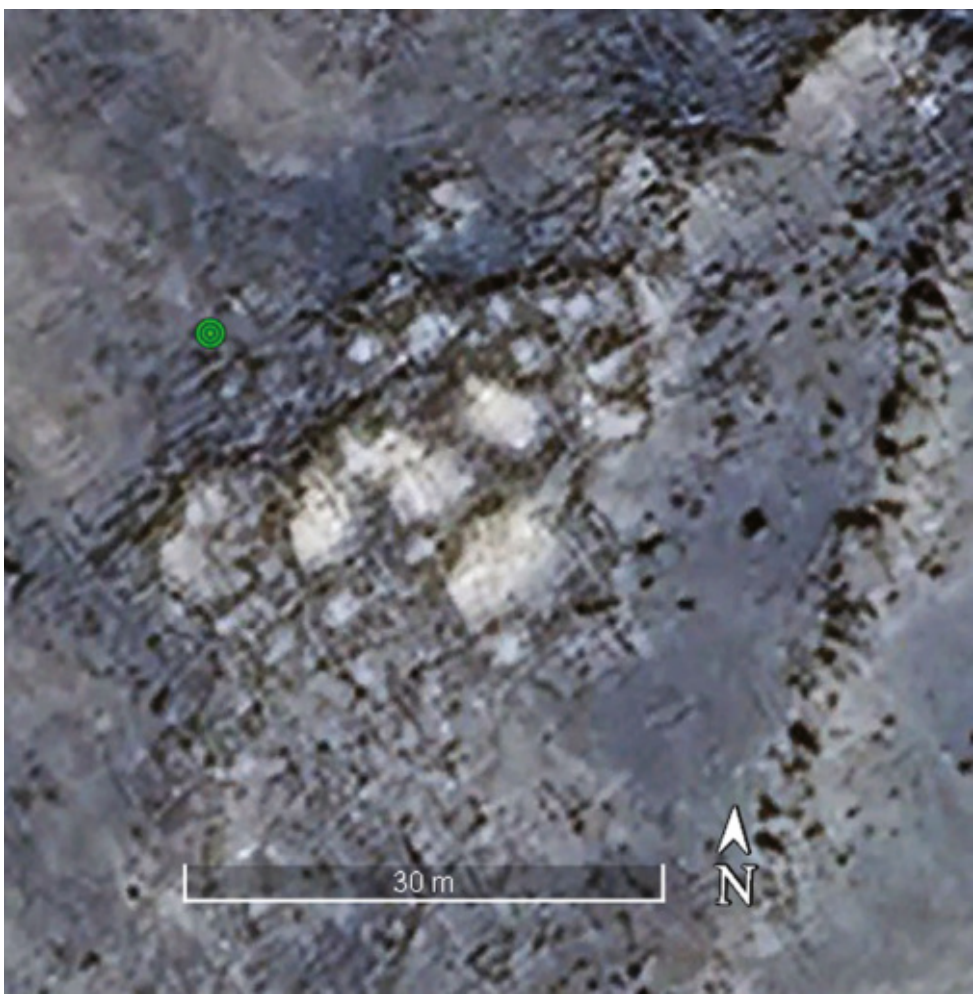

FIGURE 13
Basic house unit according to de Maigret's typology

FIGURE 14
Further example of a basic house unit

social needs of the groups. The circular unity model of the house suggests a fragmentation of the society into separate family groups.

In this way, we can identify the dwellings of basic family units. Whenever the family expanded, the circular structures could be enlarged adding more room for new members by adjoining one house unit to the other. This appears to be a common Bronze Age practice based on the presence of these typical house plans in known sites. Analyzing the new sites discovered by remote sensing, one has to conclude that most of the sites are characterized exactly by this kind of morphology and features (fig. 14).

Following de Maigret's map, sites NIG i and NIG ii fit in a particular category of Bronze Age sites identifiable as isolated compounds. In these sites, numerous circular and ovoidal areas cluster with the presence of perimeter walls around the chambers. These are isolated settlements, and their composition suggests interpretations of their social organization. These isolated compounds could have hosted a single clan or family and are located in places suitable for defensive purposes.

There are at least two other sites of the same kind investigated by the Mission that are WY i and RAQ. Despite the fact they are isolated, they can be considered as extended compounds.

3.2.2 Type Two: Sites Similar to Those Recorded in Dhamar by the American Archaeological Mission

Bronze Age sites in the Dhamar region exhibit higher complexity than the nuclear houses of the Ḥawlān villages. Sites in Dhamar are characterized by long single-rooms and large multi-room structures within rectangular plans possibly designed for some

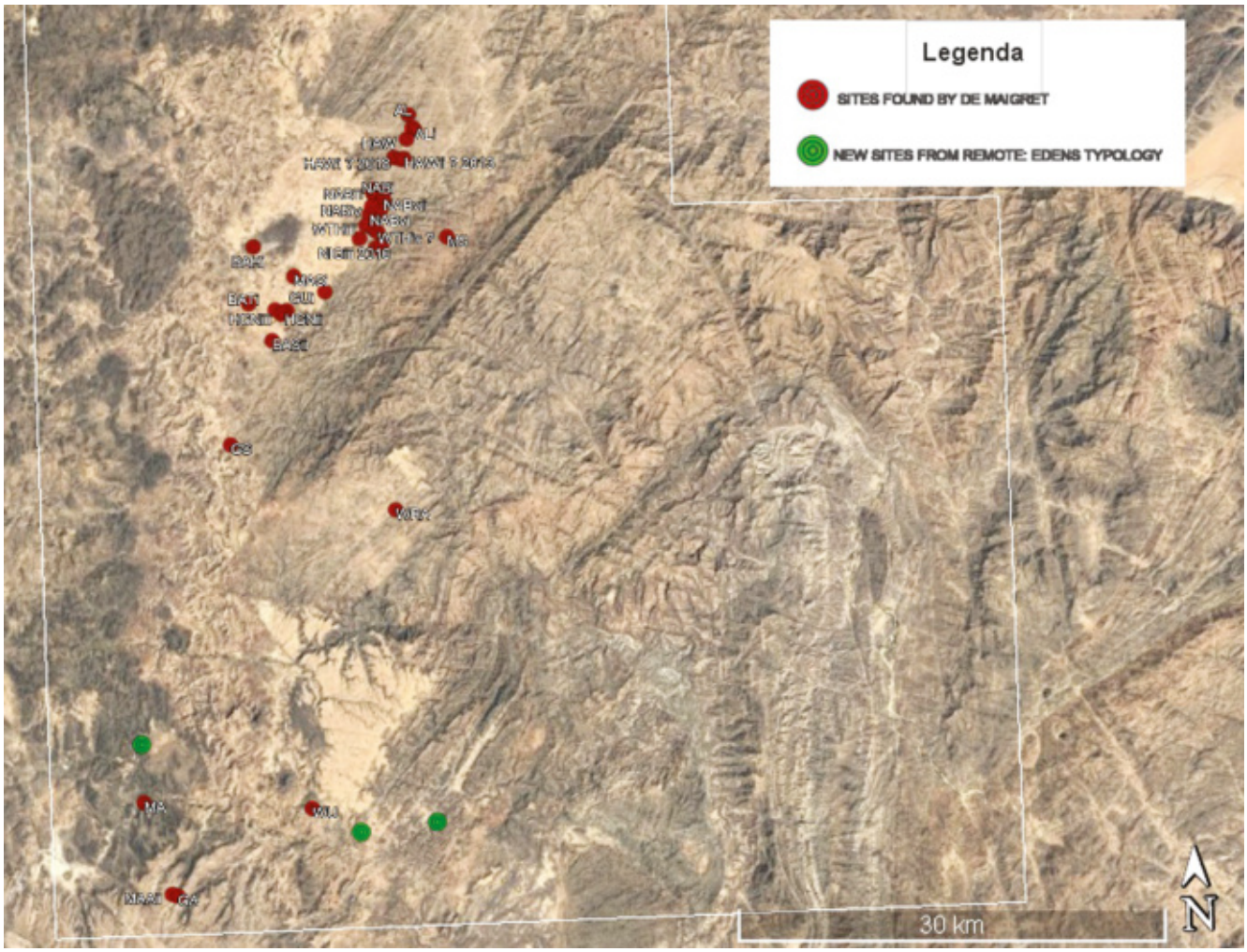

FIGURE 15
Location of the three sites which share basic features with Ḥammat al-Qāʿ

peculiar social class or as a reflection of architectonic development. The most prominent published Bronze Age site in Dhamar is Ḥammat al-Qāʿ. Ḥammat al-Qāʿ is a 4-acre site located on a flat-topped hill. It contains rectangular-shaped and multi-room structures arranged around courtyards and divided into quarters. The town is encircled by a surrounding town wall with several gates.

During the remote imaging investigation of the Ḫawlān area, three sites came to light with similarities to the Hammat al Qa' type (fig. 15).

Proceeding from west to east, the first of these sites rests on the top of a flat rocky plateau, which is characterized by rectangular buildings and delimitation walls. However, the site is close to modern agricultural structures and it is thus difficult to distinguish between the ancient and the modern ones. In order to verify this site identification, a ground truthing phase is needed (fig. 16).

The second site, comparable to Hammat al-Qa', is characterized by rectangular structures and delimitation walls and is also located on a high plateau. A modern village is located just to the west on the same plateau (fig. 17).

The third site is the best preserved. It is located at the southern end of the area and is formed by structures with a rectangular pattern that is well joined to one another. This site is located on the top of a flat rocky plateau with a southern slope that presents a level of natural defensibility. The northeastern part of the site is surrounded by a fortification wall (fig. 18).

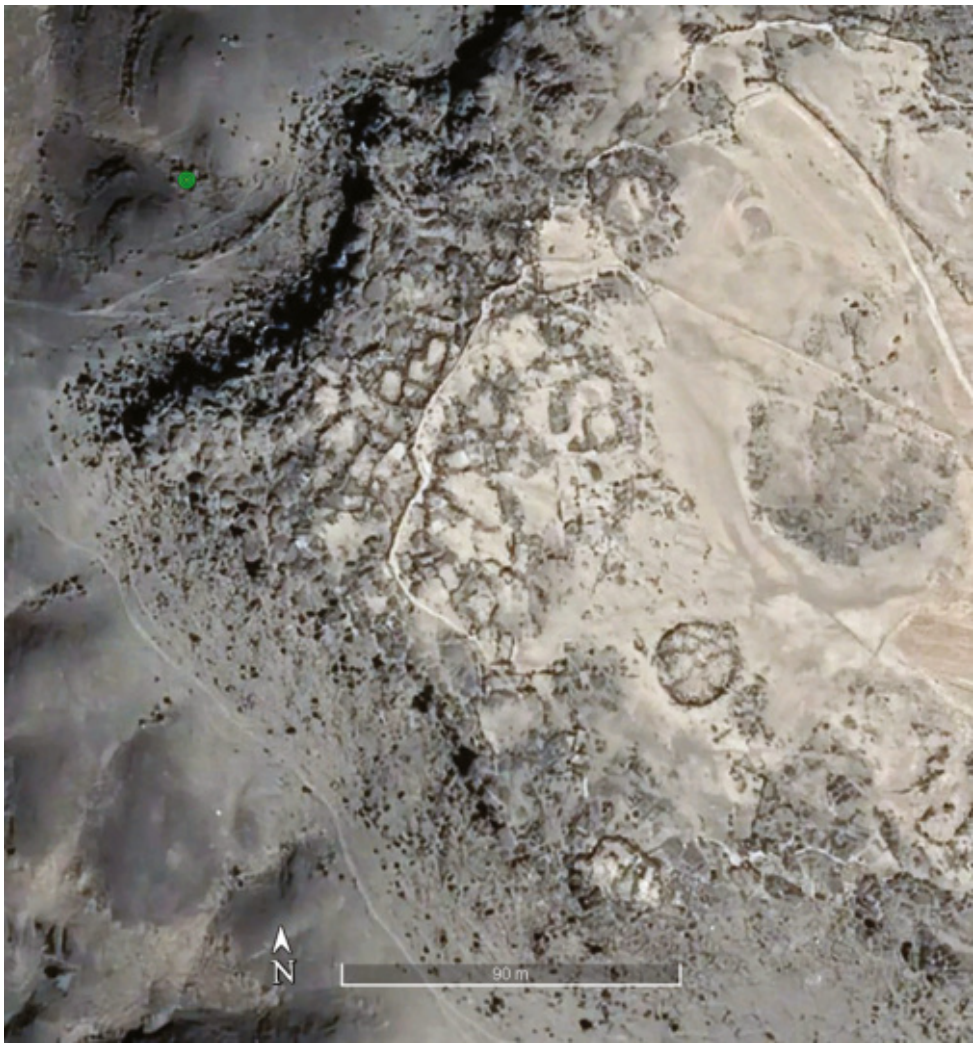

FIGURE 16
Detail of the first Ḥammat al-Qāʿ type site in the Ḥawlān area

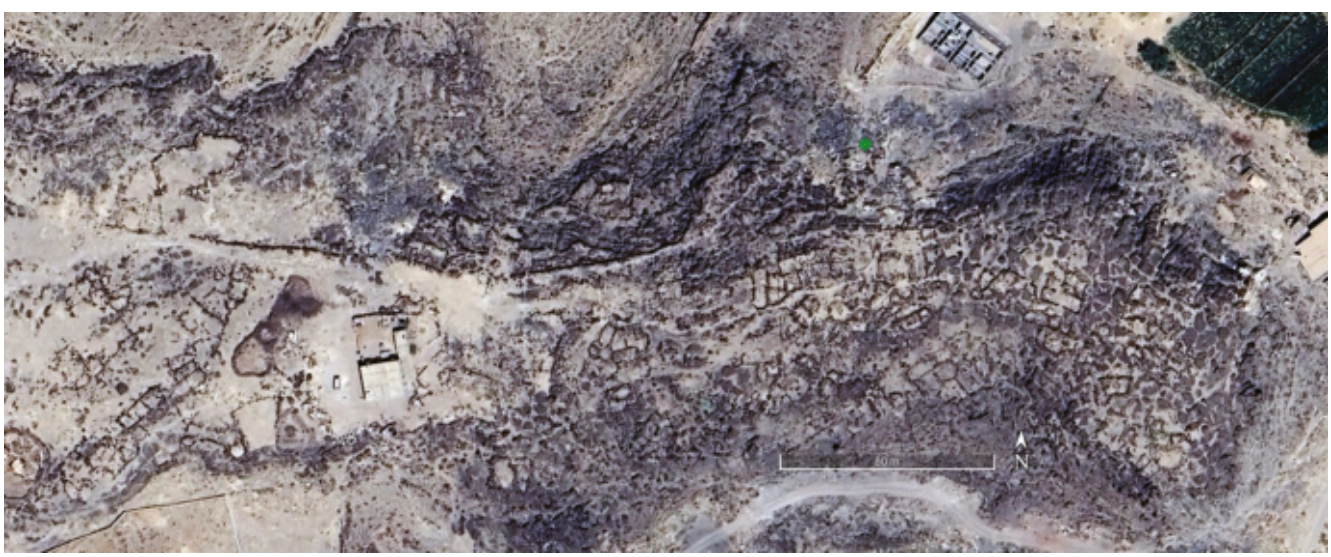

FIGURE 17
Detail of the second Ḥammat al-Qāʿ type site in the Ḥawlān area

FIGURE 18
Detail of the third Ḥammat al-Qāʿ type site in the Ḥawlān area.

The sites of this type are located in the southern portion of the Ḥawlān area. As stated by Mouton and Schiettecatte, during the 2nd millennium BC, the Ḥawlān al-Ṭiyāl started to desiccate, and the sites were abandoned as the population moved southward to the central part of the highlands, that is the Ḍamār area. There, agricultural structures such as terrace walls favored the stabilization of the soil, a process that helped the appearance of more extensive and densely inhabited sites such as Ḥammat al-Qāʿ (Mouton and Schiettecatte 2014: 152–153).

3.2.3 New Types of Bronze Age Sites

During our remote sensing evaluation, we identified new kinds of sites outside of the typical classifications given for the sites already studied in the Ḥawlān area. These sites exhibit peculiar morphological features consisting, for example, of square structures in the proximity of long walls connecting other sites together (sometimes well distant too) (fig. 19). Most of these sites have been detected in the southern part of the Ḥawlān. Once again, only ground truthing can confirm the attribution of these structures to the Bronze Age and exclude the fact that such long walls are not modern structures.

Circular structures within a wide square space are also present in the area: usually, these are similar to the turret tombs in their morphology (fig. 20). A circular structure of this kind was documented by de Maigret together with the site of WY i.

We also identified a circular structure with a previously unrecorded plan. It is characterized by internal walls crossing at the center to divide the building into four parts. From the satellite images, it appears as a cross within a circle. Potentially this structure could have had a funerary purpose (fig. 21).

Furthermore, not all sites are isolated: there are elevated plateaus densely inhabited by ancient structures with the typical Ḥawlān morphology (figs. 22–23). Some of these plateaus are densely occupied by houses and buildings and can be considered huge compounds.

FIGURE 19
Example of high plausible ancient structures (compound to the right) connected with squared structure (to the left) and connected by long walls

FIGURE 20
Plausible cultic site characterized by a circular inner structure comprised of squared "temenos"

FIGURE 21
Example of a circular structure with inner partition walls

FIGURE 22
Example of isolated plateau densely inhabited

FIGURE 23
Example of isolated plateau densely inhabited

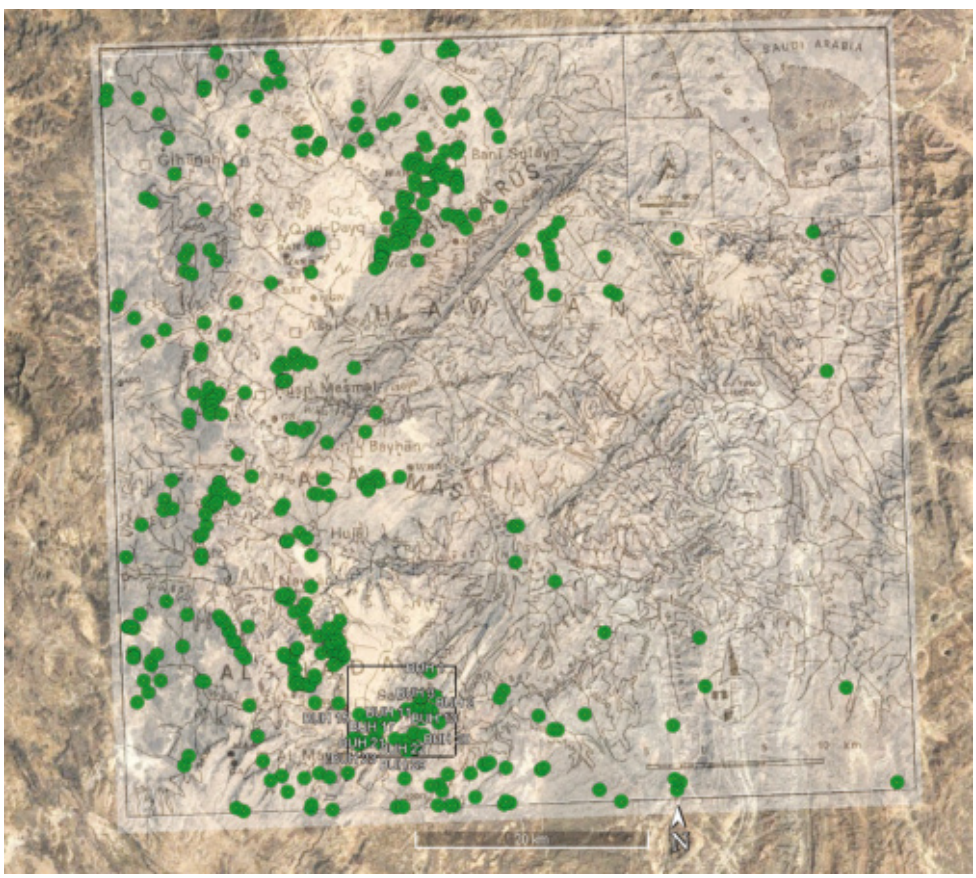

FIGURE 24
Location of Bani Buhayt excerpt to the south of the Ḥawlān area

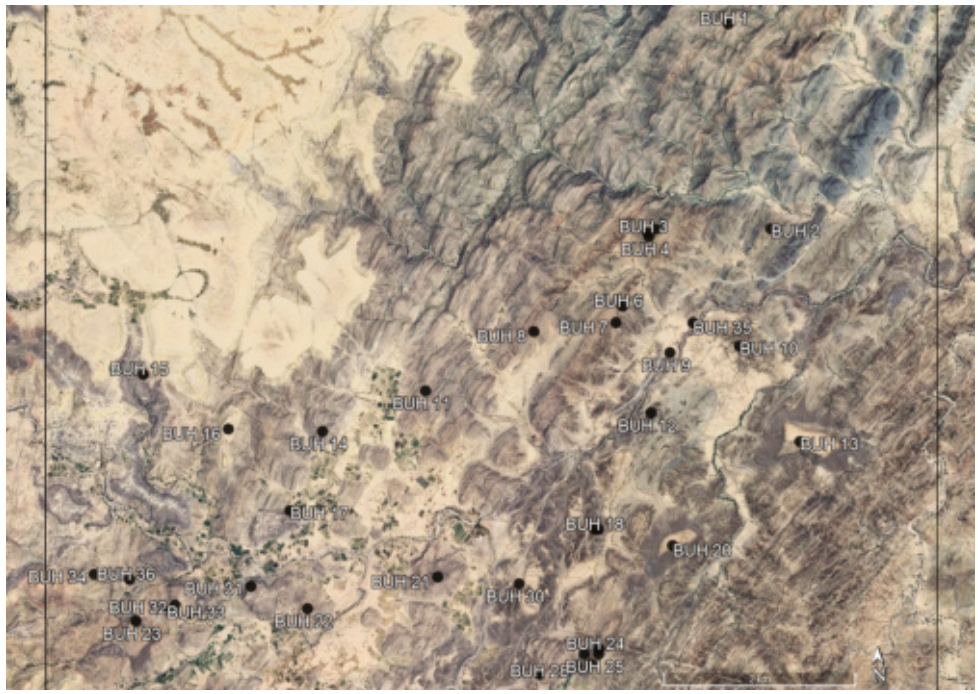

FIGURE 25
Bani Buhayt excerpt to the south of the Ḥawlān area

Name	Coordinates	Size	Typology
BUH 1	14°49'50.70"N 44°41'32.07"E	156 sqm	de Maigret's
BUH 2	14°48'41.14"N 44°41'44.61"E	258 sqm	de Maigret's
BUH 3	14°48'41.35"N 44°41'1.43"E	114 sqm	de Maigret's
BUH 4	14°48'39.80"N 44°41'1.96"E	74 sqm	de Maigret's
BUH 5	14°48'42.23"N 44°41'4.22"E	72 sqm	de Maigret's
BUH 6	14°48'16.61"N 44°40'51.91"E	860 sqm	de Maigret's
BUH 7	14°48'11.18"N 44°40'49.47"E	4.760 sqm	de Maigret's
BUH 8	14°48'9.07"N 44°40'20.68"E	107 sqm (largest)	de Maigret's
BUH 9	14°48'0.46"N 44°41'8.00"E	33 sqm (largest)	Uncertain
BUH 10	14°48'1.92"N 44°41'32.32"E	34.000 sqm	de Maigret's
BUH 11	14°47'50.30"N 44°39'42.16"E	2.000 sqm	Uncertain
BUH 12	14°47'40.40"N 44°41'0.67"E	2661 sqm	de Maigret's
BUH 13	14°47'29.05"N 44°41'52.34"E	28.331 sqm 2,83 ha	Edens's
BUH 14	14°47'37.73"N 44°39'5.77"E	587 sqm	de Maigret's
BUH 15	14°47'58.94"N 44°38'3.81"E	2.751 sqm	de Maigret's
BUH 16	14°47'39.55"N 44°38'32.88"E	200 sqm (largest)	de Maigret's
BUH 17	14°47'8.89"N 44°38'53.76"E	11.751 sqm 1,18 ha	Edens's
BUH 18	14°47'1.57"N 44°40'40.94"E	350 sqm	de Maigret's

TABLE 4
Excerpt of the summary table of the new sites in Bani Buhayt

Name	Coordinates	Size	Typology
BUH 19	14°47'1.77"N 44°40'39.82"E	163 sqm	Uncertain
BUH 20	14°46'55.40"N 44°41'6.71"E	300 m longest wall	Uncertain
BUH 21	14°46'47.33"N 44°39'44.32"E	1.168 sqm	Uncertain
BUH 22	14°46'38.09"N 44°38'58.53"E	923 sqm	de Maigret's
BUH 23	14°46'35.81"N 44°37'58.32"E	114 m longest wall	Uncertain
BUH 24	14°46'21.31"N 44°40'39.91"E	267 m longest wall	de Maigret's
BUH 25	14°46'19.60"N 44°40'39.66"E	1.142 sqm	de Maigret's
BUH 26	14°46'19.86"N 44°40'34.60"E	296 m longest wall	de Maigret's
BUH 27	14°46'16.32"N 44°40'36.88"E	2.019 sqm	de Maigret's
BUH 28	14°46'15.75"N 44°40'31.77"E	64 sqm	de Maigret
BUH 29	14°46'13.47"N 44°40'18.80"E	136 m longest wall	de Maigret's
BUH 30	14°46'44.18"N 44°40'12.67"E	109 sqm	de Maigret's
BUH 31	14°46'46.25"N 44°38'39.02"E	89 m longest wall	Uncertain
BUH 32	14°46'40.74"N 44°38'12.34"E	172 sqm	de Maigret's
BUH 33	14°46'39.22"N 44°38'9.28"E	46 m longest wall	Uncertain
BUH 34	14°46'51.99"N 44°37'44.49"E	688 sqm	de Maigret's
BUH 35	14°48'10.25"N 44°41'16.35"E	255 sqm	de Maigret's
BUH 36	14°46'49.88"N 44°37'56.71"E	2.235 sqm	Uncertain

TABLE 5
Excerpt of the summary table of the new sites in Bani Buhayt

A general repository of all remotely sensed data is in preparation. For the sake of open-access sharing and data checking, here we report only an excerpt of the table about the 36 sites found in the zone of Bani Buhayt (BUH), a zone of the Ḫawlān towards the south. We decided to report only an excerpt for reasons of space (tables 4–5).

The second and the third kinds of Edens' sites also appear in Figs. 24–25.

4 Conclusions and Perspectives

4.1 *The Richest Ḫawlān*

In 1981, the Italian Archaeological Mission began the study of Bronze Age Yemen with Alessandro de Maigret's discovery of the Ḫawlān al-Ṭiyāl sites. Today, despite the humanitarian crisis afflicting the country, archaeological research can continue thanks to an approach based on remote sensing. In this paper, the previous sites discovered and excavated by the Mission have been revisited remotely. This has allowed us to not only determine the precise coordinates for each site, which were not always possible to record during the original field seasons but also to evaluate the current state of preservation for most of the sites.

Remote sensing methods can yield a large amount of new data by aiding in identifying sites still undetected, including those in the areas already studied by past archaeological surveys. Overall, in the Ḫawlān area investigated by de Maigret (fig. 2), our remote sensing project has so far tallied 438 new sites (excluding his sites). This number is destined to continue to rise with the help of new high-definition images and the continual advances in technology that are developing almost daily.

In this paper, we have shown that it is possible to identify new distribution patterns for Bronze Age sites, such as the densely inhabited alignment of new sites in the western part of the Ḫawlān area discussed above. Most of the southern sites of the Ḫawlān area are characterized by a specific morphology, typical of the later sites of the central highlands studied by Wilkinson, Edens and Barrat (2001), namely the presence of urban features such as rectangular structures enclosed within a fortification wall already present in Ḥammat al-Qāʿ, confirming the theory exposed by Mouton and Schiettecatte about the population moving south because of the always more arid climate conditions affecting the northern highlands during the 2nd millennium BCE.

During our work, we have also identified new kinds of sites of different kinds and shapes than the sites that de Maigret previously studied in the Ḫawlān area.

4.2 *Perspectives for Further Research*

Despite the lack of ground fieldwork, we believe that an integrated geoarchaeological approach is helpful in supplementing our knowledge of the Bronze Age of Southern Arabia. To proceed further with remote sensing, the next step is to apply Landsat imagery to detect and contextualize evidence for the paleo-landscape. In particular, it aims for specific resources such as obsidian or soils that are fit for developing a vegetal covering, whether spontaneous (harvesting) or man-made (agriculture).

Finally, although the limits of the lack of ground-truthing must be underlined, this type of investigation can open doors to new data for Bronze Age settlement strategies and spread in Yemen. There is much yet to be done before we can hope to arrive at a comprehensive knowledge of the matter. Currently, remote sensing is the only methodological option that can be used by international researchers to investigate the area, pending the end of today's humanitarian crisis and the possibility of one day returning to Yemen to further study the sites directly on the field in a (we hope) not too distant future.

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