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INTEGRATED MULTI SCALE ARCHAEOLOGICAL ANALYSIS IN BÉNI MELLAL-KHENIFRA DISTRICT (MOROCCO). THE CASE OF THE FORTRESS OF IGHRAM AOUSSER

1. Introduction

The fortress of Ighram Aousser is located 10 km W from M'rirt (on the road between Khenifra and Azrou) and 120 km S of Meknés, on the so-called "mines route". The fortress lies inside the valley between the mountains of Jebel Aouam and Askar Msaouar. It is protected by a well-preserved circuit of external city walls that reaches even the height of 3.5 m and is composed by regular stones joint with thick grey mortar. The walls were covered by yellow plaster, still visible here and there, decorated with intersecting circles (25 cm of diameter). The whole complex encloses about 27 hectares and measures approximately 736 m in length from E to W and approximately 427 m in width from N to S. At least two gates existed: they are both still visible and it is probable that a third one was opened in the northern side of the external walls. The eastern gate, the one heading to M'rirt, is a typical angle entry gate and was completed by a service staircase to the *chemin de ronde* above the walls. Inside the circuit of the walls it is possible to identify a higher and fortified area called "acropolis", whose function is still unclear.

In many different areas, inside and outside the walls, many traces of mineral extraction and transformation from pre-historical times (i.e. Neolithic stone tools and slags) to the high-level production (we may say almost "industrial") of the Middle Ages have been identified (Fig. 1). It appears that during the whole life of the site almost 250,000 tons of metals (in particular iron, lead, silver galena) had been extracted and that this impressive production changed Aouam's landscape with new hills of metallic slags still visible today, where local people live.

The Aouam project has always been interested in studying and promoting the area in all aspects, thanks to a cooperation agreement between many different institutions from Italy and Morocco[1] and the local association Abghor for rural development. Together with archaeological excavations in 2014 and 2015, the team conduced cartographic and geophysical surveys, laser scanner

[1] The former Istituto di Studi sul Mediterraneo Antico-ISMA (now Istituto di Scienze del Patrimonio Culturale-ISPC) of the Italian National Research Council, under the responsibility of Dr. L.I. Manfredi and her team, Moroccan INSAP, in the person of Mr. Y. Bokbot and University Moulay Ismail of Meknes, with a whole équipe led by Prof. A. Dekayir. In addition, the work is co-funded by the Italian Ministry of Foreign Affairs and is led in association with the Commune de El Hamman and the Compagnie Minière de Touissit, Italian Cultural Institute of Rabat, represented by Dr. H. Bounajma.

modelling and photographical documentation of the site. It was also possible to collect important data for implementing a Geographical Information System (GIS) of the whole area and many archaeological samples of different materials, in particular slags, on which archaeometric analyses were led in the laboratories of the Sapienza Università di Roma, as required by a specific bilateral agreement between ISMA-CNR and the University of Meknes.

Particular attention was given to ceramic materials and metallic slags, which were divided and analyzed through XRF, SEM-EDS, PIXE, ICP-MS, XRD and according to the place of their discovery and their position in relation to the fortress, the hills of slags and the mines. It was even possible to identify which slags come from melting operations and which from the molding. Even fragments of a wind *tuyère* and of furnace walls can prove that many metallurgic activities occurred in the area. All the obtained data were inserted in a dedicated GIS and a general 3D reconstruction of the emerging structures was provided.

L.I.M., H.B.

2. Preliminary archaeological survey around the fortress of Ighram Aousser (2016)

During the 2016 campaign, archaeological surveys were performed to gain a better understanding of the Ighram Aousser's area[2]. In particular, the field-walking surveys focused on the identification of natural resources unknown until now, such as mines, water sources and stone quarries, around the fortress. The pedestrian survey strategy was systematic and intensive, proceeding to a direct survey of two defined portions of land, as to ensure uniform and controlled coverage of all areas of the researched context. This allowed controlling the reliability of the collected data. The surveyed territory was examined uniformly, proceeding by natural squares represented by land properties and cultivated fields, crossed by the team in parallel rows, at regular distances of 5-10 m, according with the good atmospheric visibility and the state of the soil, in order to offer a complete coverage of every part of the territory. The survey data were daily downloaded from different open-source software, Garmin, Geopaparazzi, Altimiter pro ACT and Soviet Military Map.

The surveyed area was divided in two principal itineraries, which were marked on the topographic map of M'rirt N1-30-VIIIb 1:50000 (Fig. 1):

– Survey 1 (blue line), NW to the fortress of Ighram Aousser, starting from the Signal mine (Itinerary 10 km). The surveys started NW of the Ighram Aousser

[2] In 2013 and 2014 two surveys were conducted, focused on the research of archaeometallurgical sites connected with the Ighram Aousser fortress (Celauro, Merola, Susanna 2016). The surveys in 2016 were carried out with the collaboration of Pasquale Merola.

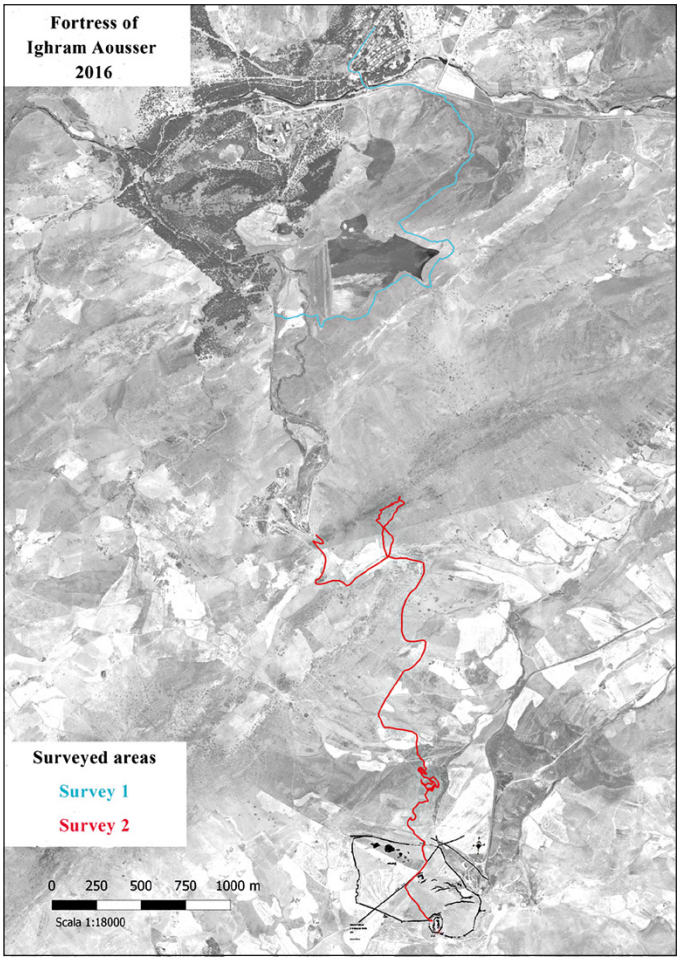

Fig. 1 – Area of the archaeological surveys performed in the northern part of the fortress of Ighram Aousser.

Fig. 2 – Landscape with the fortress from NW (in yellow).

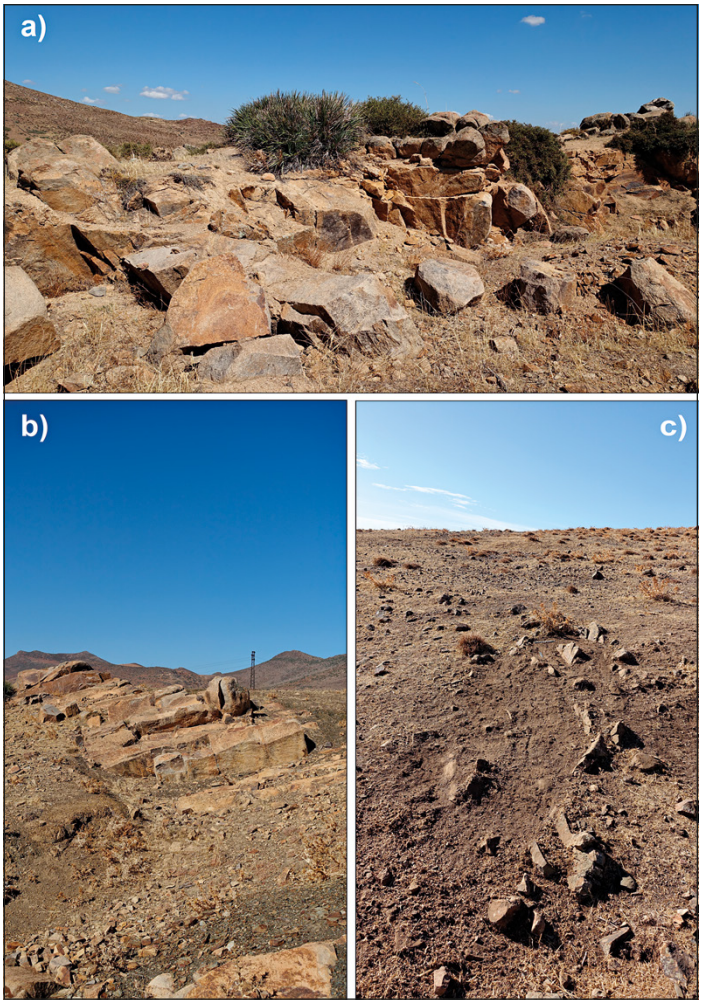

Fig. 3 – Quarries identified during the surveys (a, b) and installations pertaining to daily activities and animal husbandry (c).

fortress, where the landscape is marked by mountain chains, among which the Jebel Aouam (Signal mine 1490 m), high hills and broad planes: the M'rirt to the E and the Tanadra and Mçawar to the NW. A route, presumably used in ancient times for the connection between the ancient superficial metalliferous veins and the fortress, was covered. From the ancient vein's area we proceeded towards S up to a plane, resulting from the mechanical fill with loose material coming from the modern mines, which clearly changed the territory's orography. The

area was selected for the presence of natural water sources, identified before the survey through remotesensing technique. As of today, the area results to be rather large (380×350 m); here water, probably from a natural source, is gradually filling the artificial basin, which is rich in vegetation and local fauna. Proceeding with the survey towards Tighza, the riverbed of a stream or *wadi* can be seen which is interrupted downhill by a small artificial dam. During the walk the highest peak was reached (1439 m height); from this point, the NW sector of the fortress and the acropolis were visible (Fig. 2).
– Survey 2 (red line), NE area of the fortress of Ighram Aousser, starting from the street S 209 connecting Tighza with M'rirt (Itinerary: 8 km). The survey started from the NE area of the fortress, from the street S 209 connecting Tighza with M'rirt nearby the power plant. The area was selected for a survey due to the presence of evident man-generated cuts in the rock, which are typical of the quarrying of stone. Along the crest of the hill and in several areas on the slopes, a high number of quarry faces, approximately 2.5 km long, were identified (Fig. 3, a and b) proceeding mainly along the ridge (Tchchout-n-Kariane), which seems to be the mostly exploited area[3]. The quarry typology seems the open-air one, where rocks of different nature and dimension were cut. Descending the hill, the itinerary proceeded towards S, following the natural path along the valley floor, which is partly still in use. At 300 m approximately N of the fortress north gate, stone structures of different shape were identified in several areas of the E slope; these structures were mostly circular or ellipsoid installations pertaining to daily activities and animal husbandry (Fig. 3, c), which is an evidence of human presence not far from the fortress (Biagetti, Di Lernia 2008, 65; Mori 2013, 208). In the area, a considerable number of pottery sherds was found, which upon initial analysis, could be dated to the Islamic period.

From the first preliminary results of the exploration, the territory in which the fortress is located is rich in natural resources, water and mines exploited since ancient times. The principal routes of communication starting from Ighram Aousser run parallel (NS) to the Middle Atlas rather than crossing it towards E. The surveys are still in progress and will give us more information on the region.

S.F.

3. Remote sensing data to study the fortress area

Remote sensing and archaeological surveys were conducted in the Ighram Aousser fortress with the aim to gather new information on the site topography and the organization of the surrounding territory. The research was based on

[3] Samples from this area are taken and marked with the geographic coordinates to compare the stone of the quarries with the building stones of the fortress.

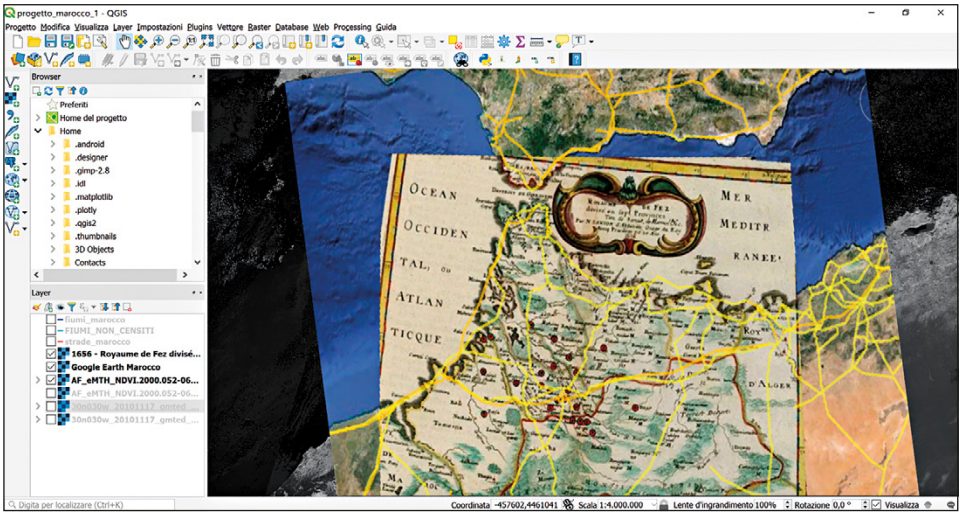

Fig. 4 – The map entitled "Royaume de Fez divisé en sept provinces tire de Sanut" is included in an open source software.

published data, historic and modern cartography, and on systematic surface and satellite survey campaigns. Published data and the historic cartography of Morocco were collected before proceeding with the survey on site and expecially on of the fortress and the surrounding area.

Sixteen historical cartographies created between the 16th and the 19th centuries were acquired on a digital support (raster format). They are characterized by a substantial difference in the representation scale, accuracy of information and stylistic and ideological details. The entire cartographic dataset, which was lacking a geographical reference system, was geo-referenced. This operation allowed superimposing the cartographic layers useful to the observation of correspondences and spatial distribution of the elements during the different periods and defining an overall synthetic overview of the landscape and its historic features (Fig. 4). The cartography used for this is not up-to-date and it is not suited, because of its scale, to the study of a small area, as the ones studied in this project.

In order to balance and overcome these limitations, remotely sensed images were included, in order to define the topography in detail and place the archaeological evidences more precisely. In particular, high spatial resolution images, such as QuickBird and WorldView-2 satellite images (with a 0.50 m/pixel resolution for the panchromatic sensor and 2.00 m/pixel for the multi-spectral sensor) were acquired. Remote data have been analyzed and transformation techniques have been applied to emphasize the information

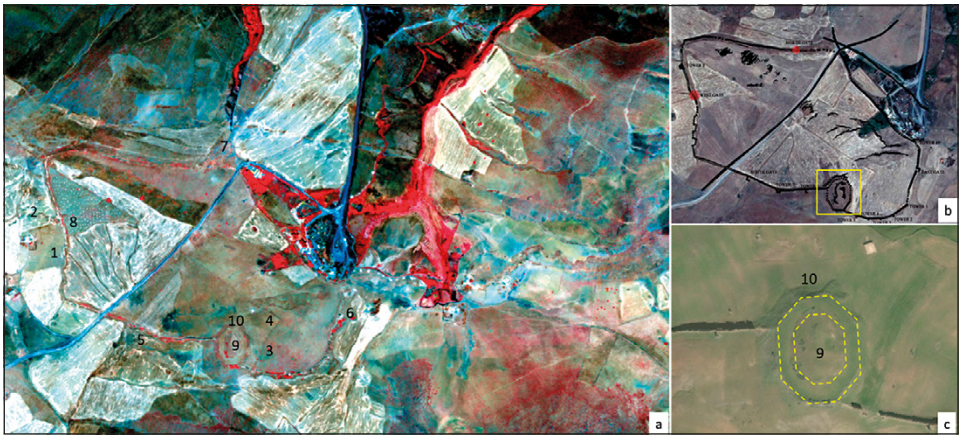

Fig. 5 – Satellite images Worldview-2 (a) with detail of the fortress of Ighram Aousser (b) and the so-called "acropolis" (c).

on the images. The historic-topographic study of such a large area of considerable interest was facilitated by the use of a GIS (Boffi 2004) able to manage, analyze and develop a large number of heterogeneous data from different sources (published data, satellite, survey), pertaining to the territory in all of its natural and anthropic components (Piccarreta, Ceraudo 2000; Scollar *et al.* 2009; Lasaponara, Masini 2012).

The results obtained through the photo-interpretation of the data recorded by the satellite offer new elements regarding the topography of the fortified area, consisting of the identification of archaeological traces related to the buildings inside the fortress, the road system inside and outside (Fig. 5a, 1-4), the location of the fortress' entrance gates and the ancient trade route along the fortress located in the central Moroccan Meseta (Fig. 5). The S and E access portals (Fig. 5a, 5-6), placed at a simple angle, clarify the fortress plan. From the interpretation of the remote image, two new possible access points to the city could be identified: the first one is situated along the N side of the fortress (Fig. 5a, 7), the second on the W one (Fig. 5a, 8). The location of the W door could be confirmed thanks to the presence of light-color linear traces (Fig. 5a, 1-2), which are presumably connected to ancient routes converging towards the hypothetical fortress' access from the surrounding land.

The other area object of this research is the so-called "acropolis" (Figs. 5a, 9; 5b; 5c, 9). It is situated inside the fortified boundary and is characterized by a small hill located to the S. On the remotely sensed images an octagonal fortification protecting the hill on all sides can be identified (on the S it lies against the fortress walls); it is protected at the corners by quadrangular

towers. An additional octagonal wall structure, visible on the surface, encloses the acropolis' summit (Fig. 5c). This topographical data is of particular importance due to the uniqueness of the octagonal structure. Only excavation data will give more information about their meaning and function. The acropolis, protected by its own boundary wall, shows on its N side a pincer-gate (Fig. 5a and 2c, 10), which allowed the connection between the octagonal hill and the fortress' internal area.

P.M.

4. Integrated procedures for the three-dimensional survey of the fortress

The three-dimensional survey of the fortress, conducted during the mission of September 2016, was aimed at the production of detailed models of the architectural structures located in the SE area of the site. The survey activities were defined starting from the real numerical models produced, during the previous campaigns, using a Riegl LMS-Z420i three-dimensional laser scanner. The activity concerned the digitization of the entire archaeological area between the walls, parts of the territories and of the reliefs close to the site, as well as the fortification structures to the SE below the acropolis. The new digitalization procedures of the walls were conducted through image-based systems. Preliminarily, the markers, located inside the citadel during the previous campaigns, were identified in the field for the registration of the different scan positions made with the TOF (time of fly) laser scanner. Of the 26 markers identified, 18 were surveyed with total station, all within the southern sector of the citadel.

Subsequently, the survey procedures of the various stratigraphic masonry units were started from the wall to the SW, called USM1, near the mine site, continuing in order until the USM7, located below the plateau of the acropolis. Both aluminium metric markers (specially made, equipped with geometric sights, a color scale and an identifying number) and flat square targets measuring 23×23 mm have been positioned near and on all the walls. 1160 images of the *septa* were then made, using a Nikon 810 camera, located as indicated in Tab. 1. The images were acquired following two procedures, the first referred to the height of the *septa*, in order to have overlapping image sequences of at least 70%, and to the architectural planes, as much as possible orthogonal to the main axis of the camera; the second aimed at increasing the accuracy of the models, progressively moving close to the areas of the walls with greater geometric irregularities and near the markers. Simultaneously with the acquisition of the images, the aluminium markers and the square targets were surveyed by means of a total station (with the help of the topographer Carlo Baione) in the same reference system of the 18 targets of the

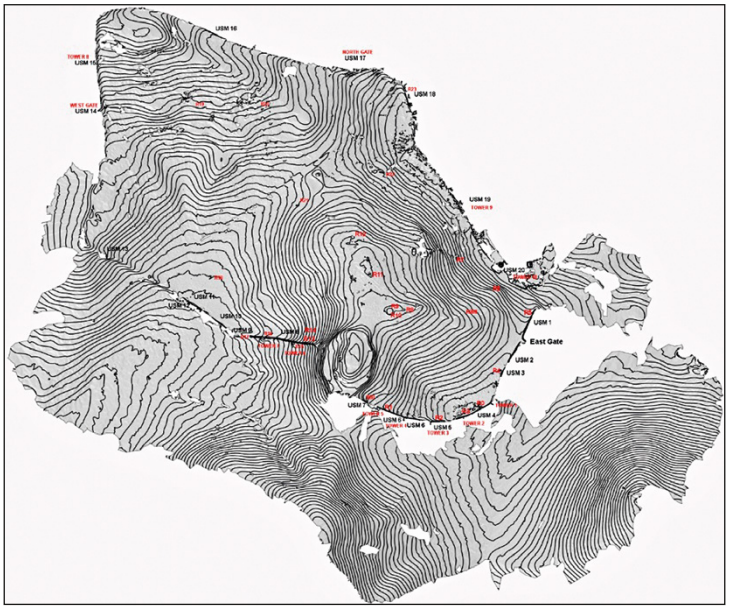

Fig. 6 – Topographic map of the area with location of the targets.

laser scanner survey, in order to topographically locate the point clouds of the individual *septa* and align them automatically with the models produced during the various surveying campaigns.

The acquired images were elaborated through two procedures, one performed directly in Morocco, during the acquisition phases, through the Agisoft-Photoscan software, aimed at the initial data verification, the other through the 3df Zephyr software, for the generation of point clouds through the interpolation of the data produced by laser scanner. Data verification and system testing procedures have been carried out through applications of the ISU3D system, developed by the researchers of the UNISOB for the survey of underwater cultural heritage, but also valid for surveys on land (Repola *et al.* 2018).

The first phase of data processing performed the standard procedures as provided by the Photoscan software, consisting of: images importing and calibration parameters of the camera and optics, images alignment, insertion of the topographic coordinates of each marker, generation of point clouds and polygonal models. This first procedure was aimed at the initial verification of the quality of the images, the coherence of the sequences of the photos with regard to the complex geometries of the *septa* and the topographic correspondence of the markers' coordinates (Fig. 6).

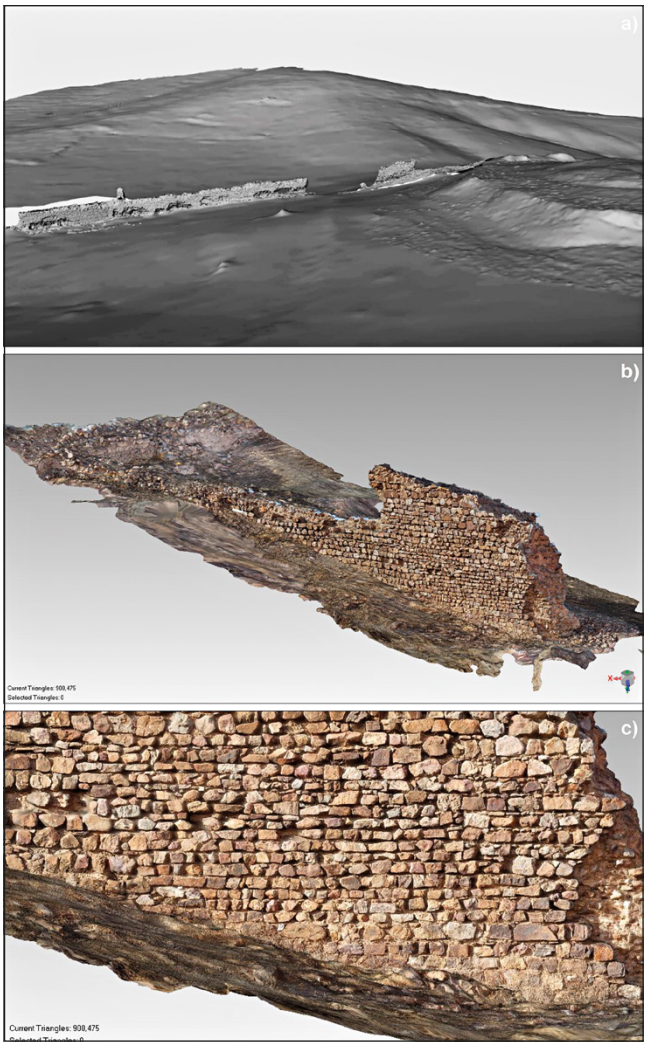

Fig. 7 – Georeferenced model of the architectural structures (a), textured polygonal model of USM7 (b), and detail of textured polygonal model of USM7 (c).

The second step of data processing, carried out in Naples, was made using the 3df Zephyr software, which allowed both the generation of high-resolution point clouds from the images and the direct import of the point clouds generated by 3D scanners. In this way, the data produced through different survey procedures, laser and photogrammetric, were managed within

a single georeferenced model, in which the different levels of accuracy of the clouds were verified and the noise elimination procedures were carried out (Fig. 7a). The procedure's following steps were: data acquisition, laser scanner clouds registration and alignment (phases previously completed) and image acquisition using a digital camera; photogrammetric dense clouds generation; photogrammetric and laser scanner data merging; laser scanner data coloring and ICP (Iterative Closest Point) refinement; mesh and texture generation; ortho-photographic DEM and measurements, polylines extraction from models. The interpolation procedures of the models from images and 3D scanner also allowed to produce and manage the textures, maintaining very high resolution levels, through which to view small details, such as the state of conservation of the mortars and stones (Fig. 7, b and c).

The models were managed in order to be used for studies aimed at the reconstruction of the walls and the structural analysis by means of Finite Element method, as well as for the production of all the drawings to support the excavation and restoration of the artefacts. Moreover, the interpolated models of the *septa* and of the territory have produced topographic-territorial and architectural plans, which showed the exact geometric pattern of the walls and highlighted the octagonal shape of the acropolis perimeter. The processing of data has also considered the future possibilities of using the site as a museum area, with special reference to the reuse of the walls for new exhibition spaces compatible with the current agro-pastoral uses of the area. The archaeological excavation and the geophysical surveys suggested that the underground archaeological structures could be sufficiently high to be used for the restoration of the rooms of different shape and size with functions connected to the museum set up of the area and current agricultural activities.

L.R.

5. Geophysical research: inductive electromagnetic prospections

Terrestrial remote sensing is an important tool to locate, map and acquire information through indirect means from sites of our cultural heritage (Campana, Piro 2009). Many non-invasive geophysical methods can give useful information for the reconnaissance of buried structures such as the magnetic method (Gibson 1986), the induced electromagnetic methods (Simpson *et al.* 2009), the electrical resistivity tomography (Compare *et al.* 2009a, b; Cozzolino *et. al.* 2012, 2014, 2019c; Minelli *et. al* 2012; Amato *et al.* 2016), the ground penetrating radar (Goodman, Piro 2013; Cozzolino *et al.* 2019a, b), the gravitational surveying (Fajklewicz *et al.* 1982), the Self-Potential (SP) method (Cammarano *et al.* 1997) and seismic methods (Campana, Piro 2009). In the case of the fortress of Aouam, taking into account the probable type, dimensions and depth of the submerged structures, the geological

characterization of the soil and the need to have extensive information in a fast way, the Inductive Electromagnetic Method (IEM) was applied and the GSSI Profiler EMP-400 (http://www.geophysical.com) was used. Data acquisition was carried out along lines filled in regular grids and spaced maximum 0.5 m. Data were collected in continuous modality (thanks to the integrated GPS in the instrument that allowed to acquire the geographical position of each measurement), using frequencies of 2 kHz, 8 kHz and 15 kHz with a vertical orientation of the dipoles. During data processing, the conductivity values were converted into electrical resistivity values and they were represented with a contouring software for the realization of a two-dimensional map.

The investigations were carried out on an area of about 8000 m² near the eastern gate and about 5000 m² on the acropolis. Fig. 8 shows the results obtained by processing the data relative to the frequency of 15 kHz. In the first area, a rather sterile situation of anthropic structures emerges, with the exception of a high square resistivity anomaly in the W side of the door. The absence of stone structures, despite the conspicuous presence of archaeological material on the ground, can support the hypothesis that at the entrance of the city there were mainly wooden structures of which there are no traces today. On the acropolis, the geophysical results confirmed the presence of a double octagonal concentric wall and also identified the position of some probable towers (indicated with pink arrows in Fig. 8). The red arrow indicates the position of a known tower.

M.C., V.G.

6. Archaeological excavation 2014-2015

First archaeological excavation in the fortress of Ighram Aousser was led in September 2014 in the NE corner of the acropolis, the SE sector of the fortress. The spot was chosen in order to identify the relation between the fortified walls of the acropolis and the external wall circuit of the fortress. The dumping removed was made of only three layers, one of which was a clear proof of abandon; the other was a thick destruction layer that covered big structures still preserved for 1-2 m. These structures can be identified as those of an angular tower external to the acropolis wall circuit and they were used in Almohad times as foundations of the outer wall of the fortress. In the same occasion, traces of a big hearth came to light, together with slags and pottery with many fire traces: all these materials and the hearth itself are probably connected to metal extraction from minerals. These discoveries actually underline the importance of Ighram Aousser as the central area of many different mining activities from medieval times to the 9th-12th centuries AD: extraction, smelting, fusion, pottery production.

In September 2015, the archaeological excavation took place inside the fortress of Ighram Aousser, on the S of the acropolis, where prospections of

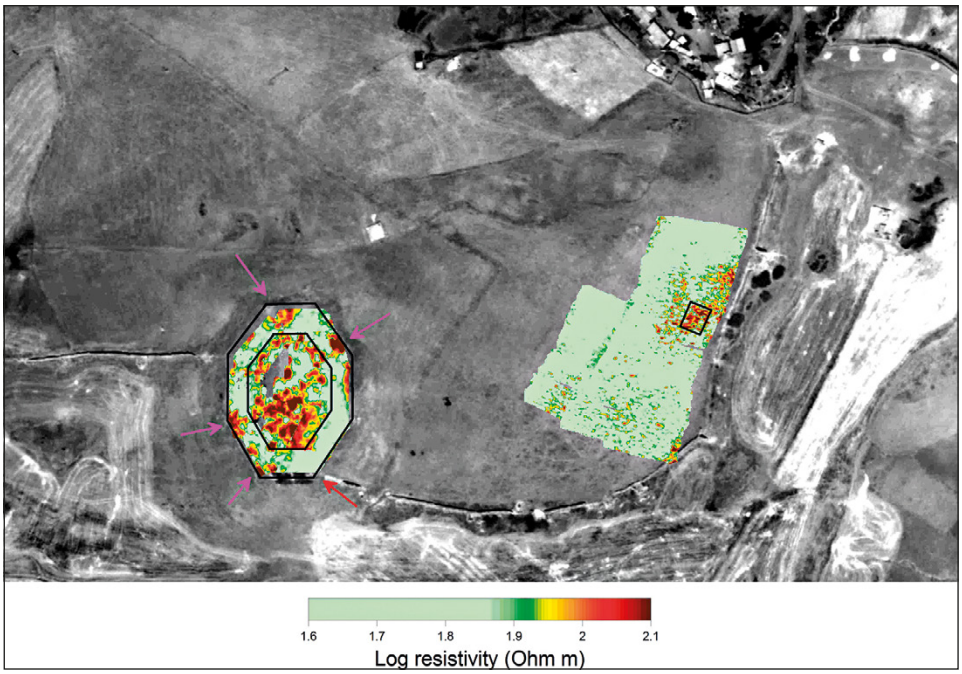

Fig. 8 – Resistivity map relative to the frequency of 15 kHz on the satellite image.

2013 had shown some interesting blocks placed like an arch that indicated the existence of a door or a general entrance. Relating to the excavation area (5×5m, 2.5 m deep), the structure is located 1 m far from the southern limit and in the middle between eastern and western sides. During the excavation, 10 different non-homogeneous sandy layers were identified, generally full of small stones and not easy to separate. It was possible to divide these layers only according to the presence of archaeological materials: for example, it was easy to distinguish US 210 from US 211 (-2.25 m), where a great number of bricks and tiles were found (43 in US 211 and 95 in US 212 below).

There was a very important change in archaeological layers (both for materials and composition) in the US 207 (from -1.00 m to -1.75 m), that was made of a much more yellow sand. From the preliminary study of materials, it appeared that this phase contained more depurated pottery, which indicates differences in function and chronology of the area. To this layer it was possible to connect the wall basement USM 206 made of irregular blocks, that confirms the more recent re-use of the sector (Fig. 9a). A hearth (F213) has been found in the SW corner of the square at level 2.40 m that covered the layer US 212. The hearth was full of fragmented animal bones (especially

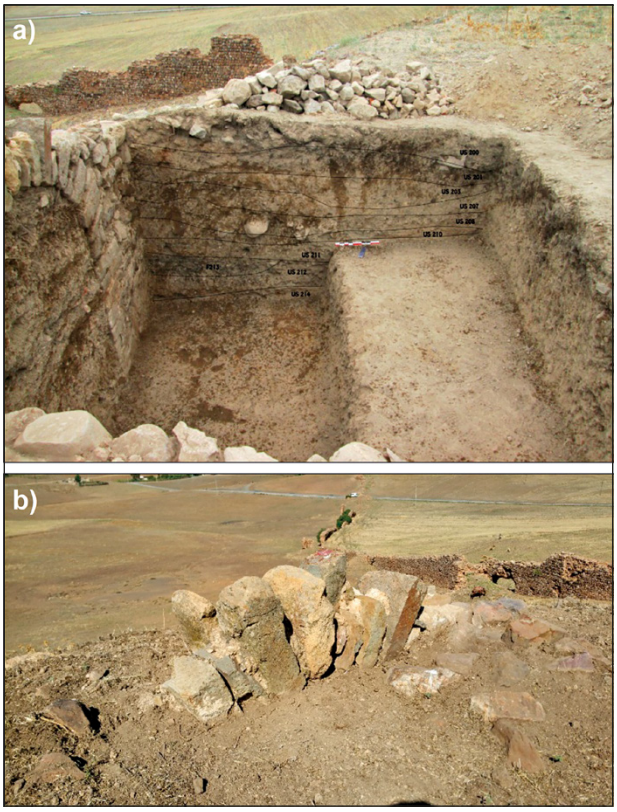

Fig. 9 – a) Layers structure in the excavation area (elaborated by F. Susanna) and b) the arch structure after cleaning of the area.

cattle and goats), coals and cookware pottery. The excavation stopped at layer US 214 without reaching the virgin ground.

A round arch and pillars, carved out of a single block (of ca. 60 cm) and two smaller ones of circa 25 cm, composed the unearthed structure (Fig. 9b). The arch (USM 202) came to light for the height of 2.85 m and is 60 cm thick at its maximum point. The extrados, especially where it has been exposed to air, is poorly preserved. Some traces of mortar (maybe added after the construction phase) are still visible between the blocks that are higher and closer to the rhombic keystone, probably for static consolidation. The ashlars are slightly irregular and they are mostly dry constructions or with poor soil mortar. They become much more regular on the pillars and they are settled with a dense, grey mortar ca. 3 cm high. The arch is clearly in phase with the walls of the acropolis (USM 205 to the E and USM 204 to the W).

The block of the circuit walls of the "cittadella" are cut and disposed in a less regular way and they are filled with a soil mortar absolutely less coherent. The construction technique of this wall is very similar to those of the USM 101, the northern wall of the acropolis that was rediscovered in the archaeological campaign of 2014.

The external southern side of the door was accurately cleaned. Thus it was possible to identify two rectangular pillars probably used as buttress. The investigation of this area will resume as soon as it will be possible to make new archaeological excavation, which are actually suspended due to some research led by the Mine and in order to allow local authorities to classify the area as cultural heritage of the Kingdom of Morocco.

L.I.M., Y.B., M.S.

7. Archaezoology of Ighram Aousser

The studied material was contained in packets labeled according to stratigraphic units (US) (Tab. 1). It consists of 626 remains, of which 331 could be determined (53%). Bone remains show the presence of several zoological groups (Tab. 2), with a clear dominance of the domestic Caprine (sheep and goat) bones. The other domestic animals represented in the site (dog, cattle and *Equidae*) are less abundant than Caprine. Suids (pig and boar) are not represented in the site. The wild animal remains are very rare and come from intrusive animals. Remains of tortoise were found in US 209 (1 *scapula*-prococacoide), US 211 (8 fragments of carapaces) and US 212 (1 fragment of carapace, 1 *humerus*), testifying the predominance of carapace fragments with respect to other bones. The morphology of all remains allows them to be attributed to the Greek turtle (*Testudo graeca*). Four bird remains were present in US 203 (1 *tarsometatarsus*), US 209 (1 radio-ulna), US 211 (1 *tarsometatarsus*) and US 212 (1 *humerus*). They indicate birds of medium size, as pigeon (*Columba* genus), but the specie(s) is (are) indeterminate. As regards the *Erinaceidae* specie, the only remainder, extracted from US 203, is a toothless mandible attributable to the North African hedgehog (*Atelerix algirus*). An auditory bulla and a maxilla fragment of rodents come from US 203. The morphology of the upper M1 is those of Shaw's jird (*Meriones shawi*).

Dog specie (*anis lupus* f. familiaris) was detected in US 207 (2 mandibles, 3 *vertebrae*, including one axis), 1 incomplete *humerus* (young), 1 incomplete *radius* (young), 1 incomplete ulna, 1 tibia distal extremity, 3 metapodials (distal condyles not epiphysed) and US 208 (2 cervical *vertebrae*). The 14 remains seem belong to the same individual. No long bone is complete and the majority of the extremities are not epiphysed. Among the three metapodials, two (metacarpal III and IV) show a fibrocartilage callus (Fig. 10a) that seems to indicate a resorbed fracture.

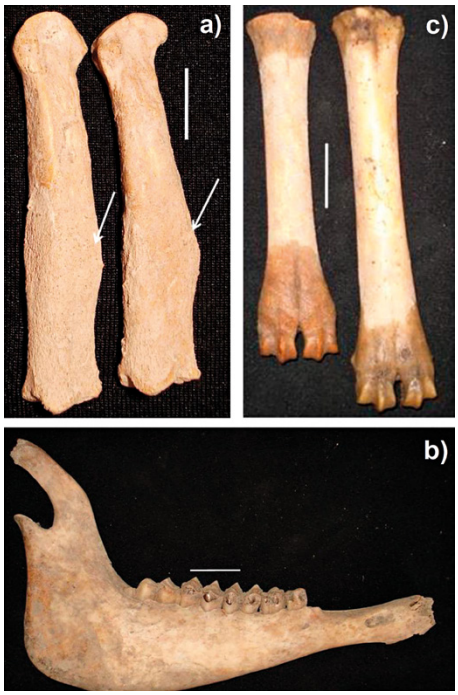

Fig. 10 – a) *Canis lupus* f. familiaris: metacarpals III and IV with callus (indicated by arrow) – the scale bar represents 1 cm; b) *Ovis aries* (sheep): right hemi-mandible lateral view – the scale bar represents 2 cm; c) *Capra hircus* (left) and *Ovis aries* (right): metacarpus posterior view.

The *Equidae* specie was found in US 201 (1 upper P3 or P4), US 203 (2 incisors, 1 lower P3 ou P4, 1 pelvis fragment, 1 femur fragment, 1 tibia fragment), US 207 (2 incisors, 1 vertebra fragment, 1 *humerus* fragment, 1 lateral metapodial), US 208 (1 radius fragment, 1 ulna fragment), US 211 (1 upper M3, 1 axis (second vertebra) fragment, 1 scapula fragment, 2 tibia fragments, 1 metapodial distal extremity) and US 214 (1 axis fragment, 1 radius fragment, 1 medial metapodial distal extremity, 1 lateral metapodial). Even if *Equidae* are represented by some isolated teeth, some *vertebrae* and some fragments of limb bones, however, no long bones are complete. It is difficult to say which equid(s) it is. The size seems to exclude the donkey, and therefore it is possibly a horse or hybrids (mule and/or hinny). A superior premolar from US 201 is notable by its very advanced wear, indicating a very old individual. The bone surfaces analysis shows the absence of anthropic traces in relation with butchery activities.

Cattle (*Bos primigenius* f. taurus) specie was observed in US 200 (1 tibia fragment), US 201 (1 vertebra fragment), US 203 (1 upper lacteal molar, 1 ulna fragment, 4 metapodial fragments), US 207 (4 vertebra, including one atlas, first

USM	Number of images
USM1	247
USM2	93
USM3	86
USM4	167
USM5	134
USM6	298
USM7	135
TOTAL	1160

ZG/US	200	201	203	207	208	209	210	211	212	213	214	TOTAL
Tortoise						1		8	2			11
Birds			1			1		1	1			4
Erinaceidae			1									1
Rodents			1									1
Dog				12	2							14
Equidae		1	6	5	2			7			4	25
Cattle	1	1	6	8		5	2		1	3		27
Domestic Caprini (sheep and goat)	2	17	37	10	17	4	8	74	62	11	6	248
Indéterminate	7	21	63	55	10	5		75	38	12	9	295
TOTAL	10	40	115	90	31	16	10	165	104	26	19	626

Tables 1-2 – 1. Location of the captured images; 2. Remain numbers of zoological groups (ZG) per stratigraphic units (US).

vertebra, 1 humerus distale extremity, 1 tibia distale extremity, 1 calcaneus, 1 first phalanx, 5 diaphyseal fragments), US 209 (3 rib fragments, 1 tibial proximale epiphysis), US 212 (1 rib fragment) and US 213 (2 upper lacteal molars, 1 radius fragment). Contrary to what was noted for the *Equidae*, the majority of the cattle remains indicate young individuals. Indeed, we note the presence of lacteal teeth and not the epiphysed extremities. No complete long bones appear in the sample and several remains show evidence of intentional fragmentation. Domestic Caprine represents the dominant group. We designate by domestic Caprine the sheep (*Ovis aries*) and the goat (*Capra hircus*) even if the distinction between the bones of these two species is not always possible. Therefore, we preferred to provide the inventory of all domestic Caprine in one table (Tab. 3).

There are essentially fragmented bones, except one hemi-mandible, one radius and two metacarpi. The right hemi-mandible (Fig. 10b), with a mental foramen under the P3, can be attributed to the sheep. The height at the withers, calculated by different coefficients, based on the complete metacarpus (Fig. 10c) is approximately 60 to 70 cm. The few remains (33), that have been specifically determined (Tab. 4), show that two species are represented in comparable proportions.

In synthesis, the collection represents a bone assembly characteristic of recent historical periods. The absence of small size bones is probably the result of the sampling technique. The sample is dominated by the bones of domestic

Skelton part/US	200	201	203	207	208	209	210	211	212	213	214	TOTAL
Horn-core					1			1				2
Skull fragments			4		1		1	1	2	2		11
Upper teeth		1						7	2			10
Mandible fragments	1	1	6	3	1			5	12	2		31
Lower teeth		1	2					6	2	1		12
Atlas				1								1
Axis											1	1
Other vertebrae					1		4	8	2			15
Rib							1					1
Scapula		1	4	2	4	1		9	11	2		34
Humerus		3	2	1	1			1	3	2		13
Radius		3	2		4	1	2	10	10		1	33
Ulna			2	1		1		2				6
Pelvis			1		1			3	3		1	9
Femur			3					3	4		1	11
Tibia			3	2				9	5	2	2	23
Talus	1		1									2
Calcaneus									1			1
Metapodials		7	7		3	1		9	5			32
TOTAL	2	17	37	10	17	4	8	74	62	11	6	248

Skeleton part	*Ovis aries*	*Capra hircus*
Horn-core	0	1
Mandible	1	0
Lower M3	1	1
Scapula	4	4
Humerus	1	0
Radius	3	3
Metacarpus	4	2
Tibia	1	4
Talus	2	0
Calcaneus	0	1
Total	17	16

Tables 3-4 – 3. Domestic Caprine (sheep and goat) bones inventory; 4. Specific determinations of domestic Caprine remains.

Caprine with both species represented in comparable proportions. No anthropic traces have been observed on the bones of the dog and equines, suggesting that their presence is not related to consumption. The presence of a very old equine and a dog who has survived a fracture are additional arguments in this sense.

A.D., O.B.

8. Development and promotion of the area of Ighram Aousser

Since the beginning of the project (Cecalupo 2016), the crucial outcome of the scientific work was the creation of a cultural center, with a museum for the conservation and the promotion of the heritage of Ighrem Aousser. To offer a complete insight on the history of the area and its contemporary state, archaeological and technic expositions are combined, with a dedicated

sector for the people who still live and work in the mining areas. Following the museographic schemes of the principal archaeo-mining museums of Europe (Negri 2000), the new *Centre du Patrimoine Minier d'Ighram Aousser*, opened in June 2019[4], has the double aim of preserving and promoting archaeological and mining materials from the area, and also of becoming a reference point for local population.

The center and museum are connected to the area, in the name of a promotion policy based on local resources, that involves social groups and creates new employment opportunities for young people as an alternative to mining work: the valorization of historical and natural heritage has its roots, then, in the valorization of human resources of the local communities. In this sense, the communication in museum – both emotional and interactive – is directed to general public and the exhibition is structured in order to allow visitors to relate themselves easily with the objects. Therefore, the center may become a truly unique product in the cultural horizon of North African museology and heritage promotion.

The center is hosted in the once recreational center for French managers, at the entrance of the French village between Aouam and Tighza. In 2018, it was chosen as the location for the *Centre du Patrimoine Minier* and, in less than two years of restorations, it was given back to the local community. Its proximity to the village of Tighza, with schools and associations, as well as to the archaeological and mining areas, preserves the strong relation with the land and the historical traces on the countryside. This may be a proper answer to some of the fundamental issues of contemporary archaeological museology: collections have to remain close to their environment or place of discovery (Negri 2000), to offer spatial and ideological proximity between objects and sites. Through this practice, museums can become the natural appendix of the sites and help in the contextualization of the archaeological finds, to generate a comprehensible exposition for visitors and dwellers.

The exposition space is dedicated to five themes (archaeology, mineral exploitation, geology, everyday life and local traditions) and offers an eye on local history and technical mining development. The archaeological section hosts 12th-13th century finds from the area of the fortress, mostly pottery and metal nails. The following section is dedicated to the metal processing and exploitation techniques in antiquity, enriched with a 3D reconstruction of an ancient melting

[4] The restoration, the exhibition setting and the opening of the center was possible thanks to many institutions. First, the Compagnie Minière de Toussit and the CNR-ISPC, in association with the Italian Ministry of Foreign Affairs and International Cooperation, the Italian Embassy in Rabat and the Italian Institute of Culture of Rabat. Great support was offered by Rotary Club Roma EUR, Rotary Club Sofia 1993, Rotary Club Pompei, Ass. A.I.M., SAMOA Restauri. Some pieces were donated by the associations for local development Abghor and Tighza Atlas. The project was followed by Lorenza Ilia Manfredi, Hassan Bounajma, Iliario Tassone, Simona Abate, Badr Ouchtouban, Chiara Cecalupo and Laura Attisani.

oven for metal extraction in a reassembled ancient environment with stones, slags, wood and grillage zone. This reconstruction is improved by educational panels dedicated to kids, with drawings and short texts to explain melting and extraction technologies. Then, the third section of the exhibition space is dedicated to geological materials and extraction tools, with photographs of the Minière and its employees in the last decades. To the local community is dedicated also a little exposition of traditional textiles prepared by local associations.

In the whole museum, space is given to learning materials like panels and videos. 3D reconstructive models of the fortress and videos on the archaeological project are displayed in a projection hall – at disposal of the local community – in order to explain the historical development of the area from pre-Roman times to now, with focus on the fortress in medieval era and on archaeological prospections of the whole region. The connection between video installations and traditional museum panels helps in differentiating the museum exhibition and underlining the diverse approaches to the site (Preite 2000).

The museum aims to become an appendix of schools and institutes of the local rural community, to be part of cultural life for the area (Bonavitacola 2008) and involve dwellers of the surroundings: at the end of the exposition path, there is a little museum library with educational games and computer workstation at schools' disposal. Archaeological excavations and heritage promotion help dwellers to give value to their own land. The *Centre du Patrimoine Minier*, seen as the first step for the creation of an archaeo-mining park, is not the endpoint of research, but the occasion of bringing to Morocco ideas of promotion of archaeo-mining heritage experimented with success throughout Europe and Italy (Negri 2000).

C.C.

9. Conclusions

The multi-methodological and multi-scale researches in the area of Ighram Aousser have allowed acquiring new data about unexplored areas. On a large scale, it was possible to ascertain and document natural resources unknown until now as mines, water sources and stone quarries around the fortress through surface archaeological reconnaissance. As regards the fortress, through photo interpretation, other possible access points to the city have been identified and the shape of the so-called acropolis has been better clarified: the walls of the fortification delimit an octagonal space, raised above the surrounding land, with external towers placed at all eight corners of the structure. Furthermore, from the remote sensing images, the three-dimensional reconstructions obtained by laser scanner and the geophysical prospections, a further octagonal structure has been recognized at the level of the walking surface of the hill. It encloses the top of the acropolis and appears to have the

same shape and the same orientation as the outermost octagonal fortification. Archaeological excavation, even if limited, allowed underlining the importance of Ighram Aousser as a central area of many different mining activities such as extraction, smelting, fusion, pottery production.

The research led in the area of Ighram Aousser represents the first step towards the development of a specific methodology that would be able to describe the production of metal in ancient North Africa. The idea is to offer a comprehensive study that aims at understanding technical methods of mining, pyrometallurgical metal processing, resource management and trade on a local, regional and Mediterranean level, as well as production process technology and artisans' know-how. Always bearing in mind, obviously, that the current findings refer mainly to the mining exploitation that dates back to the Islamic period. This requires a careful and historicized analysis of the data that may take into account the evolution of those technologies that have marked the transition from ancient times to the Middle Ages.

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ABSTRACT

The fortress of Ighram Aousser is located in Morocco, 10 km W of M'rirt and 120 km S of Meknés, on the so-called mines route. The lack of an organic and complete documentation and a concrete need to acquire new data about unexplored areas have required a multi-methodological research including the analysis of historical sources, archaeological surveys, topographic investigations, laser scanner modelling and geophysical prospections. All data were stored in a Geographic Information System, which allowed spatial analyses and the creation of thematic maps. The integrated geoarchaeological approach has led to a new archaeological map providing an updated view of the rich archaeological heritage in that territory. The article also offers a complete account of the valorization processes, the international promotion of the site and its long-lasting mining tradition.