

The Geographical Framework: Geology, Geomorphology and Alteration Processes of the Rock Art Surfaces

El marco geográfico: Geología, geomorfología y procesos de alteración de los soportes con arte rupestre

Juan José DURÁN

Instituto Geológico y Minero de España
Madrid
jj.duran@igme.es

Received: 19-05-2014

Accepted: 12-11-2014

ABSTRACT

Oukaïmeden is located in the Toubkal National Park, in the western third of the High Atlas geological domain. The geological structure of this area presents smooth folds, supracrustal thrust faults and faults placed transversally to the mean structural directions of the mountain range. There are outcropping materials from the Palaeozoic base and the Mesozoic sedimentary cover, here consisting exclusively of clastic sedimentary rocks from the Triassic period. The largest morphological feature in Oukaïmeden is the basin, limited to the north by the Tizrag morphological slope and the rugged reliefs of the Paleozoic rocks to the south, which culminate in the Jbel Angour (3.616 m.a.s.l). The most important formations are the two slopes of Triassic sandstones: Tizrag to the north, and Tifita to the south, separated by the narrow valley of the Irini River, which drains the Oukaïmeden depression to the northeast. Over these two large elements there is a remarkable group of rock carvings. However, their location vary with regard to the geological features of their near vicinity: carvings located separating strata, inside a stratum, on fractures, on fallen rocks or inside rock shelters or small cavities. Most of the carvings present a black patina with metallic reflections. Given their antiquity, their sub-horizontal position, that most of them are in open air locations and the continued use of this territory by the local population, the carvings show a wide range of alterations, described below.

KEY WORDS: rock shelters, rock engravings alteration, High Atlas, Triassic sandstones, Oukaïmeden depression.

RESUMEN

Oukaïmeden se localiza en el Parque Nacional de Toubkal, en el tercio occidental del dominio geológico del Alto Atlas. La estructura geológica de esta zona presenta pliegues suaves, fallas inversas y fallas supracorticales colocadas transversalmente a las direcciones estructurales medias de la cordillera. Hay materiales que afloran desde la base Paleozoica y la cubierta sedimentaria Mesozoica, aquí constituida exclusivamente por rocas sedimentarias clásticas del Triásico. La característica morfológica más relevante de Oukaïmeden es la cuenca, limitada al norte por la meseta del Tizrag y los relieves escarpados del Paleozoico al sur, que culminan en el Jbel Angour (3.616 m/sm). Las formaciones más importantes son las dos cuestas de areniscas del Triásico: Tizrag al norte, y Tifita al sur, separadas por el angosto valle del Irini, que drena la depresión Oukaïmeden al noreste. Sobre estos dos grandes elementos existe un notable conjunto de grabados rupestres. Sin embargo, su localización varía con respecto a las características geológicas de su vecindad cercana: grabados en separación de estratos, dentro de un estrato, sobre las fracturas, sobre rocas caídas o dentro de abrigos rocosos o pequeñas cavidades. La mayoría de ellos presentan una pátina de color negro con reflejos metálicos. Dada su antigüedad, su posición subhorizontal, que la mayoría de ellos están en lugares al aire libre y el uso continuado de este territorio por la población local, los grabados muestran una amplia gama de alteraciones, descritas a continuación.

PALABRAS CLAVE: abrigos rupestres, alteración de grabados, Alto Atlas, areniscas triásicas, Depresión de Oukaïmeden.

1. Regional geological framework

From a geological perspective, the Oukaïmeden area is located in the Atlas Mountains, the southernmost mountain range of the Alpine Orogenic Belt. The Atlas is an intra-cratonic mountain range formed by the tectonic shortening –from north to south- of the African Plate (Teixell *et al.* 2007). More specifically, Oukaïmeden is located in the western third of the High Atlas geological domain. It is found approximately in the Marrakesh meridian, to the south of the *Haouz* plain and to the north of the Anti-Atlas domain located between the *Souss* basin (southeast) and the Ouarzazate basin (east-southeast) (Hollard 1985).

1. 1. Geology of the area

The geological structure of the High Atlas in the Oukaïmeden area is relatively simple, presenting smooth folds, supracrustal thrust faults and faults placed transversally to the mean structural directions of the mountain range. It is set around the contact area between the Palaeozoic base (in the south) and the Mesozoic sedimentary cover (in the north), here consisting exclusively of clastic sedimentary rocks of the Triassic period.

1. 2. Stratigraphy

The geological materials cropping out to the surface belong to three different lithological assemblages that occurred consecutively -from the oldest to the most recent- separated by important sedimentary discontinuities and tectonic processes:

- Igneous rocks from the Palaeozoic base
- Series of red sandstones from the Triassic period
- Quaternary sediments.

The origin of the Palaeozoic rocks is mainly igneous, but a more precise age cannot be indicated. They are mainly felsic plutonic rocks of coarse grain size. Among them are sub-volcanic rocks of more basic compositions, oriented N0°-40°E and dipping sub-vertically southwards. Some of the veins in the igneous rocks are mineralized, as in the surroundings of the *Tizi n'ou Addi* mountain pass -2.950 m.a.s.l.- where there is evidence of copper minerals (malachite and azurite). There is also evidence of other zinc and lead mineralizations, and some relatively important exploitations can be found. The evidence of numerous mineral deposits near the area of contact between Palaeozoic rocks

and Triassic sedimentary materials is a significant basis for the evaluation of the role that these resources may have played in the evolution of the population in this environment.

The series of red Triassic sandstones has been described by several authors (Benaouiss *et al.* 1996; Courel *et al.* 2003). The overall interpretation is that they are distal deposits of braided fluvial systems. They present alluvial plain facies with abundant tractive sedimentary structures: dunes (cross-lamination), upper-regime parallel lamination and others. There are also other structures -sometimes protruding in the current micro-morphology- of a possible biological origin and related with fluid leaks. The stratigraphic sequence is several hundred meters deep and has been interpreted as the continental filling of a rift basin -occasionally connected to the sea- due to the presence of facies of possible shallow tidal marine origin in the middle section.

The sedimentary sequence is made up of alternating, well-cemented centimetric or decametric strata of sandstones (predominant) and quartz sandstones with fine grained and -less frequently- conglomerated sediment banks. The abundance of all kinds of sedimentary structures is noteworthy, especially in the sandstone banks, with outcroppings that offer a great diversity of micro-relief morphologies, as mentioned above. Inconsistent quaternary sediments of alluvial (valley bottom fillings) or periglacial origin lie over both materials.

1. 3. Structure

The structural layout of the two main lithological assemblages at Oukaïmeden is relatively simple. A thrust fault lying approximately WSW-ENE separates the Palaeozoic rocks located to the south of the Oukaïmeden Depression from the northern outcrop of Triassic materials. The depression runs in the same direction as the contact area.

The monoclinial series of Triassic sandstones dip slightly southwards, mainly between 10° and 30°, with layers in a range of directions from N. 30° to 75° E.

The monocline structure ends with a syncline fold to the west and east of the Oukaïmeden Depression. The *Tizi n'ou Addi* mountain pass has a series of folds and small fractures that form the periclinal end of a larger syncline fold. Towards the eastern side, beyond *Ait el Kack*, the structure ends with a smooth syncline fold.

1. 4. Geomorphology

The most remarkable feature of the Oukaïmeden area is the basin, originated by the combination of

lithologic and structural features. This basin is surrounded by positive asymmetric reliefs to the north and south, and open to the east and west by a small mountain pass and a strongly enclosed valley, respectively. Other authors have previously described this basin as a *plateau*. However, its morphology seems to be more consistent with a fluvial valley, the origins of which are probably related to the pleistocenic glacial processes broadly developed in this High Atlas area.

The basin is demarcated on the north by the *Tizrag* morphological slope -conditioned by the monocline structure of the Triassic sandstones of the northern slope (fig. 1) -, and the rugged reliefs of the Palaeozoic rocks on the south, which culminate in the *Jbel Angour* (3.616 m.a.s.l.). The depression is closed westwards by the perisynclinal enclosure of the *Tizi n'ou Addi* mountain pass, while the termination to the east is morphologically more complex. To the northwest it ends at the *Irini* ravine, and through a series of consecutive hills and valleys on the back of the *Tifita* slope to the south.

From a geomorphologic point of view the most spectacular and important formations are the two slopes of Triassic sandstones: *Tizrag* to the north and *Tifita* to the south. The first is far more prominent in the landscape than the second. They are separated by the narrow valley of the *Irini* River, which

drains the Oukaïmeden depression to the northeast. Over these two large elements providing the essential structure of the landscape -the slopes of Triassic clastic sedimentary rocks- are found all the rock engravings known so far.

On the other hand - using a more detailed scale -, the sandstones show an interesting pseudo-karst micromorphology, developed through the fractures and the sub-horizontal stratification surfaces (widely exposed at the surface). A remarkable development of black alteration patinas has also been observed in the sub-horizontal and some of the vertical surfaces, similar in appearance to the so-called "desert varnish".

The Palaeozoic materials located to the south of the Oukaïmeden Depression, the Triassic materials in the west, and the north of the *Tizi n'ou Addi* mountain pass, present clearly eroded steep slopes with a rough relief. Glacial processes must have played an important role in altitudes higher than 3.300 m.a.s.l. (Hughes *et al.* 2004), as suggested by the presence of accumulation zones with glacier cirque morphologies and sharp drainage divides showing numerous sharply angled, isolated peaks. Periglacial processes must also have had a strong influence on the Pleistocene cold phases, and continue to do so nowadays, as shown by the numerous active screes at the bases of the most protruding reliefs.



Fig. 1. General view of Oukaïmeden. Triassic sedimentary materials to the right (North), arranged in morphological slopes where the carvings are located.

2. Geological characterization of the engraved rocks

As mentioned above, rock engravings have only been located over the series of Triassic red sandstones, so far. The large majority of the carvings also share a geomorphological factor, since they were executed on the outcrops of the two morphological slopes that define the monocline of the sandstone series, the *Tizrag* and *Tifina* slopes. The spatial location of the carvings can also be explained by a third determining factor: they are confined to the intermediate granulometry of the Triassic series. They are never found in the fine-grained polytic facies or the coarse-grained conglomerated facies.

Besides these three determining factors, the locations of the carvings vary considerably according to the geological features in their near vicinity. The following locations have been detected:

- carvings executed on stratification surfaces (separating strata)
- carvings executed on internal lamination surfaces (inside a stratum)
- carvings performed on surfaces positioned perpendicular to the stratification surface (fractures)
- carvings executed on erosion surfaces (cutting the strata)

- carvings executed on fallen rocks
- carvings inside rock shelters or small cavities.

The large majority of the carvings documented so far in the Oukaïmeden area were performed on stratification or lamination surfaces and therefore oriented southwards and in the same direction as the smooth dip associated with these kinds of surfaces.

2. 1. Oukaïmeden rock shelters

As mentioned above, most of the carvings are executed on rocky surfaces, with some exceptions carved on the vertical or sub-vertical surfaces of isolated rocks or small outcrops. Nevertheless, a remarkable morphological feature of the Oukaïmeden area is the presence of numerous small rock shelters, many of them used as dwelling places by people or as stables for livestock.

These rock shelters share a similar origin, in which mechanical processes are predominant. The rock shelters are located in the more or less abrupt valley slopes and sometimes in the overhanging ledge of the upper slopes generated by differential erosion of the base and the subsequent falling of rock fragments (determined by preexistent sub-vertical fractures) from the top. This is due to the existence of strata of different granulometry and thickness in the Triassic series, the sub-horizontal position of these strata and an important fracture network. Generally,



Fig. 2. Elephants' Shelter, also called Adbasan Shelter. Some of the existing carvings are covered by sediments.



Fig. 3. OK3 Rock Shelter, near *Tizi n'Gar Issafen*. The origin of the shelter - fallen strata from the ceiling- can be clearly observed.

the rock shelters are moderate in size, from several meters to tens of meters at the front and several meters in height and depth.

Nevertheless, very few shelters have been used as a carving surface. This might be explained by the more practical uses of these spaces as shelters and dwelling areas, as mentioned above. However, some shelters contain engravings that, in some cases, are spectacular and well preserved. Moreover, they contain recent sedimentary fillings that allow for archaeological interventions. This is the case of the so-called Elephants' Shelter, also known as *Abadsan* shelter.

The most remarkable of these shelters are the aforementioned Elephants' Shelter, another one lo-

cated in *Tizrag* near the Bull mountain pass, or in local Berber language, *Tizi n'Gar Issafen*, and the last one, the so-called Elephants' Frieze.

The Elephants' Shelter (fig. 2), is located in the *Tifta* slope, near the *Abadsan* stream. It is a complex space, sheltered by a ledge made up of a thick sandstone stratum, that constitutes the back of the morphological slope. It is located at an approximate altitude of 2.300 m.a.s.l., and oriented northwards to the *Irini* River valley. The geological structure is determined by stratification oriented according to a N55° E plane, dipping 20° southwards. The shelter is one of the largest of the area, with dozens of square meters occupied by fallen blocks - from the ceiling and the walls - and also clastic sediments containing several archaeological layers. The sedimentological sequence probably contains an initial layer, with evidence of archaeological remains (4 ky BP cal.) and then a hiatus of 2.200 years, indicating the dominance of erosion processes. Then, a series of mainly clayey layers - rich in organic matter - indicating semi-inundated or very wet local conditions inside the shelter, corresponding to the last 1.800 years. Some of these last layers show very few archaeological materials.

The *Tizi n'Gar Issafen* Shelter -also called Bull mountain pass¹ - is located halfway up the *Tizrag* slope, dominating the left bank of the *Irini* River, at approximately 2.640 m.a.s.l. It is a small cavity of exclusively mechanical origins (fig. 3), where a



Fig. 4. Elephants' Frieze. Sedimentary structures in the vertical fracture plain where the carvings are located.



Fig. 5. Sub-horizontal rocky outcrop, showing no patina, with carvings on the right lower side.

sandstone slab that tilted and fell from the ceiling was used as a carving surface. The stratification determining the rock shelter is oriented N 50°/12°S.

Lastly, the Elephants' Frieze (fig. 4) is located in a rocky outcrop of the southern monocline of the *Tifita* slope, near the left bank of the *Tiferguine* stream, tributary of the *Irini* River. This is actually a vast surface arranged perpendicularly to the stratification surfaces and probably related to the presence of a fracture. The layers are oriented N 60°/15°S. An active fluvial bed and a small underground water source exists in the surroundings.

2. 2. Rock engraving alterations and possible protection measures

As mentioned above, all the engravings documented so far were executed on Triassic red sandstones and limited to facies of intermediate granulometry, as there is no evidence of engraving on more fine-grained pelitic or more coarse-grained conglomerated facies. Chronologically, the presence of carvings from different ages covering a wide period of time and several layers is evident. Most of the depictions present some kind of patina. The most representative colour of the patina is black with metallic reflections. The different patinas, their composition and evolution, as well as the possibility that they were reproduced artificially have been studied recently in Boizumault's doctoral thesis (2008). Obviously, given their antiquity, their sub-horizontal position, the fact that most of them are in open air locations and the continued use of this territory by the local population, the carvings show a wide

range of alterations –whether potential or real- due to natural or anthropic causes, described below.

2. 3. Description of rock engraving alterations

The distribution of the rock carvings in the territory has been analysed according to the area distribution described previously.

• OK1 Area ²

The carvings are executed over large stone blocks fallen from the slope. The engraved surfaces show various directions, although most of them are sub-horizontal. The main alterations are exfoliation, fractures and natural erosion.

Signposting and installing markers or a fence are possible protection proceedings.

• OK1' Area

The carvings are located on fallen blocks in the ground. The main alterations have been caused by natural erosion processes, stepping, burying, exfoliation and fracturing. Some carvings adapt to the small shapes originated by natural erosion, although the possibility of human retouching cannot be ruled out. Some carvings are also covered in vegetation and lichens. There are some clearly modern engravings (*grafitti*).

In addition to installing sing posts and markers other protection measures could include diverting the paths and the periodic cleaning of sediment and vegetation.



Fig. 6. Carvings on outcropping rock surfaces between the houses, used as a bus stop of the village of Oukaïmeden.

• **OK2 Area**

The alteration and possible protection measures are similar to those described for areas OK1A and OK1A'.

• **OK2 “Repeater” Area**

The large majority of the rock carvings are located in highly patinated stratification surfaces, in the village of Oukaïmeden. They show only a slight inclination and are placed at ground level (fig. 5).

The most frequent alteration processes -in addition to natural erosion- are exfoliation, burying by stones or fine sediments, stepping and recent surface uplifting.

The possible protection measures are the installation of fences (with walls made of local dry stone) or markers and, most importantly, protection against urban development (including the opening of new roads).

• **OK2 “Azib” Area**

This includes the *Azib* Oukaïmeden. Most of the carvings are on the ground, on stratification surfaces or on single blocks. The most frequent alteration processes are stepping, fallen blocks from the *Azib* structures, burying by sediments, covering by vegetation, fragmentation and exfoliation. Some of the carvings show holes of possible natural origin.

The necessary protection measures are the installation of markers and construction of a small wall



Fig. 7. Carvings performed on natural fracture surfaces with well-preserved patina and a modern graffiti overlapped.

-for the carving located near an *Azib* house- in addition to a general cleaning.

• **OK2 “Village” Area**

The largest portion of the carvings are on the ground, on stratification surfaces or among the houses of the village of Oukaïmeden. The main alteration processes detected are mechanical fractures (deep laminar and superficial exfoliation) and stepping.

The protection measures could include the installation of markers and regulations for new construction.

This village is one of the high risk areas, at the very heart of the village of Oukaïmeden, and some of the high quality engravings have been partially destroyed. This is a vast area, with numerous carving assemblages distributed over stratification surfaces, sometimes showing a large amount of patina, fallen blocks, vertical walls and shelter-like structures. The alteration processes are: direct mechanical fractures of the carvings, stepping, stone accumulation over the carved surfaces, exfoliation and garbage accumulation.

One of the sites that requires more urgent intervention is the rock art station located near the cross-road of the ski resort, frequented by people and livestock because it is next to the bus-stop, to the Marrakech coach line (fig.6).

The necessary protection measures are the installation of markings and fences, cleaning, the construction of a path and, in some particular cases, the

production of moulds recreating some of the most important carvings.

These carvings are located on stratification surfaces and fallen blocks on the ground. The main alteration processes are stepping, mechanical fractures, some of these affecting the carvings directly, traditional stonework activities in the surroundings of some of the rock art groups and filling the grooves of the carvings with clastic sediments.

Other possible interventions are cleaning, installation of markers and fences and the possibility of including these assemblages in the Oukaïmeden touristic route.

• **OK2 “Dam” Area**

This area is also in need of urgent intervention. It is located to the east of Oukaïmeden and shows continuous and highly patinated stratification surfaces. This area includes some of the iconic elements of the engravings documented decades ago as serpentiforms, bovids in sub-vertical surfaces, elephants etc.

The main alteration processes are the evidence of traditional stonework activities (i.e. in rock art station 7), exfoliation, fractures, stepping, metallic and concrete bases of old posts, sediment fillings and painted *grafitti* (as in rock art station 6) (fig 7).

The necessary protection measures to be taken are the removal of the existing anthropic elements, installation of markers and fences, cleaning the *grafitti* and producing moulds and replicas of some



Fig. 8. Carving on a slightly tilted stratification surface presenting natural processes of alterations.



Fig. 9. Artificial gallery to extract water, excavated in the near vicinity of the Elephant's Frieze.

of the iconic carved elements.

• OK3 Area

This includes the area of the *Tizi n'Gar Issafen* or Bull mountain pass. The most important carvings are located in a shelter-like structure with a sub-horizontal carved slab inside. There are also vast and continuous stratification surfaces and fallen blocks.

The main alterations are re-pecking, exfoliation, stepping, mechanical fractures, fallen stones over the carvings and the production of proto-kettles. Stonework activities are being carried out near some groups of carvings.

The necessary protection measures to be taken are cleaning, installation of markers and fences and the design of a special protection for the shelter. In addition, we recommend the production of moulds and replicas of some of the iconic carved elements that show evidence of alteration (large bull with curved horns) (fig. 8).

• OK4 Area

This area is also in urgent need of intervention. It includes a part of the *Tiferguine* slope. The carvings are mainly located on elements on the back of the slope (stratification surfaces, sheepback rocks) and, to a lesser extent, in a vertical frieze and some isolated rock blocks. Some of the existing carvings hold a great interest as, for instance, the carved hyena and some others, while presenting significant exfoliation -extreme in some cases (rock art station 1)- or slabbing (rock art station 17). The problems in this area are very complex and diverse: stepping, pecking, stonework, rubble, garbage, environmental degradation, etc., and the engravings are under great risk of alteration. For example, some of the depictions were executed on relatively small blocks on the ground and can be easily transported with the appropriate equipment, so a clear risk of plundering exists (rock art station 2). Some of these also show signs of fractures (bovid, near the river, located on a vertical block -rock art station 18-). In this case, the possibility of moving the block *ex situ* should be considered due to the high risk. This risk has increased recently



Fig. 10. Carving of an anthropomorph in blocks, affected by natural fractures.

due to the nearby excavations of a horizontal gallery -probably meant for water extraction- and the waste dumped in the area (fig. 9). Waste disposal requires an urgent and necessary solution.

Similarly, a specific intervention to protect the Elephants' Frieze is necessary. This would also entail mould production of some of the iconic engravings and the regulated use of the *azib* to avoid constant stepping on some of the carvings, mainly by live-stock.

• OK5 Area

This area is located between the *Tiferguine* Stream and the *Tizi Igountar*. It is a vast area, also located on the back of a geomorphological slope, which is the continuation of the previous slope. The greater part of the engravings are executed on sub-horizontal surfaces or blocks. Some of them are of great interest and importance (idols, human figures, foreshortened animals, etc.). We observed cracks (fig 10), exfoliations, stepping, burying, natural erosion, fracturing and displacements, covering by dirt and vegetation, recent carvings and pecking, accumulation of earth, direct fracture and production of proto-kettles. There is risk of plundering in some specific cases (i.e. rock art stations 2, 5 and 11).

The following are among the necessary interventions: mould production of some of the iconic engravings, considering the transportation *ex situ* of some specific carvings at risk of plundering, cleaning of earth accumulations (rock art station 15), putting the blocks back in their original positions and fixing them to the ground (rock art station 8).

• OK7 Area

This is the area furthest from the population, so there is little human presence. The engravings are located on sub-horizontal stratification surfaces and a very interesting rock shelter called the Elephants' Shelter, or *Abadsan* Shelter after the creek running next to it. We observed mechanical fractures, probably natural, modern *grafitti* overlapped to prehistoric depictions, shallow burying, vegetation and natural/anthropic sedimentation covering, natural erosion and -in some of the carvings of the shelter- re-excavation during the archaeological interventions of this campaign.

The more urgent measures to be taken are the cleaning of specific places and the construction of a path to avoid stepping on the carvings. In addition, a specific procedure for the Elephants' Shelter should guarantee the preservation of the engravings and the current and future profiles of the excavations.

3. Recommendations on the preservation of the carvings

The following recommendations are proposed regarding the preservation of the rock carvings.

- There is a need to prioritize which areas and engravings should be subject to urgent protection measures. This study suggests that some areas be considered as a priority due to the current state of the carvings, their importance, the potential risk of degradation or their proximity to population centres.
- To guarantee the preservation of faithful and exact replicas, it is crucial to select a group of iconic or representative engravings to perform moulds on.
- A set of simple field intervention strategies should be established to guarantee the preservation of the engravings (marking the rock art stations that are located near a population centre, deviating paths, building small dry stone walls, etc.).
- It is necessary to delimit the areas in which certain activities are forbidden. One of the most urgent activities to be forbidden is traditional stonework, performed near some of the rock art stations.
- Another urgent need, in the case of Oukaïmeden, is the approval of an urban regulation regarding the integration of the engravings into the landscape to guarantee their preservation by forbidding urban constructions over them or in their vicinity.
- The rock shelters containing carvings need a protection and value enhancement strategy.
- The possibility of removing some parts *ex situ* should also be studied, given the current high risk of plundering. Thus, the construction of a "museum" or interpretation centre in the village or nearby should be considered.

NOTES

1. Or OK.3 area in the present project nomenclature of art areas.
2. OK1 and following refer to the study areas of rock art and archeological sites, numbered in West (from the *Rheraya* valley) to East direction, (*Ourika* valley).