Tides of the Desert –
Gezeiten der Wüste

Contributions to
the Archaeology and Environmental History of Africa
in Honour of Rudolph Kuper

Beiträge zu Archäologie und Umweltgeschichte Afrikas
zu Ehren von Rudolph Kuper

Edited by Jennerstrasse 8

Jennerstrasse 8 comprises Tilman Lenssen-Erz, Ursula Tegtmeier and Stefan Kröpelin as well as Hubert Berke, Barbara Eichhorn, Michael Herb, Friederike Jesse, Birgit Keding, Karin Kindermann, Jörg Linstädter, Stefanie Nußbaum, Heiko Riemer, Werner Schuck and Ralf Vogelsang

H E I N R I C H - B A R T H - I N S T I T U T

UNIVERSITÄT ZU KÖLN

Heinrich-Barth-Institut für Archäologie und Geschichte Afrikas

14 AFRICA PRAEHISTORICA

Monographien zur Archäologie und Umwelt Afrikas

Monographs on African Archaeology and Environment

Monographies sur l'Archéologie et l'Environnement d'Afrique

Herausgegeben von Rudolph Kuper

KÖLN 2002

Stefan Kröpelin

Damage to Natural and Cultural Heritage by Petroleum Exploration and Desert Tourism in the Messak Settafet (Central Sahara, Southwest Libya)

Abstract

Recent petroleum exploration in the central Sahara on the Messak Settafet (Fezzan / Southwest Libya) has led to the discovery of the giant “Elephant Field”, but caused unparalleled and mostly irreversible damage to the natural desert environment and to the cultural heritage, which includes some of the world's most important rock engravings and probably the largest Palaeolithic surface site of Northern Africa. Against this background, the impact of recent off-road tourism still appears negligible.

It is imperative to prevent any avoidable damage in the future. Hydrocarbon exploration in the Murzuq Basin and the imminent oil production on the Messak must take into account the unique richness of the region by applying a systematic damage-prevention strategy. Environmental and archaeological surveys, including rescue excavations and ecological impact studies, should precede any further industrial activities.

In this context, it is proposed to set up a scheme that combines the creation of a protected areas programme, a strategy for sustainable desert tourism, and the foundation of a Desert Survey and Saharan Research Centre, which should conduct systematic surveys of southern Libya's natural and cultural heritage, aid in the damage-prevention of industrial projects and tourism, and be in charge of awareness building and training.

If only a tiny amount of the enormous petroleum revenues will be assigned to the proposed measures as a kind of compensation for the damage to the Saharan heritage, Messak Settafet – instead of being stigmatised as an example to be avoided at all costs – could become the heart of a pilot project with national and international reach.

Keywords: Sahara, petroleum exploration, cultural heritage, desert tourism, preservation.

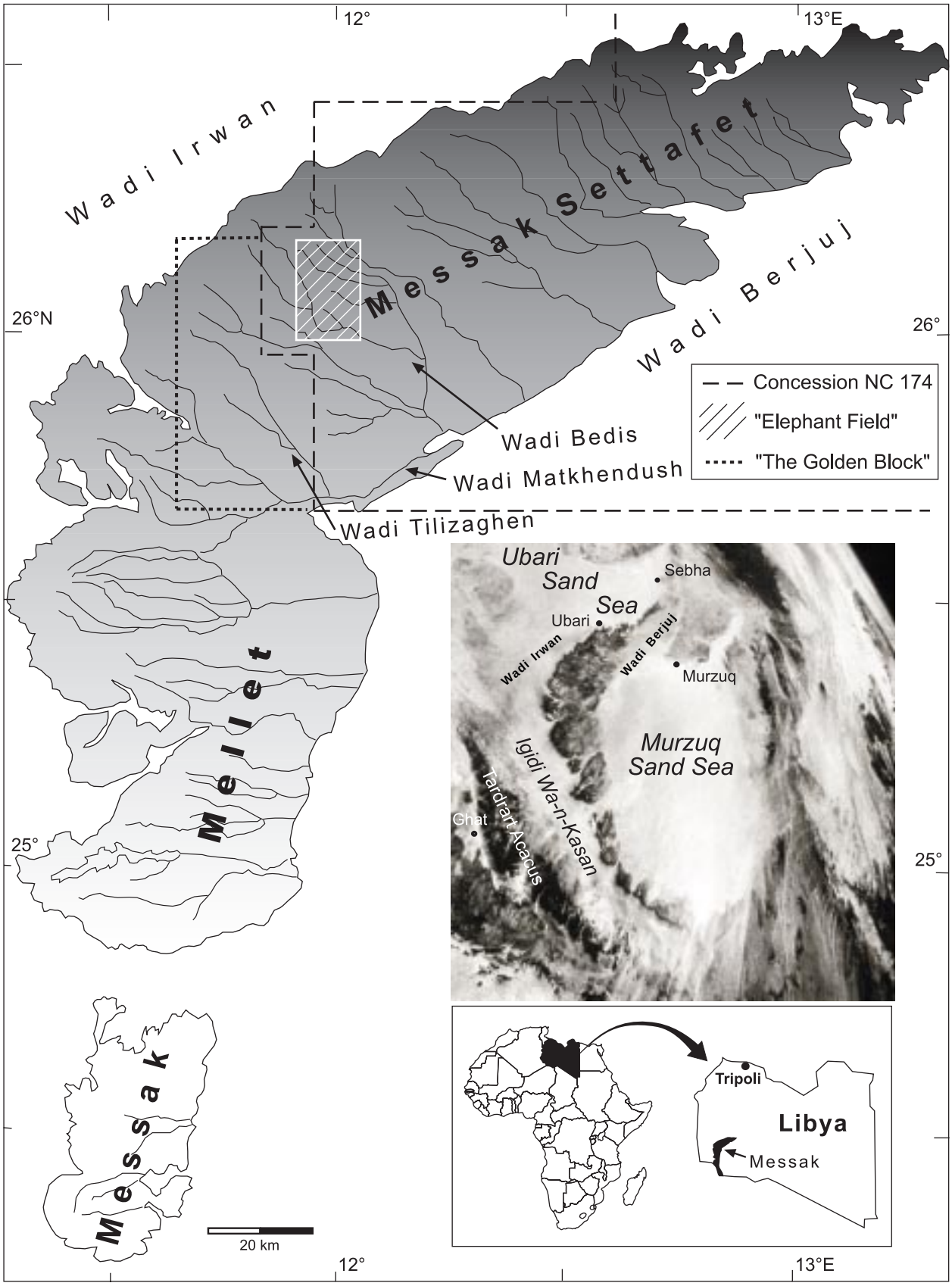
1. Introduction

1.1. Geographical framework

The Messak plateau occupies an area of approximately 350 x 80 km between the extensive dune fields of the Ubari Sand Sea to the north, the Murzuq Sand Sea to the south and east, and the Igidi Wa-n-Kassan to the west **[Fig. 1]**. The Messak can be sub-divided into two plateaus: the Messak Settafet (or 'Black Plateau' because of the very dark colour of the rock surface) in the north, and the Messak Mellet (or 'White Plateau' because of its sandy cover) in the south.

The Messak Settafet borders the large intracratonic Murzuq Basin and is built up by Mesozoic sandstone mostly consisting of mixed fluvial strata (KLITZSCH 1970). It is limited to the north by an up to 160 m high cliff that dominates Wadi Irwan and the plateau's northern foreland **[Fig. 2]**. The escarpments of the Messak plateaus were probably formed by differential erosion under humid conditions during the Tertiary and may therefore be considered as relict features in the modern arid environment (BUSCHE 1980).

The plateau culminates at an altitude of 950 m a.s.l. and declines gently in a southeasterly direction with a gradient of 1 % only. Its hamada


12°
13°E
26°N
26°
25°
Wadi Irwan
Messak Settafet
Wadi Berjuj
Concession NC 174
"Elephant Field"
"The Golden Block"
Wadi Bedis
Wadi Matkhendush
Wadi Tilizaghen
Mali
Ubari Sand Sea
Sebha
Ubari
Wadi Irwan
Wadi Berjuj
Murzuq
Murzuq Sand Sea
Igidi Wa-n-Kasan
Tardrart Acacus
Ghat
Messak
20 km
Tripoli
Libya
Messak

surface constitutes an extreme desert landscape **[Fig. 3]**. The dark colour of its stone cover originates from complex and very old rock varnish (CREMASCHI 1996). The valleys that issue close to the northern escarpment drain in a series of roughly parallel gashes into the sands of Wadi Berjuj, a large interior drainage system situated between the southern limit of the Messak Settafet and the northern edge of the Murzuq Sand Sea.

This part of Southwest Libya plays an important role for the reconstruction of Pleistocene and Holocene environments, climate change and the prehistory of the central Sahara. Nonetheless, apart from geological and rock art studies, it has received little attention compared to the neighbouring area of Wadi Teshuinat which was the subject of more detailed palaeo-environmental and archaeological field research during the past decades (KANES, ed., 1969. CREMASCHI & DI LERNIA 1999).

1.2. Ecological setting

The Messak Plateau is one of the last remaining Saharan regions to preserve an environment that until recently was virtually intact, since it had been sheltered from human impact because of difficult access and an absence of economic interest (FRISON-ROCHE 1965). With an estimated mean annual precipitation of slightly above 20 mm, the hamada of Messak Settafet is virtually uninhabited and, with the exception of a few slight depressions, very hostile to all forms of life. Vegetation and wildlife are constrained to the numerous wadis and their tributaries that cut across the plateau.

The ecosystems of these valleys are heavily depending on the seasonal or episodic water flow occurring after occasional winter rains. These ecological niches support various species of plants, which are the last relicts of the central Sahara's more humid past (SCHULZ 1987). Open water only subsists in some gueltas and in a few protected locations in the wadis **[Fig. 4]**. More

Fig. 1 Sketch map and Gemini XI space photograph (1966) of the plateaus of Messak Settafet and Messak Mellet with areas of recent petroleum exploration.

Fig. 2 Northern escarpment of the Messak Settafet, up to 160 m high. Person on top for scale.

Fig. 3 Hamada surface of the Messak Settafet plateau.

Fig. 4 Wadi Matkhendush as seen from episodic water pool near major rock art station.

Fig. 5 Lush acacia trees, Wadi Bedis.

important for the vegetation, in particular for the astonishingly flush trees, is the sub-surface water at the bottom of the sand-filled wadis **[Fig. 5]**. A provisional list of plants observed in short sections of merely two wadis (Wadi Bedis, Wadi Matkhendush) already includes more than 30 species **[Tab. 1]**.

Only animals specially adapted to extreme desert conditions can survive in the Messak Settafet. Even though high summer is hardly a favourable time to make wildlife observations, some 20 species were identified over a short survey. They include several occurrences of gazelle (*Gazella* sp.) and barbary sheep (*Ammotragus lervia*), which were identified by their tracks and droppings. Dassies and hares are represented by rock hyrax (*Procavia capensis*) and cape hare (*Lepus capensis*). Brown-necked ravens (*Corvus ruficollis*), desert sparrows (*Passer simplex saharae*), spanish sparrows (*Passer hispaniolensis*), white-crowned black wheatears (*Oenanthe leucopyga*), sand grouse and owls figure among the rather diverse bird fauna (det. J.-L. LeQuellec, Brenessard). Other observations include horned viper (*Cerastes cerastes*), lizards (*Agama impalearis* and cf. *Acanthodactylus boskianus*), scorpion (cf. *Androctonus amoreuxii*), beetle (*Pimelia angulata*), spider (cf. *Galeodibus olivieri*), two species of praying mantis, anteater and various species of butterflies, moths, flies, ants and termites.

1.3. Cultural heritage

The petroglyphs on the sandstone of the Messak Settafet probably have no equivalent in the world in terms of their number, originality and quality (LeQUELLEC 1985. MORI 1994). There are thousands of freezes mostly depicting pastoral and hunting scenes, which provide insights into symbolism and cognition of the past.

It was just the Wadi Tilizaghen in Messak Settafet where the first Saharan rock art ever was noted on July 5th, 1850, when the German geog-

Acacia cf. *nilotica*	*Heliotropium* cf. *ramosissimum*
Acacia raddiana	cf. *Juncus* sp.
Acacia seyal	*Launaea* sp.
Aerva cf. *javanica* (syn. *A. persica*)	*Liliaceae*
Aristida pungens	*Maerua crassifolia*
Atractylis sp.	cf. *Neurada procubens*
Balanites aegyptiaca	*Panicum turgidum*
cf. *Chenopodiaceae* (>2 species)	*Pergularia* sp.
cf. *Colligonum* sp.	*Poaceae*
Desmostachia bipinnata	*Pulicaria crispa* (syn. *P. undulata*)
Deverra tortuosa (syn. *Pitoranthus tortuosus*)	cf. *Rhus*
Fagonia cf. *arabica*	*Schouwia thebaica*
Fagonia cf. *indica*	*Solanaceae*
Faidherbia cf. *albida* (syn. *Acacia* cf. *albida*)	*Stipagrostis* sp.
cf. *Farsetia aegyptia*	*Zilla spinosa*
Forsskaolea sp.	

Tab. 1 Provisional list of wadi flora in Messak Settafet. (Determination: F. Darius, St. Nussbaum, Köln, partly on the basis of photographs)

rapher, historian and philologist Heinrich Barth crossed the plateau (BARTH 1857-58). A first systematic study of the rock engravings in the Wadi Matkhendush (previously called Wadi In Habeter) was undertaken under the guidance of Leo Frobenius in 1932 (FROBENIUS 1937). Wadi Tilizaghen was subsequently the subject of publications by GRAZIOSI (1942), HUARD & ALLARD-HUARD (1971), JELINEK (1985a. 1985b) and others.

The enthusiasm of geologists, desert travellers and dedicated rock art amateurs led to the discovery of a large number of further engravings and rock-cut reliefs in other valleys mostly during the past two decades (PESCE 1968. CASTIGLIONI et al. 1986. GAUTHIER et al. 1996. VAN ALBADA & VAN ALBADA, eds., 1994. LUTZ & LUTZ 1995 and others). The first comprehensive synthesis on the rock art and prehistory of the Messak based on extensive fieldwork was published only recently (LeQUELLEC 1998).

The rock engravings typically occur in the middle section of the valleys. They are less numerous towards their lower parts where the cliffs are smaller in size, and next to the valley heads where the bottom of the valleys often becomes very chaotic. They are impressive evidence of the full range of wild and domestic animals, which existed in the savannahs of the early and mid-Holocene humid phase about 11,000-5000 years ago. The spectrum includes ecologically highly demanding fauna such as giraffes **[Fig. 6]**, elephants **[Fig. 7]**, crocodiles **[Fig. 8]**, rhinoceros

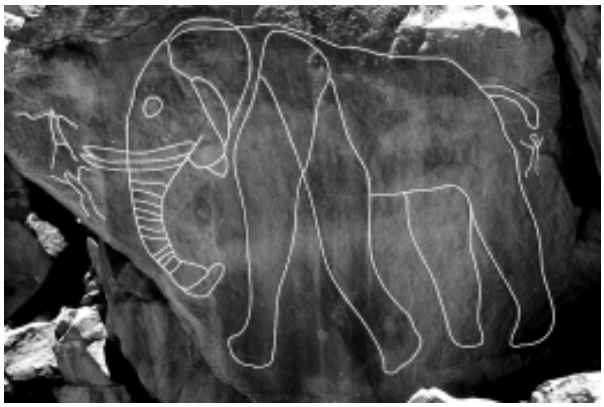


Fig. 7 Rock engraving of elephant and humans, Wadi Matkhendush. Height 1.6 m. White contour lines are computer-generated.

Fig. 8 Rock engraving of crocodile with young one, Wadi Matkhendush. Cracks are widened in comparison to L. Frobenius' photo of 1932. Length 2.5 m.

Fig. 6 Rock engravings of large herd of giraffes, Wadi Matkhendush. White contour lines are computer-generated.

Fig. 9 Rock engraving of hunted rhinoceros with animal-headed human, Wadi Mathkendush. Width 1.4 m. White contour lines are computer-originated.

Fig. 10 Rock engravings of wild cats or guenons, Wadi Matkhendush.

Fig. 11 Half relief of head of *Bubalus*, Wadi Bedis. Diameter 10 cm.

Fig. 12 Acheulean hand-axe in upright in-situ position on the Messak Settafet plateau. Scale 10 cm.

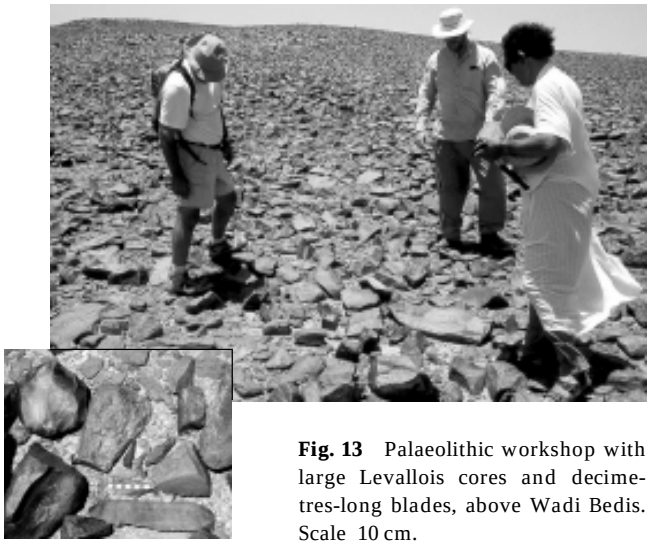


Fig. 13 Palaeolithic workshop with large Levallois cores and decimetres-long blades, above Wadi Bedis. Scale 10 cm.

[Fig. 9], wild cats or guenons **[Fig. 10]** and bovines, e.g. *Bubalus* **[Fig. 11]**. The rock art also provides detailed insights into past human behaviour and imagination, including sexuality and mythology, and living conditions in the central Sahara. There is little doubt that many still undiscovered sites in the valleys of the Messak will enhance the evidence.

Beside the rock art, lithic artefacts and monuments constitute the second pillar of the cultural legacy of the Messak Settafet. Nearly the entire plateau is littered with innumerable lithic objects that mostly date to the Palaeolithic era (Middle and Upper Acheulian, Aterian). With its very gentle slope that prevents any major erosion or accumulation outside the valleys, it presents a very ancient and stable surface that has not changed much over the past hundreds of thousands of years. This is confirmed by the presence of abundant prehistoric artefacts that have generally stayed in situ **[Fig. 12]**. The Palaeolithic occupation sites and workshops often include extraordinarily large Levallois cores, blades and other implements **[Fig. 13]**.

Neolithic sites and objects are also present. In contrast to the Palaeolithic remains, they almost exclusively occur along the banks of the valleys, or near caves, abris and other sheltered places, and are often associated with rock art sites. The material evidence includes pottery, fragments of ostrich-eggshells, arrowheads, upper and lower grinding stones, pestles, and polished axes. As an exception, the so-called “stones of Ben Barur”

occur predominantly on the plateau. This supports their interpretation as trapping stones for catching large game on the plains, which is also indicated by depictions in Wadi Bedis where a trapped bovine attached to a grooved stone is displayed (CASTIGLIONI et al. 1986: Cat. 8).

The pre-Islamic lithic monuments are also mainly situated in the vicinity of wadis. They include up to a few metres high burial mounds, stone circles and numerous monuments with one or two satellite constructions that can reach several tens of metres in length **[Figs. 14; 15]**. More recent occupation of the area is indicated by a number of "desert mosques" and Islamic tombs.

Fig. 14 Circular lithic construction on the plateau. Diameter c. 1.5 m. Sign posted by petroleum company to raise attention of truck drivers.

Fig. 15 One of the numerous monuments with satellite constructions that are tens of metres long.

2. Recent oil exploration and off-road tourism

Before the arrival of the British oil company LASMO Grand Maghreb Limited (LGML), which acted as the operating company of a consortium including the Italian AGIP-ENI and five companies from South Korea, in the Messak NC174 concession area in 1990, two other companies had already undertaken hydrocarbon exploration in the area. The impact of these (unsuccessful) operations had been relatively slight, having been essentially limited to the laying out of superficial parallel tracks at intervals of 4 km for seismic operations. In 1993, LASMO extended the tracks to a square grid of seismic lines on a 4 by 4 km basis for a more sophisticated two-dimensional (2D) geophysical exploration.

In October 1997, this exploration led to the discovery of the most important Libyan oil field in two decades in the area of Wadi Bedis, the discovery well flowing 7,500 barrels of oil per day (bopd; 1 barrel = 159 litres) of sweet 38 degrees API crude. This major breakthrough in the so-called "Elephant Field" triggered the beginning of the three-dimensional (3D) seismic exploration using a much finer grid.

Following a four well appraisal programme and the acquisition of the 3D seismic survey, the field was declared commercial in February 1999. The estimated 560 million barrel "Elephant Field" on license block NC174 is operated by LASMO with a 33% interest (www.lasmo.com, May 2001).

The major discovery and initial development of the giant "Elephant Field" has greatly increased interest for the area's potential. Many petroleum geologists and companies now believe that the Murzuq basin may well develop into a new major hydrocarbon province which will significantly contribute to Europe's energy needs in the next decades (SOLA & WORSLEY 2000).

At the same time, the increase in seismic lines, re-used as tracks, has facilitated the access to the Messak region for off-road tourism. An increasing number of individual travellers familiar with desert conditions and interested in rock art began to venture out onto the Messak Settafet since 1993. Over the past few years, organised and group tourism has been growing significantly. Groups of tens of cars, lorries and motorbikes traverse the

plateau and valleys, both on the tracks and off them. The consequences of this development are of course more severe than those previously caused by individual travellers.

Another key factor for the sharp increase of desert tourism in general was the arrival of easily available and inexpensive satellite positioning devices based on the Global Positioning System (GPS) about a decade ago that enormously facilitates the navigation in desert regions lacking reliable maps. In combination with internet sites and guide books (e.g. GANDINI 1994-1999) that are circulating extensive lists with track logs of routes and precise geographical positions of points of interests, including prehistoric and rock art sites, even the less experienced but well equipped off-road traveller can now reach remote places.

3. Nature and scope of damage

The recent petroleum exploration on the Messak Settafet has caused major damage to the natural heritage (landscape, fauna, flora, hydrology) and to the cultural heritage (lithic material, monuments and structures, rock art). Against this background, the actual harm to the area by off-road tourism still appears secondary.

3.1. Impact on the natural environment

The original seismic grid of the recent exploration involved the bulldozing of seismic lines across most of the Messak Settafet over the entire 11,300 km^2 NC 174 concession area but these were a few kilometres apart. The most important damage to the Messak Settafet only emerged from the bulldozing of a close grid of seismic lines to allow the operation of the heavy seismic vehicles for the 3-dimensional geophysical exploration of the subsurface structural geology of the petroleum reservoirs.

Over the "Elephant Field", an area of 240 km^2, there are some 50 north-south seismic lines of 25 km in length and spaced at 200 m intervals, and about 30 east-west lines of 10 km in length **[Fig. 16]**. Each line is about 4 m wide, corresponding to the blade width of the bulldozers, and often several decimetres deep to remove the loose rubble and to expose the hard rock for better seismic signals.

The length of these seismic lines sums up to about 1,500 km. Their impact on the natural environment of the central Messak Settafet is yet much more severe because of their geometric pattern which results in the complete graphic disorganisation of the landscape.

What is more, in consequence of the heavy traffic associated with the exploration works, the drivers of trucks and other heavy machinery left the seismic lines and the main tracks to avoid rocky or soft passages or to directly reach their destination. This led to the progressive enlargement of many tracks and an almost complete

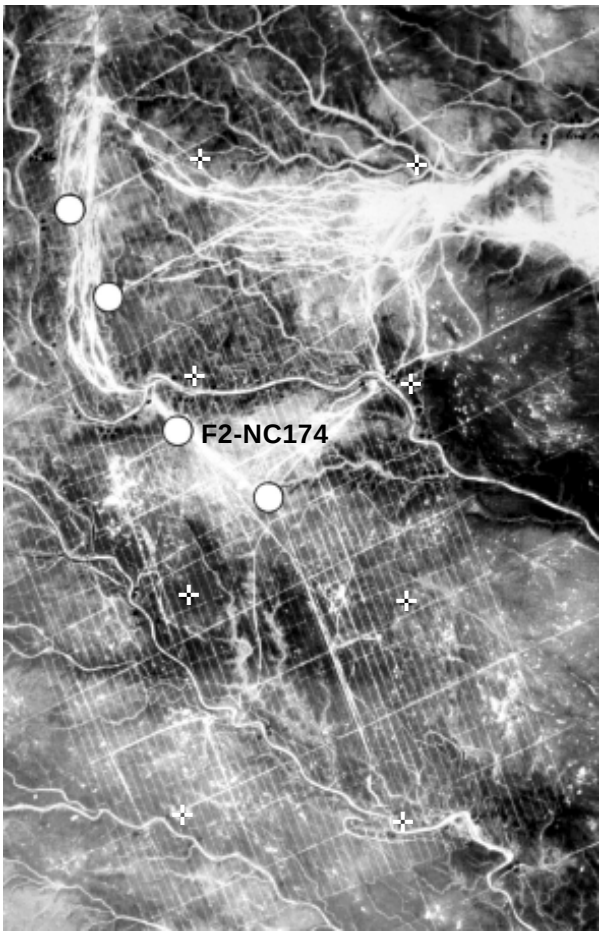


Fig. 16 SPOT image of the central Messak Settafet showing dense grid of bulldozed seismic lines in the so-called "Elephant Field". The seismic lines are 4 m wide, spaced at 200 m intervals and have a total length of 1,500 km. Note the vast destruction of the natural surface around test well drill sites (white circles) and service areas. Equidistance of cross marks 5 km.

devastation of the natural surface around the most frequented areas such as the service areas or drilling sites of the test wells **[Fig. 17]**. In addition to this, turning points, loops, shortcuts and detours have been bulldozed at each intersection with the dense network of valleys **[Fig. 18]**.

The surface deposits of the less rocky sectors of the plateau are composed of porous palaeo-soil formations, on average ten centimetres thick, and protected by a thin sealing layer from erosion and deflation by the everyday winds that cross the plateau. The destruction of the protective layer by traffic or construction works has caused the emission of large quantities of dust into the atmosphere resulting in a significant increase in dust clouds and whirls over the region **[Fig. 19]**.

In spite of all efforts by the operating oil company to clean up the four test well sites, remnants of oil spills and other pollutants have been noticed which hint at the risks of pollution to the plateau once the petroleum production is in full operation **[Fig. 20]**.

Summarising the overall impression of the industrial impact on the plateau, it is evident that the surface of the Messak Settafet can hardly ever regain its original state, even if the exploitation has not even started.

The impact on the wadi floors and slopes, even though these are much more limited in terms of extent, is just as alarming as the one upon the plateau surface because it directly affects animal and plant life. Because of their low topographic position, the wadis act as catchall for any drainage or spill of liquids from the plateau, be it sewage from the service centres or possible oil spills. For example, remnants of heavy mud from a drill site have been observed in a tributary and in a wadi section near a test well in spite of the careful removal of most of the toxic substance by the contractors of the petroleum company **[Fig. 21]**.

The damming of valleys or drainage lines by debris bulldozed at the wadi crossings, and the increase of accumulated fluvial sediments due to the surface degradation along the valleys have impeded and even interrupted the run-off in some wadis, and hence the water distribution along the valleys after the rare but intense rains **[Fig. 22]**. These changes in the hydrological system diminish or prevent the recharge of the local near-surface groundwater and thus put on risk the

Fig. 17 Aerial view of seismic lines, tracks and ravaged areas in the "Elephant Field", central Messak Settafet.

Fig. 18 Aerial view of bulldozed seismic tracks and turning points along valley in the "Elephant Field", central Messak Settafet.

Fig. 19 Progressive enlargement of tracks causing emission of dust, e.g. along the main track to the "Elephant Field".

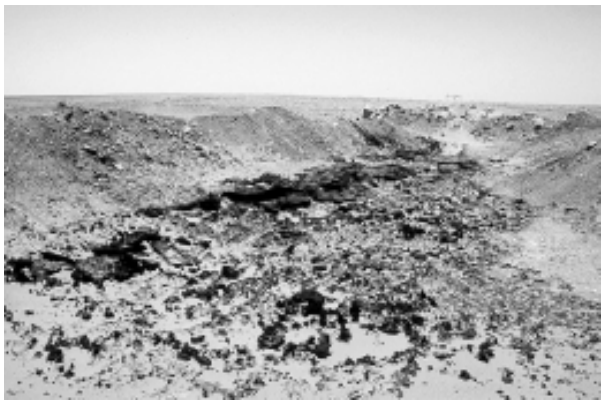


Fig. 20 Oil waste in flare pit, test well drill site F1, central "Elephant Field".

Fig. 21 Disturbed wadi bed after the removal of heavy mud from drill site spill, Wadi Bedis.

Fig. 22 Bulldozed material at wadi crossing impeding down-valley water flow after the rare rains, Wadi Bedis.

existence of trees and other plants down the valley that on their part are vital for the survival of the wildlife. The numerous wadi crossings have already disordered the migratory routes of wild animals.

There is no doubt that many animals have already fled from the operations and that most wild species will vanish from the area as soon as the planned Gas-oil Separation Plant (GOSP) and the wells, camps and routes are in operation. It is obvious that the major part of the insect population of the entire Messak Settafet will burn – possibly to extinction – in the flares of the production wells and the GOSP which will be visible over a radius of tens of kilometres.

The obvious surface damage to the plateau and the valleys should not distract from the very important risks of invisible damage, particularly those concerning the subsoil and the aquifer, which, in this very arid region, constitutes the most important but non-renewable resource. The gravity of ecological, sanitary and economic risks associated with the intended extraction and re-injection of groundwater for pushing up the petroleum should not be underestimated. They imply the possible exhaustion or contamination of the groundwater with incalculable effects on the freshwater supply of the local population in the surrounding regions and for agricultural schemes such as the agricultural farms in Wadi Berjuj.

Compared to the above mentioned damage caused and likely to be caused by the petroleum industry, the impact of recent desert tourism to the natural environment seems almost negligible, even if any off-road vehicle inevitably adds to the degradation of the unspoilt surface left, camp fires contribute to the exhaustion of wood, and rubbish is a blot on the landscape.

3.2. Impact on lithic material, monuments and structures

The Messak hamada is characterised over most of its surface by sandstone rocks that are more or less silicified and occasionally bearing silicified wood. The prehistoric population of the entire region, in the large sense of that term, came there to collect lithic raw materials, which they worked in situ in the course of nomadic or sedentary stays

while benefiting from the luxuriant valleys and the plentiful game which provided the resources for living (DI LERNIA et al. 1997). The passage of these people is attested from the Lower Palaeolithic to the Neolithic, and it is by virtue of this fact that the Messak is crucial for the study of the evolution of techniques in which the raw materials were exploited (LeQUELLEC 1998).

The exploratory works have been most damaging to this kind of archaeological evidence, above all in the 3D seismic survey area, along the main tracks, around the test wells and the camps and air strips (cf. **Fig. 19**).

Numerically, the 1,500 km long seismic lines have only destroyed about 6 km^2 or around 2.5 % of the surface of the "Elephant Field". Taking into account the main tracks serving the wells, the numerous loops and detours that accompany each wadi intersection, the areas of the air strips, of the living area and that of the future treatment plant (GOSP) as well as that of the wells and pipelines, an area of about 8.5 km^2 has to be added. The same applies to a further 50 km^2 in the area between the main airstrip and the wells which has been disturbed to such a degree that it hardly retains any archaeological interest (cf. **Fig. 17**).

Fig. 23 Lower Acheulean site with numerous chopping tools exposed in a bulldozed gravel pit close to main airstrip, central Messak Settafet. Scale of chopping tool 10 cm.

The total area irremediably lost from an archaeological point of view is therefore in excess of 23 km^2, or about 10 % of the surface of the "Elephant Field" (LeQUELLEC et al. 1999). This percentage is considerable, and proportionate damage to the near-surface or exposed and therefore fragile archaeological heritage has to be assumed, the great majority of which has been conserved without disturbance over tens or hundreds of millennia. A lower Acheulean site with numerous chopping tools exposed in a bulldozed gravel pit on the serir near the main airstrip may serve as an example **[Fig. 23]**.

Lithic monuments and structures count among the archaeological remains for which the concessionaire has drawn up protection measures (LASMO 1999). In the area of the "Elephant Field", some circular monuments, one of which with a stele, have been marked by sign posts with the intention of preventing their accidental destruction, even if the entire surroundings are already ravaged (cf. **Fig. 14**).

Large monuments such as the grave mounds and the numerous satellite constructions are easily identifiable on the plateau. Linear structures occurring at the edge of the northern escarpment probably constitute ancient outposts or lines of defence. Burial sites situated on the bottom of valleys in stony areas prove to be more difficult to recognise, as is the identification of the large number of isolated circular structures on the plateau because of their similarity with natural phenomena. Some even more vestigial stone structures of human origin can hardly be identified on the uniform ground level.

In consequence, even if no direct damage to lithic structures in the 3D seismic survey area was noted (but certainly in the 2D area), it can be taken as statistically certain that ground-level structures were affected by the extensive operations that have devastated large segments of the hamada.

In the situation described above, it is practically impossible to distinguish potential damage to the material heritage by tourism from that caused by the petroleum exploration. There is, alas, reliable indication that foreign tourists, tour operators, staff and commercial traders have illegally collected huge quantities of prehistoric artefacts (including pottery, milling and grinding stones, hand axes and other lithic implements), fossils,

minerals and meteorites in southwestern Libya and smuggled them out of the country during the past decade.

In some cases, special lightweight vehicles (quadbikes) were brought on mid-sized trucks and used for systematic collections in the most difficult locations such as the central dune areas of the Murzuq Sand Sea. It is to be feared that tons of prehistoric material have been illegally shipped to Europe and Northern America. As a consequence, often unique archaeological remains are lost for the country's cultural heritage, its museums and for scientific study.

3.3. Impact on rock art

When informed of the existence of rock engravings in the survey zone, those responsible for the seismic exploration attempted to minimise the impact of their operations. Instructions were issued to the drivers of vehicles to stay at least 50 m from the edges of the cliffs in order to avoid any rock fall that could damage engraved surfaces in the wadis.

Nevertheless, there are numerous rock slopes and rock walls near the tracks crossing the valleys, notably in Wadi Bedis, which are buried by bulldozed boulders and debris. It is out of the question to state a posteriori whether or not there had been engravings before the cutting of the tracks. Along Wadi Bedis, for example, some of the finest rock art stations have been partially buried or hidden by heaps of sands bulldozed from the wadi floor **[Fig. 24]**.

Even in areas where no engravings have been directly affected, the dense network of tracks has caused a far-reaching graphic disorganisation of their surroundings. Rock art cannot be reduced to the aesthetic contemplation of works isolated from their contexts. It is embedded into a specific unit of a landscape, e.g. a promontory between two valleys, and the intentions of the carvers can hardly be fully understood if certain elements of the ancient arrangement are missing. Such destruction is unfortunately to be observed almost everywhere where the tracks descend into the valleys.

Many engravings (for example those at Wadi Matkhendush) are veined with a network of cracks. A comparison of the actual state of some of the major stations (cf. **Figs. 8**; **9**) with the photographs taken by Leo Frobenius in 1932 (FROBENIUS 1937: Pls. XVII; LIV) indicates the widening of some fissures. The repeated vibrations caused by bulldozers and 20-ton seismic trucks cannot be expected to have improved their condition.

What has been stated on the impact of tourists on the natural environment and the lithic heritage also applies to that on rock art, i.e. that the present damage caused by tourists, rock art “hunters” and other visitors is dwarfed by the exploration works.

In some locations, however, white marks have been observed which result from the widespread practice among some enthusiasts of rock art to rub chalk across the engravings or to pencil the contours in order to increase the contrast for photography. They ignore the fact that this accelerates the erosion process and eventually leads to the degradation of the petroglyphs. Unprepared travellers who, in lack of chalk, use whatever rock comes to their hand for the same ends cause even worse effects.

Traces of plastic material used for taking casts of the engravings have been recorded at several stations. The plastic remains smudge the surfaces while the lifting-off of the plastic film has often removed the fine patina of the engravings which exposes them to erosion. Bullet holes on some of the most beautiful freezes (cf. **Fig. 6**) and the lighting of campfires near engravings rather originate from non-tourist visitors.

Fig. 24 Rock walls with numerous petroglyphs partly buried or hidden by heaps of bulldozed sand, Wadi Bedis.

In some cases it is hard to decide whether natural weathering or wilful damaging have caused the flaking-off of engraved sandstone slabs during the last decades (BERGER 1998). Isolated, less weighty engraved rocks which are often to be found in the loose sand on the bottom and at the banks of the wadis can be – and by hearsay have been – removed without a trace because of the lack of any inventory.

Though the removal and theft of prehistoric petroglyphs cannot but be considered as a criminal act by everyone, both in moral and in legal respect, it is to be feared that the number of unrecorded cases is high **[Fig. 25]**.

4. Suggestions for action

Regarding the many aspects of destruction and degradation by past and future petroleum exploration and production as well as by tourism, and being aware of the importance of the natural and cultural legacy of the Messak Settafet and the neighbouring regions, the application of a set of mitigating and preventive actions is crucial for the conservation of Libyan and world heritage (LeQUELLEC et al. 1999. KRÖPELIN 2000). The existing Libyan legislation – when respected or applied properly – offers a sufficient legal basis for the prevention of damage and for sanctioning any infringement (LAW NO. 3/1424).

Fig. 25 Petroglyph removed by tourists and confiscated at Elawen control post. Scale 10 cm.

4.1. Archaeological surveys and rescue excavations

Even if the most affected parts of the "Elephant Field" are damaged to such a degree that any surveys and rescue excavations seem useless, it is not too late to preserve less affected areas and to limit to the minimum the impact of the forthcoming petroleum production and further exploration.

For this purpose, it was proposed to proceed at the swiftest possible pace with a systematic archaeological survey of the most endangered areas, i.e. along the roads that will serve the "Elephant Field", on the construction site of the gas-oil separation plant (GOSP), on the habitation area and along the path of the pipeline (LeQUELLEC et al. 1999). The fact that most of the artefacts lie on the surface allows the application of rapid survey methods. Selected representative and coherent sites, in terms of chronology, environmental setting and occupation type, should be investigated in systematic rescue excavations.

Outside of the areas selected for more detailed investigations, significant lithic items should be collected after precise positioning and be placed in the collections at the national museums of Tripoli, Jerma and elsewhere to serve as a reference base for future archaeological studies in the Messak and surrounding regions.

Another priority is a systematic and detailed inventory of all the Messak engravings, commencing with the petroglyph stations located in the damaged zone, taking account of their situation in the now disorganized landscape. Detailed surveys of the valleys and wadi crossings will also permit a rough estimate of the scope of impact on the engravings by the bulldozers and seismic operations. They should also include regular inspections of cracks in, and damage to, the engravings to assess the impact of future industrial and tourist activities.

The archaeological surveys, the rescue excavations and all the environmental and ecological studies should be carried out by specialists in African archaeology and natural sciences with substantial experience in this kind of terrain under the supervision of the Libyan Department of Antiquities and renowned foreign institutions.

4.2. Monitoring and research

All monitoring and scientific activities aim at a comprehensive documentation of the entire natural evidence in the affected areas for future generations and to facilitate proper management of the Messak region.

The database should be designed to include all kinds of field data and analyses and be regularly updated. Based on a Geographical Information System (GIS) and high-resolution satellite imagery, it will allow the production of accurate and actual maps at various scales, including topographic, geomorphologic, ecological, hydrographical, geological and, of course, archaeological sheets.

A survey of the diverse regional flora and the fauna (mammals, reptiles, arthropods, birds, aquatic animals etc.) has to be conducted in all valleys of the 3D and 2D seismic areas. Selected sites should be the object of detailed inventories and long-term monitoring to determine the impact of operations on animal and plant life. Only a complete inventory will allow assessing future changes.

Detailed and independent studies of the hydrogeological situation are vital to determine the impact of the planned extraction and reinjection of groundwater for oil production to the regional aquifer. Impact studies should elucidate the risks from toxic materials that could contaminate the surrounding agricultural areas, threaten the regional flora and fauna, harm the rock engravings or cause respiratory illnesses. Permanent meteorological stations should be installed in order to monitor micro- to meso-climatic changes caused by the operations, in particular increases in dust whirls, storms and fogs.

In order to achieve a better degree of scientific coherence, future research in natural and cultural sciences should be extended to the Murzuq Sand Sea, which bears witness of close links with the Messak since prehistoric times.

To give just one example, some of the rich Neolithic sites there include mobile grinding stones decorated with engravings in the most beautiful style of the Messak. The destruction of these sites would definitely ruin a major opportunity of dating the period of activity of the Messak engravers and understanding the organisation of their seasonal activities.

4.3. Constructions

It goes without saying that the intented construction works should only be undertaken under the strictest damage-prevention schemes to avoid any destruction of still unharmed areas. This concerns above all the surface-consuming constructions of the 0.75 km^2 gas-oil separation plant (GOSP), the 1 km^2 habitation and service area for up to a thousand people, the airstrip extensions, the producing and groundwater injection wells, but also the linear constructions or extensions of the spinal and secondary roads, pipelines and power lines.

To reduce dust emission and to stop the enlargement of the tracks, it would be functional to use tarmac for the spinal axis between the main installations, which would allow natural processes to at least partly reseal the exposed surfaces. According to an option forwarded by the oil company, the main pipeline should terminate some distance before the northern escarpment and than follow a straight (drilled) subterranean course to avoid long circuits or the opening-up of a big trench in the cliff which would spoil the scenery.

The serir areas that are covered with white quartz gravel hold a high archaeological interest because of very ancient Acheulean artefacts occurring only slightly beneath the surface. Therefore, no more gravel pits or foundations for pylons etc. should be opened up before archaeological inspection and rescue excavations if required.

Special care should also be attributed to the treatment of sewage from the camps to minimise damage to the wadis. In the vicinity of such sensitive ecosystems, and in the interest of the personnel, the highest environmental standards with regard to water, dust, fumes, noise, lights, etc. that are operational in the home countries of the oil companies should be respected.

4.4. Restoration work

It appears useless and even detrimental to envisage the restoration of the damaged parts of the plateau by any “cosmetic” measures that have been proposed in this regard, e.g. to recover the seismic tracks with material bulldozed from the sides, or to dye the light-coloured seismic lines black using paint sprayed from aircraft.

One of the more useful measures is the restoration of the bottom of the valleys in such a way that the hydrological and plant life systems retrieve their original state as far as possible. The water flow at road crossings must not be hampered during floods by using culverts or other installations. The bulldozed heaps of sand should be carefully removed from the vicinity of rock art stations and trees along the banks of Wadi Bedis and other wadis.

The proposed closure of the access to some of the most endangered wadis would probably not prevent determined drivers of four-wheel-drive vehicles from finding a way around the roadblocks. This initiative would only encourage drivers to create new tracks causing further damage.

In fact, in the most-damaged area of the 3D seismic survey area, the increase in seismic lines has created a veritable 'labyrinth' of tracks, that, far from easing access like in the 2D area, rather complicates navigation and access for tourists.

4.5. Petroleum production and future exploration

Realising the immense environmental problems, LASMO began to change its plans for the exploitation of the oil deposits of the "Elephant Field" by proposing to reduce the number of wells by way of a technology as yet applied in offshore production and in Saudi Arabia only. By this new method it would be possible to drill laterally from the four already existing wells which would reduce the number of wells from more than 40 as originally planned to only five, and minimize the number of roads, power-line pylons and pipelines that serve them. This very positive approach would have diminished the direct impact on the plateau by at least 2.5 km^2.

According to the latest announcements, however, the first phase of development is supposed to start the production in 2002 already by using seven or eight production wells instead to produce 50,000 bopd. The oil shall be exported via a 75 km long 20 inch pipeline to the El Sharara field in the Messak's northern foreland and then in a 780 km long 30 inch pipe to the Zawai refinery near the Mediterranean coast. In the full production of the field, Phase 2 will even involve some 30 producing wells and up to 20 water injection wells with a production of 150,000 bopd (www.lasmo.com/Development/Libya/; December 2001).

In contrast to the very positive approach mentioned above which included only five producing wells, this withdrawal from the earlier plans cannot but discredit the companies' seriousness about the environment and provoke considerable concern for the future of the Messak Settafet. It is obvious that the forthcoming exploitation will imply additional destruction to the environment and to the cultural heritage, particularly in the second phase of production.

Moreover, major extensions of oil prospecting are envisaged by several international petroleum companies or are already in progress to the west of the giant "Elephant Field" in the tell-tale so-called "Golden Block" which is promising even more important oil finds (cf. **Fig. 1**), and to the south in the Murzuq Sand Sea (www.lasmo.com and personal communications).

From a conservationist's point of view, no extension of the 3D seismic survey area should be permitted as long as the same methods are applied that have led to the present situation in the "Elephant Field". Now that the Libyan authorities and those responsible in the oil companies are aware of the irreversible damage to the Messak Settafet, it is only to be hoped that a systematic damage-prevention strategy will be set up in all future prospecting.

Hydrocarbon exploration is also intended east of the Murzuq Sand Sea, in particular in the northern foreland of the Tibesti Mountains and in the Kufra basin. It is evident that the natural and cultural heritage of a major part of southern Libya is therefore at risk.

5. Coherent overall strategy

Future management plans for the Messak plateau should take into account the ensemble of the geographical and cultural province of the Murzuq basin including the Murzuq Sand Sea and the Tardrart Acacus because of their intimate natural and cultural interrelationship.

The sustainable management of such a large area can only be achieved in close cooperation with all institutions and persons involved through

a period of awareness building and education. All personnel in industry and land-management, tourist agencies and tour operators as well as policy-makers and the local population should participate in such a programme and be made aware of their specific responsibilities in the development of the region.

5.1. Harmonising expectations

The future of the Messak region raises questions that do not stand alone but generally apply to any ongoing and future industrial and tourist exploitation of the Sahara and other deserts. They aim at an approach that, at the same time, permits industrial economic development; allows the development of a quality cultural and eco-tourism for nationals and foreigners; warrants the best possible conservation of the environment and the cultural assets; and allows scientific research for a better understanding of the unwritten past of the desert.

The coordination of these contrasting categories of utilization is far from simple, above all in regions where important economic interests are at stake. In the case of the Messak, these issues can be specified to the problems whether the respect of the prehistoric heritage can be reconciled with petroleum exploration and production; in which way the Messak can be opened up for tourism before a complete inventory of its cultural heritage has been established; and to which degree the preservation of its fragile natural environment is compatible at all with the development of industry and tourism (ANONYMUS 1999).

5.2. Establishment of a protected area

The advocacy of a protected areas programme in the Messak region appears to be the best option responding to the objectives stated above even if it does not solve the immediate problems caused by the industrial impact (LeQUELLEC et al. 1999). According to this option, the irreplaceable heritage of the area would not be fully surrendered to the industrial development which itself is compliant to political and economical factors.

Independently arriving at the same results, a proposal to create an "Archaeological Park" including the Messak Settafet has been brought forward from the perspective of the neighbouring Tardrart Acacus where tourist impact is the major problem (LIVERANI et al. 2000). In spite of the fact that the Acacus is a UNESCO World Heritage Site since 1985 and spared from industrial activities, increasing tourist activity has led to an overexploitation of trees and water, and the pollution and alteration of the archaeological landscape during recent years.

A joint endeavour to achieve the status of a National Park, which includes the highest level of protection, for parts of the Messak and the Acacus must not appear unrealistic, if the Libyan authorities are decided to reconcile the need of industrial development with the conservation of their country's heritage. As an outcome of an initiative to protect the natural and cultural heritage in the southeastern Sahara of northern Sudan, a National Park centred at the Nile's once most important tributary from the Sahara, has been officially declared in 2001 ("Wadi Howar National Park"; KRÖPELIN 1993. 1996). Covering more than 100,000 km^2, it is the largest protected area on earth.

The conflict between the benefits and the effects of eco-tourism, especially to desert regions, is a matter of discussion (ARBEITSGRUPPE ÖKO-TOURISMUS 1995. ELLENBERG et al. 1997). While recognising its potential as a factor for social and economic development, and in spite of good intentions of most visitors, off-road tourism is causing increasing damage to the cultural and natural resources of desert landscapes that should be minimized by appropriate park design.

5.3. Creation of a Libyan Desert Survey and Research Centre

For several years now, Libyan authorities and UNESCO have been considering to establish a Sahara Museum in southern Libya in view of the fact that there is not a single museum or documentation and information centre on the earth's unrivalled desert, in spite of constantly growing public interest and tourism.

The Messak region with its unique collections of petroglyphs, its abundant Palaeolithic sites and

its exceptional natural environments appears to be the right location for the museum and related multi-disciplinary Saharan studies.

In this context, it is suggested that a Desert Survey and Saharan Research Centre be created, possibly in Murzuq, that could be attached to the Sahara Museum and affiliated to the Department of Antiquities. In co-operation with relevant foreign institutions and specialists, such a "Libyan Desert Survey" (LDS) would notably have the task to conduct systematic surveys, as much concerning archaeology as the natural environment, in Libya's remote desert regions, and to aid in damage-prevention by developing a strategy for sustainable industrial exploitation and tourism in the Sahara.

The Desert Survey and Research Centre should also implement training programmes, as much theoretical as fieldwork-oriented, to diminish the lack of specialised human resources in this innovative field. It should also promote a code of conduct, specially conceived for desert landscapes and prehistoric sites, among foreign and local tour operators, and establish a recognition system endorsed by Libyan conservation agencies, UNESCO and the World Tourism Organisation (WTO) for those adhering to the agreed principles (WHC 2001).

Last not least, the Desert Survey and Research Centre should be in charge of awareness building and the information of all those responsible or involved in industrial or tourist activities in the desert. Without their cooperation, it will hardly be possible to accomplish any effective and sustainable conservation of endangered areas such as the veritable open-air museum of the Messak Settafet.

6. Conclusions

The Messak Settafet contains the richest assemblage of rock engravings on the African continent, and possibly in the world. In respect of the lithic material, it is probably the largest Palaeolithic site of Northern Africa. The ensemble of the Messak plateau thus presents a cultural landscape of great coherence, from ancient Palaeolithic times to the Islamic period, and is a candidate for the listing in the World Heritage Convention.

The petroleum exploitation in the NC174 concession area has caused damage that is most likely without parallel in the entire Sahara. Most of the damage to the exceptional relict ecological system (surface, fauna, flora, hydrology) and to the archaeological material (lithic material, rock art, pre- and proto-historic monuments) is irreversible. More damage is anticipated from the imminent oil production and further exploration.

In comparison to the industrial impact, the damage caused by uncontrolled off-road desert tourism in the Messak Settafet still is negligible. From experience in other parts of Libya such as the Tardrart Acacus and elsewhere in the Sahara, however, increasing damage is foreseeable and appropriate measures have to be taken in time before another Saharan domain gets lost.

It would be naïve to believe that the natural and cultural heritage of the Messak Settafet will get a priority above petroleum exploration and production in view of the huge investments and the enormous expected benefits which for the "Elephant Field" alone are supposed to lie in the scale of 100,000 million euros. Europe's energy needs as well as the Libyan state rely on such oil fields.

From an environmental and cultural, less economic perspective, however, it is imperative to minimize any unavoidable damage and to prevent any unnecessary harm to the environment and to the cultural heritage in the future, be it by petroleum exploration and production or by off-road tourism.

It finally rests in the hands of the Libyan government to decide on the best options how to save and preserve the National and World Heritage in its desert lands. If nothing is done in the very near future to protect the natural and cultural heritage in the Messak and other endangered Saharan regions by establishing protected areas programmes, then this era will see the irreversible destruction of many important natural and cultural resources to humanity.

The conflict between economy and ecology in the Sahara was aptly formulated by the British desert explorer Ralph Bagnold: "[…] There is, in this wonderful desert, unlimited scope for many more scientific expeditions […] But for the sake of posterity it is to be hoped (I fear probably in vain) that mankind's craving for exploitation will

not lead to the exhaustion of the accumulated past, whether of water or of archaeology, in the same way as is now happening in the case of fossil fuels" (BAGNOLD et al. 1989).

If only a tiny amount of the giant revenues from the petroleum production on the Messak Settafet will be assigned to the proposed measures as a kind of compensation for the damage to the Saharan heritage, much can be achieved. In this way, far from being stigmatised as an example to be avoided at all costs, the Messak could become the heart of a pilot project with national and international reach.

Acknowledgements and dedication

I am indebted to Jean-Loïc LeQuellec for providing his experience and profound expertise that were crucial in the fact-finding mission, which took place under the auspices of UNESCO in July 1999. Much of the reasoning in this paper goes back to his intimate acquaintance with the Messak. I am also grateful to Serge Maury for advice on Palaeolithic artefacts, and to Guima Anag, Libyan Department of Antiquities, and Mustafa Salem, of the National Oil Council, for their commitment and competence, and the most productive and friendly cooperation both in Tripoli and in the desert.

This contribution is personally dedicated to Rudolph Kuper. His first mission in the Sahara in the winter 1962/63 led him on the footsteps of Heinrich Barth to southwest Libya to assist Hans Rhotert in the recording of rock art in the wadis Ertan and Tarhoscht near Ghat (RHOTERT & KUPER 1981). Hans Rhotert then told him about his expeditions with Leo Frobenius and Ladislaus Almásy in the Libyan Desert of western Egypt and northwestern Sudan. It was in this line of tradition that he established and directed the large-scale multidisciplinary research projects B.O.S. (1980-1993) and ACACIA (from 1995 on) and founded the Heinrich-Barth-Institute at the University of Cologne (1989). Beside his imposing scientific initiatives and achievements, his personal interest and concern have always aimed at the protection of the Saharan heritage to save the past for the future.

8. References

ANONYMOUS (1999) Are oil prospecting and the preservation of a unique heritage incompatible? *International Newsletter on Rock Art* 23, 1999: 11-14.

ARBEITSGRUPPE ÖKOTOURISMUS (1995) Ökotourismus als Instrument des Naturschutzes? Möglichkeiten zur Erhöhung der Attraktivität von Naturschutzvorhaben. *Forschungsberichte des Bundesministeriums für wirtschaftliche Zusammenarbeit und Entwicklung* Band 116, München 1995.

BAGNOLD R.A., Th. MONOD & H. RHOTERT (1989) One word before you start into the desert. Köln 1989 (Leaflet Heinrich-Barth-Institut).

BARTH H. (1857–1858) Reisen und Entdeckungen in Nord- und Central-Afrika in den Jahren 1849 bis 1855; 5 vols. Gotha 1857-58.

BERGER F. (1998) Wadi Mathrndush, Fezzan, Libya 1967-1977-1997. *Cahiers de l'AARS* 4, 1998: 49-51.

BUSCHE D. (1980) On the Origin of the Msak Mallat and Hamadat Manghini Escarpment. The Geology of Libya III: 837–848. Tripoli 1980.

CASTIGLIONI A., A. CASTIGLIONI & G. NEGRO (1986) Fiumi di pietra – archivio della preistoria sahariana. Varese 1986.

CREMASCHI M. (1996) The Rock Varnish in the Messak Settafet (Fezzan, Libyan Sahara), Age, Archaeological Context, and Paleo-Environmental Implication. *Geoarchaeology* 11, 1996: 393-421.

CREMASCHI M. & S. DI LERNIA (eds.) (1999) Wadi Teshuinat – Palaeoenvironment and Prehistory in southwestern Fezzan (Libyan Sahara). Firenze 1999.

DI LERNIA S., M. CREMASCHI & A. NOTARPIETRO (1997) Procurement, exploitation and circulation of raw material: analysis of the Early and Middle Holocene lithic complexes from Southwestern Libya (Tardrart Acacus and Messak Settafet). In: Schild, R. & Z. Sulgostowska (eds.), Man and Flint. Warszawa 1997: 233-242.

ELLENBERG, L., M. SCHOLZ & B. BEIER (Hrsg.) (1997) Ökotourismus – Reisen zwischen Ökonomie und Ökologie. Heidelberg 1997.

FRISON-ROCHE R. (1965) La traversée du Messak Settafet (Mai 1948). *Carnets sahariens*. Paris 1965: 189-239.

FROBENIUS L. (1937) Ekade Ektab – Die Felsbilder Fezzans; Ergebnisse der DIAFE X (10. Deutsch-Innerafrikanische Forschungsexpedition) nach Tripolitanien und Ost-Algier, mit Ergänzungen der DIAFE XII aus Zentral-Algier. Leipzig 1937.

GANDINI, J. (1994-1999) Libye du Sud-Ouest – Le Fezzan. Calvisson 1994, 1995, 1999.

GAUTHIER Y., Ch. GAUTHIER, A. MOREL & Th. TILLET (1996) L'Art du Sahara. Paris 1996.

GEOLOGICAL MAP OF LIBYA (1984) 1:250 000 Sheet Awbari NB 33 – 5. Industrial Research Centre, Geological Mapping Division, Explanatory Booklet. Tripoli 1984.

GRAZIOSI P. (1942) Arte rupestre della Libia; 2 vols. Napoli 1942.

HUARD P. & L. ALLARD-HUARD (1971) Nouvelles gravures rupestres d'In Habeter (Fezzan sud-occidental, Libye). *Bulletin de la Société Préhistorique Française* 68, Etudes et Travaux 2, 1971: 618-628.

JELINEK J. (1985a) Tilizahren, the key site of Fezzanese Rock Art; Part I: Tilizahren West Galleries. *Anthropology* 23, 1985: 125-165.

– (1985b) Tilizahren, the key site of Fezzanese Rock Art; Part II: Tilizahren East, Analyses, Discussion, Conclusions. *Anthropology* 23, 1985: 223–275.

KANES W.H. (ed.) (1969) Geology, Archaeology and Prehistory of Southwestern Fezzan, Libya. Tripoli 1969 (Petroleum Exploration Society of Libya).

KLITZSCH E. (1970) Die Strukturgeschichte der Zentralsahara. Neue Erkenntnisse zum Bau und zur Paläogeographie eines Tafellandes. *Geologische Rundschau* 59, 1970: 459-527.

KRÖPELIN St. (1993) Environmental change in the southeastern Sahara and the proposal of a Geo-Biosphere Reserve in the Wadi Howar area (NW Sudan). In: Thorweihe, U. & H. Schandelmeier (eds.), Geoscientific Research in Northeast Africa. Rotterdam 1993: 561-568.

– (1996) Suggesting natural heritage sites in remote desert areas. In: Ayyad, M.A., M. Kassas & S.I. Ghabbour (eds.), Conservation and Management of Natural Heritage in Arab Countries. Cairo 1996: 35-41 (UNESCO-MAB).

– (2000) Auswirkungen von Erdölexploration und Wüstentourismus im Messak Settafet (Südwest-Libyen). Kurzfassungen, Afrika 2000 – Perspektiven für die Geowissenschaften in Forschung und Praxis, Paderborn, Juni 2000.

LASMO (1999) Operating Procedure No OPS-003 – Archaeological Protection. LASMO Grand Maghreb Ltd., Tripoli 1999.

– (2001) www.lasmo.com

LAW NO. 3/1424 (1993) Regarding the protection of archaeological sites, museums, old cities and historical buildings. The General People's Congress. Sirte 1993.

LeQUELLEC J.-L. (1985) Les gravures rupestres du Fezzan (Libye). *L'Anthropologie* 89, 1985: 365-383.

– (1998) Art rupestre et préhistoire du Sahara – Le Messak libyen. Paris 1998.

LeQUELLEC J.-L., St. KRÖPELIN & S. MAURY (1999) Rapport de la mission effectuée au Messak (Libye) du 10 au 17 juillet 1999. Unpublished Report to UNESCO. Paris 1999.

LIVERANI M., M. CREMASCHI & S. DI LERNIA (2000) The "Archaeological Park" of the Tadrart Acacus and Messak Settafet (south-western Fezzan, Libya). *Sahara* 12, 2001: 121-140.

LUTZ R. & G. LUTZ (1995) The Secret of the Desert. The Rock Art of Messak Settafet and Messak Mellet, Libya. Innsbruck 1995.

MORI F. (1994) Le Messak Settafet, une zone d'art rupestre unique au monde. In: VAN ALBADA & VAN ALBA, eds., 1994: 2-3.

PESCE A. (1968) Segnalazione di nuove stazioni d'arte rupestre negli uidian Tilissaghen e Matrhandusc (Messak Settafet, Fezzan). *Rivista di Scienza Preistoriche* 22, 1968: 393-416.

RHOTERT, H. & R. KUPER (1981) Felsbilder aus Wadi Ertan und Wadi Tarhoscht (Südwest-Fezzan, Libyen). Graz 1981.

SCHULZ E. (1987) Die holozäne Vegetation der Zentralen Sahara (N-Mali, N-Niger, SW-Libyen). *Palaeoecology of Africa* 18, 1987: 143-161.

SOLA, M.A. & D. WORSLEY (eds.) (2000) Geological Exploration in Murzuq Basin. Amsterdam 2000.

VAN ALBADA, A. & A. VAN ALBADA (eds.) (1994) Art rupestre du Sahara. Les pasteurs-chasseurs du Messak libyen. *Les Dossiers de l'Archéologie* 197, 1994: 1-85.

WHC – WORLD HERITAGE CENTRE (2001) Report of the World Heritage Expert Meeting on "Desert Landscapes and Oasis Systems in the Arab Region". Kharga Oasis, Egypt, 23-26 September 2001. Unpublished report. Paris 2001.