Mediterranean Archaeology and Archaeometry, Vol. 17, No 4, (2017), pp. 43-59
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DOI: 10.5281/zenodo.893192

SCIENTIFIC INVESTIGATIONS INTO SAUDI ARABIAN ROCK ART: A REVIEW

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Received: 30/07/2017
Accepted: 31/08/2017

ABSTRACT

The principal findings of a project begun in 2001, of introducing scientific methodology into the study of the rock art of the Kingdom of Saudi Arabia, are briefly summarised in this paper. They include the first scientific and direct rock art datings reported from the Middle East. The project, commenced by the Deputy Ministry of Antiquities and Museums, is continuing under the auspices of the Saudi Commission for Tourism and National Heritage. It has led to the discovery of large rock art site complexes numbering tens of thousands of motifs, and to the successful nomination of major rock art properties to the UNESCO World Heritage List. More specifically, the work of this project has also resulted in a preliminary chronological sequence of Arabian Peninsula rock art, the basis of which is briefly presented in this review paper. All petroglyphs analysed so far in Saudi Arabia have been shown to be of the Holocene, with specimens dating from the Pre-Pottery Neolithic (PPN) up to the historical period.

KEYWORDS: petroglyph, age estimation, radiocarbon dating, microerosion analysis, OSL analysis, Saudi Arabia

1. INTRODUCTION

The corpus of rock art in the Arabian Peninsula, one of the largest regional bodies in the world, has not been investigated by deliberately scientific methods before 2001. Indeed, much of its prior consideration has been by casual travellers and authors who have never been to the region. For instance, the four seminal volumes Anati has published about Saudi rock art are the result of his examination of 232 photographs of one single site complex (Anati, 1968a, b, 1972, 1974). Without ever having been to the Kingdom of Saudi Arabia and without considering any rock art of the remaining parts of the country, Anati attempted to create a universal rock art chronology of the entire Peninsula. As was to be expected he failed in this (McClure, 1971: 77–80; Khan, 1998; Bednarik and Khan, 2005), and yet his false account continues to be cited as authoritative. Saudi Arabia alone, with an area of about 2.15 million square kilometres, is more than eight times the size of the United Kingdom, or over three times the size of Texas. It would therefore be impossible to establish the Peninsula's chronology from a single locality, even if proper quantifiable and testable information were available instead of a random collection of photographs.

Other reports of rock art in Arabia also tend to be interpretations of the perceived content of the rock art. They are of no scientific merits for several reasons: (1) pareidolic 'identifications' of rock art motifs constitute unfalsifiable and untestable propositions; (2) a blind test of the ability of cultural aliens to interpret rock art correctly has shown that 90% of 'identifications' were false (Macintosh, 1977); (3) neuroscience would predict that the structures, chemistry and neural wiring of the brains of ancient rock art producers differed very significantly from those of modern, literate observers of rock art (Helvenston, 2013); and (4) there is nothing in the training of, say, archaeologists that would facilitate their pareidolic discrimination being superior to that of, say, rock art tourists or children. Researchers possess no privileged access to meaning or intent: their vibes of what rock art means are no more relevant or reliable than those of any other modern person. Science demands falsifiable propositions from researchers. This does not mean that the vibes of rock art interpreters are necessarily wrong. It does mean, however, that they are untestable, idiosyncratic and scientifically trivial. Their only scientific value is what they may be able to reveal about the interpreter's neural processes or perception, much in the same way as a Rorschach blot is said to do so.

In addition to the massive body of Saudi petroglyphs, rock art also occurs elsewhere on the Arabian Peninsula. About a hundred rock art sites are known in Yemen (Jung, 1991a, b, 1994; Garcia et al., 1991; Garcia and Rachad, 1992, 1997; Braemer et al., 2007; Inizan and Rachad, 2007) and they include rock paintings which are exceedingly rare in Saudi Arabia. The Yemeni petroglyph traditions resemble those of southern Saudi Arabia and they are better documented in the north of the country than in the south. Jung (1991) lists a total of 63 sites from northern Yemen. Similar conditions are apparent in neighbouring Oman, where two notable concentrations of rock art occur, at Jabal Akdhar in the al-Hajjar mountain range (Jäckli, 1973, 1980; Clarke, 1975; Preston, 1976) and in Dhofar (al-Shahri, 1991), with a total of at least fifty sites. There is a preference for limestone regions which tend to preserve petroglyphs poorly, and these occur frequently in wadis where they are worn by floodwater. The Dhofar sites comprise extensive cave paintings as well as painted inscriptions. In United Arab Emirates, several scattered petroglyph sites have been reported (e.g. Jongbloed, 1994), but they are mostly small groups of highly schematised execution (e.g. at Wadis Saham and al-Hayl). Further north along the coast of the Gulf, even the small state of Qatar contains numerous rock art sites, where the occurrence of presumed boat petroglyphs is noteworthy (Facey, 1987), especially at the site of Jusasiyah. There are also cupules (cup marks) and game-boards on the limestone pavements (Hassiba et al., 2012). Rock art continues to the immediate north of the Peninsula, in Jordan (Horsefield et al., 1983; Alzoubi et al., 2016), where portable art has been dated through epigraphy (Betts, 1998). In northern Syria, a great wealth of pre-Islamic inscriptions (reportedly 28,000) has been described, in Safaitic, Hismaic, Thamudic, Nabatean, Greek and Latin. A considerable proportion of these are thought to be related to adjacent petroglyphs.

Saudi Arabia offers a greater body of rock inscriptions than Syria and Jordan, and a good deal of useful work has been presented on the written inscriptions of Saudi Arabia and nearby regions (e.g. Huber, 1899; Winnett, 1937; Jamme, 1966; Albright, 1969; Bellany, 1981; Livingston et al., 1985; Al-Shahri, 1991; Khan, 1993a; AlTheeb, 1999; Eichmann et al., 2006). In contrast to preceding sporadic and opportunistic forays into the extensive rock art, the Epigraphic and Rock Art Survey of the Kingdom was established in the 1980s (Khan et al., 1986, 1988; Kabawi et al., 1989, 1990; Khan, 1990). During subsequent years, the recording and cataloguing of rock art sites was conducted in a systematic and very productive approach. It led to the establishment of several large-scale protection and preservation measures in various parts of the country, including steel fences in the desert that were many kilometres long and the installation of site custodians at selected locations. Indeed, by the late 1990s, Saudi Arabia had one of the best rock art protection programs in the world.

In 2001 the then Deputy Ministry of Antiquities and Museums of Saudi Arabia commenced a project of assessing the analytical potential of Saudi petroglyphs. This was envisaged to be a logical extension of the work of the past decades of the Epigraphic and Rock Art Survey. It had become apparent that the traditional approaches, specifically the 'determination' of meanings and unsubstantiated rock art sequences were incompatible with scientific practice. Because of the archaeological importance of facilitating the creation of a chronological framework it was suggested that this mission would focus on the specific aspect of rock art dating (Bednarik and Khan, 2002).

This project had to commence with a minimum amount of credible empirical information about its subject. Most published data about Saudi rock art lacked basic evidence, such as details of site morphology, geomorphic surface conditions, types of accretionary deposits, assumed rates of exfoliation or patination, petrographic descriptions, weathering rates or indeed any forensic information relating to the rock art. Such knowledge has since been acquired for more than one hundred sites in a series of desert expeditions into mostly uninhabited areas over the past sixteen years, from the northwest to the far south of the country (Fig. 1).

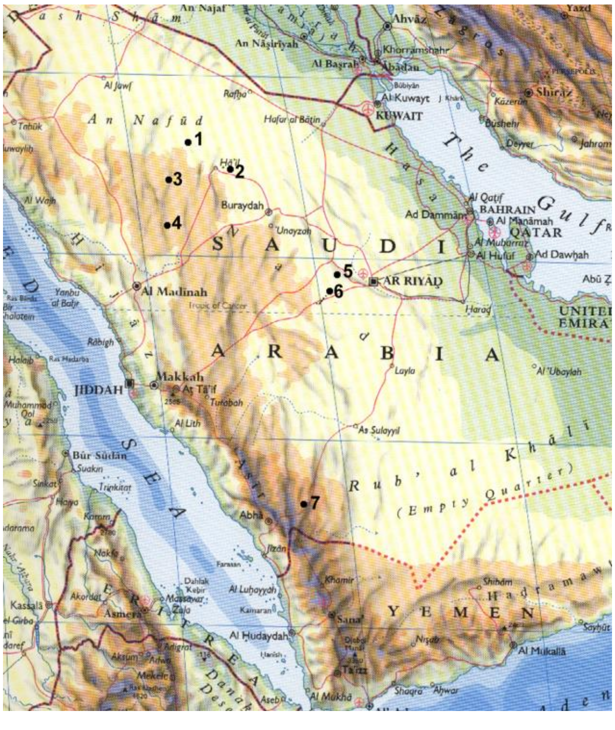

Figure 1: The principal rock art complexes mentioned in the text: 1 – Umm Sinman, 2 – Janin, 3 - Al-Mismā, 4 – Shuwaymis, 5 - Umm Asba'a, 6 - Al-'Usayla, 7 – Himā.

2. SITE DESCRIPTIONS

The sites selected for examination occur essentially in three clusters: within about 300 km of Hail in the north of the country; in the central region of Saudi Arabia, to the west and south-west of Riyadh; and in the far south, north of Najran. Most of the sites occur on sandstone facies, including partially metamorphosed sandstone. The absence of petroglyphs on granite exposures has rendered the application of microerosion analysis difficult, limiting it to where well-developed fractures were present on grains greater than sand fraction.

Primary patination as well as patination of petroglyphs had occurred at all sites, but degrees of rock varnish deposition varied considerably and such accretions were in all cases relatively weakly developed. Only one site, the Janin main site, was judged to possess sufficiently substantial varnish cover on petroglyphs to encourage sampling. No well-developed silica or oxalate accretions were observed on petroglyphs at any of the sites examined, and carbonate accretions occurring over petroglyphs or rock inscriptions were limited to one site, Umm Burqa East Site. Although we took GPS bearings at sites, precise locations are not provided in the following review for protection of the sites studied, listed roughly from north to south.

2.1 Umm Sinman main complex

The Great Nafud desert of northern Saudi Arabia covers an area of about 68,000 square kilometres. Near the small oasis township of Jubbah, 90 km north-west of the city of Ha'il, runs a distinctive rocky inselberg rising 300 to 400 metres above the surrounding endless sea of sand. Near the remains of a former lake that existed in early and mid-Holocene times is a major petroglyph site complex, extending along the foot of the escarpment for about 4.5 km. It is thought that the Jubbah lake, about 20 km long and 5 km wide at its peak, still existed 8000 years BP, before a lowering aquifer level reduced it during mid-Holocene times (McClure, 1971, 1976; Garrard and Harvey, 1977; Schulz and Whitney, 1986; Jennings et al., 2013). The presence of abundant surface water attracted a diverse fauna reflected especially in the Neolithic rock art and quite probably also a large human population. Jubbah lies on an ancient caravan route, which has led to many thousands of rock inscriptions and camel images in recent millennia. Several concentrations of rock art were inspected in this impressive site complex. Neolithic or Chalcolithic occupation sites have been documented near Jubbah (Parr et al., 1978; see also Ingraham et al., 1981). Some of these are located near rock shelters and close to some rock art panels on the nearby rocks. The stone artefacts are usually arrowheads, bifacial points, blades, side and biface scrapers, and disc cores which are supposed to be typical of Pre-Pottery Neolithic in the region.

The apparently oldest rock art at the Jubbah site complex consists of large human and animal figures, depicted in prominent places. The skill and technological sophistication evident in the petroglyphs suggests a very well established convention or genre of rock art production (Fig. 2). A second type of rock art consists of anthropomorphs and zoomorphs found in more isolated places, of mostly smaller size. Camelid figures and Thamudic inscriptions are frequently located where episodic or periodic water was available. The third of the three distinctive phases of rock art at Jubbah is associated with early Islamic or Kufic inscriptions.

Figure 2: Umm Sinman, Jubbah, large Neolithic bovid figure with several superimposed more recent phases of petroglyphs.

Of the many Jubbah localities examined most closely as part of this project, the southernmost provided a calibration site, while places to its north offered suitable conditions for microerosion analysis. The whole Umm Sinman main complex is enclosed by a well-constructed steel-mesh fence over its entire length, erected by the Ministry of Antiquities and Museums. The site complex is relatively inaccessibly from the east, i.e. from the mountain range.

Our submission of the Umm Sinman site complex to UNESCO's World Heritage List (Bednarik and Khan, 2013) has resulted in the inscription of this massive concentration of rock art on that List on 3 July 2015 (Bednarik, 2015a).

2.2 Jabal Ash Shuwayhit

A few kilometres to the north of the Umm Sinman main complex occurs a morphologically different group of sites, which also has different motif ranges. Rather than being at the foot of the rock escarpment, numerous petroglyph clusters occur well above the plain, among the peaks and hills of the mountain range. Pre-Arabic scripts are numerous, as are zoomorphs and anthropomorphs, but more recent inscriptions as well as the large 'Jubbah figures' are absent. Use of the site complex seems temporally more confined, and since it is less accessible and some distance from even ancient water sources, it is more likely related to people who crossed the mountain range at this locality. At one of the major concentrations of petroglyphs, among several Thamudic inscriptions, two written characters were selected for microerosion analysis.

2.3 Janin Cave

The deserts of Saudi Arabia have so far yielded almost no cave art, perhaps as a result of a lack of suitable carbonate facies that would promote the formation of caves. Until 2017, Janin Cave was the only known example of cave art in northern Saudi Arabia. Located about 30 km east of Ha'il and north of the highway to Buraydah, it was formed in light-coloured sandstone. The tectonic adjustment of a large portion of rock on the south face of a steep mountain along a vertical fault line created a cleft, which erosion enlarged to a fairly horizontal passage that is up to 20 m high and 10 m wide. It can be followed for about 100 m, its floor of sand and a few boulders progressively steepening until the passage ends in a talus slope. Petroglyphs are numerous along both walls as far as faint daylight can reach, but then peter out and decoration is lacking in the deepest and permanently dark part of the cave (Fig. 3). Access to the cave, located about 15 m above the sand plain, is controlled by a fence closing off the approach from the plain, and through the care of a nearby resident custodian.

Figure 3: Small section of the south wall of Janin Cave, c. 40 m from the entrance.

2.4 Janin main site

This site, a few kilometres east of Janin Cave, is located at the foot of a prominent vertical cliff atop a ridge, and on large boulders on the upper part of the slope below the cliff. It consists mainly of petroglyphs but the vertical rock face also bears a series of very faded red pictograms. On the upper surfaces of some floor boulders immediately adjacent to the cliff occur about one dozen fully patinated, large cupules, of up to 25 cm diameter and 15 cm depth. The fine-grained sandstone at the site is unsuitable for micro-erosion analysis, but the rock varnish covering many of the petroglyphs is better developed here than at other sites examined. A sloping flat panel bearing more than fifty fully patinated petroglyphs was chosen for sampling of the ferromanganous accretion destined for radiocarbon analysis.

2.5 Milihiya

West of the Janin mountains, the hills at Milihiya are low, flat and mesa-like, featuring an expansive site of scattered petroglyphs on the low cliffs and scree slopes. Stone tools abound around the base of these rises, including lithics of Palaeolithic typology. The fine-grained sandstone strata in this area are readily affected by granular exfoliation and therefore unsuitable for microerosion analysis.

2.6 Yatib

Consisting of a rocky hill topped by a cliff rising about 60 m above the plain, this spectacular petroglyph site is almost one kilometre long. A steel fence of several kilometres length encloses the entire hill and a local site custodian resides nearby. The site is located near Milihiya, about 20 km east of Ha'il. Many of its thousands of petroglyphs are visually spectacular, especially in the vicinity of the main cliff. Some can only be reached by climbing the cliff (Fig. 4). The partially metamorphosed sandstone comprises mostly grains of between 100 and 200 µm, which renders the rock unsuitable for microerosion analysis. As much as one fifth of the petroglyphs at Yatib were fashioned with metal tools rather than stone hammers, probably of steel.

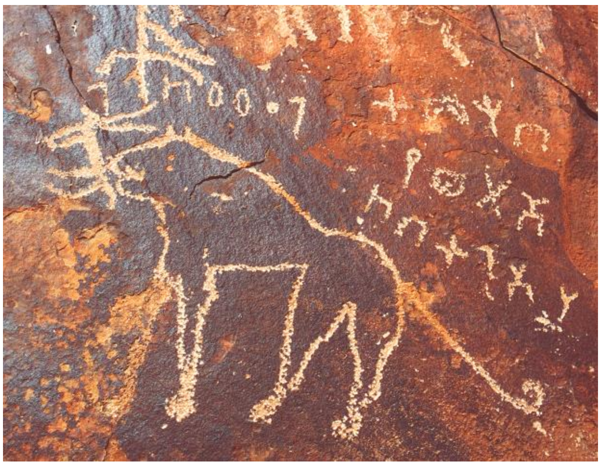

Figure 4: Yatib site petroglyphs, depicting according to the accompanying Thamudic inscription a lion.

2.7 Al-Mismā rock art complex

This new rock art complex was only discovered in 2017 (Bednarik and Khan, 2017). So far, four sites have been surveyed preliminarily, two of them being of major size. Umm Burqa East Site includes a large corpus of pictograms in the form of red haematite paintings, besides Neolithic and later petroglyphs. Rock paintings are exceedingly rare in Arabia and this is the most spectacular such site. Their occurrence at this site is due to the presence of a haematite seam in the sandstone strata forming the site. It also features two caves containing both petroglyphs and paintings, named Saad al-Rawsan and Hijab Caves, and cave art, as mentioned, is also known from very few Saudi localities. Fardat Shamous South Site, located at the foot of a nearby second sandstone stack, comprises a large inventory of petroglyphs, one of which was dated convincingly by microerosion analysis. The al-Mismā site complex is located deep in the desert west of Ha'il, far from any access road, and has remained in essentially pristine condition because of its remoteness. Its location will therefore not be made public, limiting access to researchers intent on collecting forensic information about the rock art.

2.8 Qilat al-Hissan

This minor petroglyph and inscription site is located just outside the township Hayet, about 250 km SSW of Ha'il. The region is geomorphologically dominated by geologically recent basaltic lava flows and other evidence of extensive volcanic activity. The rock art site occurs on volcanic tuff that contains occasional basalt clasts, a lithology offering no evidence for estimating the age of petroglyphs.

2.9 Jabal al-Barg

A minor petroglyph site close to Shuwaymis village, Jabal al-Barg is on a cliff formed along a wadi in the Harrat Khaybar region. Some of the rock art occurs on well-developed thin veins of conglomerate embedded in the coarse sandstone, which has facilitated microerosion analysis. A dominant image is assumed to depict a date palm, a motif that is an important emblemic and historical icon in the Kingdom of Saudi Arabia. The time of the date palm's introduction remains unknown, so the dating of this motif was of considerable interest. Smaller figures on the faintly patinated panel resemble quadrupeds such as cattle and ibex.

2.10 Jabal Raat

The Shuwaymis site complex was discovered only in 2001 (Bednarik and Khan, 2002) and still remains inadequately explored. The currently known two main sites are Jabal al-Manjor and Jabal Raat. Our submission of both to the UNESCO World Heritage List (Bednarik and Khan, 2013) has resulted in the inscription of this dense concentration of rock art, the most spectacular known Neolithic rock art in the world (Bednarik, 2015a). The remote and relatively inaccessible area far to the west of Shuwaymis village features Pleistocene/early Holocene lakebeds and a series of eroding cliffs along palaeo-wadis. The area was still densely settled in mid-Holocene times, as shown by the abundance of archaeological evidence, including numerous megalithic burial sites. Jabal Raat consists of a slope of jumbled, angular boulders, mostly 5 to 10 m in size, on which many thousands of motifs occur. The site is about 950 m long, comprising hundreds of petroglyph panels forming six clusters. Many of them bring to mind monumental masonry work, in that the very detailed and meticulously pounded large figures are rendered as 15–20 mm deep bas-reliefs, often many metres above ground (Fig. 5). The profusely decorated panels on many of these huge boulders are no longer right way up, and as they changed their orientation every time the boulders slid down the slope, new compositions were added at various times. These are all orientated differently now and many are truncated by subsequent fractures. The site therefore offers great potential for detailed seriation studies. Its geomorphological state is attributable to a deteriorating argillaceous sandstone layer causing the collapse of the overlying Cambrian sandstone strata. Random inclusions of pebble-grade grains have made the application of microerosion analysis possible. Jabal Raat is the only site so far found in Arabia that features KEM (kinetic energy metamorphosis) deposits in petroglyphs (Bednarik 2015b). Petroglyph-making hammerstones (mur-e) occur among the huge decorated blocks, consisting of a dark siliceous contact-metamorphic quartzite occurring locally. Like many others in the country, the site is now protected by a steel fence.

Figure 5: Jabal Raat, Shuwaymis site complex, one of many monumental panels of Neolithic petroglyphs.

2.11 Jabal al-Manjor

Located 1.2 km east of Jabal Raat, along a nearby escarpment rising above the sand dunes, this group of sites extends over more than one kilometre, of which about 650 m is enclosed by a steel fence. Despite its close proximity to its twin site, it remained unknown at the time al-Raat was first examined (Bednarik and Khan, 2002). Jabal al-Manjor comprises almost 200 panels of petroglyphs, many of which feature hundreds of motifs (Fig. 6). Whereas al-Raat seems dominated by Neolithic rock art, lacking presumed images of camelids and date palms, at al-Manjor more recent periods are also well represented in addition to the Neolithic, and early Arabic scripts (mainly Thamudic C/D) and even Islamic texts occur. However, there appears to be relatively little rock art that is likely to be more recent than approximately 2000 years old.

Figure 6: Jabal al-Manjor, Shuwaymis site complex, one of dozens of large panels of Metal Age petroglyphs.

Besides the two dense concentrations of petroglyphs protected by fences, there are at least another 40 sites in the Shuwaymis rock art complex, which extends over a total distance of about 5 km. The distribution of the corpus is reflected in the buffer zone of the WH listing, extending more than 3 km east-west and 5 km north-south (Bednarik and Khan, 2013).

2.12 Umm Asba'a

This site is located in the Nafud Qunayfidhah, c. 85 km west of Riyadh, in flat to slightly undulating sand desert. It consists of a prominent, widely visible mushroom-shaped sandstone column of about six metres height on an eroding rocky hill with occasional Upper Palaeolithic stone tools. Petroglyphs occur on and near the column, on coarse-grained sandstone. They consist of *wusūm* (tribal marks, plural of *wasm*; Khan, 2000), abraded grooves and several inscriptions. One of the latter, on a vertical panel on the western base of the column, presents a two-line early Islamic text, datable by its content to about 1120 years BP.

2.13 Al-'Usayla

About 115 km south-west of Riyadh, a few kilometres north of the highway to Makkah, a distinctive west-facing escarpment forms the background to an isolated rocky hill of about 40 m height. Thousands of petroglyphs occur on its cliffs and eroding boulders. The rocky shelves and plateaus of the nearby escarpment seem almost devoid of rock art. *Wusūm* seem to predominate in the lower parts of the knoll. The site's largest decorated panel is a flat vertical cliff facing south, on the upper part of the hill, densely covered with petroglyphs over a length of 7 m and to a height of 4 m (Fig. 7). The rock facies is homogenous, of well-sorted grains among which the 400–800 μm fraction dominates, with occasional grains of up to 1.5 mm diameter.

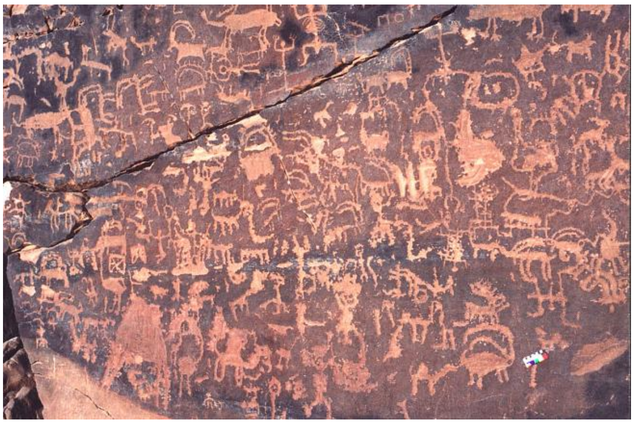

Figure 7: Al-'Usayla, part of the largest petroglyph panel. The age of the caprid zoomorph left of the scale has been estimated.

2.14 The Himā Cultural Precinct

One of the largest rock art complexes in the world, the Himā Cultural Precinct is located at the western boundary of the Rub' al Khālī (the Empty Quarter), about 80 km north of the southern city of Najran. That town is almost immediately next to the border with Yemen and has been built around the ancient city of Ukhdoud, sacked by the Himyarites in 525 CE. Although many outlying rock art sites stretch over a distance of about 130 km, the main concentration, the actual cultural precinct, extends over 55 km north to south, with the small settlement of Himā at its southern end. It includes the eastern mountains of the Jabal Qara massif and Jabal al-Kawbab, extending north as far as the road east from Yadamah. The exploration of the Himā Cultural Precinct is not complete but several hundred sites have been located and registered. The property is the subject of a current nomination for World Heritage listing. Its cultural manifestations include, besides the extensive rock art corpus, thousands of rock inscriptions, found in various scripts, such as the *al-musmad* alphabet of 29 letters, Aramaic-Nabatean, South Arabian scripts including Thamudic and even in Greek, as well as Islamic. There are also countless stone structures, especially tombs and cairns. Of particular importance is the recently proven continuation of rock art production and reverence of specific motifs in the precinct (Bednarik, 2017a).

The chronology of Arabian Peninsula rock art attempted by Anati (1968a, b, 1972, 1974) was based on selected examples of Himā rock art photographed by a group of travellers in 1951–52 (Grohmann, 1962; Lippens, 1956; Ryckmans, 1952, 1954). However, Anati himself has never been to Arabia, and his scheme was first refuted by a more thorough investigation (Khan, 1998), and subsequently by direct dating evidence (Bednarik and Khan, 2005, 2009). A survey of Saudi rock art was commenced by the then Deputy Ministry of Antiquities and Museums in 1979 (Zarins et al., 1980, 1981; Hester et al., 1984). By 1990 (Kabawi et al., 1990, 1996), some 126 sites had been recorded. Scientific methodology was first introduced in the Himā Cultural Precinct in 2004, soon after its introduction in the north of the country (in 2001; Bednarik and Khan, 2002, 2005). By 2017, more than 550 sites had been located in the Himā Cultural Precinct.

Much of this extraordinary concentration of archaeological material is due to the main caravan routes of recent millennia having to connect at Bir Himā, where several deep wells had been excavated into the sandstone strata after the lowering of the aquifer. Because this was the final water supply for caravans before entering the long stretch of desert to the north, a toll station once existed at Aïn Jamal, just north-east of Himā, where ample surface water still occurred 3600 years ago (Liritzis et al., 2013). The general region's archaeology begins with Acheulian handaxes, Mousterian flake tools (e.g. at Sha'ib Hinmat, Aïn Jamal), Upper Palaeolithic stone tools (e.g. at Sha'ib Mahash) and numerous Neolithic artefacts. Ceramic finds of mid- to late Holocene periods occur also, including at a series of tumuli in the Najd Sahī area. At present the entire region is very arid and devoid of any surface water, except episodic pools in clay pans after adequate rain. However, ample evidence of previous surface water can be found in the form of carbonate and gypsum encrustations on low rock exposures; deriving from stagnant pools of mineral-rich water, they mark the beginning of the final phase of desertification.

3. METHODS

The techniques we considered for estimating the ages of selected petroglyphs and rock inscriptions at the Saudi Arabian sites listed here were direct methods (Bednarik, 2002), including carbon isotope analysis of organic inclusions in rock varnish, microerosion analysis, uranium series analysis of re-precipitated carbonates, optically stimulated luminescence determination of quartz grains covered by mineral encrustations, degree of granular exfoliation (surface retreat), calibrated colorimetry of patination, superimposition sequences and development of macro-wanes. Traditional methods such as the apparent iconographic content of the imagery ('identification' of depicted objects) and stylistic considerations were at best used in subsidiary roles, and preferably not at all.

Surface retreat offers a viable means of estimating petroglyph age on sandstone, but its use remains seriously hampered by the lack of comprehensive basic research as well as certain analytical limitations (Bednarik, 2007: 143). More promising is the measurement of macro-wanes, especially in combination with facture-surface weathering and other direct methods (Bednarik, 1979). Although the database currently available is inadequate, it should be emphasised that this kind of 'integrated' approach would be particularly suited for the conditions found at Saudi Arabian petroglyph sites.

Because of the ubiquitous presence of datable carbon in rock substrates and the openness of their carbon system (Bednarik 1979), we are sceptical of most applications of radiocarbon determination in rock art age estimation (the exceptions being charcoal pigment, beeswax, densely crystalline re-precipitated carbonate, and materials identified either at the molecular or object level). Nevertheless, we applied the standard AMS method experimentally to a sample of ferromanganese accretion from Janin main site.

Of particular importance is the OSL determination of a sample from Aïn Jamal, from a sandstone surface that was concealed by re-precipitated calcite that excluded further exposure to daylight (for details see Liritzis et al., 2013). This time of concealment was determined in order to secure a conservative estimate of when the final surface water pool existed at this important rock art and inscription site. The same locality also provided the calibration point for microerosion analyses in the Himā region, from an early Islamic inscription dating from 1300 to 1350 years BP (Bednarik and Khan, 2005).

The most extensively applied method in this project was microerosion analysis, because Arabian Peninsula sandstones frequently contain sporadic inclusions of large sand and small pebble-fraction quartz detritus. Where these have been shattered by the production of percussion petroglyphs, they may exhibit freshly formed edges of the preferred angle of 90°, the micro-wanes on which develop as a function of time where the edge was continuously exposed to precipitation (Bednarik, 1992, 1993). The wane widths are measured by optical light microscopy on site, without physical intervention in the rock art or its support. Several microscopes were used in the work reported here (including also digital microscopes). The preferred model was a Motic SMZ143 stereo zoom microscope that had been significantly modified for the purpose and included a gradated ocular. Specific samples such as KEM specimens were studied under a Zeiss axiotron with a MCU26 3 axis controller and 10 MP Moticam camera, as well as by the scanning electron microscope Jeol JSM-35, in combination with EDAX EDS x-ray detector using WINEDS software when determining elemental composition. The microerosion method was preferred because of its non-invasive nature; because it provides more reliable quantitative and calibratable data than alternative methods do; and because in contrast to nearly all other direct dating methods for rock art it delivers 'target dates' *sensu* Dunnell and Readhead (1988) rather than minimum or maximum dates.

Finally, colorimetric analysis of ferromanganous accretion was attempted at one site in the Himā Cultural Precinct, using the methodology developed in the Pilbara of north-western Australia (Bednarik, 2009).

4. RESULTS OF AGE ESTIMATES

4.1 Radiocarbon analysis

Of the sites investigated only the main site of Janin offered rock varnish of an adequate bulk to render physical sampling advisable. The accretionary deposit showed no nanostratigraphy (Bednarik, 1979) under light microscopy. A 26 cm long antelope-like zoomorph was selected and an area of 9 cm^2 was sampled with sterile dental tools. The patina was a typical ferromanganese deposit as commonly found in the high-pH environments of deserts. Processed at the AMS facility of the Australian Nuclear Science and Technology Organisation in Lucas Heights, Sydney, it yielded -25.0‰ $\delta^{13}C$, 79.77% of modern carbon at 1 sigma error, or 1820±50 years BP (OZF900). The scar was repaired as described by Elvidge and Moore (1980), using chemicals prepared specifically for this purpose. In view of the assumed taphonomy of such accretions this result is viewed as a most conservative minimum bulk or mean age of the accretion (Table 1). Depending on the rate and degree of rejuvenation (e.g. from micro-organisms) its true age could be considerably greater and this in turn must be less than the age of the petroglyph covered by this deposit.

Table 1: Results from petroglyphs and rock inscriptions, of calibration, microerosion analysis and radiocarbon analysis.

Site	Dating	Range (BP)	Approx. age (BP)
Um Asba'a	Calibration	Known age 1120 BP	
Al Usayla	'Ibex'	3180 – 2120	E2680 + 500 / - 560
Umm Sinman main complex	Calibration	Known age 1150 to 1200 BP	
	Anthropomorph 1	5650 – 4240	E4890 + 760 / - 650
	Anthropomorph 2	7070 – 5650	E5877 + 1190 / - 220
Jabal Ash Shuwayhit	Inscription 1	3530 – 2130	E2830 ± 700
	Inscription 2	3530 – 2120	E2540 + 990 / - 420
Janin	'Gazelle'	Greater than 1820 ± 50 BP	
Jabal al-Bargh	'Date palm'	3180 – 1770	E2370 + 810 / - 600
Jabal al-Raat, Shuwaymis	Anthropomorph 1	5660 – 4960	E5310 ± 350
	'Ibex'	6000 – 5300	E5550 + 450 / - 250
	Anthropomorph 2	4940 – 4240	E4590 ± 350
	Cupule	9330 – 6220	E7968 + 1360 / - 1750
Aïn Jamal, Himā	Calibration	Known age 1300 to 1350 BP	
Ta'ar, Himā	Anthropomorph	2360 – 1570	E2109 + 250 / - 540
Fardat Shamous South Site	Bovine	6010 – 5650	E5810 + 200/ - 160

4.2 MICROEROSION ANALYSIS

Application of this method was attempted at nearly all of the Saudi sites or site complexes examined so far and it succeeded at seven of them. The method is non-invasive, purely optical, and has been described originally in Bednarik (1992, 1993; see also 2007: 129–132). In all cases α-quartz and the Umm Sinman calibration were used, except for Ta'ar where the Aïn Jamal calibration was applied. The microerosion coefficient of Umm Sinman is 2.83 µm per millennium; that of Aïn Jamal is 4.9 µm per millennium, i.e. significantly higher (Table 1). The Umm Sinman microerosion rate is the lowest so far recorded in any continent (the method has been extensively applied in all continents except Antarctica; e.g. Bednarik, 1992, 1993, 1994, 1997, 2001, 2003, 2010a; Bednarik and Khan, 2002, 2005, 2009, 2016; Tang and Gao, 2004; Bednarik et al., 2007; Tang and Mei, 2008; Tang et al., 2014, 2017; Beaumont and Bednarik, 2015; Querejazu et al., 2015; Jin et al., 2016).

The 2001 microerosion age of a supposed ibex image at Al-'Usayla is E2680+500/-560 years BP but the calibration conditions were not optimal (the 'E' preceding the number of years indicates that the result is erosion-derived, i.e. not very precise but very reliable). Conditions were better at the Umm Sinman main site, only a few hundred metres from the calibration site, where a 2.19 m high anthropomorph allowed nineteen micro-wane measurements providing an age estimate of E4890+760/-650 BP for the large figure. A second anthropomorph at Umm Sinman, examined twelve years later (in 2013), is even one millennium older, at approximately E5877+1190/-220 years BP (in all cases, microerosion ages refer to BP as being the year measurements were taken). At Jabal Ash Shuwayhit, north of Umm Sinman, two coarse quartz grains in two Thamudic inscriptions 1.5 m apart were subjected to microerosion analysis. In the letter '*sh*', a grain of 12.9 mm provided twelve readings from one edge, yielding a mean wane width of 8.0 µm. The approximate age of E2830±700 years BP places this inscription somewhere between the second and the fifteenth centuries BCE. The second letter analysed is a '*þ*', in which a 3.25 mm grain offered only five readings with a mean of 7.2 µm. This date of E2540+990/-420 BP is perhaps less reliable, but it does support the previous result. Jabal al-Barg offered excellent conditions for analysis of a dominant 'date palm' motif. Two large quartz grains in the motif's long 'trunk' provided fifteen micro-wane widths, mean value of A=6.71 µm. This translates into an age estimation of E2370+810/-600 years BP.

The spectacular Jabal Raat site at Shuwaymis has so far provided four estimates of petroglyph ages secured by microerosion analysis, the first three in 2001 and 2004, the fourth in 2013. A tall anthropomorph seems to have been made at the same time as a large caprid zoomorph occurring with it (Fig. 8). An impact-damaged 13.0 mm quartz grain in the anthropomorph yielded a mean wane width of 15.0 µm from seven measurements, implying an age of E5310±350 years BP. The ibex-like quadruped image provided ten closely ranging readings from edges on a very small grain of only 1.45 mm maximum size. Their mean of 15.7 µm translates into an age estimate of E5550+450/-250 BP. The substantial overlap in these two ranges suggests that the two motifs may indeed belong to a single event of rock art production.

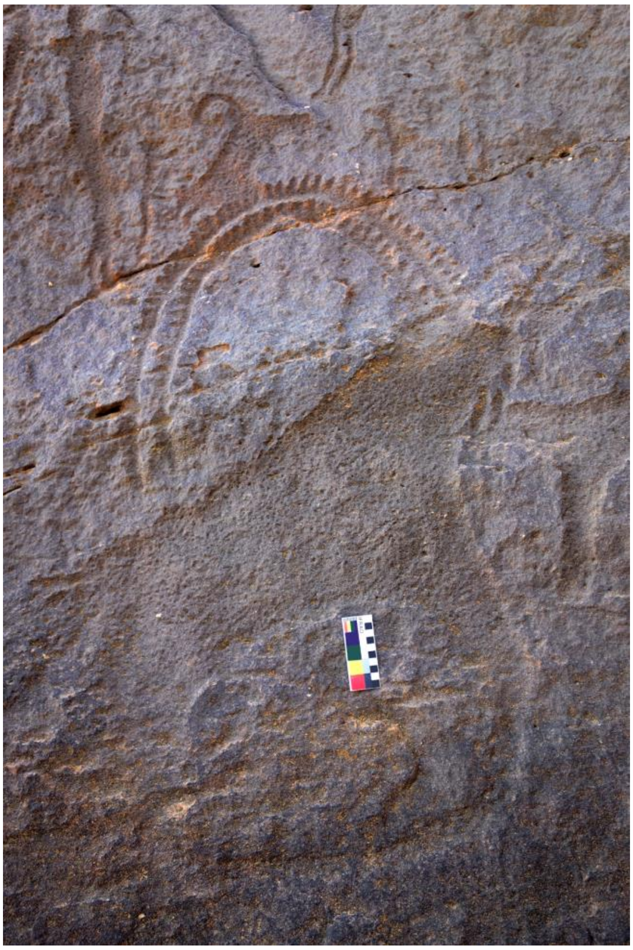

Figure 8: Jabal Raat, dated Neolithic caprid petroglyph.

About 25 m east of this composition is a large inclined rock slab densely covered by archaic petroglyphs, including very weathered cupules. Resting above it is a large block that partly conceals the engraved panel, indicating that its detachment from the rock mass above it occurred after the cupules and other petroglyphs had been created. On the newly available vertical panel, a composition of several anthropomorphs was created after that panel became precariously accessible, and in an attempt to secure a conservative minimum age for the cupule panel below, one of these figures was analysed. It is 96 cm high and yielded a total of twenty micro-wane widths from two small quartz pebbles, measuring 9.9 mm and 5.5 mm respectively. Their very narrow range provided an age estimate of E4590±350 years BP.

These three datings at Jabal Raat were secured in the early phase of the project, but in 2013 a small pebble bearing micro-battering was discovered within one of the uppermost cupules on the much older cupule panel partially concealed by the panel above it (Fig. 9). These cupules had been considered to be the earliest surviving petroglyphs of the entire site complex of Shuwaymis. Microerosion analysis of a fracture edge of this quartz grain yielded an age estimate of E7968+1360/-1750 years BP for the cupule, securely placing it and much of this petroglyph panel into the early Holocene. At present this is the earliest dated rock art known in the Kingdom of Saudi Arabia and indeed in the Middle East.

Figure 9: One of the early cupules at Jabal Raat, featuring a KEM layer. The quartz pebble on the right has yielded an age estimate of about 8000 years BP.

Very early cupules are also known from the Himā Cultural Precinct in the country's far south, such as those found in the shelter Fardat Duwaish (Bednarik and Khan, 2005: Fig. 43). However, as they are protected from precipitation microerosion analysis is unable to provide valid age determinations. A calibration curve obtained from a four-line early Islamic inscription at the petroglyph site Aïn Jamal has provided a microerosion coefficient of 4.9 µm, which so far has been applied to only one petroglyph in the region. It is an anthropomorph 'wielding a sword' (Fig. 10) at the Ta'ar site in the north-western part of the precinct. Seventeen wane width determinations from three fractured large sand granules provided a mean of 10.7 µm, yielding a provisional age of E2109+254/-534 years BP.

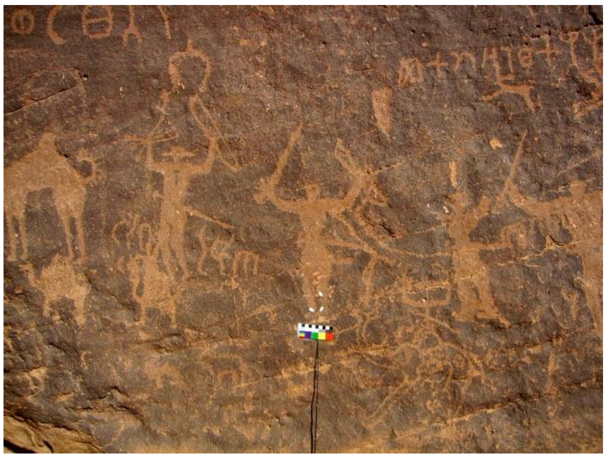

Figure 10: The central anthropomorph has been dated to about 2100 years BP. Ta'ar, north-western Himā Cultural Precinct.

Finally, in 2017, immediately after the discovery of the al-Mismā site complex, a large bovid petroglyph at Fardat Shamous South Site was subjected to analysis. A roughly heart-shaped, 8.3 mm long quartz grain bearing several impact-derived edges yielded seven micro-wane widths from one edge. Their mean of 16.43 µm places the bovid at 5810+200/-160 years BP, i.e. squarely into the Neolithic period of the region (Fig. 11).

Figure 11: Large bovid petroglyph, Fardat Shamous South Site, dated to the Neolithic via the grain located at the centre of the scale. Numerous other small pebble-grade quartz grains are visible.

These microerosion age estimates rely on the veracity of the calibration values they refer to. They are certainly highly reliable in terms of magnitude, but their precision is regarded as limited by the inherent shortcomings of the method. The primary data have imposed substantial tolerance margins on some of these results. There is also the possibility that retouch of the motif has taken place, but this is usually detectable by field microscopy (Bednarik and Kumar 2002). Finally, because no petroglyphs on granite have so far been analysed in Saudi Arabia, it has not been possible to subject findings from quartz to testing by comparison to feldspar microerosion. However, to place these qualifications in context it must be remembered that all dating methods ever used to estimate the age of rock art are subject to similar, and in many cases even more severe, qualifications (Bednarik, 1996, 2002).

Nevertheless, the close correlation between microerosion and present precipitation, already established (Beaumont and Bednarik 2015: Fig. 14), is soundly confirmed by the Saudi Arabian data. The ratio between the Umm Sinman and Aïn Jamal microerosion coefficients is 1:1.731; the ratio between the corresponding average annual rainfalls, 77:132 mm, is 1:1.714. This provides strong evidence for the internal consistency of the microerosion data, from Arabia as well as from the rest of the world.

4.3 OSL analysis

The calibration site Aïn Jamal in the Himā Cultural Precinct features the carbonate encrustation precipitated from a saturated pool or lake, as do several other sites in the region. In an attempt to determine when this accretion was deposited, i.e. when the pool of water existed at the site, optically stimulated luminescence analysis was applied to the sandstone concealed by the calcite (Liritzis et al., 2013). Four aliquots representing the geological luminescence from the deeper sandstone layer provided ED values above 40 Gy. Another two aliquots from the surface of the sandstone yielded 5.50 and 4.3 Gy respectively. Their average, 4.9±0.3 Gy, delivered a date of 3580±250 BP for the time when the bedrock was last exposed to daylight, as the deposition of the accretion commenced.

This provides important information concerning the region's hydrography and climate. Until about 3500 years ago, the area supported a highly diverse fauna, including bovids, which over subsequent centuries gradually disappeared as the aquifer retreated. By 3000 years ago, the final desertification phase was well underway, somewhat later than in the northern regions of the Great Nafud (at Jubbah) and the Harrat Khaybar region (at Shuwaymis). Most of the very extensive rock art in the Himā Cultural Precinct relates to the period postdating the final surface water deposits, after environmental stresses had commenced and as Himā developed into an important caravan node. Between 2500 and 1500 years ago, present highly arid conditions were essentially established.

4.4 Colorimetric analysis

The possibility of quantifying relative patination has been considered for almost as long as rock art has been studied (Belzoni, 1820; Basedow, 1914; Rhotert, 1938, 1952; Mori, 1965, 1974; Goodwin, 1960; Anati, 1960, 1961, 1963, 1968a), but as noted by Nayeem (2000: 35), no attempt to accomplish this had been made at the time of Nayeem's writing. Although relatively easy to do (Bednarik, 2009, 2010b), this delay is reminiscent of the comparatively late induction of colour calibration (Bednarik and Seshadri 1996) and indicative of the generally very late introduction of scientific method (in lieu of pareidolic 'identification' or archaeological method) in rock art research. The role of engraved groove depth in patination rates remains poorly understood, as does the influence of cation-scavenging microorganisms and non-organic processes of re-cycling accretionary matter. Therefore the use of patina in estimating petroglyph ages requires an intimate understanding of the processes active in patination. If the principal component of the patina were rock varnish (extraneous), patination would proceed independent of the substrate, but if the process relied largely on the oxidation of resident cations (inherent) it would be affected by the state of the exposed substrate. To make this judgment it is essential to apply field microscopy (Bednarik, 1979: Fig. 2, 2007: 170–173) which remains significantly under-utilised in this field. Comparisons of regional differences show that, apart from precipitation, the ambient pH regime is a principal influence, both in the deposition and the stableness through time of these formations (Bednarik, 1979, 2012). Variables determining patination rates and preservation include petrography, climate, micro-topography, surface geometry, orientation, chemical environment, water presence, epilithic organisms, coarseness of surface texture, directional aspects, and the proximity of cation sources such as sediments or nearby accretions.

The quantification of colour changes in rock art by chroma-meter to measure reflective properties has only led to failures (Lambert, 1995; Markley et al., 2015; cf. refutation in Black et al., 2017). Electronic optical colorimetry using a combination of a spectrometer (e.g. Tristan UV/VIS, 250–850 nm), a standard light source, a reception adaptor from the sample to the spectrometer, dedicated proprietary colorimetric software and a portable computer is too cumbersome in the field. This arrangement has to be individually adapted to each application, which deters its use under rugged conditions. Typically, rock art fieldwork occurs in remote locations, demanding simplicity in the technology used. An experimental colorimetric study of a series of patinated engraved dates and dated petroglyphs in the Pilbara region of Western Australia provided a much more robust method (Bednarik, 2009) in which series of pixel aliquots are selected from digital photographs of the dark-brown patina. Quantification of their RGB values and calibration of their mean values via surfaces of known ages are described in Bednarik (2009). The results have been found to be consistently well-aligned relative to age, while it has also been shown that there are significant differences in patination rates between different regions. This method has been applied at Najd Sahī in the Himā Cultural Precinct (Fig. 12). Five anthropogenic surfaces were selected for analysis: one of several bullet impacts caused post-1952 (c); the panel's most recent anthropomorph (d); the larger of several 'ostrich' figures (e); a Thamudic letter within that 'ostrich' figure and probably contemporaneous with it (f); and the central, apparently ithyphallic anthropomorph of the panel (g) (surfaces [a] and [b] were undated). These surfaces are arranged here in the order of increasing age and that sequence is well reflected in their colorimetric values (Table 2). This matrix is based on 1620 colorimetric readings (324 from each of five surfaces), processed from aliquots of 36 pixels as per the original study in the Australian Pilbara.

Figure 12: Part of the Najd Sahī main panel showing the five patina samples (c-g) included in the colorimetric analysis.

Table 2: Summary of the colour values of the five surfaces sampled at Najd Sahī, Himā Cultural Precinct.

Motif	R	G	B	Mean
c	205.05	135.64	86.60	142.43
d	203.56	127.48	74.81	135.28
e	176.38	101.44	52.69	110.17
f	182.54	98.94	46.07	109.18
g	175.72	98.21	46.07	106.67

The inclusion in these determinations of the mean values of the combined primary colours was prompted by the finding that they seem to have a much closer correlation to surface ages than individual values (Bednarik, 2009). It appears that random variations in primary colours are compensated for in this way, as shown by samples *e* and *f* in the above instance (which are probably of the same age). Evidently samples *e*–*g* should be of very similar ages, although *g* might be marginally older than the two others. It is also clearly apparent from Table 2 that sample *d* is distinctly younger than the group of three early surfaces, and that sample *c*, from the bullet impact, is again younger. This pattern coincides with visual discrimination of age differences and other confirming factors. In Fig. 13, these colorimetric values are plotted against time, and the Najd Sahī curve (A) is compared with that from the Pilbara (B). The distinct differences are almost certainly attributable to the much lower iron content in the airborne particulate matter in Arabia, compared with the iron-ore rich Pilbara, where cation-rich dust facilitates the ingestion of Fe and Mn by varnish-forming micro-organisms (Bednarik, 1979).

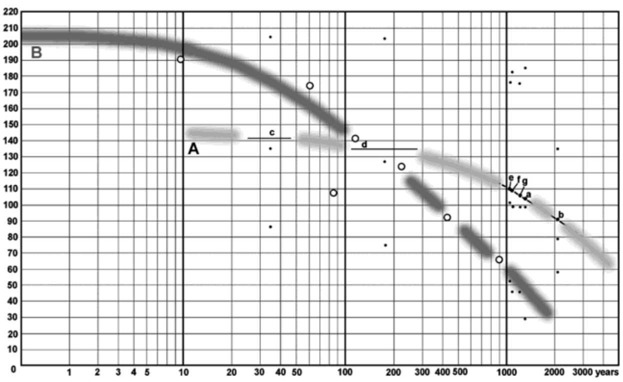

Figure 13: Colorimetric curves of ferromanganese accretions at Najd Sahī, Himā Cultural Precinct (A) and in the eastern Pilbara, Australia (B), plotted against age.

5. DISCUSSION

After many decades of speculations about the meaning and antiquity of Saudi Arabian rock art, the introduction of scientific methods in 2001 has in a relatively short time not only provided a significant amount of testable data about this vast body of evidence; it has also resulted in the refutation of much of these previous speculations. Notably Anati's more than twenty 'stylistic groups' of which over ten 'belong to Pre-literate times' (Anati 1968a: 4); his references to the Biblical Cushites who 'identified themselves with the ostrich' and performed cult ceremonies connected with an ox worship, with the use of a narcotic and with sexual rituals; and the many other demonstrations of his fertile pareidolic interpretations of a rock art he has never examined have become part of the fringe literature on rock art (cf. Jung, 1991a, b, 1994; Thomson, 1975; Zarins, 1982; Zarins et al., 1980, 1981). Nearly all of the rock art of the Himā Cultural Precinct on which he based his chronological sequence of all Arabian rock art is in fact of literate periods, as any site inspection soon demonstrates. Anati's sequence is chronologically anchored to entirely fantastical inventions, such as his 'giant toggle-pins' which he relates to irrelevant finds in Tepe Gawra and Maayan Baruch in Israel (to anyone other than Anati, these objects resemble curved swords or daggers) and his hypotheses of far-flung migrations are devoid of any evidence. Similarly, he had no ethnographic information of any kind at his disposal, when in fact the production of petroglyphs is a living tradition at Himā and images were still added there *after* Anati wrote his several books on them. So he could not know about the all-pervasive phenomenon of the *wusūm*, so crucial to understanding Arabian Peninsula rock art; or the cult of Alia, a pre-Islamic princess and deity, so crucial to understanding Himā rock art (Bednarik, 2017a).

6. CONCLUSION

In their brief history, the scientific investigations into Saudi Arabian rock art have not only resulted in the discoveries of massive new corpora of rock art (especially the Shuwaymis and al-Mismā complexes totalling tens of thousands of motifs); they have also yielded a rough chronological framework of this body through the acquisition of forensic evidence from many of the sites. The interpretation of these rock art corpora remains in a nascent state but it is currently being developed ethnographically, as is appropriate for a living tradition, and this development is assisted by epigraphic studies of accompanying texts of several pre-Islamic alphabets (Bednarik, 2017b). Unfortunately, it will take decades to erase the effects of the previous neo-colonialist approach to interpreting these cultural expressions in the Arabian Peninsula. Nevertheless, one tangible result of the scientific approach to one of the world's greatest rock art corpora has been the listing of two principal properties on the World Heritage List, which will facilitate further initiatives in the preservation and protection of this great cultural asset of the Kingdom.

ACKNOWLEDGMENTS

Thanks are due to Professor Sa'ad A. al-Rashid, for initiating this project; and to Professor Majeed Khan, for his gracious collaboration over many years. I am also greatly indebted to the many people who have assisted in the fieldwork across Saudi Arabia, especially Dr Jamal S. Omar, Waleed al-Badadawi, Mamdouh al-Rasheedi, Saad al-Rawsan, Saleh Al-Moreah, Professor Ali Ibrahim Alghabban, Dr Abdullah A. al-Zahrani, Professor Christian Robin, Dr Mounir Arbach and Giacomo Fontana.

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