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Optical Dating and Landscape Chronology at ad-Dīsa, Southern Jordan, and its Potential

Introduction and Acknowledgements

This paper reports on the use of Optically Stimulated Luminescence (OSL) dating (Huntley *et al.* 1985: 207) for establishing a chronology of soil landscapes in Jordan, and provides a time framework for the deposition of aeolian sand sheets in the ad-Dīsi area. The work was undertaken between 1989 and 1992 whilst R.N. Munro was working in the Department of Afforestation and Forests of the Ministry of Agriculture as part of the European Commission (EC) funded National Soil Map and Land Use Project (NSM and LUP), within the Ministry of Agriculture (EC Contract No SEM/03/628/005).

Following discussions with W.J. Jobling in March 1990, concerning the possible dating of soil features and sedimentary sequences in relation to the landscapes of Thamudic rock art period, a proposal was submitted by Jobling to the Australian Research Council through the University of Sydney. Field studies were conducted during 1990-92, and the OSL dating analysis was carried out in the UK and Canada during 1993 (Jobling 1993: 457).

Thanks are due to the Australian Research Council and the University of Sydney for funding; to Edward Rhodes of Royal Holloway and Bedford College, University of London, for carrying out the optical dating; and to Hunting Technical Services and the staff from the Ministry of Agriculture in 'Ammān for assistance and permission to use data from the NSM and LUP (Ministry of Agriculture 1993). Many other colleagues are profoundly thanked.

This work is dedicated to the memory of Dr Bill Jobling, friend to many in Jordan and a tireless, dedicated and original researcher of Thamudic art and its archaeology in Jordan.

Field and Laboratory Methods

The OSL technique (Aitken 1994: 175) involves sampling of sand samples under darkness to avoid exposure of samples to normal light giving rise to undesired bleaching of the electron trap and rapid reduction of the OSL signal. Laboratory treatment with HF acid removed surface layers and contamination of the quartz grains and samples were preheated to 220º C. Finally, exposure to argon laser green light gave rise to an OSL signal with detection in the blue/UV region as stored radiation was detrapped from the sample.

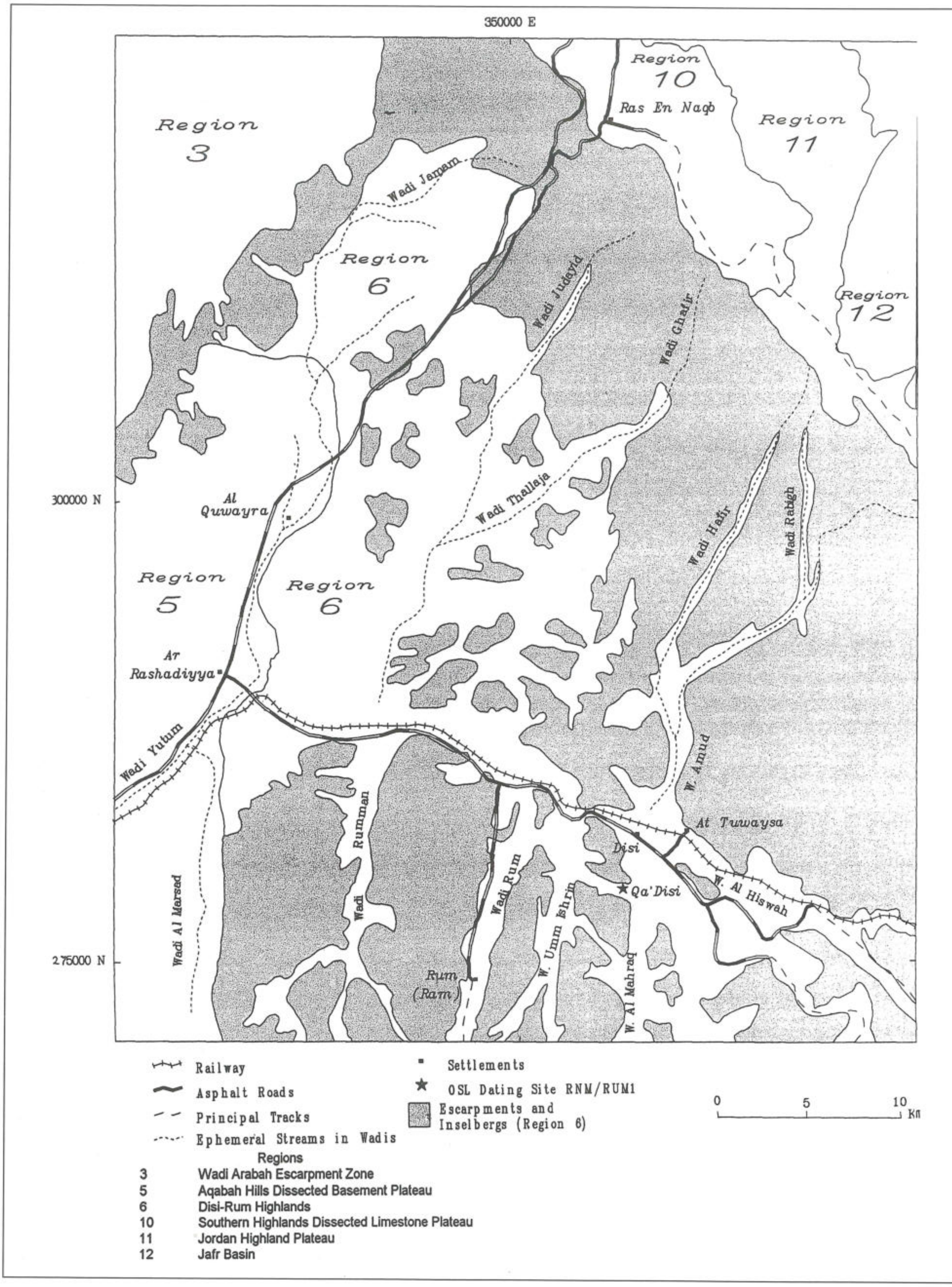
For the present research six sand samples were collected in June 1992, at 15, 35, 48, 60, 80 and 110 cm depth on the face of a section in a yellowish red sandy Typic Torripsamment soil of the Ishrin Formation (HTS 1993) located some 2500m south of the Post Office at qā' ad-Dīsa. The exact geographical co-ordinates of site RNM/RUM1 (site PW003 of the NSM and LUP) are 35.51020 degrees east / 29.62848 degrees north (JTM Grid Co-ordinates 355737 east / 279520 north) with an elevation of 795m asl, and about 0.5m above the level of the qā' ad-Dīsa playa (FIG.1).

Soil and Stratigraphic Background to the ad-Dīsa Area

The present studies have benefited from many works on prehistory, geomorphology and soils in Jordan, and in particular by Blake and Ionides (1939), Moorman (1959), Vita Finzi (1964: 19 and 1982: 23), Yaalon (1974: 91), Mitchell (1978), Garrard and and Gebel (1985), Byrd and Garrard (1990), Garrard *et al.* (1994), Macumber and Head (1991).

This study is centred in the Ḥisma, on the alluvial and aeolian units of the Wādī Ḥāfir, on the alluvium of qā' ad-Dīsa (also known as Dīsa), and on the sand sheets and dunes that lie beneath the sandstone inselbergs of Jabal Umm Nufus to the south of qā' ad-Dīsa. The lands surrounding ad-Dīsa comprise sandstone inselbergs (Osborn and Duford 1981: 113) with variable development of colluvial slope mantles (Bowman D. *et al.* 1986: 56). These pass downslope into a series of silt rich playas and salinas (*qā'*) that lie at the toeslope of alluvial fans degorging from wadis originating along the Edomite escarpment. Active sandsheets and dunes partly or completely mantle all older surfaces, whilst the thickness of the older fills in the ad-Dīsa area has been variously estimated up to 370m (Heimbach and Meiser 1971: 89; Lloyd 1969: 1).

On the fans and in the valleys upslope, gravelly and loamy alluvial sequences include a *Low Terrace*, at 1 to 1.5 above base level, with weakly developed cambic and calcic horizons and polygonal crack features, which is cut into a gravelly to loamy *High Terrace,* at ca +5 to +10m



1. Location of Optical Dating (OSL) Site at ad-Dīsa, Jordan .

with well-developed blocky structured horizons and CaCO3 concretions. The *High Terrace* merges laterally into aeolian-colluvial sandy to bouldery slope mantles that vary in composition according to their position relative to sand pathways. The ancient palaeo-sandsheets, which also have CaCO3 concretion layers and weak polygonal soil structural features, are widespread in the Rumm ad-Dīsa Wādī Ḥāfir areas.

Stratigraphy and Dating of ad-Dīsa Section RNM/RUM-1.

The ad-Dīsa site lies on a flat surface of a stabilised palaeo-sandsheet. Active sand sheets and dunes cover the surface close by, and a short distance to the north the sands pass abruptly onto the flat playa surface of qā‘ ad-Dīsa. The site is partly surrounded by cliffs and talus slopes of Jabal Umm Nafus and other low ridges formed from the Umm Ishrin Sandstone and ad-Dīsa Sandstone Formations. The profile is described as follows:

cm

0-20 Yellowish red (5YR 5/6) gritty/slightly gravelly sand; platy topsoil; surface rain crust; loose sand on surface; no concretions; strongly calcareous; pH 7.2; clear smooth to:

20-63 Yellowish red (5YR5/6) fine sand; weak subangular blocky structure; 30% small (<5mm) CaCO3 concretions; strongly calcareous; pH 7.2; clear smooth to:

63-112 Yellowish red (5YR5/6) fine sand; subangular blocky structure; 10% small CaCO3 concretions; slightly calcareous; pH 7.4; clear smooth to:

112-142 Strong brown (7.5YR5/6) sandy loam; moderate to strong subangular blocky structure; 30% subrounded CaCO3 concretions; very strongly calcareous; pH 7.6; irregular to:

142-182 Yellowish red (5YR5/6) fine sand; structureless; no concretions; strongly calcareous; base not seen.

OSL dating was used to provide dates for the older aeolian sand sheets. The results are given in TABLE 1 and show a progressive increase in age with depth.

The validity of the optical dates for the ad-Dīsa samples is considered to be within the range of OSL dating (Rhodes, 1994). The rather large uncertainties of several samples is likely due to a high scatter in OSL signals, probably as a result of dominating individual bright grains reducing precision of the dose rate (DE) determination. This is thought due to the range of different quartz host rocks around ad-Dīsa from which individual grains were derived, rather than incomplete resetting of OSL signals at the time of deposition, or the accidental exposure to light during collection. Correlation with archaeological evidence would assist in calibrating the results against other chronologies in the area.

Table1. Optical (OSL) Dating at ad-Dīsa: Dose Rates (DE) and Calculated Ages.

Sample No	Depth (cm)	Lab code	Dose RAte (DE) Gy	Age Years BP
6	15	247	4.0+/- 2.7	6,100 +/- 4,100
5	35	243	17.4+/- 7.6	23,800 +/-10,400
4	48	246	51.7+/- 10.4	72,100 +/- 17,000
3	60	245	56.8+/- 11.9	74,000 +/- 15,900
2	80	244	55.0+/- 42.9	88,100 +/- 68,900
1	110	242	101 +/- 19.6	198,000 +/- 39,800

Results from Studies in Adjacent Areas

Parallel studies have been conducted by D. O. Henry (1982: 41, 1985: 67, 1994: 265) who has worked extensively on the Rās an-Naqab escarpment of the Edomite Plateau. In the Wādī Judayid a lithostratigraphic chronology was shown for the Judayid basin (1000-1200m asl) and a climatic reconstruction made from interpretation of pollen studies in this steppe zone. These showed environmental conditions changing from slightly humid to dry in the Upper Paleolithic (40,000 to 20,000 BP) and a similar pattern in the Epipaleolithic (20,000 to 14,000 BP). In the Chalcolithic also, conditions remained moist until about 11,000 BP, and then became progressively drier.

In the Wādī al-Ḥasa, Clark (1990: 89) extrapolated results from the Negev and showed that maximum aridity in the late Pleistocene occurred after a humid interval from 32,000 to 27,000 BP. Also in the Wādī al-Ḥasa, Schuldenrein and Clark (1994) presented a landscape chronology from the Middle Palaeolithic. From 200,000 to 90,00 BP springs and travertines were associated with several cycles of soil development. Around 70,000 BP a high lake bed was present in the Wādī al-Ḥasa and at 26,000 to 20,000 BP there were high lake stands with springs. This period was followed by lake regression and channel incision, and finally in the Natufian and Kebaran (17,000 - 9,000 BP) there were swampy conditions, with alluvial fan deposition.

Interpretation of ad-Dīsa Section (RNM-RUM1) and Landscape Chronology

The interpretation of the ad-Dīsa section RNM-RUM1 suggests the following sequence of events:

a. Initial deposition of aeolian sands (142-200 cm) under arid conditions. This conclusion is based on the structureless nature of the sands, lack of gravel and CaCO3 concretions and high sand content (>85%). This phase was earlier than 200,000 BP.
b. A fluvial interval when gravel free medium-texured sediments were accumulating in a playa or *qā‘* mudflat (layer 112-142 cm). The slightly sandy nature of this layer suggests that sand may have been blowing across the playa, much as sand and dust does today

during the dry season. The presence of abundant large nebulous CaCO3 concretions, suggests that concretion formation took place due to fluctuations in a watertable in the playa. The structural morphology of the layer and the nature of the concretions do not suggest a soil forming process for the concretions. This ended earlier than 198,000 BP.

c. The succeeding layers (63-112 and 20-63 cm) are both weakly structured yellowish red sands, suggest aeolian deposition with later concretion formation by soil processes. From their position in the sands the concretions are considered to postdate aeolian deposition. There are no indications of any artifacts in these sands.

d. The surface layer (0-20 cm) is a weakly developed yellowish red soil formed on a stabilised sandsheet. It is slightly gravelly with a platy layer and rain crust at the top. Gravel content (2-5mm diameter) amounts to 30% and consists of ferruginous sandstone and quartz grains typical of materials that are weathering from the adjacent hills on ad-Dīsa and Umm Ishrin Sandstones. Various undiagnostic Neolithic or later flint artifacts are found on this stable surface, and small sherds of Chalcolithic pottery were also noted. The surface layer (0-10cm) is trampled by livestock and receives wind-blown sand. The age of this horizon, sampled below the surface of aeolian active and disturbed parts, was 6,100 BP(+/- 4,100 years). This appears to indicate the date at which the sand dunes ceased forming and soil formation commenced.

The progressive increase of the indicated ages with depth in the section appear to confirm that post depositional contamination (mixing) has not taken place. The lack of any original depositional features in the sands however was noted and may indicate that biotic activity has destroyed such features. This is seen to happen in modern sand dunes where roots, burrowing organisms and termites obliterate aeolian and other sedimentary laminations over a period of time. The profile was carefully examined after sampling to ensure that large burrows did not cross through these parts of the profile. These layers thus show aeolian deposition between 198,000 and at least as late as 24,000 BP. Given the errors shown in TABLE 1, and likely truncation by deflation, the latest deposition could be later than this.

The OSL dates appear to show that, in the ad-Dīsa area at least, a very long period of aeolian sand deposition took place during part of the Middle and much of the Late Quaternary (and Middle Palaeolithic) including the hyperarid period of the late glacial maximum at 18,000 BP. The dates may suggest four phases of deposition: at c. 200,000 BP (and possibly oxygen isotope stage 7); at 75,000 BP (possibly O.I. stage 5a); around the period 23,800+/- 10.4ka; and a Holocene event (Rhodes 1994).

What is not yet clear from this analysis is when and how CaCO3 concretion formation commenced, or indeed how it took place, whether in strongly seasonally arid/semiarid conditions, or in more arid conditions than the present. There is no indication that large concretions are forming at present in these areas, but soft 1mm sized CaCO3 concretions were noted in recent sand sheets in the region during field work, and strongly calcareous dust or loess is deflated off playas (qa') and redeposited in significant amounts on other land surfaces during dry season dust storms.

Discounting groundwater effects, soil concretion formation in the old sand sheet would have occurred as far as the limits of rainfall penetration. Annual accretion of CaCO3 around nuclei might have been very slight with gradual build-up over many years. Ancient subsurface calcareous crusts are commonly observed in the ad-Dīsa-Rumm area and represent where calcareous leachates were redeposited at sand/rock interfaces. The latter were first described by Borzatti (1984: 71). Examination of profile morphology suggests that although some truncation of the original soil surface has occurred, this concretionary layer shows that it essentially marks the end of a major phase of aeolian deposition and commencement of concretion formation.

Discussion

The stratigraphic interpretation of the ad-Dīsa section, and its relation to many other sites examined in southern Jordan, suggests that soil and concretion formation is Upper Pleistocene, rather than terminal Pleistocene-Holocene. The principal reason for this assumption is that a number of profiles show repeated cycles of deposition, concretion formation, truncation, and additional fill deposition. The concretions are not thought to have formed during the moister phase that occurred between 15,000 - 11,500 BP, documented from the Hula lake by Schwarcz (1995: 21).

Studies in southern Jordan, by Jobling (1984, 1990) and others, suggested that there was widespread Bronze Age abandonment of sites from ca 4,500 BP to 2,800 BP when an intense regional drought affected the area. Sand dunes covering over earlier stablisied aeolian landforms may date from this phase. Subsequently, climatic amelioration prevailed through to the Roman period and Mediaeval times when drier conditions again ensued. Loss of topsoil from overgrazing of the vegetation cover and deflation of broken soil surfaces broken by livestock may have led to considerable erosion and degradation. Although their implications are far from clear the presence of large cattle in panels of rock art, datable to the Nabataean/Roman period, suggest a grazing regime in the adjacent Wādī Ḥāfir area that is different from today's pastoral ecology, where sheep and goats dominate.

Data from the Wādī al-Ḥasa (Clark 1990: 89) suggest that humid intervals occurred at around 20,000 and 50,000 BP respectively. Huckriede and Wiesemann (1968: 73) in the al-Jafr Basin reported a high lake level in the later part of the Lower Paleolithic into the Levalloiso-Mousterian of the Middle Paleolithic, around 50,000 - 45,000 BP, with mudflat development and dessication occurring later, in the Upper Palaeolithic. Although it is strongly felt that correlation between these areas is at best very preliminary and sketchy they could relate to the formation of $CaCO_3$ concretions in sands and fans in the ad-Dīsa-Rumm area, which the OSL dating shows was later than 23,800 BP. Polygenetic profiles in the Wādī Rumm area may relate to the earlier period.

A suggestion that also needs to be fully tested is whether wet conditions may have existed further north in Jordan on the highland (Edomite) plateau, whilst arid conditions remained in the sandstone areas of ad-Dīsa-Rumm. This is thought likely, and the OSL dates help to show that in general the landscape at ad-Dīsa at 200,000 BP was perhaps not unlike the present. The Edomite plateau lies in Mediterranean type soil moisture and climatic regimes, as exemplified around Rās an-Naqab and above Wādī Mūsā, with flood waters originating on the hills and draining into the arid interior basins or desert lowland fringes. Soils on the plateau are deep and do not in general indicate features characteristic of arid zone soils.

In the desert zones however, such as in the al-Jafr Basin and the ad-Dīsa-Rumm areas the climate is very different and soils show a range of features attributable to aridic processes (Dan 1983: 287; Ministry of Agriculture 1993). A model is suggested with sediment laden flood waters originating on the highlands depositing their loads as fans or lakes in deep graben in the ad-Dīsa and al-Jafr areas.

The ad-Dīsa OSL dates give a maximum age of 198,000 BP (+/-) down to a depth of only 1.1m. Given the apparent thickness of sediments in the qā‘ ad-Dīsa area it is difficult to surmise on the possible maximum age of the aeolian-alluvial fills in the ad-Dīsa-Rumm region. Conversely, if the ad-Dīsa basins were filled by lake and aeolian sediments during wet phases in the Pleistocene then sedimentation of these fills could have occurred over a relatively short time, simultaneously with dune formation under arid conditions: removal and deposition of aeolian and/ or fluvial sediments in arid regions is periodic but often on a massive scale.

Conclusions

The extent of the OSL sampling in 1992 was restricted to a stabilised paleo-sand sheet and its chronology appears to overlap only the oldest archaeological finds in the area. It remains important, therefore, to utilise the evidence from the archaeological record to attempt to complete the landscape chronology of southern Jordan during the late Pleistocene and Holocene. Based on the observations made during widespread field work throughout Jordan, various soil and depositional features are considered to lend themselves to OSL dating. Landscape, sedimentological and soil features where OSL dating could assist in establishing chronologies, include as examples the following:

- aeolian deposits;
- alluvial terraces;
- aeolian-colluvial slope mantles in desert areas;
- indirect dating of rock art surfaces buried by aeolian sands;
- lacustrine deposits (in the ad-Dīsa and Mudawwara areas);
- aeolian infills of polygonal gypsiferous crusts and basaltic terrain;
- calcreted aeolian sands;
- paleosol horizons on slopes and residual plateaux;
- loess sequences along the desert fringe;
- landslip deposits such as in al-Baqa‘a Valley with sandy fills;
- sterile sandy infills at archaeological sites,
- sandy fills in man-made agricultural terraces and dams.

Fuller details of these applications were reported by Munro *et al.* (1995) and discussed at the Turin conference. It is not certain that OSL dating could be successfully carried out on field examples of all of these features, and in some cases (for example calcretes) the age of the material may exceed the maximum range of OSL range of around one million years.

The employment of the OSL dating techniques to the fieldwork of archaeologists is only beginning to be fully explored. It appears to be a particularly useful tool when examining geo-archaeological sites in conjunction with other dating methods. This research has provided a useful starting point and framework for the dating of sand accumulation at one site in southern Jordan during the Pleistocene and early Holocene. By extending the work to other landforms in the region, or all of Jordan, a more detailed chronology could be established. Data from the National Soil Map and Land Use Project of Jordan will be particularly useful in drawing up a list of land surfaces, key layers and soil horizons for which dating by OSL, or other methods could show promise.

The establishment of a chronology of landscapes furthermore could provide a measure for more detailed assessments of land use change in Jordan. In previous vegetation studies (Hunting Technical Services 1956; Long 1957; Poore and Robertson, 1964; and Ministry of Agriculture 1990) the degradation of the land cover and surface has been repeatedly noted as a trend that will reduce biodiversity and rangeland productivity. A much more comprehensive picture of land use history and chronology than exists at present has yet to be established in the Kingdom. Such a framework would also be of great benefit in assisting to define future land use policies in the region. It is considered that OSL dating could provide part of the means to provide important linkages that could bring together studies of landscape, soil and stratigraphic features, land degradation, erosion, and vegetation and climate change.

At present, a limitation in the use of optical dating for archaeologists, requiring precise absolute dates, is the large uncertainties given in the OSL dates, although it is considered that these could well be reduced by refinement in the future (E. Rhodes, pers. comm.). In general this technique, if applied to age and chronology determinations of landscapes in Jordan, will provide a useful framework for archaeologists examining specific sites or undertaking regional surveys. It is by additional testing of the method in the context of soil and sedimentary features that its general usefulness will become apparent and proven.

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