Optical Luminescence Dating of Aeolian Dunes, Sandsheets and Clastic Sabkhas of Saudi Arabia

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Abstract

Optical luminescence age dates of aeolian dunes, coastal and inland clastic sabkhas, and sandsheets in Saudi Arabia exhibit ranges that suggest paleoclimatic controls. Small barchan dunes (<10 m high) in the Jafurah and Dhana dune fields have ages typically <500 years corresponding to the latest hyperarid period (0-6000 years). Preserved old foresets exposed on the upwind side of large barchanoid dunes (>30 m high) in the eastern Rub Al-Khali have ages of 14000-15000 years corresponding to the arid period 10000-20000 years before present when Arabian lake levels were low or lakes non-existent. The absence of dune ages corresponding to the 6000 to 10000 ybP humid period when lake levels were high in the Arabian Peninsula, suggests that during these wetter times, dune formation and migration were inhibited. OSL ages from preserved foresets on the upwind and downwind sides of dunes indicate that migration rates of the large dunes in the eastern Rub Al-Khali are on the order of centimeters/year compared to measured migration rates of meters/year for smaller dunes in the Jafurah.

Sandy sabkha sediments collected at depths generally less than 2 meters have ages ranging from about 3000 to 8000 years, perhaps associated with rising water tables related to the Flanderian sea level rise which began about 12000 years ago and reached its maximum around 4000 years ago. Net vertical accumulation rates of about 4-15 cm/1000 years are calculated for these clastic sabkhas.

Two paleosols characterized by calcified rootlets and rhizoliths were sampled in central Saudi Arabia. One paleosol is preserved on a large domal dune and another on a gently rolling sandsheet. Both paleosols are covered by more recent active aeolian sands and suggest less arid conditions than exist today. Ages obtained on these paleosol horizons are 7200 and 13000 years, respectively. The oldest date recorded is 180,000 ybP in pedogenically-altered fine gravels of the Dibdibah alluvial fan near Hafir Al-Batin, northern Saudi Arabia.

Optical Luminescence Age Dating of Modern Desert Sediments and Paleosols, Saudi Arabia

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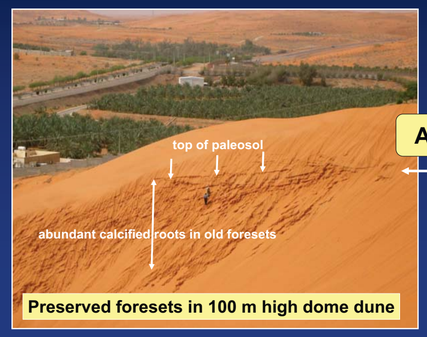
6. Dunes, Paleosols, and Sandsheets

A. 100 meter high domal dune at Az-Zilfi with reactivation surface truncating relict foresets. Relict foresets contain abundant, thin-walled calcareous rhizoliths (fossil root encrustations) up to 3 cm diameter indicating a period of pedogenesis.

B. ~ 10 meter thick sandsheet of undulating sand hills above carbonate bedrock. A sharp reactivation surface about 1 meter down separates more recent aeolian sand from underlying mottled sand with small (<1 cm diameter) calcareous rhizoliths.



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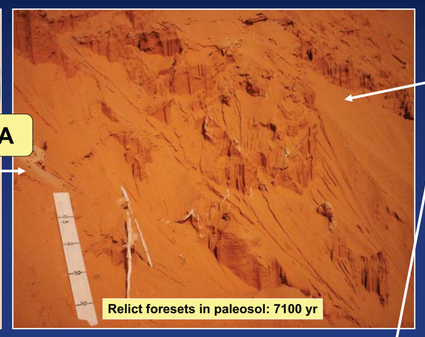

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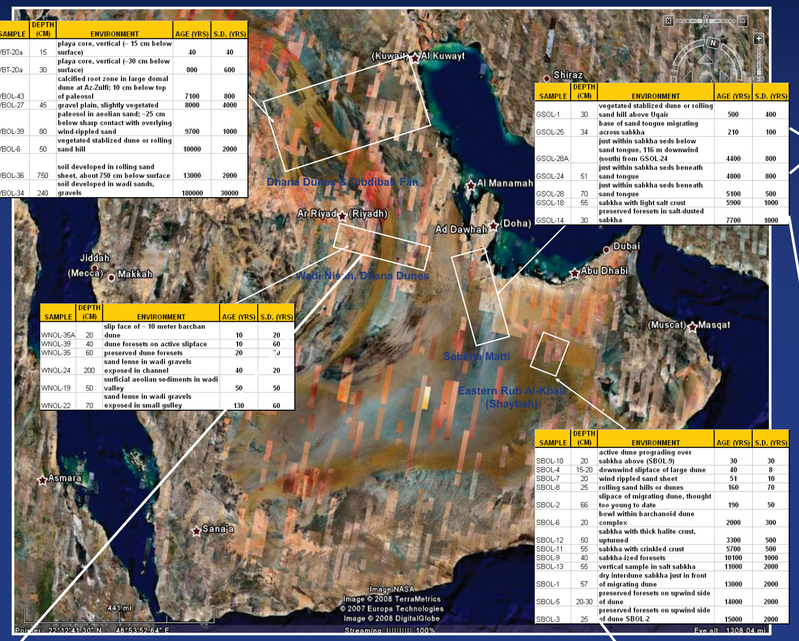
2. SAMPLE LOCATIONS AND AGES

SAMPLE	DEPTH (CM)	ENVIRONMENT	AGE (YRS)	S.D. (YRS)
WBT-20a	15	playa core, vertical (~ 15 cm below surface)	40	40
WBT-20a	30	playa core, vertical (~30 cm below surface)	800	600
WBOL-43		calcified root zone in large domal dune at Az-Zulfi; 10 cm below top of paleosol	7100	800
WBOL-27	45	gravel plain, slightly vegetated	8000	4000
WBOL-39	80	paleosol in aeolian sands: ~25 cm below sharp contact with overlying wind-rippled sand	9700	1000
WBOL-6	50	vegetated stabilized dune or rolling sand hill	10000	2000
WBOL-36	750	soil developed in rolling sand sheet, about 750 cm below surface	13000	2000
WBOL-34	240	soil developed in wadi sands, gravels	180000	30000



SAMPLE	DEPTH (CM)	ENVIRONMENT	AGE (YRS)	S.D. (YRS)
GSOL-1	30	vegetated stabilized dune or rolling sand hill above Uqair	500	400
GSOL-25	34	base of sand tongue migrating across sabkha	210	100
GSOL-28A		just within sabkha seds below sand tongue, 116 m downwind (south) from GSOL-24	4400	800
GSOL-24	51	just within sabkha seds beneath sand tongue	4800	800
GSOL-28	70	just within sabkha seds beneath sand tongue	5100	500
GSOL-18	55	sabkha with light salt crust	5900	1000
GSOL-14	30	preserved foresets in salt-dusted sabkha	7700	1000

SAMPLE	DEPTH (CM)	ENVIRONMENT	AGE (YRS)	S.D. (YRS)
WNQL-35A	20	slip face of ~ 10 meter barchan dune	10	20
WNQL-39	40	dune foresets on active slipface	10	60
WNQL-35	60	preserved dune foresets	20	70
WNQL-24	200	sand lense in wadi gravels exposed in channel	40	20
WNQL-19	50	surficial aeolian sediments in wadi valley	50	50
WNQL-22	70	sand lense in wadi gravels exposed in small gulley	130	60

SAMPLE	DEPTH (CM)	ENVIRONMENT	AGE (YRS)	S.D. (YRS)
SBOL-10	20	active dune prograding over sabkha above (SBOL-9)	30	30
SBOL-4	15-20	downwind slipface of large dune	40	8
SBOL-7	20	wind rippled sand sheet	51	10
SBOL-8	25	rolling sand hills or domes	160	70
SBOL-2	66	slipface of migrating dune, thought too young to date	190	50
SBOL-6	20	bowl within barchanoid dune complex	2000	300
SBOL-12	50	sabkha with thick halite crust, upturned	3300	500
SBOL-11	55	sabkha with crinkled crust	5700	500
SBOL-9	40	sabkha-ized foresets	10100	1000
SBOL-13	55	vertical sample in salt sabkha	11000	2000
SBOL-1	57	dry interdune sabkha just in front of migrating dune	13000	2000
SBOL-5	20-30	preserved foresets on upwind side of dune	14000	2000
SBOL-3	25	preserved foresets on upwind side of dune SBOL-2	15000	2000

3. Sabkha and Sandsheet in Sabkha Matti

A. Thin aeolian sandsheet overlying sabkha sediments with >4500 year hiatus.

B. 7700 year-old aeolian dune foresets now preserved beneath the salt-encrusted surface of a modern sabkha.

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5. Wadi Sands and Gravels and Aeolian Reworked Sands

A. Flash-flood sand and gravel deposited in a broad wadi. All sediments sampled (< 2 meter depth) in the valley were < 200 years old

B. Small (< 1meter) aeolian dunes of reworked wadi sands at the surface. Well sorted x-bedded sands (aeolian?) interbedded with poorly-sorted sand containing pebbles and granules yield an age of 50 years at 50 cm depth.

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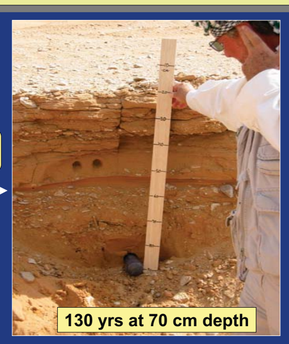

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1. Questions and Conclusions

Questions:

- What is the time available for early diagenesis in modern desert environments in Saudi Arabia?
- What is the "residence time" of sands buried in large (e.g. Rub Al-Khali) versus small (e.g. Jafurah Sands)dunes?
- When did coastal and inland sabkhas form?
- What is the age of buried aeolian dunes that have now become "sabkha-ized"?
- What is the age of extensive sandsheets?
- When did the paleosols preserved in dunes and sandsheets form?

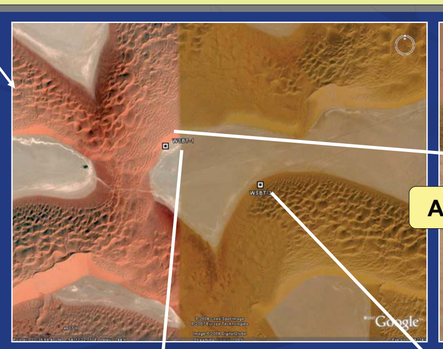
Conclusions:

- Modern desert sediments analyzed in this study exhibit a range of ages from <100 years to more than 150,000 years.
- Preserved foresets now preserved on the upwind margins of large barchanoid dunes of the Rub Al-Khali are 14000-15000 years old, implying average dune migration rates of 14 cm/year.
- Preserved foreset beds in small dunes of the Jufurah Sand Sea are <200 years, indicating much faster cycling time of sand grains with dune migration rates of meters/year.
- Clastic sabkha sediments (mostly sand) range in age from 3300 to 6000 years, approximately coinciding with the Holocene sea level rise. Vertical accumulation rates of 4-15 cm/1000 years are implied.
- Buried aeolian dunes, now beneath sabkha surfaces, range in age from 7700 to 10000 years.
- An extensive ~7-8 meter thick sandsheet in central Arabia has an age at the base of 13000 years, indicating vertical accumulation rates of >50 cm/1000 years.
- Weak, calcic paleosols are developed on large domal dunes near Zilfi which are 7100 years old. Similar paleosols are developed on 9700 year old sand sheets 125 km to the NE.
- The data indicate major inland sand emplacement during late glacial and early Holocene sea level rise (~7000-16000 years ago) followed by mid-Holocene (3500-6000 years) sabkha formation as sea levels stabilized.
- The paucity of samples dating from late Holocene (~2000 yrs.) to about the last 200 years indicates that either there was a hiatus in landform formation until relatively recent times, or that features formed since the mid-Holocene have been reworked, possibly on a bicentennial time scale.

4. Very Large Barchanoid Dunes and Interdune Sabkhas: Rub Al-Khali

A. > 100 meter high barchanoid dunes at Shaybah with relict foresets (former slip faces) preserved at upwind edge. Width of dune combined with ages of relict foresets and active foresets suggest average migration rates of ~14 cm/year.

B. Crinkle-bedded to structureless interdunal sabkha sediments from pit dune just downwind of active slipface yields an age of 13,000 yrs at 57 cm, indicating average vertical accumulation rates of 4-5 cm/1000 yrs.



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2. Description of Optically Stimulated Luminesence (OSL) Age Dating Technique

Luminescence dating, particularly using optically stimulated luminescence (OSL), is revolutionizing Quaternary and archaeological science because it allows dating of sediments and artifacts that previously could not be dated.

The OSL of a sediment is quickly lost when exposed to sunlight (tens of seconds) so many sediments are “bleached” (lack an OSL signal) at the time of deposition. After deposition these sediments accumulate luminescence which can be measured, therefore allowing the age of burial to be determined.

The upper age limit of OSL is primarily determined by the annual dose to which the sediment is exposed. This is related to the sediment’s content of uranium, thorium and potassium. Low levels of these radioactive isotopes in the sediment lead to very slow saturation of quartz and feldspar grains by released electrons, therefore ages in excess of 500,000 years may be possible. Typically OSL ages range from 100-200 years to about 400,000 years with an error of around 10%.

Recombination:

Electrons trapped in deep traps (T) do not readily recombine unless induced to do so by natural "clock-resetting events“ (e.g. sunlight), or under strictly controlled laboratory conditions. Laser light can eject charges from traps “T” back into the conduction band which allows an electron to recombine with a luminescence center “L”. This causes a photon “h” to be emitted. This phenomenon forms the basis of OSL dating.