Pinnacles and barchans in the Egyptian desert

Migrating sand dunes are on the move today, but the Egyptian oases also contain landforms left from a wetter past.

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The Western Desert of Egypt is an enormous and very barren wilderness – a classic hot desert, almost all of which is practically uninhabitable. To its east lies the Nile valley, while to the west is just more and more sand that extends into Libya and continues unbroken into the enormity of the Sahara. For 5000 years, Egypt (and its Pharaonic ancestors) has been a one-river country, with nearly everyone and everything crowded into the Nile valley from Aswan downstream to Alexandria.

Nomadic Bedouins and Berbers have lived in and traded across the deserts for millennia, but most of them have settled in a chain of four oases – Kharga, Dakhla, Farafra and Bahariya. These lie below the western rim of the low plateau of Ghard Abu Muhariq, which is formed of almost horizontal Cretaceous chalk and Eocene limestone (Fig. 1). They are not the schoolbook type of oasis, with a few palms around an isolated pool. They are broad depressions, each 50–100 km across, floored by rock platforms, gravel plains and shifting sands. The Kharga and Dakhla oases are open to the south-west; they lie at the foot of the dipslope from the Western Desert, beneath the south- and west-facing escarpments that rim the limestone plateau. Farafra and Bahariya are almost closed basins surrounded by limestone cliffs, each on a gentle anticline that has been breached by erosion.

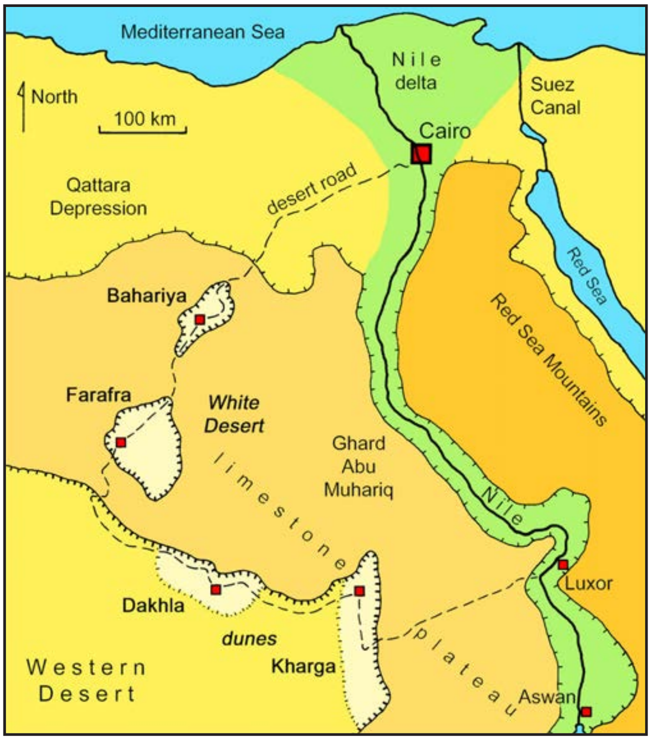


Fig. 1. Location map for the oases of central Egypt.

In the second half of the Tertiary, the oasis basins were not established and rivers from the south carried clastic sediments onto the limestone platforms in a climatic regime much wetter than today's. A scatter of sinkholes and small caves across the limestone plateaus appear to date largely from that time. Travertine banks at the north end of the Kharga oasis date from rainfall that continued into the Pleistocene, until the region turned arid about 750 000 years ago. There was an interlude of rainfall in the Devensian, which continued on a reduced scale into early Pharaonic times about 6000 years ago. Scarp retreat and anticlinal breaches had created the four oasis basins by the early Pleistocene, when they were all floored by wide, shallow lakes. Their lacustrine sediments now provide nearly a million hectares of land that is arable except for the lack of water. Annual rainfall is now less than a centimetre.

The oases do have some water resources. Each has a few natural springs. Some yield modest flows of sweet water from perched aquifers of sandstone or karstic limestone in the adjacent plateaux. Others supply warm mineralized water that rises on faults from deeper sources. Far more important is the giant aquifer that underlies all four oases. This is the Cretaceous Nubian Sandstone, which crops out in the floor of the Kharga basin and extends 600 m down to the underlying Aswan Granite. For thousands of years, wells have been dug 100 m or more deep, to yield supplies for both survival and cultivation in the oasis basins. Wells can yield hundreds of litres of good water per second, and some in the Kharga oasis have up to 15 m of artesian pressure where the ground level is now close to sea level.

Population pressure in the Nile valley has forced the Egyptian government to look west, and since 1958 the four oases have become the 'New Valley' (although it is not a continuous valley), where opportunity and development are supposed to multiply. A good tar road now makes a huge loop through the desert (Fig. 2) from Cairo round to Luxor. There are grand new irrigation schemes and housing projects in the Kharga and Dakhla oases, and more modest

Fig. 2. The road across very empty desert between the Farafra and Dakhla oases.

Fig. 3. Chalk pinnacles scattered across the White Desert of the Farafra oasis.

Fig. 4. A chalk pinnacle is sand-blasted around its base where it stands in a wind-scoured depression in the sand veneer on the Farafra oasis floor.

versions in the others. But the costs of developing the desert have proved almost prohibitive, and the water supply has fallen short of expectations.

It had been thought that the great Nubian Sandstone aquifer was recharged by natural infiltration far to the south and along the Nile. But such is not the case. The water is fossil; it is of good quality, but is old and is barely being renewed. Pumped abstraction has already put the water table in decline and there is a finite limit to how long this water resource can be 'mined' before it runs out. Some of the New Valley development is now on hold and parts are almost modern ghost-towns, but many of the long-term inhabitants continue with their traditional ways of the desert. Fortunately, the desert road is still in excellent condition and provides access to some classic desert landforms.

The white desert of Farafra

The Bahariya basin has acquired new fame for its *Paralititan*, the extremely large dinosaur whose fossil skeleton has been excavated from Cretaceaous estuarine sandstones. Some of the Bahariya hills have basalt and dolerite caps, which create their own 'Black Desert'. This forms the perfect contrast with the white desert of the next oasis basin to the south. Tertiary limestone caps the plateau that almost encircles the Farafra oasis, and its floor is cut into snow-white chalk of Cretaceous and Paleocene age, contemporaneous with the upper part of the Nubian Sandstone, which only exists further south. Sand blows across the basin floor, but there is no great supply and much of it is stacked in climbing dunes against the cliffs at the downwind, southern end.

The key feature of Farafra's 'white desert' is the host of chalk pinnacles, towers and rounded blocks rising above the surface of blown sand (Fig. 3). They are scattered across huge areas of the basin floor. Most are 2–4 m high, but there are fields of blocks, all of which are no more than a metre high. They are all made of very white chalk and make a beautiful contrast with the dark golden sands. Their upper parts are at the mercy of mechanical weathering. Thermal expansion in the hot sun creates onion-skin shells that break away from crumbly cores of very weak chalk. In contrast, their lower parts are smooth, rounded and as polished as a chalk can be, the result of sand-blasting that is largely restricted to a height of no more than a metre above ground level. The wind that drives the sand is deflected around the rocks and scours out peripheral bowls in textbook style (Fig. 4). But the wind and the heat only modify older landforms.

The isolated chalk pinnacles are karst features. They date from dissolution in late Tertiary and early Pleistocene phases of wetter climates. Pinnacles of

Fig. 5. Chalk towers are fossil karst landforms in the White Desert (note the person standing on the right for scale).

this style are common in karsts of warm and wet environments. They can form above ground where they are fretted by rainfall to leave sharp crests and ridges. Or they can form below a cover of permeable soil, where corrosive groundwater attacks from all sides to leave rounded bosses. The Farafra pinnacles have lost all surface detail to millennia of sand blasting and thermal weathering, and their exact origin cannot be determined. In China, they would be called 'stone teeth', mainly formed below a soil cover.

Close to the pinnacles, and cut in the same white chalk, there are groups of taller towers, 10–15 m tall (Fig. 5). While their tops and faces are also shattered by weathering, they do have some sand-blasted parts lower down, but most of their bases are protected by aprons of talus fallen from above. They appear to be the remains of true karst towers that once stood above an alluviated basin floor, at which level their bases were undercut by dissolution and lateral stream erosion. A few larger towers survive close to the encircling escarpment, but they are merely remnants of differential scarp face retreat. The pinnacles and towers appear to be relics of an early Pleistocene karst landscape that has been progressively destroyed since the climate turned arid and the soils were lost on the wind. White ghosts of the past, they now attract a trickle of tourists in search of yet more weirdly shaped rocks in the desert.

The migrating dunes of Kharga

Largest and lowest of the four oases is Kharga. Its floor is down to the Nubian Sandstone, and the high limestone escarpment to the north and east is undercut by a shale slope. Kharga has long attracted itinerant geomorphologists to its splendid dunes. Its western flank is marked by a sea of long seif dunes, and barchans are being driven across it by the prevailing wind from the north. Seif dunes are the long ridges aligned with the prevailing wind where there is a steady supply of sand and periodic cross winds prevent the ridge breaking into isolated dunes; they are typically about 50 m high and six times as wide, and may stretch for tens of kilometres.

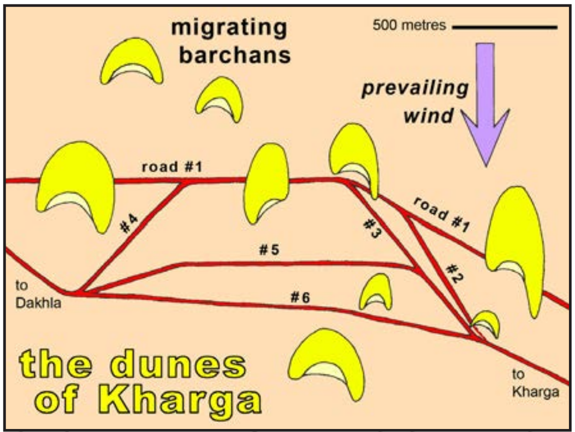
Barchans are the isolated crescentic dunes that move across the desert floor; each is typically 50–300 m across and 5–20 m high. They are created by unidirectional wind with a more modest supply of sand, sometimes in between seif dunes. Sand grains are rolled up the windward slope and then tipped on the lee at the angle of rest of about 34°. The flanks have smaller amounts of sand to be moved and therefore advance faster to create the distinctive crescentic shape.

The relentless movement of the Kharga barchans attracted early scientific study, and rates were measured nearly a hundred years ago by Llewelyn Beadnell, who subsequently described them in the *Geographical Journal* of 1910. Today, they are very accessible, as many lie within sight of the highway from Kharga west to Dakhla (Fig. 6).

About 50 km west of Kharga town, there is a particularly active cluster of barchans. They are driven

Fig. 6. Perfect barchan dunes, each about 200 m across, migrating towards the camera from the distant plateau on the north-western side of the Kharga oasis.

Fig. 7. An old section of the Kharga-Dakhla road is lost under a massive dune (barchan A on Fig. 8).



the Pleistocene source deposits on the limestone pla-

south by the steady north wind that carries sand from the Pleistocene source deposits on the limestone plateau of Ghard Abu Muhariq, which may be translated as the 'dune with an engine'. The wind blows from the north on four days out of every five, and on nearly 100 days per year it exceeds the critical velocity of 20 kph when it becomes effective at moving sand across the desert floor. A single barchan may contain over 200 000 tonnes of sand. So when one migrates on to a road or over a house, its control or removal may be difficult, expensive or simply uneconomic (Fig. 7).

The road to Dakhla is threatened, or has already been diverted, on many stretches. It is currently struggling to survive under the relentless onslaught of a cluster of nine barchans (Fig. 8). The original asphalt road has been rebuilt five times, and the old blacktop roads can now be seen disappearing under five of the dunes. Lines of half-buried telegraph poles offer further testimony of the sand accumulation (Fig. 9). The oldest of these roads dates back about 40 years, and only two are currently negotiable. Advancing barchan A is threatening the newest road, #6, but has already passed over road #5, which will therefore return to being the road in use. However, another smaller barchan, H, is threatening both roads at their junction (Fig. 10), and may demand building road #7 in the near future.

With less sand to move in the same wind, the smaller barchans move faster. Beadnell measured an advance of just over 10 m per year by a large barchan 20 m high, while a barchan just 4 m high travelled nearly twice as far. The pattern of barchans is therefore constantly changing, and their interference in the smooth flow of the wind creates degrees of asymmetry in their crescentic form (Fig. 11, and recognizable on nearly all the barchans in the map, Fig. 8). These advance rates imply that the sand could have migrated from anywhere on the plateau or even from the Mediterranean coast since the mid-Pleistocene desiccation of the climate.

With their larger volumes of sand, seif dunes migrate much more slowly than the barchans. The Kharga–Dakhla road rounds the nose of a long seif dune just east of the barchan cluster, and sand is being excavated from its toe before it covers the road. Blowing sand accumulates in the lee of any obstruction, which is why it builds up in any road cuttings aligned across the wind. The engineering response is to build roads on low banks, which are swept clean by the wind, but this is not enough to withstand the onslaught of an advancing barchan. Houses gather sand in their lee, and can be partly or totally buried by barchans. Some stone houses in the Kharga oasis have had an upper storey added for use while a low barchan passes by, until the dune is gone and the ground floor is again accessible. Shortage of water is not the only challenge to living in a desert.

Fig. 8. Sketch map of the barchan cluster (lettered for reference) and six routes of the Kharga–Dakhla road (numbered in sequence of their construction).

Fig. 9. (bottom left) Old telegraph poles mark the route of road #1 beneath barchan J.

Fig. 10. (below right) Barchan H is moving from right to left, towards the road junction.

Fig. 11. (bottom right) The firm top of barchan D is rippled where the wind is picking up the sand. In the middle distance, the loose, downwind slip-off slope of barchan E marks its site of sand deposition and its advance towards the road, with the far side of its crescent advancing faster than the near side.