The Mound Springs of Northern Ntwetwe in Makgadikgadi: Implications for the Makgadikgadi Management Plan

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Abstract

The origins of crescent shaped mounds on the floor of Ntwetwe pan have long been debated. The preferred explanation is that they are barchan dunes, of aeolian origin, indicating a former very dry period. In detail, their morphology is inconsistent with this hypothesis. Morphological evidence is presented to show that they are mound springs. Upward discharge of water persists today, but the building of the mounds pertains to a former, wetter period when the discharge was stronger. The source of the water is the karstified hinterland. There the exposed palaeolake floors are pitted with numerous small pans and groundwater recharge is excellent. It is this recharge that sustains the discharge associated with the mounds in Ntwetwe pan. This situation has important implications for the Makgadikgadi Management Plan. The resulting potable water and sweet grasses in Ntwetwe are essential to the game migrations, for which the area is famous worldwide. The conservation and sustainability of this ecological system depends entirely on resource management outside the area presently defined for development and protection, that is, in the recharge area. Overabstraction of groundwater or pollution would be detrimental, as has been seen in Australia. It is strongly recommended that the system is protected by the formation, as for the Okavango, of a buffer zone that encompasses the essential recharge area. This would signal the need for extra vigilance regarding developments here.

Introduction

The Makgadikagadi pans area has a long history in the international literature largely because of the opportunities it offers for palaeoclimatic reconstruction (Thomas and Shaw 1991). Although overshadowed by the Okavango Delta as a tourist destination, the importance of the pan system in this respect is increasingly recognised. This unique resource is now being developed. The Makgadikgadi Development Plan is in progress. The truism that a resource cannot be successfully developed and conserved unless its nature and how it functions are known is apposite. Here we contribute to an essential component of this understanding, the origin of the mounds, earlier believed to be barchan dunes, on the floor of Ntwetwe Pan.

Although there has been some dissent about the origin of the features (Grove 1969, Cooke 1980 and Besler 1983), the preferred explanation of these is that they formed as dunes on the floor of the pan (Thomas and Shaw 1991). Their crescent shapes strongly suggest this. Recent research (Burrough *et al* 2012), while recognising anomalous features, incline to the earlier suggestion that these are forms that developed under arid conditions. Here we summarise recent evidence that presents an entirely different mode of formation, which carries important implications for the Makgadikgadi Management Plan.

Methods

The geomorphology of northern Ntwetwe pan and its hinterland in the palaeolakes area to the north was characterized using Google Earth images, orthophotos and air photo stereopairs. Extensive geomorphological and hydrogeological fieldwork was undertaken in the hinterland as part of a government of Botswana project (Hydrogeological Impact Assessment of the Gweta Sewage Ponds). More recent fieldwork was undertaken in the pan area but, because of the severe access problems, was restricted to ground-truthing of features identified from images.

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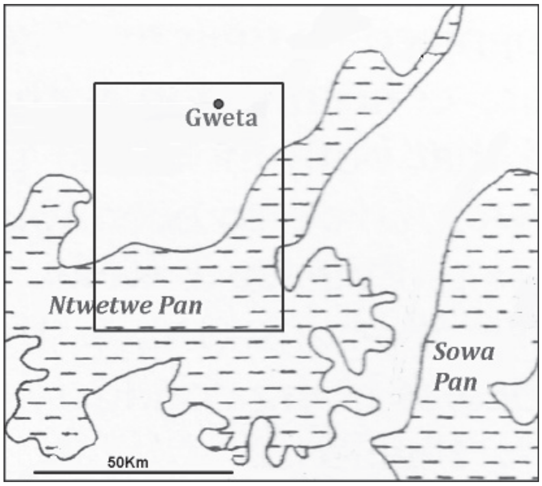
The Forms of the Pan Floor Mounds

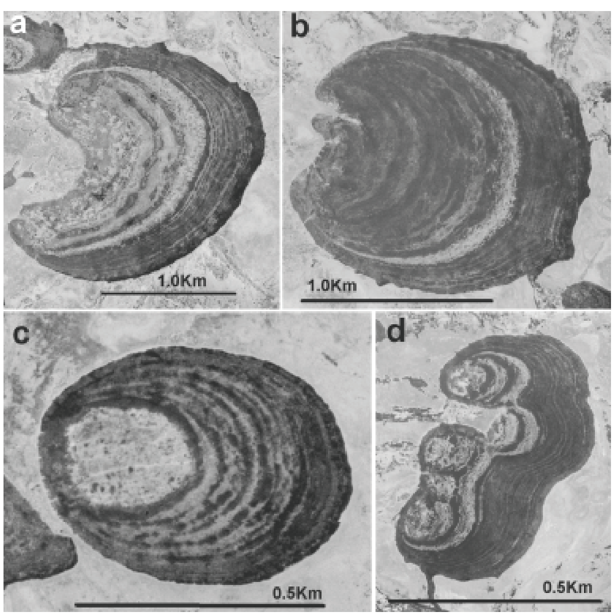
The location of the study area is given in Figure 1 below. Furthest from the perimeter of the pan, the mounds are more clearly separated.

Figure 1: The study area



Forms vary. Some 10% have an open crescent shape (Figure 2a). More commonly the 'horns' curve inwards, partially enclosing or entirely closing a central 'eye' such as in Figure 2b and 2c). Bands of different tones are very conspicuous on images but undiscernable on the ground. The bands are more tightly arranged on the east sides, more widely spaced towards the west and north west. In the eyes the tones are chaotic. The curvature of the forms and the pattern of the tone bands prompted the hypothesis that they are modified barchans dunes. Closer to the pan margin, the discrete mounds become progressively linked to form long, sinuous forms. Figure 2d shows incipient linkage of a group of discrete forms. Figure 3 shows a typical area of sinuous mounds.

Figure 2: Variation in forms of discrete mounds: (a) open crescentic forms; (b) intermediate forms between the open crescents and entirely closed; (c) oval forms; (d) incipient linkage of rounded mounds, transitional to the linked forms closer to the pan margin.



The hypothesis that these are modified dune forms faces many difficulties. The change in spacing of the tone bands, particularly of the arcuate discrete forms, would be expected to be the dune crests, the highest points. However, this change is deceptive. The mounds are predominantly flat. Minor summits may lie on either side of the assumed crest. Another problem is the infilling of the eyes. This cannot be explained by erosion of the arms where the eyes are as high as, or even higher than, the arms.

The mounds are generally low. There is a clustering of elevations between 910 and 914m, some 5-9m above the pan floor at 905m, but by far the most abundant are small mounds rising less than a meter above the floor (McFarlane and Long 2015).

Hydrology

The elevation of the pan floor is controlled by the level to which deflation, erosion by wind, can operate. This is, in turn, controlled by the groundwater level since only dry material can be removed by the wind. The pan floor level is consistently at 905m. In the area of linked forms near the pan margins, however, the elevation of the floor is varied and this can be attributed to variations in the groundwater level, as can the variety of elevations of open water bodies. The water is very variable in quality, as seen by the changes of colour on the Google Earth images and by animal tracks. These focus on some pools, evidently potable water, while others are ignored. Differential evaporation of rainfall cannot provide an explanation for such varied water bodies. The alternative is upward discharge of groundwater. The numerous very small, low mounds on the pan floor support this hypothesis.

Figure 3: Linked, sinuous forms, occurring nearer to the pan margin than the discrete forms

Figure 4 shows two such mounds, less than 1m above the pan floor. Figure 4a is an example of an island of grass in a salt sea, for which there can be no other explanation than upward discharge of relatively fresh water. Figure 4b shows a similar island with conspicuous vegetation zoning, presumably reflecting variable tolerance of water quality. Upward discharge of potable water is, in places, even strong enough to support ponds of potable water on the tops of the linked forms.

Figure 4: Variations in the very small, circular mounds at pan floor level. Figure 4(a) indicates a 'grassed island in a saline sea'; (b) vegetation zoning, interpreted as expressions of varying tolerance of changes in water salinity

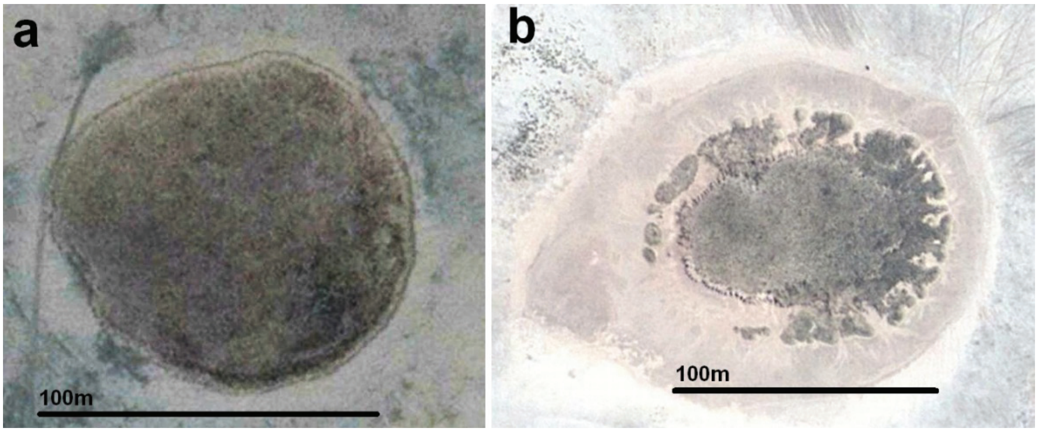
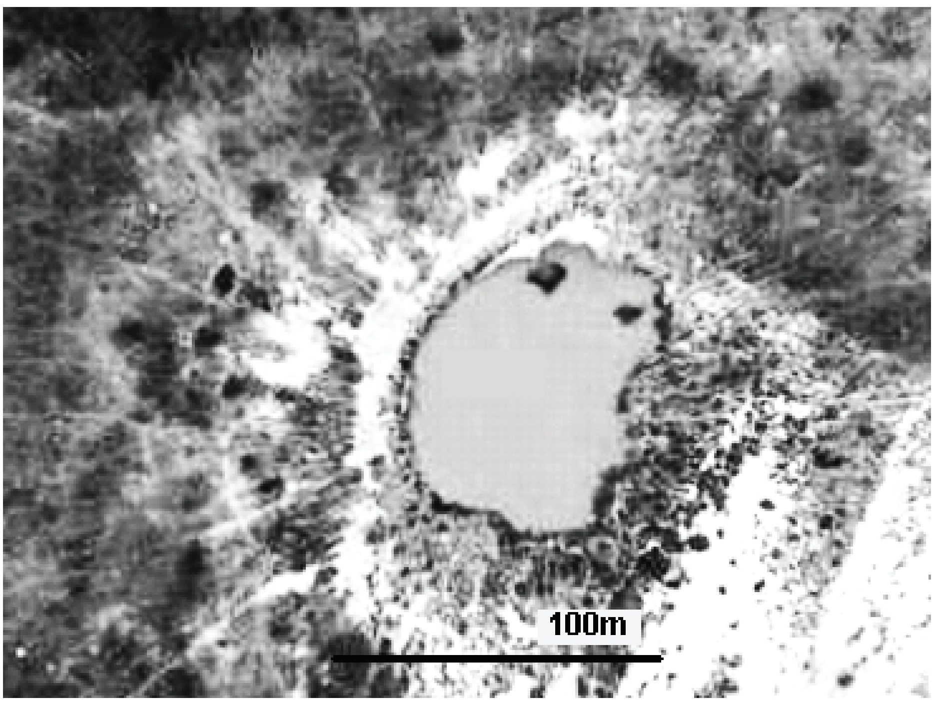


Figure 5 shows one such potable water pan, occurring at an elevation of 913m, some 8m above the pan floor level less than 250 m to the north.

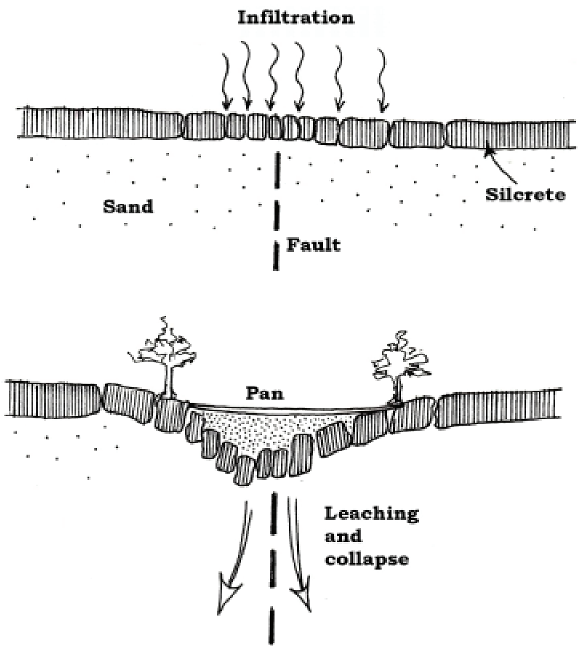
Figure 5: A pan of potable water on the top of a linked mound form. At 913 m elevation it is some 8 m higher than the dry pan floor at 905 m, less than 250m to the north. Note the game tracks.



We failed to find evidence to support the hypothesis that the mounds are modified barchans dunes. The hydrology supports a model of formation as mound springs. Upward discharge of water clearly operates even under today's relatively dry conditions. In the wetter past it would have been sufficiently vigorous to discharge sand, silt and clay, these being deposited to form the mounds.

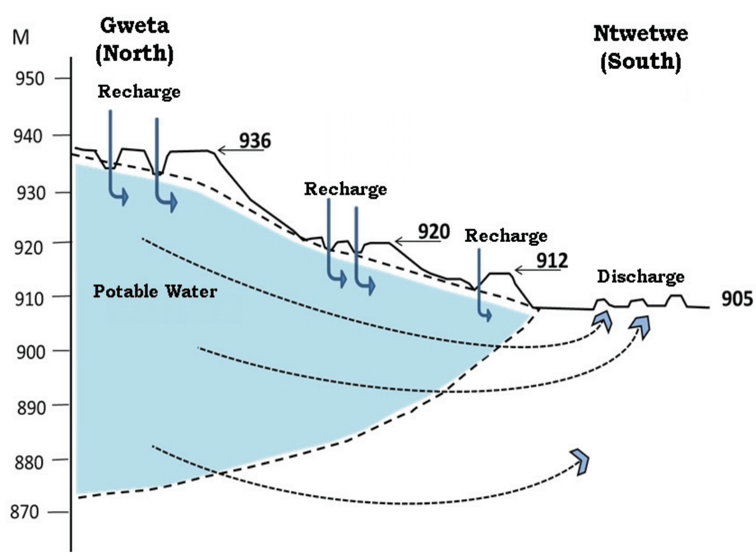
The source of the recharge is the palaeolake floors of the hinterland, the 936 and 920m levels around Gweta. The floors are strongly karstified, with the formation of abundant small pans. These form by leaching through the silcrete capping, particularly where fractures favour infiltration (Figure 6).

Figure 6: Hinterland recharge. Silicate karst pans formby infiltration through the fractured or faulted silcrete capping of older palaeolake floors



Here there is excellent recharge of the groundwater by rainwater infiltration. The piezometric gradient is towards the pan floor, where the recharged water is discharged (Figure 7).

Figure 7: Schematic representation of groundwater paths from the recharge hinterland area towards Ntwetwe pan floor.



Conclusion

The occurrences of potable water and sweet grass on the north side of Ntwetwe pan are essential to the wildlife, supporting world famous zebra migrations. The development of this environmental resource for Botswana's tourist industry holds much promise. However, its sustainability presents issues that must be addressed. Mound springs are well described from many parts of the world, particularly Australia. Their recognition in Botswana, for the first time, invites comparison with issues that have arisen elsewhere and how they were addressed. An in-depth study by Keane (1997) of mound springs from the edge of the Great Artesian basin of Australia highlighted the shrinkage of the water ponds associated with the mounds, caused by groundwater abstraction in their vicinity and in particular in the hinterland, the recharge area. Their shrinkage is of great concern to the users of the spring mound water resources. At Ntwetwe, the geographic scale of the recharge/discharge system is much smaller. A rapid response would be expected. The sustainability of the mound springs environment would be seriously and rapidly jeopardised if groundwater abstraction were increased in the recharge area or if the recharged waters became polluted.

The environmental impact assessment (EIA) experts should be in a position to assess the threat to the spring mound system. However, this is likely to depend on an appropriate level of hydrogeological knowledge, which may not be available, particularly to experts from other countries. At this stage an essential pre-emptive move is needed to at least signal a hazard warning. A buffer zone around the Okavango Delta has been recognised as necessary to designate an area within which particular caution is needed regarding development which could impact on the security of the deltaic environment. It is strongly recommended that the Makgadikgadi Management Plan gives very serious consideration to the creation of a similar buffer zone in the mound recharge area to signal the need for very stringent control on groundwater abstraction and pollution.

References

Besler, H 1983. 'The Response Diagram: Distinction Between Aeolian Mobility and Stability of Sands and Aeolian Residuals by Grain Size Parameters', Zeitschrift fur Geomorphologie, Supplement Band, vol. 45, pp.287-301.

Burrough, SI, Thomas, DSG, Bailey, RM and Davies, L 2012. 'From Landform to Process: Morphology and Formation of Lake-bed Barchans Dunes, Makgadikgadi, Botswana', Geomorphology, vol. 161-162, pp.1-14.

Keane, D 1997. 'The Sustainability of use of Groundwater from the South-western Edge of the Great Artesian Basin, with Particular Reference to the Impact on the Mound Springs of the Borefields of Western Mining Corporation. EV403 –Environmental Engineering Design 4. Department of Civil and Geological Engineering Investigation Project'.

Cooke, HJ 1980. 'Landform Evolution in the Context of Climatic Change and Neo-tectonism in the Kalahari of Northern Central Botswana', Transactions of the Institute of British Geographers, NS 5, pp.80-99.

Grove, AT 1969. 'Landforms and Climatic Change in the Kalahari and Ngamiland', Geographical Journal, vol.135, pp.191-212.

McFarlane, MJ and Long, CW 2015. 'Pan floor 'Barchan' Mounds, Ntwetwe Pan, Makgadikgadi, Botswana: Their Origin and Palaeoclimatic Implications', Quaternary International, vol. 372, pp.108-149.

Thomas, DSG and Shaw, PA 1991. The Kalahari Environment. Cambridge: Cambridge University Press.