WHEN IS A DESERT NOT A DESERT?
THE PAST AND FUTURE OF AFRICAN DRYLANDS

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by

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INTRODUCTION

I first set foot in a dryland just under 25 years ago. This was the Kalahari Desert in southern Africa, and yet around me I saw trees, cattle, a profusion of antelope and, in northern parts of desert, large herds of elephant and buffalo. Was this really a desert? It was certainly called one, but didn’t obviously look like one. Over the ensuing 7 months I conducted field research in the Kalahari for my doctorate, and embarked on a process of attempting to understand and unravel part of the complex history of environmental dynamism that this extensive area of southern Africa has undergone over past millennia.

That process of investigation, into the dryland dynamics and responses to global change, continues today. When I started as a graduate student, this research was sometimes viewed by others as mere intellectual curiosity, to which questions of ‘why?’ - including from the then Professor of Geography here at Oxford, Jean Gottman - temptingly elicited my response of ‘because it is interesting and unknown’. 2006 is the United Nations ‘International Year of Deserts and Desertification’. Today, dryland research is framed by agendas that extend beyond pure intellectual research - which in any case one should never be ashamed or shy of - to issues that relate to major scientific debates as well as those that are practical, political and humanitarian. In that context, Geography as a discipline has much to contribute and offer to dryland science. Geography’s concerns with spatial relationships, and processes of change over time, are of course shared with other disciplines. But the way in which both natural and social science dimensions are embraced rigorously within a University Geography Department does facilitate the potential for both a vital set of interactions and the cross-fertilization of agendas and intellectual ideas; a set of engagements that are perhaps harder to achieve in other disciplinary contexts.

From the inaugural lectures that I have attended here in Oxford and in other institutions, and through talking to those who have given such an address themselves, it seems that there is a range of routes that have been pursued, but with some identifiable threads within them. I have looked closely at what other people have said in their inaugurals, and it seems that some take the occasion as an opportunity to reflect on their past achievements, while many others seek to present agendas for intellectual activity and research in the future. Since I have been in post here in Oxford for two years, this might perhaps barely be called an inaugural lecture. However, being a Libran, of which a commonly stated trait is indecisiveness, I shall pursue elements of both routes. But I shall do so through consideration of what I consider to be a set of critically important environmental issues, in a part of the world in which I have had the privilege to conduct research in for a quarter of a century.

Multi-scaled environmental dynamics, occurring over timeframes from sub-decadal to hundreds of thousands of years, shape the landscape. Changes relate to the linkages between terrestrial and atmospheric systems, and impact bidirectionally on human potentials and opportunities, with strong teleconnections and feedbacks across the global system. Drylands, including the driest deserts but also sometimes densely populated dry subhumid regions, are not the distant, peripheral or forgettable places

1 The term dryland is used here in preference to desert. Drylands incorporate a range of moisture regimes, but in all cases a mean annual moisture deficit results from potential evapotranspiration exceeding precipitation. Rainfall is also markedly seasonal in occurrence
that Europeans have sometimes viewed them as, but in fact occupy almost 50% of the Earth’s land surface\(^2\). This 50% includes regions that have repeatedly been, and continue to be, fought over for their strategic position or great mineral wealth, as well as substantial areas of highly developed nation states, including the USA, and the rapidly emerging new super-economies of China and India.

That 50% also includes less developed and very poor areas, including a substantial proportion of the African continent. Today, because of factors including global economic inequalities, HIV-AIDS, land degradation and the potential impacts of 21\(^{st}\) century global warming, Africa, and the dryland regions within it, are the centre of significant but often insufficient attention including, for example, the ultimately disappointing G8 initiative at Gleneagles in 2005, and in the UK, the efforts of numerous NGOs as well as government level the activities of the Commonwealth and Foreign Office (CFO) and Department for International Development (DFID), including their African climate initiative to which my colleague Dr Richard Washington continues to make a major contribution.

There has arguably never been a time when it has been more important to pursue robust investigations into the nature, complexity and linkages of environmental change in drylands or in Africa. In the remainder of the lecture I want to explore how we know, and what we know, about environmental change in drylands, with a particular emphasis on the geomorphological, Quaternary, and society-environment research that I have been involved with, principally in southern Africa.

As a scientific discipline, Geography, with its interests in both the people and physical environments of place, is well situated to conduct these investigations, and has a long and distinguished history of doing so in the UK. Three brief examples illustrate this. First, the work of Ron Peel, formerly Professor of Geography at Leeds and Bristol but out of Cambridge, provided over five decades meticulous insights into the geomorphology of North African deserts, especially in the context of a better understanding of the role of water in shaping desert landscapes, and the processes of rock breakdown\(^3\). Second, Brigadier Ralph Bagnold, a career soldier with the Royal Engineers and an Engineering graduate of Cambridge, who in fact collaborated with Peel on a major expedition to Libya in 1938, was the doyen and father of modern aeolian science. His research, published in papers but also in 1941 as ‘The physics of blown sand and desert dunes’\(^4\), was based on wind tunnel experiments carried out at Imperial College London, and observations and measurements made in the deserts of North Africa. Bagnold was never formally a geographer or a geomorphologist, but informally it is indisputable that he was the former, while in the latter context his introduction of experimentation and the principles of physics into investigations of sediment transport processes indisputably set the standard for post-war process geomorphology.

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\(^3\) For example, see R.F.Peel (1966) ‘The landscape of aridity’. *Transactions, Institute of British Geographers*, 38: 1-23. This is the transcript of his address as President of the IBG, and summarises significant ideas and contributions made over several decades of field-based research.

\(^4\) R.A. Bagnold (1941) *Physics of blown sand and desert dunes*. Methuen, London. See also R.A.Bagnold (1990) *Sand, wind and war*, University of Arizona Press, Tuscon. This book contains his memoirs, which show how Bagnold’s science played out within his role as an army officer and an engineer.
Third is the work of A.T. (‘Dick’) Grove. Also from Cambridge, and a student when Ron Peel was on the staff in that Geography Department, Grove made major contributions in the deserts of northern and southern Africa, especially through combining detailed mapping of geomorphological features through air photograph analysis with meticulous field verification. It was arguably Grove’s work in the 1950s and 60s that established the framework for subsequent geomorphological investigations of long term environmental change in African drylands. He systematically mapped and identified features, first in the Sahel belt, and then, a decade later in a paper that has proved highly influential in my career, in the Kalahari. Dick Grove’s other contribution has been to create a legacy within modern dryland science not only in African environments but in systematic dryland geomorphology. That legacy is through the people that conducted their doctorates under his supervision at Cambridge, and in turn, those that they have subsequently supervised.

Enquiry-based scientific research in drylands has often shown little regard for the disciplinary boundaries that science, and academia, uses as a means to organise its activities. In the last 20 years, as environmentally-focussed scientific research in a range of disciplines has attempted to engage with big issues that have a strong human dimension, there has been a growth in the use of the term ‘Earth System Science’, including in the UK by the Natural Environment Research Council, as a means to describe its scientific mission. ‘ESS’, introduced during the 1980s by NASA as a framework for its research involving remote earth observation, is used variously as a term for an intellectual agenda, methodology, paradigm, or even by some as a ‘super discipline’ to organise research that regards the earth, including its human component, as a holistic and linked system. There are some obvious areas of relevance of this approach within the study of dryland environmental systems. Nonetheless, at a recent international conference organised by the British Society of Geomorphologists (until 2006, the British Geomorphological Research Group) to consider the relationship between geomorphology and ESS, at which my colleagues Diana Liverman and Heather Viles, as well as myself, gave invited keynote addresses, the usefulness of ESS

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5 A.T. Grove (1958) ‘The ancient erg of Hausaland and similar formations on the south side of the Sahara’. *Geographical Journal* 124: 526-533 not only mapped extensive dune fields and dried lakes in the Sahel belt, but also proposed, on the basis of mapping the notional position of contemporary isohyets, the degree of rainfall reduction that would be needed to reactivate vegetated dunes south of the 6 inch isohyet.


7 These include Andrew Goudie, formerly Chair of Geography at Oxford and now Master of St Cross College, and Andrew Warren, who held a personal chair at University College London. Both have been highly influential individuals in dryland geomorphology in the UK and worldwide, with Warren’s influence also stretching to socio-environmental interactions, especially amongst pastoralists. Nick Lancaster, Research Professor at the University of Nevada’s Desert Research Institute and a major figure in aeolian process geomorphology, was also a student of Grove’s, as was Mike Meadows, Professor of Geography at the University of Cape Town. Andrew Goudie supervised the D.Phils of amongst many others Ian Livingstone and myself, both dryland geomorphologists, and Rita Gardner and Nick Middleton, key figures in geography for other reasons. Andrew Warren supervised the PhD of Giles Wiggs, an aeolian geomorphologist and colleague of mine when at Sheffield, and now in Oxford.


9 Held at the University of Loughborough in June 2006.
as a concept and guiding framework for future research into critical global environmental issues was critically evaluated and even contested. So, as I consider my main theme, of the past and future of drylands, particularly in Africa, we might also reflect on the contribution that Earth System Science as a paradigm may make to investigating complex environmental issues, or whether it is simply an attempt by scientists from a range of disciplines to do what Geography already has a history of doing rather effectively.

KALAHARI

It is well known that the Kalahari, except in its extreme southwestern areas, is not a true desert today, in the sense that levels of aridity are not as high as standard definitions for a desert require\(^\text{10}\). Nor, on the whole, does it meet the lay-persons expectations of a desert: though there are sand dunes, in vast, extensive fields, they are generally covered to various degrees by vegetation and they are not generally active in terms of the operation of aeolian processes. This characteristic was well expressed almost a century ago in the memoirs of A.W. Hodson, the first colonial policeman of the Bechuanaland Protectorate\(^\text{11}\), who in 1912 wrote that this was

‘not quite an ordinary desert….In some parts it is covered by thick bush, in others it consists of open plains upon which good grasses flourish, whilst the remainder is made up of a sea of sand hills…and constitutes by far the most dreary and depressing part of the desert’\(^\text{12}\).

From the 1950s, and especially the 1970s, onwards, the Kalahari has also experienced a dramatic expansion of agricultural activities, commonly in the form of livestock farming, but locally even including market gardening and viticulture. In all cases, there is a high dependence on groundwater usage to facilitate the functioning of agriculture in an environment that is notable for its absence of surface water. The presence of these activities adds further to the impression of the Kalahari being a very un-desert like environment.

The missionary David Livingstone and the German geologist Siegfried Passage, respectively in the mid- and late- 19\(^\text{th}\) century, and the geologist Alex du Toit in the early 20th century\(^\text{13}\), all suggested on the grounds of sedimentary evidence that the extensive Kalahari dryland\(^\text{14}\) had experienced what we would now call major environmental changes. In recent decades, considerable advances have been made in reconstructing detailed and highly temporally resolved records of global climate change, especially from the isotope and sediment records preserved in ice cores and marine cores\(^\text{15}\). Even from terrestrial sites, where records are needed to give us the

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\(^{10}\) See for example the definitions and moisture criteria discussed in Thomas (1997), Chapter 1 in D.S.G. Thomas (ed) *Arid zone geomorphology* (Wiley, Chichester).

\(^{11}\) Now Botswana, the nation state on which the Kalahari is centred.


\(^{14}\) Some 2.5 million km\(^2\), at its maximum geological extent. See D.S.G. Thomas and P.A. Shaw (1991) *The Kalahari environment*. CUP, Cambridge, for a full discussion of Kalahari terminology and extent.

spatial patterning and complexity of how climate changes translate to environmental changes, a range of proxies, such as fossil pollen, ancient DNA, and sediment isotopes provide the means from which Quaternary scientists reconstruct past ecosystem and landscape conditions. But for dryland regions, these reconstructions can prove more challenging than in more temperate regions, as Ron Peel wrote in 1966, ‘...aridity being inimical to life, we cannot expect much positive evidence about former deserts from palaeontology, nor do we get it’.

Thus the application of pollen analysis, as well as isotope analysis, and so on, have proved of limited use in the Kalahari, though there are rare useful examples from sites in marginal locations, and there are some promising future developments using new exciting proxy data sources. Of note here is the analysis of fossil hyrax middens, which are widespread features of the mountainous escarpment rim that separates the coastal belt including the Namib Desert from the interior Kalahari basin in western southern Africa. Hyrax middens accumulate over millennia, as these rodents are creatures of habit and defecate and urinate in the same locations from generation to generation over thousands of years. Initial studies suggested that the middens contained an early Holocene record, but the initial stages of a three year Leverhulme project suggest not only that many middens are much older, but that their laminar structure contains a high resolution isotope and pollen record of environmental change that may be of great palaeoenvironmental value.

Even with the potential of this record, it will not answer all the questions about environmental changes in the extensive dry flat interior of southern Africa. Geomorphological and associated sedimentological evidence, as mapped by Grove, in the form of the extensive dunefields and lake shorelines around currently dry but massively extensive lake basins, has been the basis of palaeoenvironmental reconstructions in the region for several decades. But when, and how, did such geomorphological features develop? And what is their significance to understanding earth-system dynamics?

New analytical methods applied to geomorphological and sedimentological evidence are now providing significant answers to these questions. Only in the last decade or so

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16 Peel (1966) op. cit, p4.
17 For example, the application of radiocarbon dating to lacustrine carbonates initially appeared promising in the Kalahari in the 1970s. Ultimately it has been tainted by problems of sample contamination, the incorporation of old carbon, etc. Some studies, for example of the isotope records in cave speleothems, have proved rigorous records, but the sites where such techniques can be applied are limited, for example, to the few cave sites on the eastern and western margins of the Kalahari region. See D.S.G. Thomas and P. Shaw (2002) ‘Late Quaternary environmental change in central southern Africa: new data, synthesis, issues and prospects’. Quaternary Science Reviews 21: 783-797, for a consideration and analysis of past and recent research and methods.
18 For example, K. Holmgren and PA Shaw (1998-9) ‘Palaeoenvironmental interpretation of cores from Large stalagmites: an example from Lobatse II Cave, Botswana’. Theoretical and Applied Karstology 11-12: 23-34.
20 Commenced in January 2006, the project is a collaboration between Oxford and Cape Town Universities, with Brian Chase the postdoctoral researcher.
have we been able to obtain systematic, detailed and chronologically rigorous data that allows these questions to be answered reliably, in the context of the Kalahari and other dryland regions. One reason for this is the advent of Optically Stimulated Luminescence (OSL) dating, which, through its ability to provide depositional ages for sediments dominated by quartz (or feldspar), allows chronometric reconstructions over time scales from hundreds to tens of thousands of years. For environments, including drylands, where preserved organic material is limited compared to more temperate regions, and which therefore did not benefit from the scientific revolution offered by the likes of radiocarbon dating over the past 60 years, this has greatly enhanced the contribution that can be made to global reconstructions of climatic and environmental dynamics over the last glacial and interglacial cycle, and even longer. In OUCE we have, and it is no boast, the best equipped, and largest, luminescence dating facility in the UK if not the world\(^2\). Bringing together the previously disparate luminescence dating facilities in Archaeology and Geography. With recent new staff appointments, we now have the capacity to take forward the application of this less than routine dating method to answer critical environmental science questions in a range of contexts.

Two examples will demonstrate how knowledge of dryland change in the Quaternary period of geological time, and at time scales of millennia to decadal, is developing through the effective application of luminescence dating and the integration of an understanding of system dynamics based on process studies, modelling, and monitoring.

**DRYLAND LAKES**

The first relates to reconstructing the timing and presence of great lakes in the present drylands of Africa. Unlike the lakes of tropical Africa, where organic-rich lake floor sediments possess a range of palaeoenvironmental proxy data sources, dryland lake basins generally have abiotic sediment accumulations or are subject to deflation during dry stages that has the potential to remove previously accumulated sediment\(^2\). A different approach is required to palaeoenvironmental reconstructions in dryland basins, and this involves a focus on the shoreline features that mark the former extent of large water bodies.

There are a number of ongoing palaeoenvironmental investigations in African dryland basins. This includes research conducted through a project funded by the NERC EFCHED (Environmental Factors in the Chronology of Human Evolution & Dispersal) research programme, and ancillary activities. Basins studied included investigations in Libya, where a major lake, Palaeolake Fezzan, with an estimated area of 130,000 km\(^2\), has been identified through geomorphic, sedimentological and archaeological investigations\(^2\). Lake Chad, on the western fringes of the Sahel belt, is another basin that not only hints towards a complex history of late Quaternary expansions up to a

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\(^2\) OLDLAB (Oxford Luminescence Dating Laboratory) is a joint facility of OUCE and the Research Laboratory for Archaeology and the History of Art.


\(^2\) The Fezzan research at Oxford has involved Dr Simon Armitage, now a lecturer at Royal Holloway, University of London.
massive 360,000km$^2$, and contractions, but which has experienced extremely rapid drying out in the past three decades. Its recent desiccation has created a dry basin that my colleague Richard Washington and others have recently identified as the world’s largest current source of atmospheric dust$^{24}$. In East Africa, Malawi’s Lake Chilwa, still a big lake today and an important source of protein for an agriculturally depleted nation, has remarkably distinct former beach ridges that testify to an even greater extent during, as our preliminary OSL ages suggest, four phases in the past 40,000 years. Clearly these lakes, and their fluctuations in extent, suggest complex linkages and interactions with climate systems, atmospheric processes and people. Lake dynamics, and rates of change, warrant detailed systematic investigation.

I want though to illustrate the nature of this research through an excursion to the lake basins of central southern Africa, the palaeolake Makgadikgadi complex, which at its greatest extent, covered an area of approximately 120,000 km$^2$, or four times the size of Belgium. We$^{25}$ have been working here for the last 20 years, and our efforts are now benefiting greatly from the application of OSL dating to shoreline sediments and the reconstruction of lacustrine features through the use of digital terrain models derived from remote sensing products$^{26}$.

In Victorian times a lake in the middle of the Kalahari region was a quest for the missionary and explorer David Livingstone, and subsequent European travellers and explorers. Livingstone finally ‘found’ this lake in 1849. He named it Ngami, after asking the local people who had taken him there what it was called. Ngami in fact means ‘lake’ or ‘great water’ in the language of the Bayiere people who are indigenous to the area, since called Ngamiland, and now at administrative district of modern Botswana. It is interesting to note that Livingstone was responsible for naming more than one ‘lake lake’ in Africa, as he did the same with Lake Nyasa.

On several occasions in the past 150 years Ngami has dried or filled, in part as the flow of water to the basin is affected by changes in the low-angle channel distributary system of the Okavango Delta, from which it is fed today. Livingstone noted, on the basis of raised shell beds, that even the lake that he observed had been bigger in the past, and in one of his letters in 1850 he wrote that ‘the country generally is unquestionably drying up’$^{27}$. A few years later other European visitors, notably Charles Andersson and William Baldwin, recorded the progressive drying of the lake$^{28}$. By the 1950s, John Brown, travelling in an expedition across the Namib and Kalahari deserts to assess the water resources of the region, wrote regarding Ngami ‘that only through the use of a map did we know that they were on the floor of Ngami’$^{29}$.

$^{24}$ Washington and Todd (2005) op. cit.

$^{25}$ This has included long term collaboration with my colleague Professor Paul Shaw, formerly of the University of Botswana and now at the University of the West Indies in Trinidad, and a number of other individuals.

$^{26}$ The D.Phil. of Sallie Burrough, funded by the NERC EFCHED programme. Dr Frank Eckhardt, of the University of Cape Town, has provided DTM products that have greatly assisted the research.


$^{28}$ Charles Andersson 1856 Lake Ngami, or expeditions and discoveries during four years wanderiungs in the wilds of south western Africa. Hurst and Blackett, London.

The drying up of southern African lakes and water bodies was of great concern to the authorities of the Union of South Africa in the early 20th century, and was part of a wider concern about Africa’s desiccation that had grown from interpretation of the reports of Victorian travellers in the continent. This led on occasions to grand plans, which were somewhat hydrologically flawed, to reverse the trend through a series of river diversions to water the arid regions. None was more extreme that the plans of Ernest Schwartz, a South African Professor of Geology, to create a series of artificial lakes in the Kalahari. A few years later these ideas were thoroughly debunked by du Toit, who instead proposed wells and boreholes as the only way to water the Kalahari for development, the exact process that occurred from the 1950s onwards.

Ngami is just part of a bigger more complex lake system, the Palaeolake Makgadikgadi complex. Livingstone suggested that ‘The Ngami is merely a reservoir for the surplus waters of a much larger lake or marsh, containing numerous islands, about 150 or 200 miles beyond’. This is of course what we now call the Okavango Delta. On its own, Ngami is not necessarily a good palaeo-climate indicator because of the Okavango distributary issue. As a whole though, this immense basin system is potentially a major source of data on regional precipitation and hydrological changes, within a catchment system that includes rivers sourced in the Angolan highlands as well as the upper Zambezi. We can model lake level responses to filling and evaporation changes using DTMs, or digital terrain models. Applied to satellite data, they allow the ground-based shoreline survey work of the 1980s by the likes of Paul Shaw to be checked and verified, and key sites for field investigations and sampling to be targetted.

Attempts in the 1980s to date lake high stands through the application of radiocarbon dating to carbonates within shorelines or from basin floors fail to meet the standards expected today for geochronology research, because of the problems associated with what are called ‘hard water effects’, post-depositional secondary carbonate precipitation and, most significantly, inadequate understanding of the formative conditions of the carbonates. The application of OSL dating to shoreline features in the system as a whole and to the individual basin components is finally allowing the palaeoenvironmental potential of these features to be realised, and has the potential to reveal significant information on regional climate as well as the responses of different sub-basin components of the system. We await the results of analyses that should be completed in 2007.

An additional factor of import however is whether and how lake bodies of the magnitude of Palaeo-Makgadikgadi affected their regional climates, as Schwarz suggested in 1920. There is some modelling work now being conducted to this end, and it is vital to pursue this issue in order to enhance our ability to disaggregate regional climate signals from local precipitation enhancements due to the presence of a large water body itself. As a first critical step however, the robust and detailed chronologies

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31 Du Toit (1927) *op. cit.*
32 Livingstone (1850) *op cit.*
33 Paul Shaw, my colleague in Kalahari fieldwork for much of the past 20 years. Formerly of the University of Botswana, he is now starting a new geography department in Trinidad for the University of the West. Key papers from this work include p.a. Shaw (1988) ‘After the flood: the fluviolacustrine landforms of northern Botswana’. *Earth Science Reviews* 25:449-456. Much is also reported in Thomas and Shaw (1991) *op. cit.*
of lake level fluctuations being provided by OSL will allow the timing of lake high stands to be placed within wider chronologies of low latitude responses to global climate forcing.

DUNE FIELDS

My second example of evidence of major Quaternary environmental and climatic changes in African drylands is also geomorphological. Inactive continental sand dunes, today largely identified by a covering by vegetation and a degradation of form from that of active-state dunes, have been recognised as evidence of formerly expanded desert conditions in Africa for almost 50 years, since the previously discussed work of Grove\textsuperscript{34}. Extracting the maximum palaeoenvironmental data from these features has however been something that has only been achievable in the last decade. Palaeoenvironmental records, however well dated, also need to be interpreted in the context of understanding the controls on the environmental processes that led to their development, while in dryland regions, even the systematic mapping of system components can prove extremely challenging. Developments in monitoring, modelling and process measurement in geomorphology, together with the chronometric developments in OSL in particular, are now facilitating major advances in understanding dryland dune behaviour and development\textsuperscript{35}.

Three reasons lie behind a better ability to extract palaeoenvironmental utility from dated dune records. First, the processes responsible for linear dune development and activity today have remained somewhat elusive. Second, the relationship between sand transport and vegetation cover is now understood to be a complex one, and simple ‘on-off’ models of dune activity in relation to the presence or not of vegetation are now known to be highly simplistic, as a consequence of lab and field experimentation and modelling of surface roughness effects on aeolian processes. Third, OSL dating, as with lake shoreline studies, has provided a means of developing chronologies of dune development. Together, these developments effectively allow us to coax the palaeoenvironmental record to conduct a series experiments about environmental responses to changing conditions in the climatic parameters that act as process drivers.

Let us look more closely at how debates and uncertainty about geomorphic processes can have an often neglected effect on palaeoenvironmental reconstructions, taking linear dune development as an example. Despite being the most common desert dune type, the development of linear dunes has been poorly understood with, for example, many theories in the literature of the relationship between linear dune orientation and formative wind regimes\textsuperscript{36}. These include dune extension under strong unimodal winds, development in bimodal wind regimes, with dunes streamlined into the resultant vector direction of seasonally variable wind regimes, and, one of the oldest and most persistent theories, development under the influence of so-called parallel helical vortices in the lower atmosphere. From the perspective of understanding the

\textsuperscript{34} Grove (1958, 1969), op. cit.
atmospheric circulation conditions under which now-inactive linear dune fields developed, identifying formative regimes of modern dunes is important for providing analogues for the now-inactive dune development. Remote earth observation systems, field monitoring and investigations of limited climate data from meteorological stations within dune fields have elucidated this issue.

Today, development under seasonally bimodal wind systems is regarded as the principal means by which linear dunes develop\(^37\). Thus from a palaeoenvironmental perspective, only mean vector circulation can be deduced from ancient linear dune orientation- though if at a particular location current circulation patterns create mean vectors close to dune orientation it may be possible to make stronger statements about past circulation.

Meticulous empirical measurement of sand transport and transport initiation on surfaces with different vegetation covers\(^38\), supplemented by long term monitoring of dune dynamics both in the field and remotely\(^39\), have in the last decade revealed a lot about how aeolian activity on dunes varies according to surface (cover) conditions. To cut short and summarise a long and complex set of data and interpretations, while some sand transport can occur on surfaces with over 14-17% vegetation cover, this is only under rather high wind velocities. For dune development and widespread activity to occur, surface cover needs to be less than about 14%, and winds need to be relatively persistent for sediment accumulation to occur. In effect these two sets of findings may seem to tell us the obvious- that it needs to be dry and windy for dunes to develop, but in fact these data sets give us the material to begin to be able to parameterise the environmental conditions under which these now inactive, but extremely extensive, dune systems formed.

Since the first OSL chronologies of southern African dune development, published in the mid 1990s\(^40\) and based on samples collected painstakingly from manually dug pits in dunes all over the Kalahari, advances in field sampling technologies and in laboratory protocols have provided the tools to achieve detailed spatial chronologies of dune system development in the late Quaternary. The initial OSL chronology of Kalahari dune development and aridity, based on just under 50 samples and collected and analysed over a period of three years, is now in the process of considerable reinterpretation.

Three new projects, all linked to D.Phils, have generated almost 250 OSL ages from dunes, either published or in press, and a further 100+ currently in the laboratory. These studies represent intensive and detailed records of the development in the last 100,000 years or so of three regions of southern Africa’s dune fields\(^41\). Through

\(^{37}\) Thomas (1997) op.cit.


\(^{41}\) The doctoral research of Brian Chase (2005), Matt Telfer (2006) and Abi Stone (in progress).
intensive vertical sediment sampling at multiple dune locations, and the subsequent laboratory dating of these samples, we can determine rates of dune accumulation as well as the frequency and timing of accumulation episodes. These data not only give us a palaeoenvironmental record of dune activity or aridity, but a record that also provides information that can further our understanding of patterns and processes of dune development. The detail and degree of sensitivity in these records would have been unobtainable 10 years ago, when field sampling was slower and more laborious and laboratory protocols generated less robust ages. It is not uncommon now to sample a dune site to a depth of 10-15m in less than a day, with samples collected at 0.5m intervals through a dune profile. In one to two weeks of fieldwork, perhaps 80 to 100 samples can be collected, allowing either a small area of a dune field or dune system to be sampled intensively, or a wider area to be covered in relatively high detail. By contrast, in 1991 it took five weeks to collect 30 samples from different areas of the Kalahari, and except for a limited number of locations where road cuts or borrow pits gave deeper exposures, the depth of sampling at each dune site was little more than 2 metres.

Once laboratory procedures have been completed, with accumulated doses determined by either single aliquot laboratory procedures or even the use of standardised growth curves, and dose rates determined by field or laboratory methods, what do these data tell us? For the Kalahari region, and the dune systems on the west coast of southern Africa, the full integration of the findings into palaeoenvironmental models is in progress. For the purposes of this presentation, it is significant and sufficient to note four key considerations.

First, we now know that these dune systems have been active and dynamic often in the last 100,000 years, that activity was not, as previous models suggested, focussed just at the last glacial maximum (21-23,000 years ago), but in multiple phases including even the Holocene Hypsithermal (or warm period), 4-8000 years ago. Second, that when linear dunes were active in the Kalahari they often accumulated rapidly, as evidenced by several metres of dune body thickness covering a narrow range of OSL ages. Third, dune activity is primarily driven by aridity, but enhanced windiness, even without an increase in aridity above present levels, can also trigger dune accumulation in some contexts. This is evidenced from findings from the west coast dune fields, and correlation of dune accumulation ages with the proxy records, of rainfall and windiness, derived from marine sediment core records from the Atlantic Walvis ridge, off the west coast of Namibia. Fourth, dunes have been very active even within the last 1000 years, and in some cases, the last few centuries. The latter finding points towards these being geomorphic systems that are highly sensitive to climate change: far from being geological relics, the southern African dune fields are potentially

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reactivated easily and frequently, with significant implications for human use of the landscape and, as we will see later, for landscape dynamics in the face of global warming impacts later in the 21st century.

**DRYLAND FUTURES**

There is ample evidence from the past century to indicate that dune systems and landscape with an aeolian legacy can be sensitive to human disturbance - evidence from the American mid west in the 1930s and 40s, the so-called ‘dust bowl’ years, from the effects of grazing pressures on vegetated dune landscapes and, very recently, from the effects of the devastating deep drought that has affected the Canadian prairies in the late 1990s and early 21st century, which has been little reported in the UK.

But what about the indirect effects of human agency on drylands and on Africa in the form of global warming impacts on climate and environmental systems in the 21st century? The modelled predictions of climate warming are well known, with rates and absolute values of possible change unprecedented in the instrumental and proxy historical records. The envelope of end of the century predicted temperature rise ranges from 1.4 to $5.8^\circ C$, though the probable increases lie closer to the former than the latter value.

How will these changes possibly affect African environments, including drylands? Is there danger ahead? There are in fact to date few direct investigations of possible environmental consequences, especially in terms of landscape dynamics. This is odd, on two counts. First is that there is a large research effort into human adaptation to climate change in the 21st century, but save for a few environments, such as coasts, this research rarely considers details of the environmental conditions, beyond key climate parameters, that people will actually have to adapt and respond to in the coming decades. Second is that attempts to cost the effects of global warming, and identify the drivers of these costs, such as the recent Stern Review, would benefit from data of modelled land surface changes when considering, for example, potential changes forced on agricultural systems. Two recent studies illustrate a possible way forward, and both tell us a lot about both the ways in which landscape dynamics might be modelled and how climate predictions may be used to drive models of landscape change.

The first, published in the journal *Science* earlier this year, was an analysis of how human access to water in Africa may alter in the 21st century due to climate change. Taking the non-linear relationship between drainage density and rainfall, and using a relatively optimistic climate change scenario based on declining carbon emissions to the atmosphere, changes in drainage network density were modelled. In some regions

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46 This is a complex topic beyond the scope of this lecture, though Oxford possesses many expert researchers in this field, including in OUCE. This includes being a major partner institution in the UK’s Tyndall Centre for Climate Change research. For an overview of mainstream global warming issues and the science behind key issues and predictions, see IPCC (2001) ‘Climate Change 2001: Synthesis Report’ IPCC: Geneva/CUP: Cambridge.


of Africa, including presently drought-prone southern Sudan, Eritrea and in East Africa Tanzania increases in effective precipitation modelled by 2099 lead to an increase in channel systems and thus potentially improve people’s access to water. In others, including much of the North and southern Africa dryland regions, drainage density decreases- by for example 40% in Mali and 75% in the Okavango system of the northern Kalahari. If correct, human impacts could be catastrophic.

The second, work that we conducted and published in Nature in 2005, used our knowledge of the physical processes of sand transport to create a model of how dune system dynamics relate to key ground surface and climate variables. The model was then applied to the region covered by the extensive vegetated Kalahari dune fields, and driven by climate data outputs from three GCMs, using a range of different carbon emission scenarios. Dune dynamics were modelled on a monthly basis for the whole of the 21st century, so that seasonal and year to year variability, as well as long term trends, could be explored. The dune model predicts an increasing level of dune activity in the southwest Kalahari by 2040, and across the whole region, as far north as western Zimbabwe and western Zambia, after 2070. Importantly, this was regardless of the climate model used or the emissions scenarios assumed. Given our growing knowledge of how frequently and extensively these systems have been active in the past, based on our OSL dating work, this is not so surprising in a geomorphological context. From a social perspective however, it is perhaps of great concern. We know, from other work that we have been conducting including the Tyndall Centre for Climate Change Research ‘Adaptive’ project in southern Africa, that societies and households do recognise subtle climate changes and do respond effectively to the environmental changes that they bring, as long as socioeconomic frameworks permit this. But the changes modelled for the future in both these examples are neither gradual nor subtle: they represent significant environmental dynamisms that could prove exceedingly challenging to societies.

SO WHEN IS A DESERT NOT A DESERT?

The narrative of research in African drylands that I have attempted to provide has simply touched the surface of a complex world and a complex history of research and investigation. Science and exploration in southern African drylands has involved some big names: Livingstone, Andersson, Passarge and so on. African drylands have attracted many people, in the quest of many different things- even the story book character Biggles has allegedly visited the Kalahari, where he even met a local gentleman who had benefited from this University’s overseas recruitment efforts!

In Geography, and in Geomorphology in particular, there is a clear legacy owed by some of us today to the insights and perceptiveness of Peel, Bagnold, Grove, and here

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50 Global Climate Models or General Circulation Models.
51 See http://www.geog.ox.ac.uk/research/projects/adaptive/. Publications are forthcoming, including a major paper in the journal Climatic Change in 2007.
in Oxford, to Andrew Goudie. My desert and dryland involvement has expanded over the 25 years since I first set foot in the Kalahari. Through a series of research grants, the supervision of 28 doctoral students and eight post-doctoral researchers, an array of international engagements with amongst others the United Nations Environment Programme, UNESCO, IGCP, the British government’s Department for International Development, NGOs including Oxfam and most recently the Tyndall Centre. These have led me to lead or participate in research projects in various parts of Africa, as well as in the United Arab Emirates, Kuwait, Iran, and now through new engagements and new graduate students, in China, Mongolia and the Aral Sea basin. The technologies and tools that we have at our disposal now, and their careful application, are allowing us to piece together the complex past histories of dryland environments.

Their dynamism, in response to external drivers including climate change, is profound, and also, as the evidence from dune and other terrestrial systems increasingly suggests, rapid. To answer the question posed in the title of this lecture: deserts have often not been deserts in the past 100,000, even past 10,000 years, while equally there is much evidence of the dramatic and extensive expansion of desert conditions beyond their current extent within the same time frames.

Through the last 25 years it has struck me what a privilege it is to be a Geographer, albeit one with Geomorphological tendencies. That privilege is brought home even more when engagement with the development of Earth System Science seems sometimes to offer at best little more than a designer label for what already exists and potentially, as espoused recently by Nick Clifford and Keith Richards, a series of contradictions or universal simplifications in order to ‘scale match’ different phenomena and variables. Interestingly, in a recent review of aeolian geomorphology and ESS, Giles Wiggs and I have noted that, despite aeolian research frequently polarizing in the past 20 years into reductionist process investigations and large scale, often remotely sensed, analyses of depositional bedforms, it is presently engaging on a series of large scale investigations into aeolian system responses to global warming- the sort of work that might legitimately be labelled as ESS, and the type of work that is allowing critical research questions into dryland futures to be addressed. It is able to do this because of, rather than despite, the diversity of scale approaches to critical research questions over recent decades. This diversity reflects the Peel-Bagnold-Grove legacy.

As it stands, ESS has the potential to undervalue the significance in environmental systems of spatial diversity and differentiation. As Geographers have long recognised, that diversity stretches to societies as well as environments, and our work in Oxford, on adaptation to climate change in southern Africa, suggests that this differentiation is potentially a key part of natural resource using societies’ ability to cope with rapid change. In both the natural and social worlds, there remains, especially in the still under-researched environments of Africa and in drylands, a need for scientific research that attempts to unravel and explain difference, and the reasons for that difference. At what is approximately the mid point of my career, I hope to continue to conduct, and inspire in others the desire to conduct, that research which ultimately may contribute to answering the big questions that we face in African and dryland environments.

Phillip Tobias is possibly Africa’s most honoured scientist, an anatomist and anthropologist who in his early career worked with the San of the Kalahari and who became a significant member of the anti-apartheid movement. I have been fascinated by his recent autobiography\(^{55}\), not least because in it he shows how big scientific questions can often only be addressed by cutting across the artificial divides that create disciplines within academia. I will conclude with a quote from that book, not from Tobias himself, but one cited from a Professor Jim Neel, who in 1981 was President of the International Congress of Human Genetics. Those of us who are investigating scientific issues that we feel are of wider social importance, such as climate change and the implications of global warming, would do well to heed these words:

_We are a privileged group at a privileged time in the development of scientific thought and understanding- privileged not in the arrogant use of power but to witness and contribute to an unfolding story whose final implications we can only dimly foresee._\(^{56}\)

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\(^{55}\) Phillip Tobias (2005) _Into the past: A memoir._ Picador Africa: Johannesburg.

\(^{56}\) Ibid p123.