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INTRODUCTION

African Palaeoclimate and Human Response: A Special Issue of the *African Archaeological Review*

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Abstract Acknowledging the patchiness of palaeoclimatic data, as well as a new appreciation of how complex the forcing mechanisms of Africa's climates are, it would be premature to propose a grand synthesis of the continent's climatic backdrop to human history and prehistory. That said, this "state-of-the-art" sampler from several regions of Africa serves several purposes. Although chronological resolution—palaeoclimatic and archaeological—continues to improve, the warning "Causation, Correlation or Co-incidence" still very much applies to all exercises in explanation. Even in those cases of high-resolution climatic sequences, dating of the corresponding prehistoric sequence often proves disappointing. And lastly (ending on an optimistic note), each contribution to this special issue features one or more new techniques of climate data extraction that might usefully be applied continent-wide.

Résumé Lorsqu'on considère l'éparpillement des données paléoenvironnementales, ainsi que l'état actuel de notre compréhension de la complexité des mécanismes de forçage des climats de l'Afrique, il serait prématuré de proposer une synthèse générale concernant l'impact des climats sur l'histoire et la préhistoire des Hommes. Bien que la résolution chronologique des données paléoenvironnementales et archéologiques continue de s'améliorer, il est cependant nécessaire d'indiquer que les explications présentées ici comme des « Causes, des Corrélations ou des Coincidences », ne sont encore actuellement que provisoires. De plus, même dans les cas où les séquences

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paléoenvironnementales utilisées sont datées en haute résolution, les séquences préhistoriques correspondantes présentent souvent des datations décevantes. Ceci dit, cet échantillon de l'état actuel des recherches effectuées dans plusieurs régions d'Afrique présente plusieurs buts car, en particulier pour terminer sur une note optimiste, chaque contribution à cette publication spéciale utilise une ou plusieurs nouvelles techniques pour extraire des données paléoenvironnementales ou paléoclimatiques qui pourraient être utilement appliquées à l'ensemble de ce continent.

Keywords Palaeoclimate · Causation · Correlation · Chronological resolution · Proxy data

Africa is vast. And this self-evident areal vastness is complemented by the equally overwhelming scale of Africa's variability of ecological and cultural developments, an appreciation of which is put into ever more stark relief when new methods from the historical sciences are applied to the past of the continent's peoples, their institutions, and their environments. We present here a special issue of the *African Archaeological Review* featuring syntheses of our present, sub-continental-scale understandings of palaeoclimate change and human response, from North Africa, Northeast Africa, Madagascar (including relevant southwest Indian Ocean data), and western, central, and eastern Africa. Embedded in these syntheses are summaries of recent or ongoing research programs. These last were selected specifically because they report on novel or experimental investigations of palaeo-environmental data collection, or new analytical techniques from the field or laboratory, that tease out better insights from climate proxies. The advances in the historical sciences applied to the vexing problem of "climate change—cultural change" interaction, whether those sciences are archaeological, palaeoenvironmental, or in the realm of meteorological physics (see Maley and Vernet 2015), are a source of great hope for the future.

Before writing a general synthesis of Africa's past climates, more regional-scale work is necessary. Indeed, there are still too many pesky realities of inter-decadal, inter-century, and inter-millennial variability that frustrate our present attempts at resolution. There remain too many recalcitrant realities of areal patchiness that caution us not to extrapolate too broadly from the relatively few high-intensity climatic sequences available to us. And all prehistorian readers of this journal will join us in mourning the spottiness of the archaeological research record for this vast and culturally vibrant continent. Here, rather, we present some regional samplers of the "state of the art" in the African examination of palaeoclimate change (its dimensions, subtleties, and physical causes) and human response thereto (see also Manning and Timpson 2014). To be sure, concerning the backdrop to the development of sub-Saharan populations, recently many significant publications converge on the conclusion of a disconnect between their evolution into their presently recognizable form and the appearance of agriculture (which, in many cases, is only added to their foodways as much as several millennia later) (Neumann 2003, 2005; see Ozainne *et al.* 2014). A similar conclusion recently has been reached concerning the Bantu speakers who, with their great migratory phase, initiated their expansion in the savanna zone of southern Nigeria (Patin *et al.* 2014). Lastly, in the very different context of the Near East, the first Natufian villages (around 12,000 BCE) precede by some 4000 to 5000 years the full domestication of animals and agriculture (Willcox *et al.* 2009).

Take-Away Themes

This collection of essays begins with a flagship article. Jean Maley and Robert Vernet (2015) piece together, in one coherent cloth, the best evidence from western and central Africa, from the southern Sahara through the fringe of the great forest, for cultural change and climate change. This vast region is noteworthy from a climatological perspective because, as one can see in Fig. 1 of their article, successively wetter climates follow one upon another in a relatively regular way from the southern Sahara to the shores of the Gulf of Guinea with vast latitudinal climatic "bands" stretching from the Atlantic to the Nile in the east. Such areal regularity of climate over such an extent is virtually unique across the Earth and, as such, it allow the authors, as they compare climate events with cultural developments over a period of 4000 years, to take the position that climate variation must always be front-and-center in any explanation of cultural change. Further, one of the persistent themes of this article is the explanation that this remarkable zonal regularity of climate and bio-environments is interrupted in a significant way by the great rivers. From west to east, the Senegal, the Niger, the Chari and Logone, and finally the Nile have their sources in the southern Sudano-Guinean zone. In the latter, the annual precipitation is certainly greater but where, during certain episodes, there occurred years of high rainfall that were out of phase with what was going on in the Sahelian zone, where there was a contemporaneous severe arid phase. To explain this phenomenon, the authors present an explanatory hypothesis in their text. A good example of this climatic out-of-phase phenomenon is shown by the variations of Lake Chad during the seventeenth century. Indeed, during this period, the lake overflowed into the Bahr el Ghazal thalweg that flowed north up to Borkou, at the same time that the center and northern part of the basin itself was experiencing an increase in aeolian activity. In effect, the high level of the lake reflected conditions not in the lake's surrounds, but rather those at the headwaters of the two feeder rivers, the Chari and Logone, where rainfall was quite abundant—as can be deduced from the overflowing of the lake. Maley and Vernet, however, cannot include the Nile in their synthesis because that river's two sources (the Blue Nile and the White Nile) originate in zones where the rainfall profiles and variations are different and often in opposition. The long-term tendencies of the annual rainfall regime at the source of the Blue Nile, situated as it is on the Ethiopian Plateau, tend to correlate with the aforementioned Sudano-Guinean zone, whereas the rainfall variations at the source of the White Nile in the region of Lake Victoria, in a more southern and equatorial position, have been demonstrably out of phase with those of the Ethiopian Plateau. The out-of-phase contrast of these two areas is, for instance, shown throughout the Holocene by the work of Blanchet *et al.* (2013). The upshot is that the Nile has had an individual long-term history that does not allow it to be compared to the rivers of western Africa.

As inclusive as it is, as expansive in its scope as it is, Maley and Vernet fully admit that their article underscores the problems rife for all prehistorians and palaeo-ecologists trying to tickle out the subtleties of human-climate interaction. These problems are not exclusive to the African continent (although, because of Africa's underpopulation by archaeologists and "clumped" coverage by palaeoclimatologists, the continent perhaps displays some extreme knowledge entanglements). These problems are fully admitted by "human archaeo-ecologists" (if we may coin a phrase) in, for example, the northern (Van der Leeuw and Redman 2002) and eastern Mediterranean basin (Kaniewski *et al*. 2013; Weiss 2012), or the eastern US Southwest (Dean 1996, 2000) where, arguably, the intensity of archaeological research and the depth and robustness of the palaeoclimate record are most fully evolved. The Maley and Vernet essay here develops and underscores three persistent cautions that should be heeded by anyone attempting a palaeoclimate and human response exercise in Africa.

The first caution is, not surprisingly, the determination of the Big (Nasty) "C's" of explanation: causation, correlation, and (simple) coincidence. We have far too many warnings from elsewhere (*e.g.*, the Great Drought and Ancient Pueblo migration debacle, for example—see Adler *et al.* 1996; Cordell 1996, 2000) to think that simple display of a time-chart, with a dramatic climate surprise or shift of climate mode, against the beginning of a new cultural horizon or the putative beginning of a new state or empire, tells us anything definitive about how the former *caused* the latter. Indeed, why not the other way around? In the Middle East, some archaeologists try to find the roots of a culture phase (Kaniewski *et al*. 2013), or to "quantify" their collapse (Weiss 2012). Yet, we are starting to see in the human ecology and in the archaeological literature sophisticated ways to think about sustainability, response flexibility, and resilience of human systems (Halstead and O'Shea 1989; see McIntosh *et al.* 2000; Tainter 2000, 2003). These are elements of the intellectual toolkit that eventually will allow us to parse out the examples featured by Maley and Vernet, case by case (and initially in the cases they present as boasting the most robust human and environmental data), in terms of directionality of causation (if indeed present), or most globalized reasons for correlations (that is, if a local climate change did not cause a major perturbation in a local culture or adaptive system, but both were profoundly influenced by a larger forcing event).

Causation, correlation, or coincidence—the first cautionaries of any interpretation of human response to climate change. And the second caution expressed in the Maley and Vernet article is inextricably entangled with the first—the problem of inappropriate chronological resolution. [At this point, we hear archaeologists heave a collective groan.] In Africa, especially but surely not exclusively, we must admit that when the poor coverage of the prehistory of the continent (the aforementioned underpopulation by field archaeologists, relative to other world regions) linked to the physics-based limitations of radiometric dating techniques, the beginnings and ends of major cultural phenomena are, at best, fuzzily situated in time. Details of the evolution of major cultural phenomena are equally blurry. Take the example of the first "mega-state" of the Western Sudan, the so-called Empire of Ghana: Estimates of its beginning range from the first centuries BCE to the last centuries of the first millennium CE. And was it even a proper state (with all the implications of expansionism, despotic rule, a command economy…); or was it a more-or-less loose confederation of largely autonomous local polities? Archaeologists are so dependent upon radiocarbon, but have to admit to the reduction in crispness of resolution that comes from the requirement of reporting dates to two-sigmas AND to the realities of the deVries anomalies to our correction curves. One such anomaly is the infamous Halstatt Plateau, which means that radiocarbon dates between 800 and 400 BCE cannot be resolved any closer than that 400-year span (see Taylor 1996)—just when Africa may be inventing iron (Deme and McIntosh 2006; Killick 2001, 2015), with all the attendant implications for radically new environmental adaptations. AMS dates have been a godsend for dating geological samples (such as the lake core or swamp and bog cores described by Coutros and Douglas, and Cheddadi *et al.* 2015). But in reality, the chronological fuzziness of the environmental sequences from most parts of Africa parallel the aforementioned ambiguities in the archaeological record.

This chronological-resolution caution is why some are trying so hard to find new, potentially more precise and high-resolution dating methods (*e.g.*, experiments in OSL [English Heritage 2008] and a new push to produce archaeomagnetic dating curves [Donohoo-Hurley *et al.* 2013]). Looking to the future, it is likely that chronology will be first tackled in those (far too) few places featured by Maley and Vernet as having the best, indeed the only, acceptable volume of past and ongoing palaeoclimate sequencing and archaeological discovery research. This is the third cautionary take-away theme of their essay: the extreme patchiness of the palaeoclimate and palaeoenvironmental picture of Africa. We do have a smattering of first-rate sequences. Those few signal localities include especially Lake Chad or the ensemble of cored Eastern African lakes, or (perhaps) the Middle Niger floodplain of Mali, punctuated by only a few isolated points on the map, especially Lake Yoa in Ounianga, north Chad (Kröpelin *et al.* 2008, and Francus *et al.* 2013) or Lake Bosumtwi or the ODP (Deep Ocean Drilling program) deep marine cores off the coast of Mauritania, or a few new offshore sedimentology projects off the Senegal and Congo Rivers (the last too recent to have been fully appraised by the palaeoclimate community). However, as explained by Maley and Vernet, the complexity of the climate mechanisms in northern tropical Africa, related mainly to successive latitudinal bands, show that it is not possible to extrapolate climatic sequences from hundreds or thousands of kilometers away, as for instance between the Niger Bend and Lake Bosumtwi. But as demonstrated in this paper, correlations are possible through the same latitudinal and climatological band (see their Figs. 1 and 2).

However frustrating may be the patchiness of well understood climate sequences across Africa, the overall optimistic tone of the six essays in this special issue can be attributed to new work done at an accelerating pace—all over the continent. These essays present much of that new work and, especially, describe new data extraction or laboratory analysis techniques that will one day soon help to diminish the sting of the three cautionaries.

The take-away themes of Rachid Cheddadi and his ten coauthors' (2015) investigation of anthropogenic changes to Moroccan Rif and Middle Atlas mountain landscapes have clear implications for the debate among archaeologists and human ecologists (rather, a discussion in the background—see McIntosh 2004, especially pp. 59–62). Just how heavy was the human footprint on the landscape before agriculture—before sedentarism and post-hunting and gathering demographic expansion? Or with agriculture, but before large-scale irrigation or state-organized farming estates? Or with pastoralism, but before modern breeds and herding practices? Here, in the case presented by Cheddadi *et al.*, forest coverage remained largely intact through millennia of apparently "light-footprint" utilization, until the Roman imposition of Pb, Cu, and Zn metallurgical industries around 2000 years ago—that is, quite late. Before that, it is exceedingly difficult to differentiate vegetation perturbations, often small in scale, as caused by natural disturbances (especially forest fires) from human landscape alterations. This appears to be the case for foraging, hunter-gathering occupation and, somewhat surprisingly, for the first, low-density farming and pastoral communities as well.

Perhaps by contrast, Peter Coutros and Peter Douglas (2015) report on a linked (and in conception, recursive) campaign of coring at Lake Fati in the Middle Niger (Mali) Lakes Region and the intensive archaeological survey within the adjacent Gorbi Valley.

The valley is at the distal end (terminal last kilometers) of the discharge basin for this still-functioning peri-Saharan lake. Its position attracted permanent and mobile populations for millennia, throughout the late Holocene palaeoclimatic declines documented by Maley and Vernet. The result is a spectacular mosaic of Late Stone Age and Iron Age sites. This archaeological landscape represents, potentially, a high-resolution archaeological record of the comings and goings, adaptations, and eventual exploitation-system collapses of peoples who were, for millennia, attracted to this relatively welcoming microenvironment. Tellingly, the landscape was also within a southern Sahara becoming more and more difficult in which to sustain communities that clearly once thrived in the Gorbi Valley. The core sequence tells us more about the earlier Holocene palaeoclimate oscillations, and especially about a moving (latitudinal) front of the precipitous end to the African Humid Period in West Africa. This contribution is a very welcome example of how, at least in "marginal, high-stress" environments, local and climate perturbations can have precipitous ramifications for embedded human adaptation systems.

In "Holocene habitation with oscillating water levels and paleoclimate of Lake Turkana, Kenya" by Wright *et al.* (2015), a paleoecological overview of changing subsistence and climatic systems over the last 12,000 years is presented. Reconstructions of lake levels were made from OSL and radiocarbon dating of coquinas in beach ridges and an exhaustive survey of archaeological materials housed in the National Museums of Kenya formed the basis of the cultural interpretations. Human responses to high lake levels during the African Humid Period include adoption of low-mobility fishing strategies while transitions to more mobile forms of subsistence are inferred during the Middle Holocene, when lake levels were highly variable. Variability in Middle Holocene lake levels is attributed to relative intensity of both the East African Monsoon and West African Monsoon, affecting the distribution of Atlantic-derived moisture across the Ethiopian Plateau and Central Africa (Forman *et al.* 2014). Mobile pastoral systems develop within this climate regime, gradually replacing more lacustrine-focused sedentary fisher-hunter-gatherers who previously inhabited most of northern Africa. By the end of the Holocene, a diverse array of subsistence economies had developed within the Turkana Basin, all of which were adapted to xeric conditions that onset at the conclusion of the African Humid Period. Within the last 200 years, inhabitants of the Turkana region have been linked to the global economic system *via* missionary, commercial, and government outposts, which bring foodstuff and infrastructure now seen as critical for sustaining life in this harsh climatic zone.

The take-away theme of "Archaeology and Palaeoclimate Reconstruction in Madagascar," by Kristina Douglass and Jens Zinke (2015), is the realization that, although islands have tended to be considered as unities by prehistorians looking at human responses to climate change, Madagascar has a frustrating variety of regional and local climate realities that mock attempts to interpret overall climate response. Each environmental sub-zone needs its own high-resolution palaeoclimate sequence, complemented by the kind of landscape archaeological survey described by Douglass and Zinke for the southwest coast of the island. Here (as in the Cheddadi *et al.* article, 2015), we see the difficulty of retrieving the human effect on the landscape of low-density, foraging populations—difficult, but not hopeless. In Madagascar, the story is complicated by the eventual need to sort out the contributions of climate change, environmental alteration, and human exploitation to the mass extinction of the island's megafauna. The simpleminded causative narrative of megafauna meeting their end soon after the (rather) recent arrival of the first humans is complicated by new archaeological evidence for a far longer human presence.

Ending, as the special issue begins, with a rather larger-scale synthesis, Maria Gatto and Andrea Zerboni (2015), present Holocene supra-regional environmental changes as trigger for major socio-cultural processes in Northeastern Africa and the Sahara. Here also, over the vast area they cover, their take-away theme is that local, sub-regional environmental conditions must be known to a tight chronological resolution, in order for any argument of a climate driver to cultural change to hold any weight at all. Here, at the regional scale, is the playing out of Maley and Vernet's second cautionary—that climate sequences developed from proxy evidence some hundreds of kilometers away can only be applied to distant situations with great caution.

When the conveners of this issue solicited articles, we asked the contributors not only to provide regional or sub-regional syntheses of our current palaeoclimate knowledge, but also to highlight new techniques being explored in their regions. We now pass to those promising new (or refined) methods of data extraction or analysis.

New or Improved Methods

We thought it useful to expose Africanists working anywhere on the continent to new methods being pioneered in the areas covered by our authors. To be sure, in some cases, we witness new suites of laboratory analyses applied to data extracted with tried-and-true means (new geochemical tests applied to lake sediment cores, for example). However, in the case of the use of distinctive signatures of fatty acids from plants reported on by Gatto and Zerboni, the potential is enormous to have proxies for exotic, domesticated (as opposed to their wild brethren), or parasitical (weeds at the margins of fields) land plants recoverable long after any direct seed or plant evidence perished (for more, see Gebru *et al.* 2009; Terwilliger *et al.* 2008, 2011). They also discuss the need for new radiometric dating methods (OSL, IRSL, and cosmogenic nuclides) in order to isolate rapid climate events in the sedimentological record. Lastly, they mention the use of stable isotopes (especially C, N, and O) on lake sediments, soil horizons, and spring tufas.

Wright *et al.*'s review of the paleoecology of the Turkana Basin was derived from a lake level reconstruction published by Forman *et al.* (2014, and in progress). In those studies, relict beach ridges were sampled for sedimentologic profiles, OSL and lacustrine mollusks were carefully selected from coquinas for AMS ^{14}C dating. Barometric altimetry and differentially corrected GPS measurements were taken from the sampling locations in order to control both longitudinal and elevational locations. The lake level reconstruction incorporated data from previous studies (Brown and Fuller 2008; Butzer 1980; Garcin *et al.* 2012; Halfman *et al.* 1994; Owen *et al.* 1982), but assigned confidence values to the data on the basis of the credibility of the sample's accuracy.

Using x-ray fluorescence scanning and powder x-ray diffraction, Coutros and Douglass applied a suite of light and heavy stable isotope analyses (C, N, and O, Sr); relative proportions of K, Fe, Al, Si, Mn; proportionality of various iron carbonates and terrestrial leaf waxes (delta2H); and magnetic susceptibility to their two long cores from Lake Fati. Their article is "hot off the press," as it were, and so these analyses will be reported more fully elsewhere (see Douglass 2014). Here, they emphasize the potential of micro-stratigraphic analyses of (hopefully) non-perturbed lake bottom cores, especially for sediment type and density, magnetic susceptibility, high-resolution AMS dating, and suites of terrigenous and lacustrine microfauna and macrofauna.

Complementing the theme of highly resolved analysis of cores, Cheddadi *et al.* make the case for well dated and contextualized pollen sequences from wetlands and peat bogs, from which pollen arrays suggest plant species associated with human "disturbances" (field, olive and fruit orchards). And in their study, the pollution caused intensive exploitation of Pb, Cu, and Zn which left their inevitable heavy-metal signatures.

Especially exciting is the coral coring reported by Douglass and Zinke for the southwest coast of Madagascar, part of a long-overdue program of exploitation by palaeoclimatologists of the extraordinary Indian Ocean coral beds. These corals give a monthly or bi-monthly resolution for hundreds of years in the past. They are especially useful when correlated with nearby or South African (*e.g.*, Makapanskat Cold Air Cave) speleothems: not to ignore, as they remind us the value of comparing nearby terrestrial and marine proxies. The Eastern African Indian Ocean corals are every bit as good, and in some cases more exciting, than even the better investigated corals of the Galapagos (Dunbar and Cole 1993; Dunbar *et al.* 1994; Dunbar, personal communication to RJM; Toth *et al.* 2012). Douglass and Zinke, additionally, report on the potential of micro-charcoal in sedimentary profiles. And very exciting is their discussion of coprophilous fungi (*e.g.*, *Sporomiella* spp.) as a proxy for herbivorous megafauna and Madagascar's now-extinct large avian herbivores (the various species of ratites, the shells of which are massively represented at coastal archaeological sites, may be amenable to O and C isotopic analysis). Last, but not least, they report on a new project to determine a hatching profile, combined with the geochemistry of extinct elephant bird eggshell found in indisputable human exploitation contexts (following Clarke *et al*. 2006).

Final Thoughts

These six articles, we believe, should leave prehistorians optimistic about the future of climate change and human response studies in Africa. Thinking even further into the future of research, we can hope that with tighter chronological resolution on climate and cultural change that is the promise of new dating methodologies, we can someday also address the issue of how the hand of humans affected or even irremediably changed local-scale or mesoscale climate histories. What were the effects of humans' long use of fire as a tool to manipulate the African landscape (Eichorn 2012)? Further, precocious pastoralism spread across the northern sweep of the continent by the mid-Holocene (Gifford-Gonzalez 2005; Smith 1992), leading eventually to the astonishing proliferation of (presumed) cattle-oriented sites. We see the astonishing density and diversity of such sites throughout the Sahara, from the Adrar to the north (semi-permanent, transhumance camps?) (Bordes *et al.* 2010, pp. 170, 229, 354), throughout Mauritania (best known from years of excavation and reconnaissance of the large, permanent, stone-built enclosures and habitations at the Dhar Tichitt and Dhar Nema), all the way south to the Gorbi

Valley—(see Coutros and Douglass 2015). What might have been the long-term landscape and environmental (including climate) effects of those many, many thousand herds? And, considering the vast fields of iron-smelting furnaces documented in Mauritania, Senegal, and Niger (Killick 2015; Robert-Chaleix and Sognane 1983)—all those belching furnaces, all that fuel combusted, and woodland thus consumed—if all those prodigious blacksmiths in effect created a "parkland," an artificial wooded savanna-like landscape where, lacking that activity, full forest would have reigned, how then must the heavy hand of humans be factored into thinking about the environmental and climatic evolution of Africa?

Lastly, concerning the expansion of iron metallurgy during the first millennium B.C.E., we should also raise the question of what might have been the role of the deeply catastrophic erosional phase, climatic in origin, that struck between *ca.* 2500 and 2000 BP from the equator to the Sahel and southern Sahara. It now appears likely that this erosive phase correlates tightly with high-amplitude variations in the Pacific ENSO (El Niño) (Toth *et al*. 2012), in a way reminiscent of the correlation of the strong arid phase of the fifteenth century C.E., as demonstrated in the Maley and Vernet contribution. Clearly, we are just at the start of what will be an exciting period of ancient Africa's complex entanglements of palaeoclimate and human response.

We remain committed to the Africanist historical scientist's mantra:

More data. More local sequences. More archaeologists on the ground. And more *cousinage* with paleaeoclimatologists!!

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