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Chapter 1

The Journey East

1.1 Introduction

The proposition that migration and dispersal played an important role in early human evolution was put forward by Henri Breuil a hundred years ago (Breuil, 1912) and marked a significant shift in the way Palaeolithic culture history would come to be portrayed (Boyle *et al.*, 1963; Chazan, 1995). Breuil inspired his students, including Miles Burkitt and, especially, Dorothy Garrod – who would go on to become pioneers in British Palaeolithic archaeology (Smith, 2009) – to look beyond the confines of mainland Europe in their search to understand the emergence of modern humanity. Nonetheless, despite Garrod's famous discoveries in Gibraltar (Garrod *et al.*, 1928) and the tradition of research she instigated in the Levant (Garrod and Bate, 1937), much of the scholarship generated on this subject in the time since has still been concerned with the first appearance, practices and subsequent spread of *Homo sapiens* in Europe. Regionally specific research programmes that examine modern human settlement of Africa and Asia have only begun to emerge recently in any quantity (e.g. Akazawa *et al.*, 1998; Barker *et al.*, 2007; Brantingham *et al.*, 2004; d'Errico and Blackwell, 2005; Gamble, 1993; Gamble and Soffer, 1989a, 1989b; Haidle and Pawlik, 2010; McBrearty and Brooks, 2000; McBrearty, 2007; Mellars, 1990). While there is no doubting the importance of the European record, it represents only a tiny portion of the lands colonized during the early dispersal of our species. As Breuil (1912: 238) remarked, and as Garrod demonstrated, Europe is but a small peninsula of Africa and Asia (Clark, 1999). To fully appreciate the character of our species, the call remains the same today as it did a hundred years ago: we must look further afield.

Until the beginning of this century, the position held by most scholars, based largely on the European data, was that a package of behaviours regarded as quintessentially those of modern humans (including symbolic representation, use of ornament, technological and subsistence innovation) did not appear until *c.* 40,000 years ago. Their arrival in the archaeological record was linked closely to the first sustained colonization of western Eurasia and the European peninsula by *H. sapiens* (Mellars, 2005). The process of adaptation to the harsh climate and environments encountered, as well as contact and competition with indigenous

H. neanderthalensis populations, became the principal sources of explanation for the appearance of these traits, which then through migration, were assumed to become established across much of the rest of the world.

Over the last decade, new discoveries, particularly from Africa, have been pushing back the genesis of many of these defining attributes to periods long before the colonization of Europe (e.g. McBrearty and Brooks, 2000), raising questions about the strength of previous interpretations and leaving us to re-examine the place of the European sequence in a global interpretation of early human development. Some archaeologists (e.g. Finlayson and Carrión, 2007) propose that it is perhaps more prudent to view the European sequence as the product of a population of *H. sapiens* adapting survival mechanisms they already possessed to meet a new set of regionally specific challenges and opportunities. The European record may give us an expression of how a population of African *H. sapiens* coped with resource structure and competition from other species in what was broadly a sub-Arctic landscape; but it represents only one of potentially several regional stories of early human dispersal and of developmental trajectories in early humanity.

Removing Europe from the centre of the Palaeolithic world has the effect of democratising pioneer settlement, with each enclave of humans less liable to be judged against the standards of cultural development in the European evidence. It also does something else: it challenges the notion that a single suite of behavioural traits can be applicable to all adaptive circumstances. As well as being European centred, under prevailing orthodoxy, humanity also had a firmly one-track mind that was out of step with one of the key principles of evolutionary biology: that adaptation is situational.

Once the characteristics of behavioural modernity had been attained, the assumption had been that they were fixed in early human populations to be carried around the world: a superior codex of practice that could be bent to the requirements of any situation. This perspective was underpinned by the long-standing tradition of comparative studies that has examined the behavioural similarities and differences between *H. sapiens* and *H. neanderthalensis*. Consequently, very little systematic attention has been paid to the possibility that there existed significant behavioural variation between different regional populations of early *H. sapiens*. Wherever variance in behaviour was observed between regions tended to be explained away by appealing to local restrictions in material resources that were 'inhibiting innovation' and development or else to cultural degeneration – in other words, almost always starting from the premise of how was complexity lost. If populations must acclimate to different ecological settings, behavioural adaptation needs to be dynamic, not fixed; it needs to be viewed as a process, not a faculty.

Evolution by natural selection and the emergence of new species are fundamentally predicated on the adaptive process of organisms to new habitats and the consequential and eventual emergence of reproductive isolation and speciation. Although there remains considerable uncertainty about the timing and relative contribution of the many forces which can cause speciation, the long-known but less-studied significance of ecological barriers is now being championed as a potentially dominant factor (e.g. Schemske, 2000, 2010). In the late 1940s, Mayr (1947: 266, 285–6) argued that the first step towards speciation involves the founding of a new intra-specific population whose broader ecological tolerance (possibly due to its existence near the periphery of a species' range) enables expansion and whose geographic situation is or becomes spatially segregated from the parent population. The differing ecological factors that come into play in a newly colonized habitat lead to evolutionary divergence by adaptation. In this way, adaptation may be defined as the processes of modification through which an organism converges on a closeness of fit to the affordances of an environmental setting through its survival and successful reproduction, and through its presence, also affects changes within that setting (i.e. niche construction; Laland and Brown, 2006). In this process the stability and heterogeneity of the colonized environment will be crucial to determining the extent of selection pressures acting on a population (Kirch 1980: 103). To assess this for human prehistory, we must turn to the palaeoclimatic record.

As well as being affected by long-term cycles of climate deterioration and amelioration, palaeoclimate research has determined that over at least the last 100,000 years, the Earth has been subject to much shorter term climatic fluctuations, operating over centuries or even decades – timescales that would have impacted directly on our ancestors' societies across and within generations. The effect this had not only on the routes and timing of hominin dispersals but also on the very processes of adaptation and the roots of human behaviour, therefore, needs to be considered much more closely. A better understanding of how groups adapted under different regional settings whilst subject to the capricious climates of the last 100,000 years not only has great importance for our understanding of how we have been shaped as a species but has profoundly important implications for how we will continue to adapt and survive in the future.

Few palaeo-anthropologists would argue that the behavioural and demographic traits visible in the Palaeolithic record – the evidence of human dispersal, settlement and cultural character – were strongly shaped by the way early humans responded as individuals and socially as groups to the opportunities and challenges of different environments. It is, therefore, unfortunate that investigation into the extent to which local conditions affected group survival and behavioural development has tended to remain somewhat obscured behind the dominance of European data sets and perceptions. The emerging and older archaeological evidence from Africa is now successfully challenging this (even if findings from this continent are still often defined according to European behavioural criteria). It is with the aim of further expanding such a revision that this book explores the inter-related impact of regionality, behavioural contingency and the effects of attenuated climate change on the localised processes of early human adaptation. It takes as its geographical area of focus that part of the northern and eastern hemispheres that has, despite established local traditions of archaeological investigation, received the least systematic attention with respect to early human behaviour, namely, Asia.

1.2 The Palaeolithic of Asia

Traditionally, Asia is recognised as comprising the vast eastern province of Eurasia. This landscape covers almost 30 per cent of the world's total land surface area, or 44,579,000 km^2. The *Encyclopaedia Britannica* defines Asia geographically as the area east of the Suez Canal and Ural Mountains. Asia is bounded by the Arctic, Pacific and Indian oceans and by the Mediterranean Sea to the west and by the Timor and Arafura seas to the southeast. As well as the mainland, Asia's geographical area also includes numerous islands. Of particular interest in this study is Southeast Asia. During periods of glaciation at higher latitudes and reduced sea level, many of the islands in this part of the region (including Borneo, Java and Sumatra) were incorporated into a single landmass that extended the Asian mainland into the southern hemisphere. Molengraaf and Weber (1921) made early reference to this as the Sunda Shelf and to the emergent continent as 'Sunda Land' (hereinafter 'Sundaland'). In extent, this landmass (and the modern continental shelf) covers *c.* 1,850,000 km^2 (Movius, 1948), or an area equivalent to that of the state of Queensland, Australia.

Prehistoric research in Asia has a long, if still comparatively unintegrated, history. Sections of the Palaeolithic record, in places such as China, Siberia, India, Indonesia and Malaysia (*see* e.g. Barker *et al.*, forthcoming; Bellwood, 2007; Davis and Ranov, 1999; Derev'anko *et al.*, 1998; De Terra and Movius, 1943; Haslam *et al.*, 2010; Heine-Geldern, 1945; Ranov and Davis, 1979; Tweedie, 1953; van Heekeren, 1957; Wu and Olsen, 1985), continue to be separated by expanses of land that are far less well-known, such as vast stretches of central Asia or the Tibetan Plateau. This situation is improving. For example, a rejuvenated programme of systematic Palaeolithic archaeology in the Philippines is making significant strides in prehistoric knowledge in that part of Island Southeast Asia; however, across Asia, local traditions of outstanding research have limited reach to wider audiences because of linguistic, financial and occasionally political constraints. Hard economic realities have also made archaeology a less than attractive or indeed practical career path for young Asians; a situation that leaves the ranks of prehistorians there considerably and consistently thinner than in the countries of Europe or North America. Interest in the value of archaeological heritage is, though, on the rise, and it is beginning to draw governments, business, the general public and academia to this sphere, heralding, it is hoped, a fundamental change in the subject's recognition and potential.

Prior to the second half of the twentieth century, colonial administrators featured prominently in the emergence of prehistoric research in several parts of South and Southeast Asia. Fortuitously, some of these individuals held certification in archaeological training as this was deemed a useful preparation for colonial duties (Dennell, 1990) and probably helped inspire curiosity. As a result, nascent investigations undertaken in these regions kept pace with discoveries and techniques being developed in Europe. For example, in 1883, Robert Bruce Foote, a superintendent of the Geological Survey of India, began pioneering Palaeolithic research at the Billa Surgam caves in the Kurnool District of Andhra Pradesh, India (*see* Haslam *et al.*, 2010); while in 1886 and 1891, the first curator of the Taiping Museum, Malaya (Leonard Wray Jr.), was also actively exploring cave sites of archaeological interest in the Malay Peninsula (Wray, 1897, 1905). Both initiatives were being conducted less than a decade after the first assertions had been published in North America about the Palaeolithic settlement of that continent (Grote, 1877) and slightly before General Pitt-Rivers, one of the pioneers in scientific excavation in Britain, had begun his seminal work at Cranborne Chase in Dorest (1887–98; *see* Renfrew and Bahn, 1991). In Southeast Asia, work was also spurred on by a certain amount of subtle rivalry between the colonial powers. Collings (1938: 575) wrote in the journal *Nature* when announcing the discovery of the first Pleistocene site on the Malay Peninsula – a river terrace site called Kota Tampan – that it was 'with regret' that it had taken so long to find anything, given how close Malaya was to Java, then a Dutch possession.

At the same time as early investigations in Malaya, in Java, the finding of the Wajak skull by van Rietschoten in 1889 (Jacob, 1973) – which would turn out to be that of an anatomically modern human (Storm, 1995) – was closely followed by the historic discovery between 1891 and 1892 of a skull cap, femora and teeth belonging to the archaic hominin *Pithocanthropus erectus* (now *Homo erectus*) by the Dutch anatomist Eugene Dubois (1896). On the mainland, in China, the finding of hominin fossils attributed to the species *Sinanthropus pekinensis* (also now considered to have been *Homo erectus*) at Choukoutien (hereinafter Zhoukoudian) added to the list of evidence for the presence of archaic humans in east Asia and, in conjunction with other finds of the time, including the Javanese evidence, a proposed central Asiatic origin for humanity (Black, 1926). Indeed the formation of the Chinese Cenozoic Research Laboratory – part of the Geological Survey of China and a cornerstone of Chinese Palaeolithic studies – came about as a direct result of the finds and the questions raised by the Zhoukoutien material (Black, 1934). It is worth remembering that at this point in time, all the major hominin fossils were being uncovered not in Africa, but in Eurasia, and most in these two isolated areas of its eastern provinces. Neither of the first classic discoveries made in these locales was met with resounding acceptance (*see* Dubois, 1896; G.E.S., 1934). It is perhaps to a certain degree ironic that one of the most vocal alternate prognoses for the *Pithocanthropus erectus* skull cap from Trinil was that it belonged to a microcephalic modern human (Dubois, 1896); a similar contention, rightly or wrongly, laid upon the recent diminutive hominin remains from Flores (e.g. Jacob *et al.*, 2006).

As well as pioneering Palaeolithic archaeology in Asia, investigations also tended to import foreign attitudes to social change and prehistoric classification, with direct (and sometimes unfavourable) comparisons to the European sequence, none of which particularly helped elevate the profile of Asian archaeological records, their continued investigation or indeed perceptions about their value and need for protection. The concluding comments of Hallam Movius in his 1948 report *Lower Palaeolithic Cultures of Southern and Eastern Asia* are well-known and unintentionally came to typify this position. More positively, though, this same passage also highlighted the uniqueness of the anthropological and archaeological legacy held inside this vast and varied landscape – a feature that continues to bring forth more than its fair share of surprises:

> Southern and Eastern Asia as a whole was a region of cultural retardation. Therefore, it seems very unlikely that this vast area could ever have played a vital and dynamic role in early human evolution, although very primitive forms of Early Man apparently persisted there long after types at a comparable stage of physical evolution had become extinct elsewhere. (Movius, 1948: 411)

While evidence of anatomically archaic hominins of Lower Pleistocene age (*c.* 2.85–0.77 million years ago) continues to be uncovered in Asia – with finds from the Georgian site of Dmanisi principal among the more recent of these – as the age of the Flores material testifies (*c.* 74–17,000 years ago), taxonomic puzzles here are also extending into the much more recent past. New discoveries in the Philippines (Mijares *et al.*, 2010) and Siberia (Krause *et al.*, 2010) point to the possibility of further additions to Asia's ledger of hominins, while the proposed antiquity of modern human remains in China at *c.* 100,000 years ago (Lui *et al.*, 2010; Shen *et al.*, 2002) even challenges, if controversially, the existing model of *H. sapiens* dispersal out of Africa. Much has been made historically of the relationship between *H. sapiens* and *H. neanderthalensis* in Europe; the potential for contemporaneity between hominin species in Asia looks to match, if not exceed, this, with late-surviving archaics, the possibility of precociously early moderns and *in situ* evolution. Although the importance of Africa is now firmly established (and mostly accepted) as the cradle of humanity through fossil and genetic records, whatever role Asia held in the unfolding history of our genus and our species, the steady accumulation of often quite sensational discoveries would attest that it was complex and vital – and anything but a 'backwater'.

1.3 Human Adaptation in the Asian Palaeolithic

The anthropological finds from Asia continue to stir both fascination and controversy in equal measure. As with the general picture of Palaeolithic hominins across this continent, the data, though, still only come from a comparative few islands of understanding amidst a sea of unknown possibilities. Detailed regional reviews of hominin dispersal into Asia continue to be exceedingly rare. Dennell's (2009) excellent *The Palaeolithic Settlement of Asia* and Norton and Braun's (2010) timely *Asian Paleoanthropology* volumes are the latest additions to a slim catalogue; though like almost all other works on this area of the Palaeolithic, their stated concern is with the migration of ancestral species of *Homo* rather than with *H. sapiens*. There is growing interest within archaeology towards our species' behavioural evolution in its regional and adaptive contexts (*see* Brantingham *et al.*, 2004; Burroughs, 2005; Gamble, 1993; Hetherington and Reid, 2010; Potts, 1996b; Rockman and Steele, 2003) and an exceedingly wide literature on traditional interpretations of modern human culture and its Palaeolithic ancestry. What there is not, however, is any concerted attention towards tackling directly the importance and distinctiveness of the Asian record when it comes to these issues. Equally, while there are well-established English-language texts on the prehistory of Southeast Asia specifically (most notably Bellwood's (2007) essential work, *The*

Prehistory of the Indo-Malaysian Archipelago, now in its third edition), the matter of how the first *H. sapiens* adapted to the tropical conditions and changing landscapes of Southeast Asia has not been the subject of a dedicated exposition. Through its coverage, the current volume encourages debate about both these under-represented spheres of Palaeolithic research.

In the first half of the book, discussion of the evidence progresses at its broadest scale to establish a thorough overview of the topic. In this way, Chapter 2 introduces basic features of the global palaeoclimatic record and of climate conditions during the glacial–interglacial phases of the Pleistocene epoch. It also presents evidence concerning the rapidity of climate change during this epoch and its potential impact on hominins at visible, inter- and intra-generational scales. Chapter 3 summarises current knowledge on the initial spread of early hominins from Africa into western and eastern Eurasia and the emergence of regionally specific trajectories of biological and cultural evolution. Chapter 4 expands upon this theme with specific reference to *Homo sapiens*, presenting an assessment of the Middle–Upper Palaeolithic transition in Europe and the evidence surrounding each of the principal components of the behavioural package displayed by modern humans in that record. This evidence is then placed into the context of emerging and independently distinct African and Asian sequences of modern human behavioural development. Chapter 5 considers the genetic and archaeological evidence for the Southern Route Hypothesis, which traces perhaps the most likely path of successful colonization beyond Africa. Whereas hominin dispersal and settlement during the Lower and Middle Pleistocene can be broadly tied to a climatic schedule, records of climate change during the Upper Pleistocene are much more extensive and fine grained. The archaeological record for this period is also chronologically much more precise, though confident correlations between the two streams of data remain, for the most part, only possible at a millennial scale. Nonetheless, increasingly unstable climate and palaeo-environmental change were demonstrably the circumstances under which the pioneering dispersal of *H. sapiens* occurred.

Beginning the second half of the book, the discussion in Chapter 6 becomes more narrowly focused on Southeast Asia and on one time period: the Last Termination to early post-glacial. It is by this point that archaeological chronologies more closely match the resolution of climatic records, making it possible to track and compare rapid climatic, environmental and human behavioural changes. The chapter presents details of those changes that affected Southeast Asia and the technological adaptations in organic and inorganic media that emerged at that time. Chapter 7 explores what is known about early tropical subsistence and settlement practices in this part of the world and compares faunal assemblages from a sample of five sites in Island and Mainland Southeast Asia to assess patterning in early foraging strategies (drawing on the author's own experience working in East and West Malaysia and Vietnam). In Chapter 8, the mechanisms of early human dispersal and adaptation to the local conditions in the region are studied through modelling the dynamics of human colonization. From this emerges a reasoning as to why there would have been distinctly regional trajectories in early human behaviour, how Palaeolithic cultures developed and even how they may have differed from those of the Holocene.

The book makes, ultimately, three propositions. Firstly, it advocates that modern human behaviour is evolutionarily emergent rather than attained – an on-going process, not a faculty restricted to our species' infancy – and that it was subject (though not exclusively) to strong external selective pressures prior to the Holocene and stronger internal selection pressures thereafter. This is not to suggest any kind of sudden shift in the way humanity has been affected by selective forces. There is, for example, growing evidence that climate change has continued to feature during the recent period, affecting society in different ways through the Holocene (e.g. Burroughs, 2005; Hetherington and Reid, 2010). Rather it is to highlight a trend towards the increasing impact of internal cultural dynamics in recent millennia. Secondly, the book proposes that the increasing pace of climatic instability was a premier driver in hominin dispersive and adaptive trajectories since at least the last inter-glacial and perhaps earlier. Thirdly, it argues that regionalism in early *H. sapiens* behaviour developed to a significant degree through the demographic and acclimation processes of colonizing new or remodelled environments under these conditions of climatic caprice.

The simplicity and perhaps overly deterministic nature of these propositions are acknowledged from the outset. The importance of environmental and climatic changes on the development of particularly early human society, though, should not be underestimated (*see* e.g. Finlayson, 2004; Kirch, 1980: 147). This book is one attempt at a synthesis of the growing body of evidence now requiring us to consider what may become a new global reality about our species' past. It argues that the place of Asia within that past can no longer be left ignored, despite the challenges this creates; to do otherwise would very likely result in a seriously biased if not spurious picture of the early phases of the human journey.

The consequences of these propositions are potentially far-reaching, for they also have the capacity to push Palaeolithic archaeology beyond its traditional confines within the discipline of archaeology. The unique perspective that the study of Palaeolithic societies offers on the behavioural evolution of our species is well placed to make a major contribution to the ecologically and climatically oriented paradigm that is emerging within Western science more generally and our need to adapt to modern climate change rather than simply either to ignore or try to somehow halt it. The arguments presented are also, therefore, offered as one tentative step towards extending the study of the human past into the human future; of demonstrating that our humanity arises out of a long, varied and crucially *on-going* journey.

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Chapter 2

The Pleistocene Planet

2.1 Introduction

The Earth's climate system experiences many cycles of change. Long-term, stately shifts ultimately stemming from the Earth's orbital geometry and the movement, creation and subduction of the planet's tectonic plates have taken it from extremes of warmth with ice-free poles to extremes of cold with massive continental ice sheets and expanses of polar ice. The earliest and perhaps deepest of Earth's glaciations arose during the Precambrian eras of the Palaeoproterozoic (2.5–1.6 billion years ago (Ba)) and Neoproterozoic (1000–542 million years ago (Ma)). Geological evidence suggests that during these massive glaciations, ice sheets extended to low latitudes (Hoffman and Schrag, 2002) and created planetary conditions that have been described as either 'Snowball Earth' or 'Slushball Earth' scenarios, depending on the proposed completeness of global glaciation (Micheels and Montenari, 2008). Rather than restricting or extinguishing life, however, they may have been instrumental in assuring its diversity. Deglaciation from the second of these deep freezes is linked to the opening of myriad ecological niches and may have played a significant role in paving the way for the Cambrian 'explosion', an array of new multicellular life forms that appeared after *c.* 575 Ma (e.g. Hoffman and Schrag, 2000; Narbonne and Gehling, 2003).

By contrast, the high to mid-latitude Quaternary glaciations commencing after 2.58 Ma were neither as deep nor as extensive, but they too are coincidental with the emergence of a highly diverse life form that would eventually have such planet-enveloping proportions that its impact on the biosphere may warrant its own geological epoch – the 'Anthropocene' (Crutzen, 2002). The glacial and interglacial cycles that characterize the Quaternary emerged as the consequence of long-term cooling, thought to be partly attributable to the uplift of the Tibetan Plateau. The last phase of the Quaternary also marked the climax of a long period of increasingly pronounced global climatic instability. This chapter introduces the essential chronology, mechanisms and pace of deep-time planetary climate change and the accumulating evidence for abrupt climate shifting during the Upper Pleistocene – the context in which our species, *Homo sapiens*, the last of the hominin forms to arise in Africa and the only one to survive, would begin to colonize the planet.

2.2 The Quaternary Period

The glacial cycles that formed the context for the evolution of anatomically modern humans in Africa and their expansion across Asia, Greater Australia and Europe are shown in Figure 2.1 (*see* Gibbard *et al.*, 2005). The Quaternary period (or system) is currently subdivided into two epochs (or series), the Pleistocene and the (present-day) Holocene – though the latter, strictly speaking, represents just the most recent of many warm interludes that have appeared through the course of the Quaternary. It does, however, mark a major stabilization in climatic conditions (Petit *et al.*, 1999); if Crutzen's proposal is adopted formally, the Anthropocene will be the third epoch and the one in which we have been living since the late eighteenth century.

Until 2009, the Quaternary period was officially recognised as commencing *c.* 1.8 Ma. The then unofficial alternative base, favoured by many working in the field of Quaternary science, was more than half a million years earlier than this, at 2.58 Ma. The 1.8 Ma baseline was designated as a Global Stratotype Section and Point (GSSP) through reference to a type geological section in Vrica, Calabria, in Italy in 1984 and following the 27th International Geological Congress in Moscow thereafter. Authorities who favoured the much earlier base argued that the scale of changes observed *c.* 2.58 Ma exceeded those seen at *c.* 1.8 Ma, indicating this to have been, globally, the more important threshold (Anderson *et al.*, 2007). That transition coincides with the appearance of ice-rafted debris – material dropped to the ocean floor from melting icebergs (*see* Section 2.3.2) – at mid-latitudes as well as the start of pronounced, planet-wide changes in sedimentary and biological systems on land. The *c.* 2.58 Ma horizon signalled the intensification of a long-term cooling trend that stretches back deeper into the Neogene (now defined as the most recent period before the Quaternary and starting *c.* 23 Ma) within the current Cenozoic era. The horizon is also commensurate with global geomagnetic stratigraphy that registers a major shift in the Earth's magnetic poles at this time; the 1.8 Ma GSSP was situated close to the end of the Olduvai geomagnetic event – a much shorter-lived shift known as an *excursion*. Following a partition for reassessment of the status of the Quaternary (Gibbard and Head, 2008), as of June 2009, the Executive Committee of the International Union of Geological Sciences (IUGS) formally ratified the 2.58 Ma base (Gibbard *et al.*, 2010). The Quaternary is defined by this new standard herein. The Late Quaternary of this book's title refers to the last 126,000 years, i.e. the present interglacial, the last glaciation and the preceding interglacial (*see* Walker, 2005).

2.2.1 Pleistocene Chronology

The other major chronological divisions used in the present study are based primarily on the Global Chronostratigraphic Correlation Table (POSTERstratchart v2011). The Lower Pleistocene is taken to begin *c.* 2.58 Ma and is the approximate time of the Gauss–Matuyama reversal in the Earth's geomagnetic field (Gibbard *et al.*, 2005). This first part of the Pleistocene epoch lasted until around the time of the Matuyama–Brunhes reversal at *c.* 775 thousand years ago (KBP; Gibbard and van Kolfschoten, 2005). The following sub-epoch, the Middle Pleistocene, covers the interval from this time (*c.* 775 KBP) until *c.* 126 KBP, ending slightly at the Blake geomagnetic excursion (Gibbard, 2003; Gibbard and van Kolfschoten, 2005). For clarity, herein the *Upper* Pleistocene is defined as lasting from *c.* 126 KBP to 11,700 BP – the formally recognised base of the Holocene (Gibbard and van Kolfschoten, 2005; Walker *et al.*, 2009). The *Late* Pleistocene is informally defined as comprising the period *c.* 40 KBP to 11,700 cal. BP, commencing at the Laschamp geomagnetic excursion – ($^{40}Ar/^{39}Ar$) dated to 40 ± 2 KBP (Guillou *et al.*, 2004).

A sizable portion of this book is concerned with a sub-stage of the Late Pleistocene described as the Last Termination. The termination point in a glacial cycle was defined as

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the mid-point in the rapid warming phase after a final glacial maximum (or Pleniglacial; e.g. Fairbridge, 1972). The Last Termination is defined here more broadly to encompass the period from the height of the Last Glacial Maximum (LGM) to the Pleistocene–Holocene boundary: *c.* 22,000–11,700 cal. BP (*after* Björck *et al.*, 1998; Blockley *et al.*, 2006; *see also* Denton *et al.*, 2010). A standardized dating of the LGM itself remains problematic as different regional records did not necessarily reach a temperature minimum concurrently (Ehlers and Gibbard, 2007). Herein the LGM is taken to span the period *c.* 26,500–19,000 cal. BP, an estimation based on global ice-sheet extent and onset of retreat (*after* Clark *et al.*, 2009).

Calibrated radiocarbon (^{14}C) dates are presented here as cal. BP or cal. KBP (thousands of years) before a 'present' defined as 1950 and are used particularly in Chapters 6 and 7 to standardize comparison between the archaeological and climatic records. Unless otherwise stated, and to help maintain consistency, all quoted calibrated ^{14}C dates were obtained using the Fairbanks_0107 calibration curve to 1 standard deviation (*see* Fairbanks *et al.*, 2005; Appendix, this volume). Uncalibrated radiocarbon dates and estimated dates – including genetic relative dates (*see* Endicott *et al.*, 2009) are given as (lowercase) bp or kbp values. All other radiometric dates (e.g. thermoluminescence (TL) dates), annual increment (e.g. ice-core chronologies), other relative and age equivalent dates (e.g. oxygen isotope stratigraphy) appear capitalized and are quoted wherever appropriate and possible with lab numbers, error margins and the methods used to obtain them (*see* Walker, 2005, for a detailed discussion of different Quaternary dating methods). Finally, the term *Palaeolithic* is reserved exclusively for discussion about Pleistocene material cultural (archaeological) evidence; it is not used as a term with geochronological reference.

2.2.2 Milankovitch Cycles

On the premise that surface temperatures on the Earth should vary according to regular and predictable changes in the planet's orbit and axis of rotation, the concept of Astronomical Theory was published in a book by J. Croll in 1875 called *Climate and Time*. In the early 1920s, this theory was elaborated by the Serbian geophysicist M. Milankovich and has since become central to our understanding of the passage of the ice ages that have characterized the Quaternary.

The effect of solar and other gravitational forces means that the Earth's orbit goes through a cycle from being nearly circular to more elliptical and back again over the course of *c.* 96,000 years – this is referred to as its *eccentricity*. As well as passage through this cycle, the planet's rotational axis describes another: moving *c.* 3° (between 21°39′ and 24°36′) and back again over the course of *c.* 41,000 years – this is the *obliquity of the ecliptic* (the ecliptic being the plane of the Earth's movement around the Sun). Finally, because of the gravitational influence of the Sun and the Moon, the Earth also wobbles slightly on its axis. This has the effect of varying the season when the Earth is closest to the Sun (its perihelion). This cycle, which in fact is probably two closely interlocked ones, takes *c.* 19,000–23,000 years to complete and is called *precession*. In combination, these are known as *Milankovitch cycles*, and they have a profound effect on the amount of insolation received by the Earth and how it is distributed around the globe (Hewitt, 2003). The total amount of incoming solar radiation is largely determined by the planet's eccentricity; the interaction of the other cycles affects how insolation is distributed at different latitudes. Owing to the predictability of these cycles, Milankovitch was able to estimate the receipt of insolation and hence the likely prevailing temperature at the surface during different periods in the Earth's history.

Two obstacles, though, initially hampered the general acceptance of this hypothesis. The first of these was identifying which aspects of the insolation budget were the most critical to climate change. Depending on which latitude and season were adopted, different models could be produced, giving a variety of chronological scenarios. Estimates for the last