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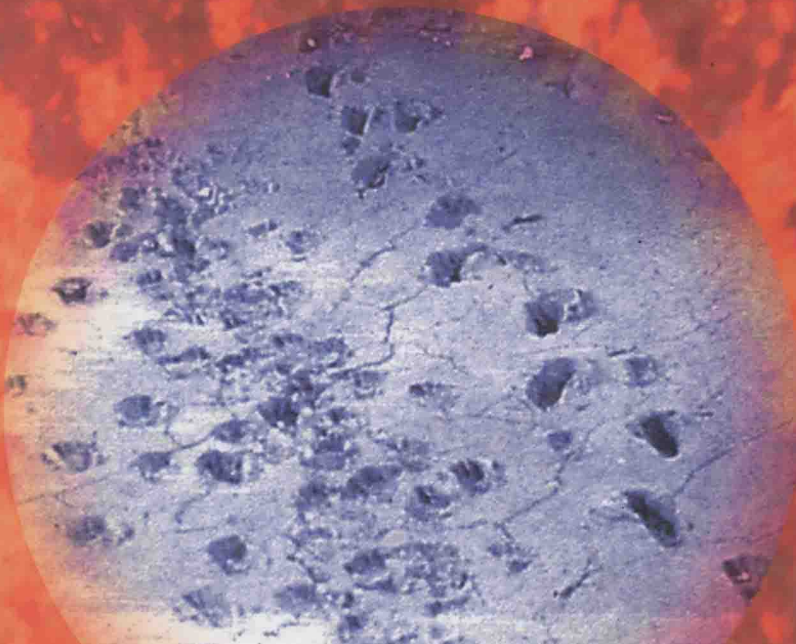
QUATERNARY GEOLOGY AND THE ENVIRONMENT



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Preface

> As for modern Science, it rises from refereed articles which are never more than ten years old. Even if palaeoclimate studies go back to tens of thousands of years, they were never published more than thirty years ago.
>
> Michel Serres, in *Le Contrat naturel* (*Nature's Contract*)

Quaternary studies have been considerably developed and refined during the last 20 years or so. Research has progressively extended to the whole world. For around a century, the geographic field of study extended first from Western Europe to the Alps and the Mediterranean world, then to the Middle East and Sahara, and finally to Eastern Africa and North America. Based on communications presented at the meetings of the International Quaternary Association (INQUA) in Beijing (1991) and Berlin (1995), the current interests are seen to develop into new geographical areas, as a result of the growth of Quaternary research groups: in China (loess and Central Asia deserts), India (Thar desert), Australia, the Andes and South Africa.

Investigation techniques have been refined. Geological sections are now analysed with sophisticated tools. Prehistoric diggings are now very technical affairs. The fine sifting of sediments provides access to microfauna. Absolute dating methods have improved and diversified. Isotopic measurements of water, through their fossils, and the recent revelations from oceanic and glacial cores have brought new light on palaeoclimates.

In these conditions, the study of the Quaternary reaches a precision unequalled in the other geological periods. The research fields become so specialized that even scientists have trouble synthesizing all the results.

There exist several books in French about the Quaternary, but, despite their high quality, they most often treat matters near prehistory. No review book has appeared since Chahine's in 1972, whereas there are many books in English.

The present book is a textbook aimed at specialists in Quaternary geology, as well as all teachers, researchers, students and enthusiasts fascinated by the recent past of our planet, which often explains its present, and sometimes its future. Data from the Quaternary period indeed enable estimation of the more and more tenuous interactions between humans and their environment, in order to predict future evolution.

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Introduction

> The Quaternary is the study of a recent past which extends into the current period.
>
> H. de Lumley

The Quaternary is the geological era extending back some 2,400,000 years. Its two main characteristics are the mobility and dynamism of its physical and biological processes. Mobility is revealed by changes in natural balances which are rapid on the geological time scale. The Quaternary is thus distinguished by variations in climate and consequently in ecosystems. According to climatic changes, flora and fauna fill regions with fluctuating climatic boundaries, whereas humans, moving first in mobile and scattered groups to ensure their subsistence, get slowly organized in societies.

The other main definition of the Quaternary – dynamism – takes movement and change as essentials: dynamism of mountain runoff, evolution of river beds, changes in sea or lake shorelines, expansion, mutations, organization of human societies since the early Neolithic.

The Quaternary is therefore not, for the wider public, the object of faraway and fixed research that other geological eras (e.g. Primary or Secondary) represent, in which complete periods of the Earth's history remain poorly known.

For ages before the Quaternary, chronology techniques are based on flora and fauna variations, on sea transgression and regression mechanisms, on the resources of petrography and tectonics to explain plate tectonics, volcanism, orogeny or metamorphism. Continental deposits are precious to the study of the Quaternary, but, owing to a lack of significant fossils, they are only ancillary to the study of older geological periods. And climatic variations, which are established with difficulty in the absence of the complete range of flora and fauna, remain coarsely sketched before the Quaternary.

Conversely, in the Quaternary, the abundance of flora and fauna, the variations in their geographical distribution, the studies of erosion and sedimentation processes as a function of climate and vegetal cover, from knowledge of palaeoclimates obtained

Table I.1. Main subdivisions of the Quaternary.

Ages (1,000 years)	Geological stages	Palaeomagnetism
0	Holocene	Brunhes
10		
50 100	Upper Pleistocene or: Recent Quaternary	
150		
	Middle Pleistocene or: Middle Quaternary	
700	Lower Pleistocene or: Lower Quaternary Villafranchian	Matuyama
2,400	Beginning of Quaternary	
4,500	Plio-Villafranchian	

through marine and glacial cores, and finally the presence of fossil man, are among many reasons that explain why Quaternary history is mainly climatic.

The name 'Quaternary' was coined in 1829 by J. Desnoyer to define the marine deposits more recent than the Tertiary basins of the Bassin Parisien. H. Reboul published in 1833 the first Quaternary geology work. In 1939 C. Lyell suggested the definition within the Quaternary of the Pleistocene, as the period of the main glaciations, and the Holocene (a term coined in 1967 by P. Gervais) representing post-glacial times. Because of the climatic variations between glaciations, the Pleistocene is divided into three periods: Upper, Middle and Lower Pleistocene, with different durations. The beginning of the Quaternary is still called Villafranchian, a stage created in 1865 by L. Pareto to designate lacustrine and continental deposits following the Pliocene, found in the Piedmont basin near the town of Villafranca, Italy. The Villafranchian period covers a long time interval on the scale of the whole Quaternary, between the end of the Pliocene and the beginning of the Pleistocene.

In this book, the word Quaternary covers the whole geological era enclosing the Villafranchian, Pleistocene and Holocene (see Table I.1).

The age limits of the different stages in the Quaternary vary slightly with region, because of the deposits and criteria used to determine them.

The most delicate problem is the Tertiary–Quaternary boundary. Climatologists, geologists and palaeontologists have long argued about it. In the international

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geology meetings of London (1948) and Algiers (1952), it was decided that the beginning of the Quaternary would be linked to the first large climatic deterioration recorded in Europe around 1.8 Myr. This date was kept until the more recent meetings of Moscow in 1982 and Ottawa in 1987. In the meetings of Beijing in 1991 and Berlin in 1995, the advancement in research enabled extending the beginning of the Quaternary to 2.4–2.5 Myr in Consensus seems to have been reached, based on the palaeomagnetic scale, placing the boundary between the normal Gauss period and the reverse Matuyama period at 2.4 Myr.

This consensus is supported by several correlated events which occurred around the Earth at this time (see Chapter 10). Climatic variations become more rapid. Cold weather appears with humidity, as in China, Central Europe or the Chad Basin (Maley, 1980; Servant and Servant-Vildary, 1980). Loess sedimentation begins in China and in Alaska. Tertiary flora and fauna disappear, sometimes in vast numbers. The large Tertiary mountain chains undergo a major orogenic crisis, deforming the piedmont deposits. The consequences of the uplifts of Tibet and the Himalayan Chain are critical: increased coarse sedimentation, extended aridity over the Tibetan plateaus, more dynamic monsoon flux over the Himalayas. Tectonic movements and climatic changes modify drainage, moving toward patterns later found throughout the Quaternary. Finally, some authors believe that hominids start their diasporas at this time.

However, research on the subjects presented in the last two INQUA meetings, in Beijing and Berlin, shows that the will to define the lower limit of the Quaternary is faltering. This certainly results from research in various disciplines and in many more geographic areas, where the conditions of sedimentation, the diversity of landforms, and the conservation of fossils enable a more complete approach, extending investigations to less determinable time spans and to facts that are difficult to correlate. The same inquiry shows that the different periods of the Quaternary are not studied with the same interest. For example, in the Beijing congress, the Pliocene–Quaternary boundary still represents 14% of communications about chronology problems. In Berlin, this drops down to 6%. The Lower and Middle Pleistocene correspond to 12% of the communications in Beijing, but 28% in Berlin. This is attributed to a recent upsurge in interest for these poorly known periods. Conversely, the largest portion concerns the recent Pleistocene, the Dryas and the Holocene (i.e. less than 100,000 years of the 2.4 Myr) 72% of the communications in Beijing and 76% in Berlin). It should also be noted that the boundary between the Recent Holocene and the Holocene accounts for only 4% of communications in Berlin, compared with 19% in Berlin. The portion of prehistory in chronology sessions remains small (8% in Beijing, 11% in Berlin), with 5% of the 8% in Beijing and 10% of the 11% in Berlin concerning only the Neolithic. Chronology-related communications represent only 24% of all communications at the Chinese meeting, compared with 28% in Germany.

If we now look at the percentage of each topic relative to all topics (Figure I.1a), we see that regional aspects of research naturally play an important part: the study of Chinese loess forms 9% of the topics presented in Beijing, and only 4.5% in Berlin. Conversely, North and East European plains correspond to 14% of the topics in

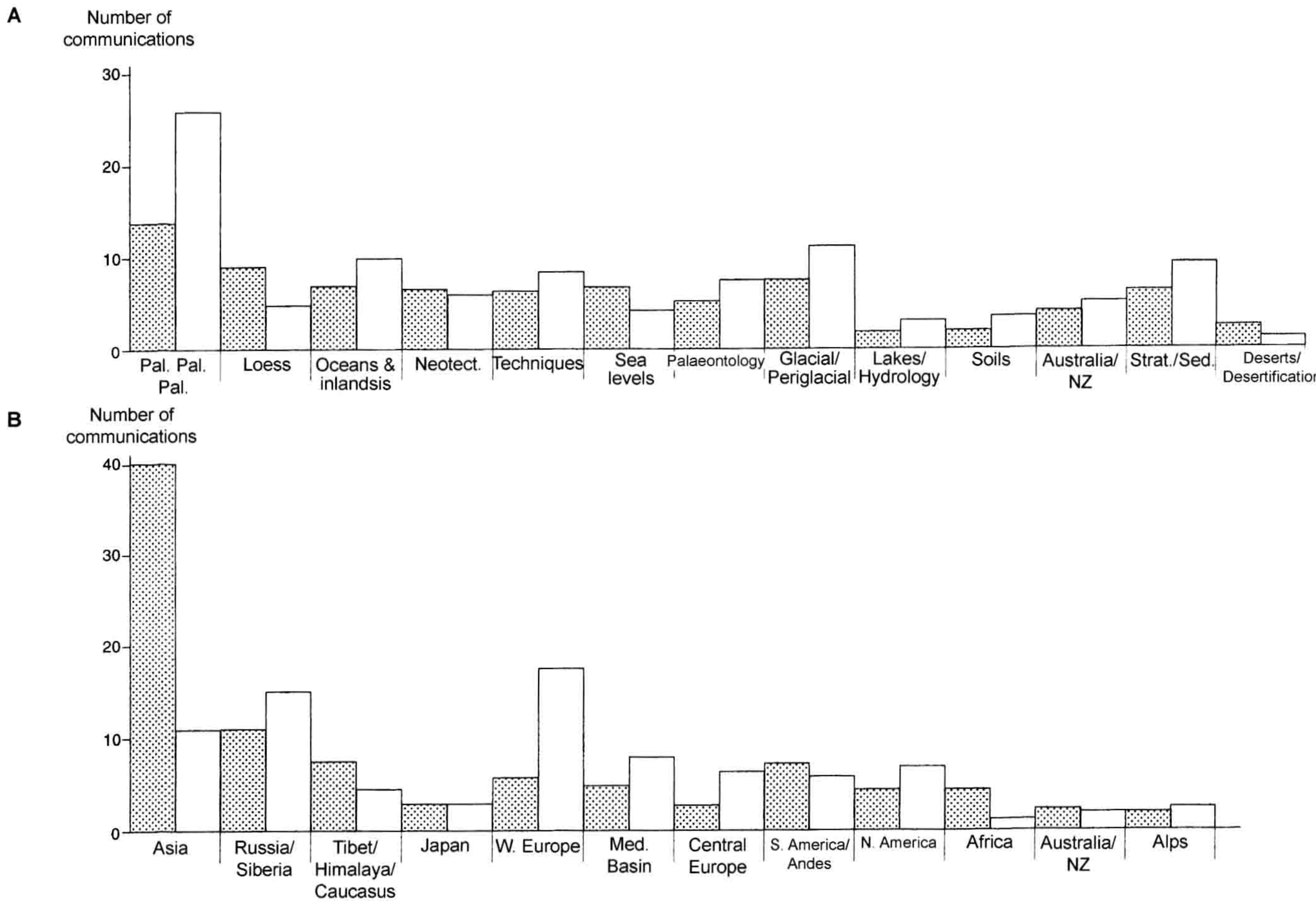

Figure I.1. (a) Comparative evolution of research topics between the meetings of Beijing (1991) and Berlin (1995); (b) comparative evolution of the regions studied.

Berlin, and only 4.3% in China. It must also be noted that the presentation of ongoing research is predominant: glacial and marine cores (e.g. Heinrich layers and Dansgaard–Oeschger events) play a part in 7% of topics in Beijing and 10% in Berlin. In 4 years, new discoveries account for the relative progression of these topics linked to scientific exploitation of cores taken in inlandsis and the ocean studies. The North Atlantic now corresponds to 1.5% of this topic, whereas it was nearly absent in Beijing.

Similarly, the progress between the two meetings in subjects like the study of periglacial and glacial deposits is significant. This progress is related to the presence of a larger number of scientists interested in these questions in Berlin (e.g. the German–Polish plain, Scandinavia or Northern Canada). Conversely, in Beijing, loess studies were best represented. We should also remark that Quaternary volcanism and karst are presented in less than 1% of communications. Prehistory remains very discrete, in part because it benefits from its own scientific meetings.

Figure 1.1b deals with the regions studied and the evolution of areas of research between the two meetings, and shows a few interesting points. The location of the two organizing cities explains the interest to a greater extent of Asia in one, and Western Europe in the other. We also notice the increasing interest from both parties in Russia and Siberia (including the Caucasus and Altai Mountains), and the Mediterranean Basin (in the latter Italian researchers are the most dynamic: 4% of 8% of topics in Berlin and 2.3% of 4% in Beijing). Another ineresting fact is the quasi-absence of Africa and the Alps in Beijing, and their presence in Berlin. However, to be complete, this study ought to have been conducted on the previous meetings as well, where studies of the African continents and the Alpine chains were more numerous.

This book does not present itself as an encyclopaedia, with the authors charged with putting forward the main characteristics of this geological period – for example, alteration and soils, slope formation, lake and river deposits, aeolian structures, glaciations, ocean studies, sea level changes, flora, fauna and human fossils. Instead, it was decided that the Quaternary should be described by means of natural environments which have always characterized the Earth, but which fluctuated during the Quaternary, mainly because of the climatic variations.

'The environment is termed natural when the main elements are not, or not much, transformed by Man' (Demangeot, 1992). Rocks, beaches, ergs and swamps are some examples. The environment is no longer natural when presenting human artefacts: irrigated fields or greenhouse cultures, buildings, factories, airports, etc.

For most of the Quaternary, the effects of humans are absent. From the Bronze Age, around 1700 BP (before present), the pressure of human societies starts to influence natural environments, especially in the plains and hills of the Mediterranean Basin (Leveau and Provensal, 1993).

Current studies deal mainly with recreation of palaeoclimates and palaeoenvironments. Research ends up describing large natural regions or natural palaeoenvironments. From the poles to the equator, these include: first the glacial regions; second the circumpolar and temperate regions in which traces of frost and periglacial erosion can be observed, along with fossil traces of passing inlandsis and mountain glaciers; third the Mediterranean environments at the boundary of temperate and arid regions, where the climatic, tectonic and human mobility mentioned above are essential; fourth the arid environments where dry landforms co-exist alongside past landforms from wetter times; and finally tropical environments where past and present chemical alterations are predominant. These regions, and especially Africa, are also the ones from which human groups slowly dispersed since the beginning of the Quaternary.

The abundance of available markers, the varied techniques for dating and studying sediments, the freshness of information and fossils, accord with a multidisciplinary and detailed approach of these natural palaeoenvironments. These studies are regional. They use data characteristic of precise natural environments. These can now be observed at other latitudes, because of the climatic changes throughout the Quaternary. The scientific approach commonly used consists in comparing the indices of a fossil environment with those of similar nature in a modern environment. This is called a *transfer function*. For all these reasons, we chose to present the study of the Quaternary through different natural environments.

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