Current Trends in Quaternary Geochronology

by Julie Brigham-Grette

The past decade has seen major advances in methods of dating Quaternary deposits. New isotope and chemical techniques involving, for example, radiocarbon, fission tracks, uranium-trend methods, thermoluminescence and amino acids, are now routinely used, together with paleomagnetic and oxygen isotope studies, to calibrate stratigraphic sequences and to date specific materials. Nevertheless, there are limitations in all these methods that have to be understood before such age determinations can be used properly. (Ed.)

Introduction

It has been said many times that the most fundamental need of any study in Quaternary stratigraphy, archaeology, or paleoecology is a firmly based geochronology. Without it we cannot understand the dynamics of the ocean-atmosphere system, rates of evolutionary change, sedimentation, and geomorphic processes, and there can be no proper regional or global correlation of critical events.

During the last 10 to 15 years there has been a rapid increase in knowledge of dating methods, and we have witnessed the development of new techniques (Fig. 1) that attempt to reach beyond the confines of the traditional radiocarbon method (see Rutter, 1985, for a general review). In many instances, such as thermoluminescence dating, methods initially conceived in the 1930s, 1940s, and 1950s have been resurrected due to improvements in speed and precision of techniques of measurement. The amino acid analysis of a single fossil sample in the early 1960s required as long as a week; the same sample today can be processed with better precision in half an hour.

In order to decide what technique or set of techniques to use in any given stratigraphic setting, an understanding is required of the basic assumptions implicit in the methods in question, as well as an appreciation of the actual age resolution desired. Sampling frequency is, as always, an important consideration. There is, however, a certain amount of inherent variability in all geochronologic techniques, both relative or "absolute." This variability may be in a geological source like contamination by weathering, fluctuations in the temperature or groundwater history, or in an analytical source such as the reproducibility of replicate samples on even the most up-to-date laboratory equipment. The resolution of climatic fluctuations and their rates of change in any geomorphological system are no better than the precision of the dating method being used and the sampling interval. Although this may seem rather obvious, many ignore it to obtain pieces of detail verging beyond the edge of scientific speculation. Such conjecture is certainly a critical part of scientific creativity, but only so long as that line between actual data and speculation is clearly defined.

Advances in Techniques

Geochronological techniques developed and refined over the past fifteen years have led to the revision and rethinking of the stratigraphy and paleoclimatic implications of deposits in many areas. Paleomagnetic and isotope stratigraphy in deep-sea cores (e.g. Shackleton and Opdyke, 1973) finally convinced everyone that the time-honoured four-fold subdivision of the glacial history of both North America and Eurasia was much oversimplified. This revelation shook the foundation of long-held concepts of the nature of the Pleistocene and compelled reconsideration of the complexity and patchy nature of deposits once forced to conform to the traditional subdivisions. Refinement of the loess stratigraphy in central Europe (e.g., Kukla, 1975, 1978; Fink and

Kukla, 1977) provided one of the first land-based records to concur with this more dynamic view of Pleistocene history. As another example, the original four-fold subdivision of the glacio-fluvial terraces emanating from the Alps are broken down into as many as 13 different sequences (Brunancker et al., 1982).

Fission-track and paleomagnetic methods have helped to identify glacial tills from 2.2 to 2.5 Ma old in the midwestern U.S.A., nearly one million years older than the type Nebraskan (Easterbrook and Boelstorff, 1984). In the Pacific Northwest, similar methods have been used to demonstrate that the Salmon Springs Drift, once thought to be of early Wisconsin age based on an

Figure 1: The useful timespan of various Quaternary geochronological techniques. ESR - electron spin resonance.

enrichment radiocarbon date of 71,000, is actually closer to 800,000 yBP, requiring considerable revision of the regional stratigraphy and glacial history (Easterbrook et al., 1981). Deposits in the Old Crow Basin of the Canadian Yukon, previously regarded as early Wisconsin in age on the basis of physical stratigraphy (Hughes, 1969), are now known to be older than 1.2 Ma based on fission-track dates on the Little Timber tephra (J. Westgate, personal communication).

Advances in accelerator radiocarbon dating now make it possible to determine the numerical age of samples weighing less than a milligram without, however, extending the maximum upper limit of the traditional beta-counting procedure. Amino acid geochronology has recently contributed to our understanding of marine interglacial deposits of Europe (Miller and Mangerud, 1985; Bowen et al., 1985). Dating methods using Th/U and electron spin resonance continue to offer two alternatives for the absolute age of the Holsteinian interglacial, with Sarnthein and others (1986) arguing for stage 11, while Linke and his colleagues (1985) prefer stage 7. Even the inevitable oxygen isotope time scale has been tuned to the rhythm of the Milankovitch orbital sequence (Imbrie et al., 1984). Vita-Finzi (1973) and others have gone so far as to suggest that conventional chronostratigraphic terms be abandoned altogether in favour of simple geochronometric dates as a frame of reference.

Commentary

Geochronology in the broadest sense is a joint effort between the chemists and physicists, who develop and improve the theory and analytical basis of different dating methods, and the field worker, who applies the methods to materials of stratigraphic context. Often there is a long delay between an analytical breakthrough and the dissemination of that information to field researchers and eventually to their students. Therefore, it is especially important that both groups keep each other informed so as to avoid the dilemma of the uncritical researcher who accepts a radiocarbon date or a uranium series date without considering the problems and possible errors involved in determining it.

Field workers should be well informed as to the inherent sources of variability in different methods. Too often a particular technique gains a bad reputation simply because the field worker lacks an understanding of its physical basis and inherent limitations. Most numerical dates are simply a measure of statistical probability, and it is up to the field worker to interpret what the numbers really mean with reference to the stratigraphy.

The variables and assumptions involved in all Quaternary dating methods used for Quaternary studies will no doubt provide the impetus for advances in geochronological techniques in the years to come. A special focus will be on methods, such as uranium-trend dating, to fill in gaps in determining the absolute age of middle Pleistocene materials (125,000 to 750,000 yBP). Such advances will not only improve our understanding of the Quaternary, but also improve the science of geochronology as well.

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