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PREFACE

COSMOGENIC ISOTOPE PALEOGEOPHYSICS - PALEOASTROPHYSICS AND NATURAL VARIATION OF COSMOGENIC ISOTOPES

In order to confirm the radiocarbon half-life of 5568 ± 30 years, based upon then available measurements, Willard Libby (1955) produced the first calibration of the radiocarbon time scale, using samples of known age dating back to 5000 BC. He concluded that this half-life was valid and that the $^{14}C/^{12}C$ ratio of atmospheric CO_2 was sufficiently constant to permit accurate dating of paleoevents. A few years later, this assumption was brought into question by Hessel de Vries' (1958) discovery of fluctuations of the $^{14}C/^{12}C$ atmospheric ratio of up to 2% during the Little Ice Age, involving an inaccuracy of the time scale of 160 years. Shortly afterward, workers in the United States demonstrated that the de Vries effect 'wiggles' were superimposed upon longer-term trends (Ralph & Stuckenrath 1960; Suess 1961; Damon, Long & Sigalove 1963). At the International Radiocarbon Conference in Cambridge (Godwin 1962a), accurate measurements were available to designate a new half-life (5730 ± 40 years) (Godwin 1962b) for geophysical-geochemical purposes, and it was then apparent to all attendants that systematic calibration of the radiocarbon time scale was essential (see Damon 1987, for a history of the calibration of the radiocarbon time scale).

Willis, Tauber and Münnich (1960) showed that the de Vries-effect secular variations extended back over the past 1300 years, and appeared to be cyclical, with a period of about 200 years. Shortly thereafter, Stuiver (1961, 1965) demonstrated that the de Vries effect was the result of modulation of radiocarbon production by solar activity. At an earlier date, Suess (1955) had demonstrated a rapid decrease in atmospheric ^{14}C activity resulting from injection of ^{14}C-depleted CO_2 into the atmosphere from combustion of fossil fuels (the Suess effect). It then became apparent that there were generally three categories of possible causes for secular variation of atmospheric ^{14}C: 1) variations in the global rate of ^{14}C production; 2) variation in the rate of exchange between geochemical reservoirs accompanied by changes in the inventory of the various geochemical reservoirs of CO_2; and 3) variations in the total C content of all reservoirs that contain significant amounts of ^{14}C (atmosphere, biosphere, hydrosphere and sediments).

By the time of the 12th Nobel Symposium on "Radiocarbon Variations and Absolute Chronology" held in Uppsala during the summer of 1969, the most significant causes of secular variation of atmospheric ^{14}C had been identified (Olsson 1970): changes in the Earth's dipole moment, changes in solar activity and changes in climate. Attention had also been drawn to possible changes in the galactic cosmic-ray flux entering the solar system, such as those caused by supernovae explosions (Konstantinov & Kocharov 1965; Lingenfelter & Ramaty 1970) or possible intrusion of antimatter into the solar system (Libby 1965). Thus, the 12th Nobel Symposium was a 'watershed' dividing the earlier exploratory research and the subsequent developments in ^{14}C research. The results of 1200 intermediate-precision ^{14}C measurements on tree rings provided the basis for subsequent paleogeophysical-paleoastrophysical studies (Damon *et al.* 1980), until high-precision calibrated dates back through the 8th millennium BC were published following the 12th International Radiocarbon Conference held in Trondheim in June 1985 (Stuiver & Kra 1986). A new set of data will shortly become available with the publication of the new Calibration Issue 1993 (Stuiver, Long & Kra 1993).

Most early research was based on decadal or bidecadal tree-ring samples. The study of solar variations additionally requires annual data to examine the solar activity in both its harmonic and chaotic phases. It is important to extend available data beyond the last 10,000 years and into the last glacial age. The use of other isotopes in other natural archives, such as ^{10}Be in polar ice, is an essential adjunct to complement ^{14}C and, more importantly, to extend our paleogeophysical-paleoastrophysical work back over hundreds of thousands and even millions of years. New instrumental concepts are evolving (Pavlov, Kogan & Gladkov 1992), as well as a new understanding of solar physics (Nesme-Ribes & Mangeney 1992).

It is important to recall that instrumental measurements of geophysical fields and astrophysical phenomena extend back only a few centuries. The use of cosmogenic isotopes opens a window into the much more distant past. The diligent reader of this issue will be rewarded with an overview of the advances and future directions of a relatively new field.

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