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CLIMATE RECORDS IN CORAL SKELETONS

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INTRODUCTION

The subject of calibrating and interpreting chemical information in coral skeletons has gained importance over the past ten years for purposes of interpreting changes in past environments. However, the study of the chemistry of coral skeletons is certainly not new. Chemical analyses of trace elements in coral skeletons have been around for literally decades while the first pioneering steps in the field of stable isotopes in coral skeletons were presented in the papers of Weber in the early 1960s (Keith and Weber, 1965). These efforts were mainly descriptive and it was not until the 1970 that the first coherent explanations emerged on the factors governing the fractionation of carbon and oxygen isotopes in coral skeletons (Weber and Woodhead, 1970) as well as minor elements such as Sr, Mg, and Na in coral skeletons (Amiel et al., 1973; Weber, 1973, 1974) and trace elements (St. John , 1974). The studies of Weber and Woodhead (1972) and Weber (1974) were principally useful in establishing a relationship between temperature and the oxygen isotopic and strontium concentration in corals.

The real usefulness of chemical information in coral skeletons only became apparent after the existence of density bands were discovered (Knutson et al., 1972; Macintyre and Smith, 1974; Buddemeier et al., 1974). The annual density bands in coral skeletons were similar to tree rings and hence the chemical information could be analyzed within this annual chronology. The first investigations to utilize this approach were published by Goreau (1977) and Emiliani et al. (1978). Although these studies led to information on when during the year the density band formed, the mechanism of sampling the skeleton was still crude and these workers failed to detect the full annual range of temperature in the oxygen isotopic and strontium composition as predicted from the original studies. In 1979 two important studies were published. One by Smith et al. (1979) grew corals under carefully controlled conditions determined a more precise association between Sr and temperature. The second was by Fairbanks and Dodge (1979) which was the first study which really established that the full range of temperatures could be detected in coral skeletons using the oxygen isotopic composition. Fairbanks and Dodge also suggested that the degree of correlation between the carbon and oxygen isotopic composition was determined by correlation between the amount of sunshine and the temperature. In those instances where the sunniest portion of the year occurred during the warmest time of the year, there would be an inverse correlation. If the time of greatest insolation occurred during the coolest time of the year, a positive correlation would result. The next significant advance to take place was the publication of a paper by McConnaughey (1989) which described a new theory on the isotopic fractionation of both carbon and oxygen isotopes. This work introduced the idea that significant kinetic effects influenced the isotopic composition, with slower growing corals approaching isotopic equilibrium with respect to their environment. McConnaughey also suggested that the reason that coral skeletons were not in oxygen isotopic equilibrium with their environment was that because metabolic CO_2 which was depleted in ^{18}O, did not have sufficient time to come into isotopic equilibrium with their surrounding environment. The 1990s saw the publication of the first attempts to use the isotopic records to help to retrospectively predict climate. In particular attempts were made to use the isotopic composition to help predict instances of ENSO (Cole et al., 1993). Most unusual in this regard was the recognition that the isotopic composition of the water the growth environment of the coral was not constant and that it was strongly influenced by the salinity which in turn was influenced by precipitation and runoff. The dependence of the oxygen isotopic composition on both salinity and temperature meant that workers needed a proxy for salinity or a second proxy for temperature. The Sr content was possible candidate but its use had been limited as the methods used to analyze Sr (atomic absorption) had a precision of approximate 5%, much to large to detect small changes in the strontium concentration caused by temperature. In 1992 a paper was published by Beck et al. (1992) which used the analytical method of thermal ionization mass spectrometry to analyze the concentration Sr with a reproducibility of less than 0.1%. This improvement in precision has meant that it is now possible to construct chronologies of both oxygen isotopes and strontium and use the two signals to extract temperature and salinity. Over the past five years there have been many additional influential and important papers including attempts to use more difficult to measure trace elements to ascertain information about changes in the nutrient status. The interpretation of one parameter, the carbon isotopic composition, has however remained elusive. Early promise that the carbon isotopic composition might be an indicator of insolation has proven to be too simplistic an approach and suggestions have been made that its is influenced by parameters such as reproduction, changes in heterotrophy and autotrophy (Swart et al., 1996).

This papers in this symposium represents a further extension of the advances which have been made in the study of proxy records in coral skeletons. The large number of papers on the subject which were both originally submitted for this theme session and the Coral Reef symposium speak to this advance and represents a significant increase in numbers over the Guam meeting.

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