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Cenozoic carbon isotope shifts and marine biological productivity: a review.

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Benthic foraminiferal carbon isotope records are widely used as a tracer of the global carbon cycle. Carbon isotope maxima accompany times of ice expansion at the Eocene/Oligocene (33.5 Ma) and Oligocene-Miocene (23.0 Ma) boundaries as well as the middle Miocene, an interval of relative global warmth (16-14 Ma). A negative carbon isotope shift occurs in the late Miocene (7-8 Ma) signifying the development of permanent Pacific to Atlantic Ocean carbon isotope gradients. Here we review proxy reconstructions of primary paleoproductivity and numerical modelling results focused on resolving the factors that lead to the observed associations between apparent changes in the carbon cycle and global climate change. Reconstructions of paleoproductivity, which are based on benthic foraminiferal accumulation rates (Herguera, 2000) show clear increases in productivity during the Eocene/Oligocene transition (Diester-Haass and Zahn, 1996; 2001; Diester-Haass and Zachos, 2003; confirmed by other proxies, e.g. Zachos et al., 1996; Salamy and Zachos, 1999; Schumacher et al, 2004), and during the Oligocene-Miocene transition (Diester-Haass et al., in review), which may reflect the effects of enhanced productivity and carbon burial as global climates cooled. The carbon isotope maximum spanning the middle Miocene interval of warmth, on the other hand, cannot be explained by changes in marine productivity (Diester-Haass et al., 2009) contrary to the "Monterey Hypothesis" of Vincent and Berger (1985). Here numerical box models show that it is the storage of light carbon in terrestrial reservoirs (e.g., in lignite deposits) that can account for the observed increase in marine [U+F064]13 values. The Late Miocene negative carbon isotope shift occurs during a time of generally enhanced primary productivity and has received much attention in the literature (Farrell et al., 1975; Prell et al, 1992; Dickens and Owen, 1999; Grant and Dickens, 2002). Numerical sensitivity tests indicate that both, the transfer of carbon between the terrestrial and the marine reservoirs as well as increased productivity can explain the magnitude of the observed changes (Diester-Haass et al., 2006). Taken together it is becoming apparent that different aspects of the carbon cycle are involved in shaping the benthic foraminiferal carbon isotope record. Geochemical models are essential to test whether changes in one aspect (e.g., carbon transfers between reservoirs) or another (e.g., biological primary productivity) can explain the observed variations.