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The ormer (*Haliotis tuberculata*): A new, promising paleoclimatic tool

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ABSTRACT

This study aimed to investigate the environmental controls on the oxygen isotope composition of shells of the European abalone, *Haliotis tuberculata*. Seasonal $\delta^{18}O$ profiles from the outer prismatic layer of four abalone shells, collected live in northwest Brittany (France) in 2002 and 2012, were compared to local temperatures and salinities. According to the findings herein, $\delta^{18}O$ variations in abalone shells corresponded to seasonal variations, and thus, shell composition represented a reliable tool for aging and growth studies. Seawater temperatures estimated from the abalone collected in 2012 reflected the in situ measured temperatures, but the reconstructed temperatures from shells of the three specimens collected in 2002 deviated from measured temperatures by 2.5 °C. This overestimation of temperatures corresponded to a "kinetic effect" related to very high annual abalone growth rates; thus, it could be corrected by applying +0.53‰ to the $\delta^{18}O_{shell}$. This methodology was then applied to a fossil (6000 cal yr BP) collected in the Bay of Biscay. Given the worldwide distribution of both live and fossilized abalones, the results of the present study showed that this genus represents a promising paleoclimatic tool.

1. Introduction

Knowledge of past environmental variations is a prerequisite for understanding possible future climate changes in a warming world. Environmental parameters, such as ocean temperature and salinity, have been directly measured only over a relatively short instrumental period (Hurrell and Trenberth, 1999; Smith and Reynolds, 2003). For time intervals prior to 1860, stable oxygen isotope values of carbonates serve as an important temperature proxy. The temperature dependency of oxygen isotope fractionation has been quantified for inorganically precipitated calcite (Urey, 1947; McCrea, 1950; O'Neil et al., 1969; Kim and O'Neil, 1997). The temperature dependency of oxygen isotope fractionation has also been established for living organisms, both in the field and in laboratory cultures, for corals (Reynaud-Vaganay et al., 1999), mollusks (Epstein et al., 1953; Grossman and Ku, 1986), and planktonic foraminifera (Erez and Luz, 1983; Bernis et al., 1998; Barras et al., 2010). Thus, analysis of the oxygen isotope values ($\delta^{18}O$) in mollusk shells can provide a precise determination of the temperature of the water in which the animals lived (Krantz et al., 1984; Kennedy et al., 2001; Chauvaud et al., 2005).

Shells of bivalves have received considerable attention in paleoclimate studies; in particular oysters (Kirby et al., 1998; Kirby, 2001; Lartaud et al., 2010; Ullmann et al., 2010; Harzhauser et al., 2011), scallops (Hickson et al., 1999; Chauvaud et al., 2005; Johnson et al., 2009), mussels (Donner and Nord, 1986; Freitas et al., 2005), and clams (Arthur et al., 1983; Schöne et al., 2004; Gillikin et al., 2005; Schöne et al., 2005). However, the shells of gastropods are often more difficult to use. This problem can be partly attributed to the morphology of gastropod shells and partly to the difficulty in preparing cross-sections to reveal internal growth patterns (Schöne et al., 2007; Radermacher et al., 2009; Tao et al., 2013). Internal growth patterns are useful to place the geochemical data into a temporal context. So far, no aging technique based on growth pattern analyses has been established and validated for abalones (Ward, 1986; Day and Fleming, 1992; Erasmus et al., 1994; Day et al., 2001). The use of stable oxygen isotopes was proposed as an alternative method for aging abalone shells in determining growth rates for fisheries management (Gurney et al., 2005; Kim and Hudson, 2007; Naylor et al., 2007; Roussel et al., 2011) and stock discrimination (Lee et al., 2002). To our knowledge, stable isotopes of abalone shells have not been employed to reconstruct paleo-environmental changes.

Abalones are widely distributed in temperate and tropical waters throughout the world (Shepherd and Steinberg, 1992). *Haliotis* species

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