Chemie der Erde 75 (2015) 65–72

Contents lists available at ScienceDirect

Chemie der Erde

journal homepage: www.elsevier.de/chemer

Stable isotopic signatures of the modern land snail *Eremina desertorum* from a low-latitude (hot) dry desert—A study from the Petrified Forest, New Cairo, Egypt

Kamaleldin M. Hassan*

Department of Radioactive Sedimentary Deposits, Research Sector, Nuclear Materials Authority, Cairo, Egypt

ARTICLE INFO

Article history:
Received 25 October 2013
Accepted 30 September 2014
Editorial handling - A. Deutsch

Keywords:
Desert land snails
Oxygen isotopes
Carbon isotopes
Climate
Dry soils
C3/C4 plants

ABSTRACT

This study was conducted on recent desert samples—including (1) soils, (2) plants, (3) the shell, and (4) organic matter from modern specimens of the land snail *Eremina desertorum*—which were collected at several altitudes (316–360 m above sea level) from a site in the New Cairo Petrified Forest. The soils and shell$_{E.\ desertorum}$ were analyzed for carbonate composition and isotopic composition (δ^{18}O, δ^{13}C). The plants and organic matter$_{E.\ desertorum}$ were analyzed for organic carbon content and δ^{13}C. The soil carbonate, consisting of calcite plus minor dolomite, has δ^{18}O values from −3.19 to −1.78‰ and δ^{13}C values −1.79 to −0.27‰; covariance between the two values accords with arid climatic conditions. The local plants include C3 and C4 types, with the latter being dominant. Each type has distinctive bulk organic carbon δ^{13}C values: −26.51 to −25.36‰ for C3-type, and −13.74 to −12.43‰ for C4-type plants.

The carbonate of the shell$_{E.\ desertorum}$ is composed of aragonite plus minor calcite, with relatively homogenous isotopic compositions ($\delta^{18}O_{mean} = -0.28 \pm 0.22‰$; $\delta^{13}C_{mean} = -4.46 \pm 0.58‰$). Most of the δ^{18}O values (based on a model for oxygen isotope fractionation in an aragonite-water system) are consistent with evaporated water signatures. The organic matter$_{E.\ desertorum}$ varies only slightly in bulk organic carbon δ^{13}C values (−21.78 ± 1.20‰) and these values suggest that the snail consumed more of C3-type than C4-type plants. The overall offset in δ^{13}C values (−17.32‰) observed between shell$_{E.\ desertorum}$ carbonate and organic matter$_{E.\ desertorum}$ exceeds the value expected for vegetation input, and implies that 30% of carbon in the shell$_{E.\ desertorum}$ carbonate comes from the consumption of limestone material.

1. Introduction

Land snails are gastropod mollusks with carbonate shells; their lifespan according to Heller (1990) varies from one species to another, with the majority of species living to around 1–2 years. The snails contain geochemical sensors of environmental change, mainly in the form of isotopic signatures. These organisms are susceptible to dehydration in arid or semi-arid regions by losing water via evaporation from body fluid. The amount of water loss depends on the relative humidity of the ambient environment, which in turn, is controlled by the temperature and pressure of the system. Because land snails are active during night and following rains (generally at temperatures between 10 and 27 °C and relative humidities above 70%), it has been assumed that snails' growth (i.e. secretion of the shell) takes place during times of relatively moist conditions when snails tend to be active (see Balakrishnan and Yapp, 2004, for references). Consequently, the oxygen isotopic compositions of their shell carbonate may potentially record that of meteoric water at the time of shell precipitation, and should reflect conditions under a comparatively narrow range of moderate temperatures and high relative humidities. While some efforts from semi-arid and arid areas to relate the oxygen isotopic compositions of snail shells and local precipitation have failed (e.g. Goodfriend and Magaritz, 1987; Goodfriend et al., 1989; Colonese et al., 2007), several others studies have shown a relationship between local meteoric waters and δ^{18}O values of snail shells (e.g. Yapp, 1979; Bonadonna et al., 1999; Goodfriend and Ellis, 2002; Zanchetta et al., 2005; Yanes et al., 2008).

The values of δ^{13}C of the snail shells, on the other hand, are related to the isotopic composition of respiratory CO_2 derived from the assimilation of vegetation-based food resources (McConnaughey et al., 1997; McConnaughey and Gillikin, 2008) and to the isotopic composition of carbonates ingested by the snails (e.g. Goodfriend, 1987; Yanes et al., 2008). In contrast, the δ^{13}C values of the shell-bound organic carbon are primarily related to the isotopic composition of the vegetation diet (e.g. C3 vs. C4)

---

* Tel.: +20 27585831.
E-mail address: egy100@yahoo.com

http://dx.doi.org/10.1016/j.chemer.2014.09.002
0009-2819/© 2014 Elsevier GmbH. All rights reserved.

of the snails (Stott, 2002). In short, the $\delta^{13}C$ values of land snail records should reflect the $\delta^{13}C$ compositions of carbon sources that the organism consumed (e.g., Goodfriend and Magaritz, 1987; Goodfriend, 1988, 1990, 1992; Goodfriend and Ellis, 2000, 2002; Balakrishnan et al., 2005a,b; Yanes et al., 2008, 2009). These compositions are a reflection of the climatic conditions such as humidity or aridity of an environment.

There still remain large uncertainties in the feeding behavior and physiology of land snails, and consequently the isotopic compositions of snail carbonate and organic matter. Thus, the $\delta^{18}O$ and $\delta^{13}C$ components in the snail paleorecord are not precise indicators of the environments of snail-shell formation, but are most usefully reviewed along with other evidence of snail ecosystem conditions. Here, the author has integrated stable isotope data from recent desert communities at the New Cairo Petrified Forest, including soils, plants, as well as shell carbonate and organic matter of the land snail *E. desertorum*. The objective is to assess stable—O and C isotope signatures extracted from the carbonate and organic matter of the snail in relation to environmental variables characterizing their ecosystem. This, in turn, should allow us to better interpret the isotopic signals contained in the modern and fossil records of this snail, a species also occurring in fair abundances in other locations in Egypt (Biggs, 1959; FMNH, 2013; VBG, 2013) and Palestine (Mienis, 2004).

2. Materials and methods

The study area (Fig. 1), a natural reserve desert covering ~6 km² is located in New Cairo, about 20 km east of Old Cairo, Egypt. Low altitude predominates, with elevations from 290 to 375 m above sea level (masl). The exposed rock unit in the area known as the late Eocene Maadi Formation is made up of sand, gravel and calcareous shale (Hermina and Lindenberg, 1989), with a large number of silicified tree trunks (El-Saadawi et al., 2011). The soils there are dry, consisting of sand plus minor amounts of clay and carbonate, with minimal organic matter. Vegetation is limited to a few species of dry grasses and small shrubs. There are numerous well-preserved snail shells of variable sizes lying on the ground or buried partially by sand and gravel (Fig. 2) where no living population is present at the moment. These shells, identified as individuals of *Eremina desertorum*, were seen on slopes, open sites and, to a lesser extent, in direct association with vegetation and broken pieces of fossilized tree trunk. They appear of recent age where organic matter—a dry brown/dark substance—is occasionally found inside the upper whorls, which is mainly derived from decompositions of snail body tissues.

For this study 37 samples were selected from several sites (between 316 and 360 masl; Fig. 1): (1) 5 samples of soils, (2) 10 samples of plants, (3) 12 samples of shell$_{E.\ desertorum}$, with very similar sizes and shapes, and (4) 10 samples of organic matter$_{E.\ desertorum}$ that had been trapped in the upper whorls of snail shells and was then removed after the shells were chopped into sections. The soil and shell$_{E.\ desertorum}$ samples were dried at room temperature and then were ground and converted to powder, so each analyzed aliquot represents a homogenized specimen. Powder samples were analyzed by X-ray diffraction (XRD) using a Philips X'Pert diffractometer (Cu-radiation) and were analyzed for magnesium (Mg) and calcium (Ca) contents by titration against EDTA after acid digestion at the Central Laboratory Sector of the Egyptian Mineral Resources Authority, Cairo.

Aliquots of the shell$_{E.\ desertorum}$ for determinations of their $CaCO_3$ content and isotopic composition were reacted in 105% phosphoric acid in vacuo at 90 °C with an individual sample Multicarb device attached to a GVI IsoPrime isotope ratio mass spectrometry (IRMS). The resulting CO_2 was cryogenically purified of H_2O vapor at −94 °C, concentrated on a cold finger at −180 °C, and introduced directly into the IRMS inlet at the Stable Isotope Laboratory, University of California, Davis, USA. Bulk soil samples were processed similarly, but analyzed using a common acid bath autocarbonate device attached to a Fisons Optima isotope IRMS. Multiple samples of a laboratory marble standard (UCD-SM92) which was previously calibrated against NBS-19 (limestone), were weighed and analyzed with the samples in order to standardize the stable isotope data to V-PDB (Vienna Pee Dee Belemnite) and to compute wt% $CaCO_3$ content of the samples through a regression comparison of the standard mass to mass 44 beam intensity. Isotopic data are expressed in per mil (‰) values using standard delta (δ) notation: where $\delta^{13}C$ or $\delta^{18}O\ (‰) = [(R_{sample})/(R_{standard}) - 1] \times 1000$ and R is a $^{18}O/^{16}O$ or $^{13}C/^{12}C$ ratio. Precision is ±0.07‰ for $\delta^{13}C$ and ±0.04‰ for $\delta^{18}O$ ($\pm 1\sigma$). The analytical precision of the measured $CaCO_3$ content is ±0.14 wt% for soil and ±0.1–5.6 wt% for shell$_{E.\ desertorum}$ samples.

Samples of the plants and organic matter$_{E.\ desertorum}$ to be measured for their organic carbon content and isotope composition were reacted with HCl to dissolve carbonates and then water washed. The samples were dehydrated in an oven at about 80 °C, and then ground. Subsamples of 1–4 mg were weighted into tin capsules and analyzed for weight percent of organic carbon in a Vario EL Cube elemental analyzer (EA), where combustion of the samples occurred at 1000 °C. The CO_2 produced after combustion was analyzed on a PDZ Europa 20–20 IRMS attached to the analyzer (the Stable Isotope Facility, University of California, Davis, USA) and the carbon isotope results are reported in δ notation, as ‰, with respect to the V-PDB standard. EA-IRMS precision (standard deviation determined from duplicate samples, using G-7 Peach leaves, G-18 Nylon and USGS-41 as the reference materials) was ±1.4 wt% for organic carbon analysis and of ±0.2‰ V-PDB for $\delta^{13}C$ ($\pm 1\sigma$) in the samples.

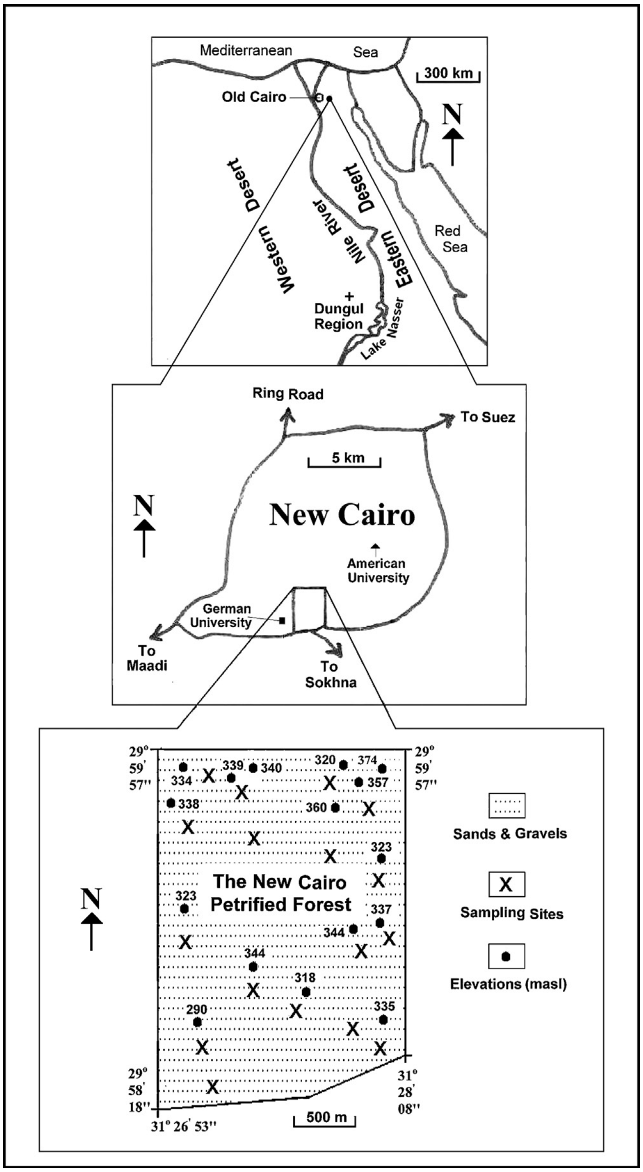

Fig. 1. Geographical location of the study area, with sampling sites and elevations.

3. Results

The powder X-ray diffractograms with identifications of minerals are shown in Fig. 3. In the samples of the shell$_{E.\ desertorum}$, aragonite was identified as the main component with a minor amount of calcite. In the soils hosting these shell samples, on the other hand, in addition to the major mineral quartz, amphibole, plagioclase, kaolinite, and calcite low in magnesium were identified by XRD analysis as minor components; they were associated with minor amounts of dolomite.

The $CaCO_3$ contents of the shell$_{E.\ desertorum}$ samples ranged from 94.7 to 99 wt%, while the CaO ranged from 53 to 53.5 wt% and the