Evidence from fluid inclusions extends the record of seawater chemistry by ~300 million years, from ~544 Ma to ~830 Ma

NATALIE SPEAR[1]*, H.D. HOLLAND[1],
JAVIER GARCIA-VEIGAS[2], T.K. LOWENSTEIN[3]
AND ROBERT GIEGENGACK[1]

[1]Earth and Environmental Science, Univ. of Pennsylvania, Phila., PA 19014, USA (*correspondence: nahilln@sas.upenn.edu)
[2]Univ. of Barcelona, Barcelona 08028, Spain
[3]Department of Geological Sciences, State Univ. of New York at Binghamton, Binghamton, NY 13902, USA

We analyzed primary fluid inclusions in halite from marine evaporites in the ~830-Ma Browne Formation of the Officer Basin in Western Australia by the Cryo-SEM-EDS technique. The parent seawater, calculated from the concentrations measured in those inclusions, contained ~565 mmolal Cl^-, ~456 mmolal Na^+, ~50 mmolal Mg^{2+}, 9-12 mmolal Ca^{2+}, $\geq$ 3 mmolal SO_4^{2-}, and ~1 mmolal K^+. The concentrations of the major ions, except K^+ and possibly SO_4^{2-}, fall within the known range of Phanerozoic seawater composition. Ours is the first direct measurement of the composition of Mid-Neoproterozoic seawater, and extends direct documentation of seawater chemistry by ~300 Ma.

We sampled the Browne Formation from two cores (Empress 1A and Lancer 1), both from the western Officer Basin, a large intracratonic basin that covers an area of ~525,000 km^2 in Western and South Australia. In spite of the distance between the two studied wells (~264 km), the lithology and thicknesses throughout the sedimentary succession of the encountered Browne Formation are remarkably similar.

The amount of sulfate in the Mid-Neoproterozoic ocean was closely linked to the amount of oxygen in the atmosphere and deep ocean. Our estimates suggest that Mid-Neoproterozoic marine-sulfate concentrations were considerably lower ($\geq$ 10%) than modern values. By terminal Neoproterozoic time, the composition of fluid inclusions in halite and the mineralogy of evaporite rocks indicate that seawater-sulfate levels rose significantly, to 50 to 80% of modern concentrations, a trend that parallels a similar increase in atmospheric and oceanic oxygen. By imposing a tighter constraint on the sulfate levels of Neoproterozoic seawater, we can define more accurately the circumstances and timing of the oxygenation of the Earth's atmosphere and oceans.

Geochemical evolution of prehistoric magma sources beneath Mt. Etna

E.A. SPENCE[1], H. DOWNES[1]*, J. BLICHERT-TOFT[2],
J.G. BRYCE[3] AND E. HEGNER[4]

[1]Dept of Earth and Planetary Sciences, Birkbeck University of London, UK (*correspondence: h.downes@ucl.ac.uk)
[2]Ecole Normale Supérieure de Lyon, Lyon, France.
[3]UNH Earth Sciences, Durham, New Hampshire, USA.
[4]Dept of Earth and Environmental Sciences, Ludwig-Maximilians Universität, Munich, Germany.

Prehistoric alkalic lavas of Mount Etna representing a ~70 ka time span, sampled from four vertical sections in the southern wall of the Valle del Bove (VdB), exhibit geochemical and isotopic variations distinguishing them as six separate lithostratigraphic and volcanic units within the newly defined framework of Etna [1]. Intersecting geochemical correlations between lavas highlight their stratigraphic relationships, and new isotopic data such as $^{87}Sr/^{86}Sr$ (0.7033-0.7036) and $^{206}Pb/^{204}Pb$ (19.76-20.02), indicate subtle changes in evolution of the magma sources beneath Etna. The alkalic centres of the VdB and modern Etna no longer tap the source(s) of ancient Iblean magmatism (2.6-1.4 Ma) [2]. Isotopic variations indicate that the oldest unit Salfizio-1 (>85 ka) tapped a mantle source similar to present-day Etna ($^{87}Sr/^{86}Sr$ >0.7035), while four other units relate more closely to the source of historic Etna magmatism ($^{87}Sr/^{86}Sr$ <0.7035) [3]. The sixth group, part of Piano Provenzana formation (~42-30 ka) of Ellittico, has the most chemically evolved lavas (58-62 wt% SiO_2) and exhibits lower Hf and Nd isotopic ratios and less radiogenic $^{206}Pb/^{204}Pb$ and $^{87}Sr/^{86}Sr$ than the oldest unit, implying that the temporal trend generally observed in the evolution of Nd-Sr isotope systematics breaks down over a ~70 ka period. Mt. Etna's unique position on an accretionary wedge related to the Calabrian Arc, formed during convergence of the African and Eurasian plates and close to the extensional Malta Escarpment [4], presents a complicated tectonic evolution model for Etna magmatism. Subduction processes, slab rollback of Ionian oceanic lithosphere and upwelling asthenospheric mantle are all likely to introduce chemical and isotopic heterogeneities into the convecting mantle.

[1] Branca *et al.* (2011) *Ital. J. Geosci.* **130**, 265-291. [2] Trua *et al.* (1998) *Contrib. Min. Pet.* **131**, 307-322. [3] Viccaro and Cristofolini (2008) *Lithos* **105**, 272-288. [4] Doglioni *et al.* (2001) *Terra Nova* **13**, 25-31.

DOI:10.1180/minmag.2013.077.5.19