

## A Mission to Really Early Earth: When Did the Earth Become Suitable for Habitation?

T.M. HARRISON<sup>1</sup>, S.J. MOJZSIS<sup>2</sup>, R.T. PIDGEON<sup>3</sup>,  
T.R. IRELAND<sup>1</sup>, V. BENNETT<sup>1</sup>, M. HONDA<sup>1</sup>,  
B.P. BOURDON<sup>4</sup>, F.J. RYERSON<sup>5</sup>, Y. AMELIN<sup>6</sup>, AND  
J.L. KIRSCHVINK<sup>7</sup>

<sup>1</sup>RSES, Australian National University

<sup>2</sup>Dept. of Geological Sciences, University of Colorado

<sup>3</sup>Department of Geology, Curtin University

<sup>4</sup>Institut de Physique du Globe, Paris

<sup>5</sup>IGPP, Lawrence Livermore National Laboratory

<sup>6</sup>Geological Survey of Canada

<sup>7</sup>Div. of Geological and Planetary Sciences, Caltech

When did conditions suitable for life emerge on Earth? Since the necessary energy source and organic building blocks for biogenesis were available during the earliest stages of planetary evolution, the question reduces to: When did suitable conditions and liquid water first appear at the Earth's surface? The earliest evidence of biologic activity is in the form of  $\geq 3.82$  Ga marine sediments, suggesting that life may have emerged during the Hadean (4.5-4.0 Ga), an eon for which there is no known rock record. How can we determine whether an environment conducive to life was extant during this era? The discovery of 4.3-4.4 Ga detrital zircons from Jack Hills, Western Australia, offers the prospect of gaining unprecedented insights into surface conditions during the earliest phase of Earth evolution. O isotopes in these zircons suggest the presence of a hydrosphere and continents only 200 Ma after accretion – conditions favourable for emergence of life – challenging the view their development did not begin until  $\sim 4.0$  Ga. We have begun to characterize the age of  $10^5$  Jack Hills zircons to understand: 1) *The age and origin of the atmosphere*.  $\geq 4.3$  Ga zircons retain a memory of terrestrial Pu/U, an unknown but key parameter in interpreting Xe isotopes in terms of the age of the atmosphere. Inclusions within these zircons indicate that the melt protolith formed at the Earth's surface and suggest the existence of a mature Hadean sedimentary cycling system. These inclusions may contain a record of  $fO_2$  that is in part related to the presence or absence of reduced C at the Earth's surface. 2) *A paradigm for early crustal evolution*. Evidence of short-lived  $^{146}\text{Sm}$  (i.e.,  $^{142}\text{Nd}$ ) should be preserved in  $>4.0$  Ga continental crust if differentiation began early and produced high Sm/Nd reservoirs. While Sm/Nd data are interpreted to indicate slow, early crustal growth, early depletions may have been re-homogenized. Lu-Hf isotope data of  $>4.3$  Ga Hadean zircons transcend this ambiguity. 3) *The initiation age of the terrestrial geodynamo*. Ultra-sensitive analysis methods show that a Jack Hills zircon carries an intrinsic remanent magnetism, raising the possibility of constraining the timing of geodynamo activation.

## Variable $^3\text{He}/^4\text{He}$ ratios in volcanic lavas caused by isotopic fractionation

D. HARRISON<sup>1</sup>, T. BARRY<sup>2</sup> AND G. TURNER<sup>1</sup>

<sup>1</sup>Department of Earth Sciences, University of Manchester, Manchester M13 9PL. dharrison@fs1.ge.man.ac.uk

<sup>2</sup>Cardiff University (BAS/NIGL), Cardiff, CF1 3YE

$^3\text{He}/^4\text{He}$  ratios are commonly used to distinguish mantle domains, for instance those sampled by mid-ocean ridge basalts (MORB) (i.e.  $\sim 8R_a$  for the Atlantic province) and primitive plumes (i.e.  $\sim 39R_a$ , Iceland), where  $R_a$  is the  $^3\text{He}/^4\text{He}$  ratio normalised to the air value,  $1.39 \times 10^{-6}$ . These He data require the existence of isolated reservoirs, within sections of the mantle that have different time-integrated (U+Th)/ $^3\text{He}$  and have remained isolated for long periods of time. Helium isotope signatures therefore offer a powerful tool for constraining mantle sources for volcanic samples *provided* that the samples analysed have retained the helium isotope signature characteristic of their respective mantle source. It has been noted however that helium isotope variability is sometimes observed over small geographic distances, and within single volcanic centres or mid-ocean ridge segments. This may reflect: (a) small-scale heterogeneity in the mantle or temporal and spatial changes as volcanic systems evolve and/or migrate with plate motion (as observed in Hawaii and Iceland); (b) the effects of crustal-level processes, variable contamination of a homogenous source signature by assimilation of local crust/crustal fluids into the magma, crustal  $^3\text{He}/^4\text{He} \sim 0.05R_a$ , (c) in-growth of radiogenic  $^4\text{He}$  during crustal residence. De-convolving the cause(s) of these He isotope variations are difficult and in studies reporting only He isotopes and no other noble gas data, ambiguous at best. Noble gases also often appear to be de-coupled from other chemical tracers that could help illuminate this problem. As an alternative to (a), (b) or (c) it is theoretically possible to mass fractionate helium isotopes in a crystalline phase. If substantial diffusive He-loss occurs from a sample, a fractionated residue will be left behind in the remaining fluid inclusions, thus providing a further possible explanation to account for small-scale isotopic variation. In this contribution we report new noble gas data from a series of young co-genetic Siberian lavas and show that the variation in He isotope ratios are likely caused by mass fractionation. Our motivation is to highlight that the He isotope structure in some volcanic settings may be due to isotopic fractionation as opposed to contamination by shallow-level crustal components; this may also explain the apparent de-coupling of He from trace element tracers. This is of relevance to analyses from ocean island settings (OIB) and continental lavas where low He concentrations appear to be endemic and are therefore particularly susceptible to isotopic modification.