PRIMORDIAL KRYPTON IN THE TERRESTRIAL MANTLE IS NOT SOLAR G. Holland[1], C. J. Ballentine[1] and M. Cassidy[2], [1] S.E.A.E.S. University of Manchester, Oxford Road, Manchester, M13 9PL, U.K. g.holland@manchester.ac.uk, [2] Department of Geosciences, University of Houston, Houston, TX 77204-5503, U.S.A.

Introduction: Noble gases are key tracers for the origin of volatiles in the terrestrial planets and of interaction between mantle reservoirs and the atmosphere. General consensus is that material accreting in the solar nebula and nebula gases from the Sun itself were incorporated into the terrestrial planets, providing a starting point for models of planetary evolution. However, the isotopic signatures of these accretion processes are often masked by air contamination and therefore deviations from air may be <1%, requiring high precision measurements. Typically, oceanic basalts, continental diamonds and xenoliths have provided the noble gas data for the mantle.

Our current work focuses a suite of samples from individual wells that extract almost pure (>99%) CO_2 from beneath New Mexico, USA. These well gases are sourced from deep within the sub-continental lithospheric mantle (SCLM) and have been shown to contain magmatic volatiles retained from the earliest stages of planetary formation [1]. Uniquely, these gases provide essentially unlimited amounts of sample for high precision measurements which, coupled with improved instrument precision from the new generation of noble gas mass spectrometers, allows us to investigate accretionary processes.

Helix multicollector mass spectrometer: Recent acquisition of the Helix multicollector noble gas instrument manufactured by GV (now Thermo Scientific) provides an improvement in precision of at least an order of magnitude over single collector instruments. At present the spectrometer is operating with 5 Faraday bucket collectors and 10^{12} ohm resistors. Mass resolution is ~1000 for all collectors and peaks are flat to 1 part in 5000 over 300ppm of peak top. This allows determination of isotopic compositions with a precision of ~0.5 permil for major isotopes (beam size 50-250mV). Data errors incorporate internal precision (1σ) and standard error of air calibrations over the sampling period.

Kr data: ^{82}Kr/^{84}Kr/^{86}Kr have been measured in 15 samples from individual wells from the Bravo Dome region, USA (figures 1 & 2). Each sample measurement has been repeated 6-10 times. ^{78}Kr beam is too small for required precision, ^{80}Kr cannot be resolved from $^{40}Ar^{2+}$ and ^{83}Kr cannot be measured simultaneously with ^{82}Kr and ^{84}Kr due to detector spacing.

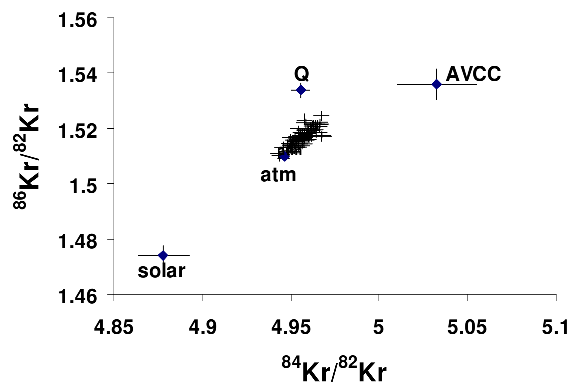


Figure 1: *Individual analyses of all samples (n=125) Solar system reservoirs are solar wind, Q – the primary heavy noble gas carrier in meteorites, and AVCC – the average from bulk carbonaceous chondrite measurements [2].*

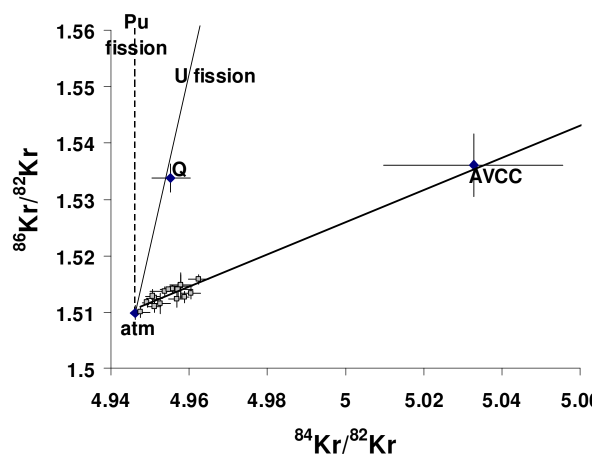
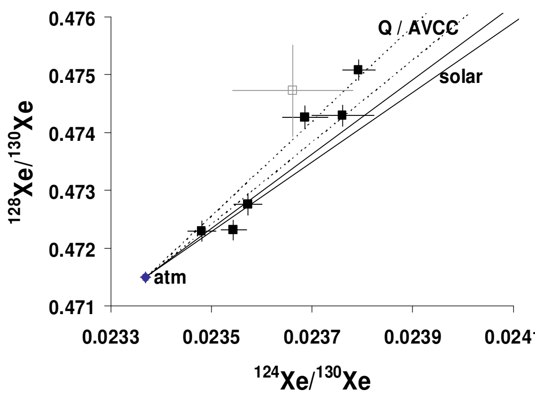


Figure 2: *Averages of multiple measurements for each sample, which have also been fission corrected. This correction incorporates crustal U fission determined from ^{136}Xe excesses of [1] and mantle Pu-U fission from [3].*

Preliminary Xe data: ^{124}Xe/^{126}Xe/^{128}Xe/^{130}Xe have been measured in 6 samples from individual wells from the Bravo Dome region, USA (figure 3, below). This work is ongoing.



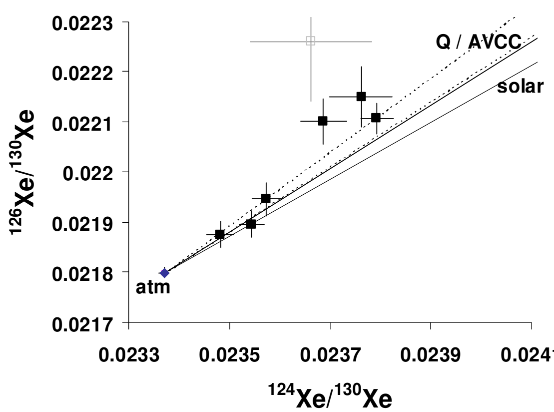


Figure 3: *Non-radiogenic Xe showing a clear primordial component. Mixing lines between air and a primordial Xe component are also shown: the solid lines show air–solar mixing including error on the primordial component and the dashed lines are air–Q mixing. Xe data are consistent with a planetary origin required by Kr data. Solar system Xe components are from [4]. Grey datapoints are from [5].*

Conclusion 1 – Earth's noble gases are not acquired directly from solar wind: Several current models require that the Earth acquired its volatiles from direct capture of the solar nebula by gravitational attraction. Our new Kr and Xe data presented here are inconsistent with this hypothesis and are completely consistent with meteoritic material as the primary source of primordial volatiles in the Earth. Bulk meteorite data which includes presolar material in addition to 'planetary' gas is a better match than the ubiquitous carbonaceous noble gas carrier, phase Q, alone.

Conclusion 2 – Earth has a hidden Xe reservoir: The ^{84}Kr/^{132}Xe ratio in the primordial mantle is calculated from nonradiogenic Kr and Xe excesses to be ~15. This is significantly higher than AVCC with ^{84}Kr/^{132}Xe ~1 or any other major heavy noble gas carrier in carbonaceous chondrites (e.g. Q, P3) with ^{84}Kr/^{132}Xe in the range 0.8-2 [2,6]. This high terrestrial Kr/Xe ratio, also observed in the atmosphere, was thought to be due to sequestration of Xe into a hidden terrestrial reservoir although no evidence for this reservoir has been found [7,8]. Our data, particularly Kr isotopes, suggest that noble gases from bulk meteorites containing a variety of host phases best match the isotopic composition of the primordial mantle. This implies preferential selection and accretion of specific noble gas carrier phases did not occur and the heavy noble gas elemental abundance pattern present in AVCC was transferred to the Earth without loss of Xe. That we now appear to be missing >90% of Xe requires a hidden reservoir for Xe within the Earth.

References: [1] Holland G. and Ballentine C.J. (2006) Nature 441, 186-191. [2] Busemann H. et al. (2000) MAPS 35, 949-973. [3] Pepin R.O. and Porcelli D. (2006) EPSL 250, 470-485. [4] Pepin R.O. and Porcelli D. (2002) RIMG 47, 191-246. [5] Caffee M. et al. (1999) Science 285, 2115-2118. [6] Wieler R. (2002) RIMG 47, 21-70. [7] Bernatowicz T.J. et al. (1984) JGR 89, 4597-4611. [8] Bernatowicz T.J. et al. (1985) GCA 49, 2561-2564.