EXTRATERRESTRIAL HELIUM (He@C_{60}) TRAPPED IN FULLERENES IN THE SUDBURY IMPACT STRUCTURE Luann Becker* and Jeffrey L. Bada Scripps Institution of Oceanography, University of California at San Diego, La Jolla, CA 92093-0212B, USA, Robert J. Poreda, Department of Earth and Environmental Sciences, University of Rochester, Rochester, NY 14627, T. E. Bunch Space Science, NASA/ARC, Moffett Field, CA 94035.

Introduction Fullerenes (C_{60} and C_{70}) and have recently been identified in a shock-produced breccia (Onaping Formation) associated with the 1.85 billion-year-old Sudbury Impact Crater (1). The presence of ppm levels of fullerenes in this impact structure raises interesting questions about the processes that led to the formation of fullerenes, and the potential for delivery of intact organic material to the Earth by a large bolide (e. g. asteroid or comet). Two possible scenarios for the presence of fullerenes in the Sudbury impact deposits are: (i) That fullerenes are synthesized within the impact plume from the carbon contained in the bolide (1); or (ii) that fullerenes are already present in the bolide and survived the impact event.

The correlation of carbon and trapped noble gas atoms in meteorites is well established (2). Primitive meteorites contain several trapped noble gas components that have anomalous isotopic compositions (3) some of which may have a presolar origin (4). Several carbon-bearing phases have been recognized as carriers of trapped noble gases including SiC, graphite and diamond (5). It has also been suggested that fullerenes (C_{60} and C_{70}) might be a carrier of noble gas components in carbonaceous chondrites (6). Recently, fullerenes have been detected in separate samples in the Allende meteorite (7,8). C_{60} is large enough to enclose the noble gases He, Ne, Ar, Kr and Xe but is too small to contain diatomic gases such as N_2 or triatomic gases such as CO_2. Recent experimental work has demonstrated that noble gases of a specific isotopic composition can be introduced into synthetic fullerenes at high temperatures and pressures; these encapsulated gases can then be subsequently released by the breaking of one or more carbon bonds during step heating under vacuum (9). These thermal release patterns for He encapsulated within the C_{60} molecule (He@C_{60}) are similar to the patterns for acid residues of carbonaceous chondrites (5) suggesting that fullerenes could be an additional carrier of trapped noble gases in acid residues of meteorites.

Analysis/Results In order to characterize the noble gas compositions of the Sudbury fullerenes, we undertook a systematic study of acid resistant residues throughout the carbon-rich layer (Black member) of the Onaping formation. Samples were demineralized and extracted using standard techniques (1). The Onaping extracts were analyzed using several techniques including UV-Vis adsorption, electro spray mass spectrometry and laser desorption (linear and reflectron) time-of-flight (TOF) mass spectrometry (LDMS). The Sudbury fullerenes were then separated and purified using HPLC coupled with a photo diode array detecter (10). The HPLC extracts containing the purified fullerenes were loaded into a metal tube furnace within a glove box under a nitrogen atmosphere in preparation for noble gas analyses. The ^3He and ^4He content of the fullerene extracts were measured using previously reported standard techniques (9).

Discussion Fullerenes (C_{60} and C_{70}) in the Sudbury Impact Structure have been found to contain trapped helium with a $^3He/^4He$ ratio greater than 5 x 10^{-4}. The $^3He/^4He$ ratio exceeds the accepted solar value by more than 30% and is more than 10 times higher than the maximum reported mantle value. Terrestrial nuclear reactions or cosmic ray bombardment are not sufficient to generate such a high ratio. The $^3He/^4He$ ratios in the Sudbury fullerenes is similar to those determined for interplanetary dust particles. The greater than solar ratios of $^3He/^4He$ in the Sudbury fullerenes may indicate a presolar origin, although alternative mechanisms occurring in the ISM to explain these high ratios (e.g. spallation reactions, selective helium implantation etc.) cannot be entirely ruled out. We are currently attempting to isolate enough fullerene material to measure anomalous Ne (or Kr or Xe) contained within the C_{60} [e.g. the "pure" ^{22}Ne component] (5) and thus determine whether the Sudbury fullerenes are indeed presolar in origin.

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