Miller Range 05029: Evidence for a Large Impact on the L Chondrite Parent Body >4.5 Ga. J. R. Weirich[1], A. Wittmann[2], C. E. Isachsen[3], D. Rumble[4], T. D. Swindle[3], and D. A. Kring[5]. [1]School of Earth and Space Exploration, Arizona State University, 781 E. Terrace Rd., Tempe, AZ 85287, USA (weirichjohn@gmail.com), [2]Department of Earth & Planetary Sciences, Washington University, One Brookings Dr., St. Louis, MO 63130, USA, [3]Department of Planetary Sciences and Lunar and Planetary Laboratory, 1629 E. University Blvd., Tucson, AZ 85721, USA, [4]Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Rd. NW, Washington, District of Columbia 20015, USA, [5]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, USA.

Introduction: ^{40}Ar-^{39}Ar dating (a variant of K-Ar dating) is a widely used chronometer to study impact heating because the low closure temperature means mild shock events do not affect the K-Ar system, but strong shock events (i.e. large impacts) reset the K-Ar system. Most ^{40}Ar-^{39}Ar ages of highly shocked ordinary chondrites are 50 Ma to 1.5 Ga, or 3 to 4 Ga, with very few other ages [1]. Miller Range (MIL) 05029 is interesting because it is a complete melt with no shock features, and has an unusually old ^{40}Ar-^{39}Ar age.

Brief Description: MIL 05029 is a 132.7 g meteorite, and is paired with MIL 05136. It is classified as an L impact melt [2], and consists of large orthopyroxene grains with interstitial feldspar, both of which are poikilitically enclosing olivine grains.

Procedures: Chemical analyses were obtained with the NASA-Johnson Space Center's Cameca SX-100 microprobe. Modal abundances were calculated using reflected light, BSE maps, and elemental X-ray dot maps. Oxygen isotopes were determined on a Thermo Fisher Scientific MAT 252 mass spectrometer at the Carnegie Institution of Washington. Three splits of MIL 05029,5 were analyzed using a VG5400 noble gas mass spectrometer at the University of Arizona. Further details on all procedures can be found in [3].

Results: Oxygen isotopes and chemical compositions of major minerals for MIL 05029 are consistent with L chondrites. Modal abundances of major minerals in MIL 05029 are mostly consistent with L chondrites, but there is obvious metal depletion (~75%) and plagioclase enrichment (~40%).

A Widmanstätten-like pattern has developed in one of the metal grains, indicative of slow cooling. The lamellae of this grain were too small for analysis, but the metallographic cooling rate (corrected for P abundance) was calculated to be 14 ± 7 °C/Ma from kamacite-taenite paired metal grains.

Combining the ^{40}Ar-^{39}Ar ages of three different splits together gives an age of 4517 ± 11 Ma. The presence of Cl-derived Ar prevents identification of trapped Ar, but if we make the extremely unlikely assumption that all the ^{36}Ar is terrestrial atmosphere an absolute lower age limit of 4.48 to 4.50 Ga is obtained.

Discussion: While the ^{40}Ar-^{39}Ar age of MIL 05029 is 4517 ± 11 Ma, slow cooling indicates the impact occurred earlier. A metallographic cooling rate of ~14 °C/Ma, which records the average rate between 700 and 400 °C, indicates the impact occurred at least ~20 Ma before the ^{40}Ar-^{39}Ar age. Steady cooling down to the measured ^{40}Ar-^{39}Ar closure temperature of MIL 05029 (~40 °C) would indicate an age older than the solar system. More likely, the cooling rate was not steady below 400 °C due to excavation by a second impact, the closure temperature is not 40 °C, or the metallographic cooling rate (which is only accurate to an order of magnitude) was closer to 100 °C/Ma.

Endogenous magmatism is ruled out by oxygen isotope, mineral composition, and mineral abundances, which suggest an L chondrite origin. Since the L chondrite parent body did not melt, MIL 05029 must have formed as a deeply buried impact melt. Slow cooling, metal/sulfide depletion, and the clast-free nature of MIL 05029 all suggest formation in a melt sheet instead of a melt dike.

A cooling rate of ~14 °C/Ma would place MIL 05029 in the thermal regime of the L5-L6 boundary of an onion shell model. [4] calculated this depth to be 5-12 km on the 100-200 km diameter L chondrite parent body. Using scaling laws [5], excavation to this depth would require a 25-60 km diameter crater. A crater of this size on a 100-200 km diameter asteroid would cause rheological weakening or shattering [6,7]. Given the old age of this meteorite, the parent body would have been undergoing thermal metamorphism. Hence, MIL 05029 may provide evidence as to why the onion shell model of thermal metamorphism does not work on the L chondrite parent body [8], because shattering would disrupt the otherwise steady cooling.

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