I-XE ANALYSIS OF A MAGNETIC SEPARATE FROM LODRANITE GRA95209.

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Introduction: Lodranites and acapulcoites are classed as primitive achondrites, having bulk chemistry similar to that of ordinary chondrites but lacking the characteristic chondritic texture as a result of high-temperature processing and partial melting [1,2]. In addition to their similar chemistry and mineralogy these two achondrite groups have indistinguishable oxygen isotopes, have experienced similar thermal histories and have similar exposure ages [3] and are thus believed to arise from a common parent body. Mafic silicate compositions are intermediate between E and H chondrites, and rare relict chondrules suggest that the parent body formed from chondritic material [2]. Lodranites are distinguished from acapulcoites largely on the basis of grain size, although it may be that differences represent a continuum rather than distinct groups [4,5]. Despite their high-temperature history, a number of isotopic systems are in disequilibrium within these meteorites – carbon isotopes in graphite inclusions within a single metal grain from GRA95209 vary by up to 86‰ [6], and nitrogen isotopes in Acapulco vary both between and within different mineral phases [7]. These meteorites provide a rare insight into the differentiation of small planetary bodies. Knowledge of the time-scale over which melting and melt migration occurs is potentially useful in understanding the evolution of the terrestrial planets.

Previous age determinations. Ar-Ar ages for acapulcoites range from 4.50 to 4.56 Ga [2, 8-11]. Lodranite Gibson has an Ar-Ar age of 4.49 Ga [1], and the intermediate type EET84302 has an age of 4.519 Ga [11]. Extensive studies of Acapulco have resulted in a suite of ages, all of which support an early age for formation and metamorphism of the parent body. Pb-Pb [12] and Mn-Cr [13] ages for Acapulco appear to be concordant when referred to the angrite LEW86010, and suggest these isotopic systems closed in Acapulco 2.8Myr later than in LEW86010. The precise Pb-Pb (4.557Ga) and I-Xe (8Myr later than Bjurbole) [14] ages of phosphates from Acapulco have been used to place I-Xe ages on an absolute time-scale by making the assumption that the closure temperature of the I-Xe system is similar to that of the Pb-Pb system in the phosphates, although this assumption has been questioned [8].

Noble gas content: Acapulcoites and lodranites contain surprisingly high, but variable, concentrations of trapped noble gases, comparable to those found in relatively unprocessed ordinary chondrites [2,15-17]. The trapped gas is isotopically similar to Q gases [18] but fractionated in favour of the heavy elements. Several, but not all, lodranites contain excesses of ^{129}Xe, but it is not clear if this arises from the in situ decay of ^{129}I or is an inherited component as suggested by [7]. Ar-Ar analyses suggest the presence of parentless ^{40}Ar in some high-temperature releases, which together with the high noble gas concentrations suggests the possibility of retention on a planetary scale of some incompatible volatiles, possibly complicating the interpretation of the I-Xe chronometer.

GRA95209: This rock, although classified as a lodranite on the basis of texture and grain-size [19], has features that make it intermediate between lodranites and acapulcoites [5,20,21]. It is reported to contain three distinct lithologies – a matrix of sub mm-sized metal and silicate grains, metal poor areas and metal rich areas (veins and sheets). The metal poor areas contain an opaque mineral assemblage that reflects more oxidising conditions than the metal rich areas. It has been suggested that the prominent metal sheet in GRA95209 originated from a distant source region that experienced higher temperatures than the bulk of the meteorite, thus oxidising some of the graphite within the metal. This interpretation is supported by observations of carbon isotopes in graphite inclusions [6]. GRA95209 shows no evidence for loss of a basaltic melt, and little evidence for significant loss of a metal-sulfide melt [5]. The rock is classified as shock stage 2 (weakly shocked) and is slightly weathered (WB).

Experimental: A portion of GRA95209 from allocation 26 (matrix) was crushed and a magnetic separate produced using a hand magnet. An aliquot from this separate was analysed for noble gases using 4 temperature steps and standard procedures on the MAP 215-50 mass spectrometer at the Physikalisches Institut, University of Bern. Further aliquots were neutron irradiated (thermal fluence 8.4×10^{18} cm^{-2}, fast fluence ~ 3.4×10^{19} cm^{-2}) and subsequently analysed for xenon isotopes using laser stepped heating on the RELAX instrument [22] at the Earth Sciences Department, University of Manchester.

Results: Data from laser stepped heating xenon isotopic analysis subsequent to neutron irradiation of four samples from GRA95209,26 are shown in the figures below. I/Xe ratios were generally large resulting in small corrections for trapped gas, and so the results are plotted as age spectra rather than isochrons. In each case the model $^{129}I/^{127}I$ ratio increases monotonically with release temperature to a value slightly lower than that of the Shallowater standard (1.125×10^{-4}). No age plateaux were observed. Concentrations of uranium, barium and tellurium, iodine (inferred from induced fission xenon, neutron capture to give ^{131}Xe or neutron capture on ^{127}I to give ^{128}Xe) and xenon were significantly different in the four samples, suggesting that the magnetic separation procedure has not isolated a unique host phase for these elements. Mineralogical studies of the material are in progress.

Discussion: It seems unlikely that inherited parentless ^{129}Xe would result in such simple age-spectra, and so we shall assume here that all the excess ^{129}Xe was produced by in situ decay of ^{129}I and consider the implications. The upward trend in model ages with release temperature is suggestive of a thermal disturbance of the I-Xe system, resulting in loss of ^{129}Xe from less retentive sites. In this case, the largest inferred $^{129}I/^{127}I$ value (or equivalently the earliest model age) is a strict bound on the latest age at which closure originally occurred (assuming previously open system behaviour). Equally, introduction of terrestrial iodine by weathering (as frequently observed in antarctic meteorites) could explain the observed structure in the age spectra, and this explanation is supported by the decreasing amount of xenon indistinguishable from air released in early temperature steps for some samples. The earliest model age would then still be a bound on the closure age. The event recorded by original closure of the I-Xe system was presumably cooling after partial melting at about 1350K. The intrusion of a metal vein into GRA95209, apparently from elsewhere on the lodranite-acapulcoite parent body, may have been responsible for disturbing the I-Xe system.

Clearly, partial retention of ^{129}Xe began early. High temperature model I-Xe ages for the magnetic separate from GRA95209 vary from 1Myr to 6Myr later than closure in the Shallowater or Bjurböle I-Xe standards. If this reflects cooling after the formation of a metal-sulfide rich melt, it is not inconsistent with the I-Xe age of phosphates in Acapulco of 8Myr later than Bjurböle. The apparently earlier closure in GRA95209 may be because the closure temperature in the Acapulco phosphates was somewhat lower than the unknown iodine host phase in the GRA95209 magnetic separate. The apparent age difference may also be the result of different cooling rates.

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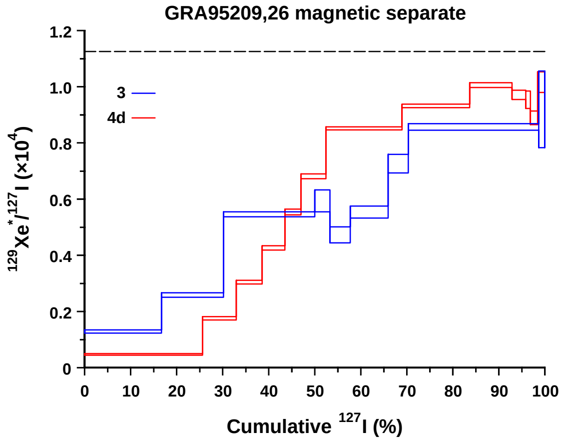

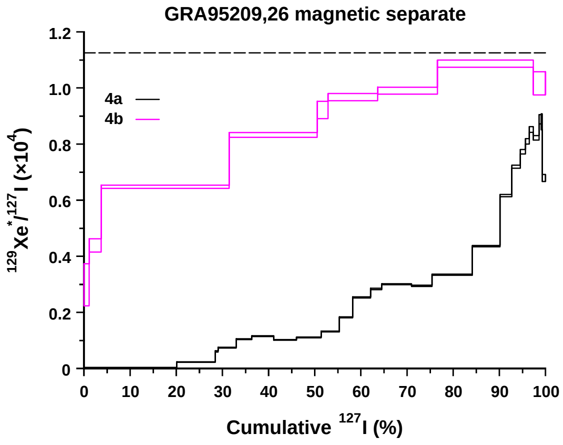

The figures show step-heating I-Xe data for four samples of a magnetic separate from GRA95209,26. The dashed line represents the Shallowater initial iodine ratio of $^{129}I/^{127}I = 1.125\times10^{-4}$.