REGOLITH BRECCIA (OURIQUE) WITH IMPACT MELT CLASTS AND OTHER DEBRIS FROM AN H-CHONDRITE PARENT BODY. David. A. Kring, Barbara A. Cohen, Timothy D. Swindle, and Dolores H. Hill, [1]Lunar and Planetary Laboratory, 1629 E. University Blvd., University of Arizona, Tucson, AZ 85721 (kring@lpl.arizona.edu).

Introduction: The Ourique meteorite fell in Portugal 28 December 1998, producing a small pit in the ground and scattering debris over at least 55 m [1]. Officially classified as an H4 ordinary chondrite without any special characteristics [2], it is clear that the sample is a complex, gas-rich [3], breccia with regolith affinities. The meteorite contains light and dark lithologies, including shocked constituents, and at least two types of igneous clasts, one of which may have been generated by impact melting and reduction of H-chondrite material. Preliminary $^{39}Ar/^{40}Ar$ analyses indicate the latter type of clast was produced 4.45 ± 0.02 Ga. This age is far older than most other impact melt ages in H-chondrites.

Macroscopic Description: The overall albedo of Ourique is dominated by two distinct lithologies: light colored clasts in a relatively dark matrix. The dark lithology is medium light gray (N6 [4]) to medium gray (N5). The brighter lithology is light gray (N7), although it has easily visible constituents that range from very light gray (N8) to medium light gray (N6). Both lithologies are lighter in color than other brecciated H-chondrites we have recently studied. Portales Valley and Orvinio are light olive gray to olive gray (~5Y 5/1) and medium dark gray to dark gray (N3-N4), respectively [5-7]. Ourique also contains small amounts of a darker lithology which has igneous silicate textures and, in one case, is coated by a shell of metal-sulfide material. These clasts are medium dark gray (N4) to dark gray (N3), similar to the incompletely impact-melted Orvinio meteorite.

Petrography of Host Chondrite and Exotic Clasts: The host chondrite contains textures and mineral compositions typical of H-chondrites. However, shock-deformation has clearly affected the meteorite to various degrees, ranging from comminution to incomplete shock-melting of pyroxene and olivine (Fig. 1). The breccia also contains clasts that are not composed of typical H-chondrite material. One of these clasts has an assemblage of silica and pyroxene (Fs_{29-24}). Because this is an igneous product, it likely came from a different planetesimal. The pyroxene has a high concentration of MnO (~1.1 wt.%) and a relatively low wt.% FeO/MnO value (17 *vs.* 22 in host chondrite), which also suggests it was not produced from H-chondrite material. However, because analyses of a silica-bearing clast in another ordinary chondrite [8] demonstrated that the FeO/MnO value in pyroxene varies in silica-crystallizing systems, the planetary source of the igneous clast remains uncertain.

There are several other igneous clasts in Ourique, some of which can be quite large (over 1 cm), and also seem to have a separate origin. These clasts are dominated by olivine with a Cr-rich (~1 wt.% Cr_2O_3) feldspathic mesostasis that is variously glassy to cryptocrystalline (Fig. 2). The olivine is more reduced than that in the H-chondrite host (Fa_{7-10} *vs.* Fa_{18}), but rare crystals have cores with compositions identical to the H-chondrite host.

The core olivine compositions suggest the melts were produced on an H-chondrite body, rather than on another type of planetary body. We also suspect that the melts have an impact origin rather than a magmatic origin, because (1) there are other shocked, incompletely-melted olivine-rich fragments of H-chondrite material in Ourique and (2) there is no independent evidence of magmatic or volcanic activity on an H-chondrite planetesimal with abundant surviving H4 material.

To estimate the cooling rates of these clasts, we examined the morphology of the metal-sulfide assemblages. The largest melt clast is 14 by 5.5 mm in section (although it was likely larger because it is truncated by the edge of the meteorite). The clast is surrounded by a metal-sulfide rim that is up to 3 mm thick and contains a metal-sulfide spherule that is 0.5 x 0.8 mm in diameter. The metal has cellular structure and occasional dendritic arms. Several other additional metal-sulfide clasts with similar internal structures are scattered throughout our thin-section. The dimensions of the internal structures suggest cooling rates between 10 and 1000 °C/s based on the technique of Scott [9], which is applicable to temperatures between ~1400 and 950 °C. These cooling rates are comparable to those obtained for metal-sulfide clasts in Tysnes Island (H3-6), Weston (H3-6), Pulsora (H3-7), Dimmitt (H4), and San Emigdio (H4), but faster than those obtained for other clasts in Weston, San Emigdio, Rose City (H5), and Tell (H6) [9]. These cooling rates are also more than 13 orders of magnitude faster than the cooling rate of some of the metal in Portales Valley (H6) [5]. The Ourique metal-sulfide particles appear to have cooled close to radiative conditions, consistent with an asteroid surface environment, while the Portales Valley samples require much longer conductive cooling, consistent with a deeply buried setting.

^{39}Ar/^{40}Ar Geochronology: Laser step-heating was used to determine the age of one of the large impact melt clasts. Microcores weighing about 0.5 mg were extracted from section, irradiated, analyzed with a VG5400 mass spectrometer, and appropriate corrections applied. The first sample analyzed exhibits a plateau over more than 50% of the ^{39}Ar released, corresponding to an age of 4.45 ± 0.02 Ga. This spectrum shows signs of possible recoil effects. If all of the Ar in the sample is considered, then we calculate an age of 4.41 ± 0.02 Ga, so little or no gas loss has occurred in events more recent than 4.4 Ga.

Discussion: Ourique has clasts that appear to record the earliest silicate melt-producing impact on an H-chondrite parent body detected thus far, with the possible exception of Portales Valley [5; D.D. Bogard, personal communication]. Most impact melt clasts in H-chondrites are much less than 1 Ga old [7,10]. The paucity of pre-4.0 Ga impact ages in ordinary chondrites may stem from the low survival rates of material that was near enough to the asteroid's surface early enough to show the effects of such an impact [10,11]. The cooling rates imply that these impact melts were produced in an asteroid surface environment. Solar wind in the breccia [3] also indicates that some of the material was within a millimeter of the surface. It might be possible to determine the total amount of time various clasts spent in a near surface environment [12] by picking the breccia apart, analyzing individual clasts, and comparing the amounts of cosmogenic neon to those seen in bulk samples [3]. However, it is likely to be extremely difficult to determine how many surface events there were or when they occurred.

The impact event that produced the impact melts changed the redox state of the material, producing olivine with Fa_{7-10} compositions from olivine with Fa_{18} compositions. The cause of the reduction is unclear, although we are investigating the possibility that the cause may be related to the unusually light C isotopic carrier that Franchi [3] identified.

At least one clast of a different planetary body seems to be incorporated into the regolith breccia: the silica-pyroxene clast that likely came from a differentiated body. A search for additional foreign clasts is underway.

Acknowledgements: We thank Mike Farmer for providing samples of Ourique.

References: [1] Galopin de Carvalho A.M. and Fernando Monteiro J. (1999) *A propósito do Meteorito de Ourique*, Câmara Municipal de Ourique, 27 p. [2] Grossman J. (ed.) (1999) *Meteoritics Planet. Sci.*, *34*, A169-A186. [3] Franchi I.A. et al. (1999) *Meteoritics Planet. Sci.*, *34*, A38. [4] Rock-Color Chart Committee (1991) *The Rock Color Chart*, GSA, Boulder, CO. [5] Kring D.A. et al. (1999) *Meteoritics Planet. Sci.*, *34*, 663-669. [6] Grier J.A. et al. (1997) *LPS XXVIII*, 467-468. [7] Grier J.A. et al. (2000) in preparation. [8] Ruzicka A. et al. (1995) *Meteoritics*, *30*, 57-70. [9] Scott E.R.D. (1982) *GCA*, *46*, 813-823. [10] Bogard D.D. (1995) *Meteoritics*, *30*, 244-268. [11] Bogard D.D. and Garrison D.H. (1999) *LPSC XXX*, #1104. [12] Caffee M.W. et al. (1991) In *The Sun in Time*, Univ. Arizona Press, 413-425.

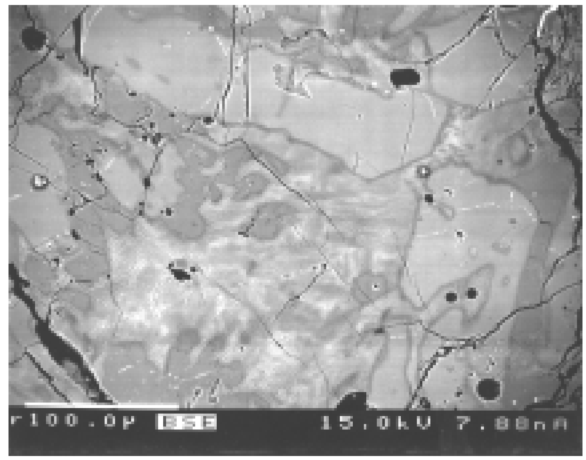

Fig. 1. Clast in which olivine amd pyroxene was being resorbed during a shock event, before rims of more magnesian olivine crystallized during cooling.

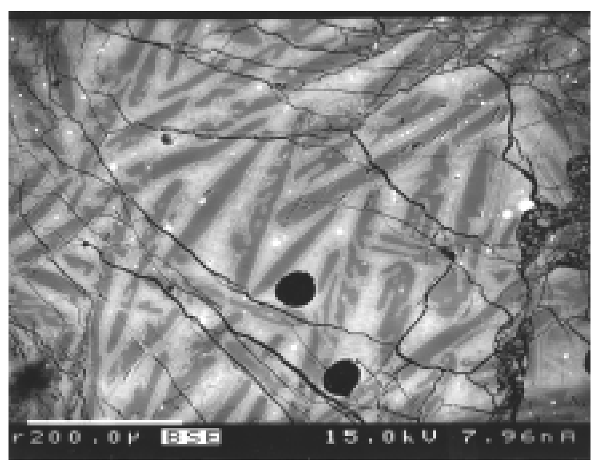

Fig. 2. Clast in which magnesian olivine crystallized from melt. Olivine compositions are more magnesian than the olivine in the H-chondrite host and rare olivine cores in other clasts, suggesting reduction during the melting event.