CHONDRITIC IMPACT MELTS AND CRATERING PROCESSES ON ASTEROIDS; E.R.D. Scott, P. Maggiore, G.J. Taylor, K. Keil and D. Szuwalski, Institute of Meteoritics and Department of Geology, University of New Mexico, Albuquerque, NM 87131.

Introduction. Impact-melt rocks commonly occur in ordinary chondrites as clasts in fragmental and regolith breccias [1-3], but rarely as whole rocks [4-6]. We have identified two L chondrites as impact melts, Chico and Point of Rocks (stone), and have made a petrologic comparison of these rocks with other impact-melted chondrites. We aim to elucidate the abundance, size and distribution of melt in craters and ejecta on chondritic asteroids, the times of melt-producing impacts, and the production of meteoroids. This is essential for understanding the geologic evolution and collisional history of asteroids.

Petrology. a) Textures. Chico and Point of Rocks, which are probably paired, consist of relatively clast-free, impact-melt regions 5-10 cm across separated by heavily shocked chondritic regions, which themselves contain 10-30 vol.% of in situ shock melt (melt pockets [7]). Melt crystallized largely to microporphyritic textures with clinopyroxene crystals poikilitically enclosing olivines (Fig. 1); other regions contain olivine phenocrysts or submicron material. In Ramsdorf, there is pervasive shock melting; only a few of the larger crystals are probably unmelted relicts. What appear at low magnifications (<50x) to be regions (>5 cm wide) of fairly normal type 4-5 chondritic material are largely composed of olivine and clinopyroxene phenocrysts (1-50 μm in size) in glass. Achondritic regions >2 cm in size appear at low magnifications to contain clasts, but at high power, igneous textures like those in "chondritic" regions are observed throughout. Other chondrites in Table 1 contain rounded, shocked (and unshocked) chondritic regions 1-10 cm in size separated by 1-5 mm wide melt veins (Fig.2). Melt crystals in these veins are generally submicron in size and commonly surround 0.1-1 mm wide clasts. Melts in all chondrites are depleted in mm-sized metal grains common in chondrites. b) Compositions. Olivine and pyroxene phenocrysts in impact melts (Table 1) have surprisingly uniform FeO concentrations, like those of neighboring chondritic regions and clasts. This reflects rapid crystallization of melts, not metamorphism. In Orvinio, CaO concentrations of olivine and low-Ca pyroxene are higher in melted zones than in chondritic regions as in Shaw [4], while olivine clasts have intermediate CaO contents. In Sete Lagoas, clasts and chondritic regions have low CaO contents in olivine, typical of type 4-6 chondrites (0.01-0.05%), but in Chico, Lubbock, Point of Rocks and Ramsdorf, the melt, clasts and chondritic regions all have enhanced CaO in olivine, reflecting higher temperatures in clasts and chondritic regions. Metallic Fe,Ni in Chico contains 0.3-0.6% P, 12-14% Ni and small schreibersites, as in other shock-melted chondrites [8].

Geologic setting. Despite detailed information about the post-shock thermal history of many impact-melted chondrites, we do not know their post-impact locations. Since the most heavily shocked ejecta have the highest ejection velocities, and largely escape from small bodies [9], our samples probably come from melt sheets within craters and from crater walls. Ages. Almost all shock ages of whole H-L-LL chondrites are 40-1200 Myr [10,11]. This implies that little impact melting occurred during accretion of the ordinary chondrite parent bodies, consistent with predicted impact velocities of <1 km/sec [12]. However, Rubin et al. [2] argue that most impact-melt clasts in L and LL chondrites formed prior to metamorphism, 4.4 Gyr ago. Their chief criterion is the uniformity of FeO contents of olivines and pyroxenes in melt clasts; but data for recent impact melts (Table 1) suggest that better petrographic criteria are needed to identify pre-metamorphic impact melts. Interestingly, we have no impact melts that were produced during the recent impacts on asteroids that exposed meteorites to cosmic rays. Even the large impact 5 Myr ago which removed several km^3 from the H chondrite body [13] did not provide us with impact melts from this event. We surmise that either little melt was produced (e.g. low impact velocities), ejected melt rocks were friable or that dynamical filters rejected fast-moving, heavily shocked material. Volume of melt. Ordinary chondrite parent bodies contain only a few tenths of a percent of impact melted material. Much melt may however have been lost. Carbonaceous chondrite bodies contain very little material shocked above 10 GPa, (silicates with undulose extinction are rare), and very much less than ordinary chondritic and achondritic asteroids. We do not understand why, but surmise that hypervelocity impacts are rarer on C chondrite bodies, these bodies are too small to retain shocked material, or that physical properties of carbonaceous material preclude the production of much shocked material.

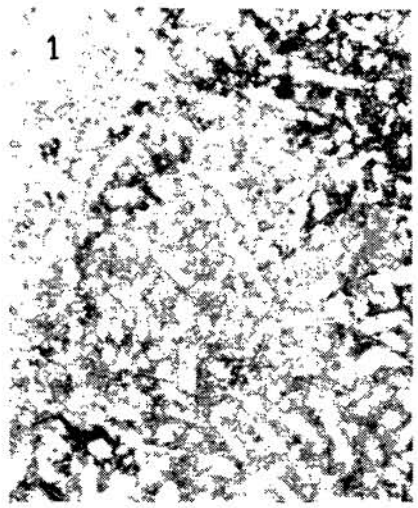

Fig. 1. Transmitted-light photograph of impact melt in the Point of Rocks (L6) chondrite showing microporphyritic texture. Width 3.4 mm.

Fig. 2. Transmitted light photograph of Sete Lagoas chondrite showing veins of dark shock melt surrounding light-colored H5 material. Width: 15 mm.

References: [1] Fodor R.V. et al. (1980) Meteoritics 15, 41. [2] Rubin A.E. et al. (1983) Meteoritics 18, 179. [3] Fodor R.V. and Keil K. (1976) GCA 40, 177. [4] Taylor G.J. et al. (1979) GCA 43, 323. [5] Miyamoto M. et al. (1984) JGR 89, 11581. [6] Rubin A.E. (1985) Rev. Geophys., in press. [7] Dodd R.T. and Jarosewich E. (1979) EPSL 44, 335. [8] Smith B.A. and Goldstein J.I. (1977) GCA 41, 1061. [9] Cintala M.J. et al. (1979) In "Asteroids" (ed. T. Gehrels), Univ. of Arizona, p. 579. [10] Bogard D.D. (1979) ibid. p. 558. [11] Nakamura N. and Okano O. (1985) Nature 315, 563. [12] Goldreich P. and Ward W.R. (1973) Astrophys. J. 183, 1051. [13] Anders E. (1978) In "Asteroids: An Exploration Assessment" (eds. D. Morrison and W.C. Wells), NASA CP-2053, p. 57. [14] Gomes C.B. and Keil K. (1980) "Brazilian Stone Meteorites", Univ. New Mexico, p. 105.

Table 1. Silicate compositions in impact-melted chondrites

			Olivine			Low-Ca Pyroxene		
Meteorite	Region	Type	% Fa Mean	%Fa σ	%CaO Mean	% Fs Mean	% Fs σ	% Wo mean
Chico	chondritic	L6	25.1	0.9	0.07	20.9*	0.4*	2.0*
	melt		25.2	0.5	0.06	-	-	-
Lubbock	chondritic	L5	23.8	0.3	0.10	20.1	0.4	1.3
	melt		24.3*	0.3*	0.11*	-	-	-
	clasts		23.4	0.4	0.11	19.6	0.9	1.8
Orvinio	chondritic	H6†	18.6	0.3	0.01	16.5	0.8	1.1
	melt		17.7*	1.7*	0.09*	15.9*	0.9*	2.7*
	clasts		18.5*	0.6*	0.04*	16.0	0.7	1.0
Point of Rocks	chondritic	L6	23.4	0.4	0.08	18.4	0.9	2.0
	melt		24.6	1.2	0.08	19.4	1.0	2.0
Ramsdorf	melt	?5‡	22.4	0.7	0.20	18.2	0.8	3.2
	relicts		21.7	0.4	0.25	15.5*	2.2*	2.7*
Rose City	chondritic	H5	18.6	0.3	0.10	17.0*	1.9*	1.7*
	clasts		18.0	0.4	0.05	-	-	-
Sete Lagoas	chondritic	H5§	18.7	0.3	0.02	16.5	0.6	1.4
	clasts		18.8	0.4	0.04	16.6	0.5	1.4

* 1-10 analyses, otherwise 10-50; † not L; ‡ O isotopes ($\delta^{18}O$ 4.50, $\delta^{17}O$ 3.22) are not L group (R.N. Clayton, unpubl.); § may be different from H4 of Gomes and Keil [14].