
INTRODUCTION. The initial study of the recently discovered Rio Cuarto impact crater [1, 2] noted many unique features associated with loess target materials and the impactor, at least two of which are pertinent to this study: (a) the crater was formed by low angle impact into unconsolidated loess which resulted in uniquely formed loess impactites and, (b) the impacting meteorite was an H5 ordinary chondrite.

IMPACTITES. Three major groups of impactites are being investigated: (I) impact consolidated loess; highly porous (vesiculated), sintered to partially melted at grain boundaries. (II) impact consolidated loess; highly porous (vesiculated), with large areas of complete melting. (III) twisted, glassy objects [1; 2 & 3 this conf.]. The melt-indurated impactites, i.e., incipient grain boundary melting (types I & II; Figs. 1 & 2) contain few examples of mechanical shock although several plagioclase and quartz grains contain planar elements. The major effect from impact shock appears to be melting. In addition to partial melting of quartz and feldspar, partial melting of Ti-Fe2O3 resulted in eutectoid textures and melt reaction rims that consist of pigeonite, SiO2-rich glass, and magnetite formed around augite. (Fig. 3). Discussion. Previous experimental studies of energy partitioning by oblique impacts [4,5] indicated that heating by mechanical shear may be more important than shock heating as impact angles decrease (15-45° from hor.). Although peak shock pressures in solid and particulate targets decrease as $v^2\sin^2\theta$, vaporization and melting were observed to increase as $v^2\cos^2\theta$; this process may impart disparity between observed peak shock levels and impact melt generation. This may be further enhanced for Rio Cuarto due to the high porosity of the loess substrate.

IMPACTOR. The impactor is an ordinary H5 ordinary chondrite based on the examination of two fragments that shows an olivine composition of Fa18 and opx of Fs17 (30 grains each measured) with MD of <3%. Most petrographic indicators [6] also suggest a 4/5 metamorphic grade. Fragment A, initially described by [1], has a discontinuous melt rim = 1 mm thick (Fig. 4) with sparse gas vesicles. The rim consists of olivine quench crystals (cores, Fa15-20; mantles, Fa25-38), interstitial, partly devitrified quench glass (FeO = 25 wt%; ferrohypersthene devitrification crystals) (Fig. 5) and irregular-shaped FeNi metal/FeS dendritic-textured globules (Fig. 6). Terrestrial weathering has altered the metal to Fe-oxides. However, the cooling rate during solidification can still be estimated [7] from the spacing of the dendrite arms of the pseudomorphically replaced metal; 22 measurements indicate a cooling rate of $\approx 1000^\circ$ C/sec (through the interval 1400-950°C). Fragment B is devoid of a melt rim and any apparent shock features. Discussion: melt rim origin. Two plausible formation scenarios are considered; (a) atmospheric entry ablation and, (b) partial melting during passage through the impact cloud. The observed textural and compositional characteristics are unlike any that we have observed in ablation rims of 9 ordinary chondrites. Ablation rims invariably contain magnetite without the globules found in the rim of the Rio Cuarto chondrite. This implies a different FeO2 formation environment for the Rio Cuarto rim compared with typical atmospheric ablation, although characteristics are unknown for ablation rims of large impacting bodies. Ablation rims also contain more glass, quench olivine is commonly very fine-grained, and the rims are highly vesiculated in comparison to the Rio Cuarto rim. This Rio Cuarto chondritic impactor fragment was found in one of the downrange craters. The unique impactor characteristics and its survival in a downrange crater provide important clues for energy partitioning during oblique impact. Experiments [4,8] reveal that energy partitioned to the impactor also decreases as sin$^2\theta$. At sufficiently low angles, the impactor ricochets with reduced levels of fragmentation while retaining a significant fraction of the kinetic energy [4]. Larger ricochet fragments are observed to impact at hypervelocities prior to arrival of vapor and melt from the primary crater uprange. The low shock level, occurrence, and unique pattern of melting are consistent with passage of this fragment through and partially melting in the transient impact vapor cloud as suggested in [1]. This fragment may represent either a surviving ricochet fragment or a piece of the impactor spalled during entry and retained in the wake.
Rio Cuarto Loess Impactites: Bunch T. E. et al.


Fig. 1. Photomicrograph of type I impactite showing a network of incipient grain melt, vesicles, unmelted material, and tiny clusters of dusty Fe$_3$O$_4$ (black). Scale = 0.15mm. Fig. 2 SEM-BSE image of type II impactite showing vesicular intergranular glass, unmelted grains, dusty Ti-Fe$_3$O$_4$ and Fe-rich glass (near scale bar). Scale = 0.1mm. Fig. 3 SEM-BSE image. Melt reaction corona of pigeonite + SiO$_2$ glass + Fe$_3$O$_4$ around augite. Scale = 0.01mm. Fig. 4 Photomicrograph of chondrite melt rim (arrow). Mostly composed of acicular olivine. Scale = 0.5mm. Fig. 5 SEM-BSE image of rim showing olivine quench crystals, glass and partially melted chondrule olivine (arrow). Scale = 0.1mm. Fig. 6 SEM-BSE image of dendritic-textured FeNi (now Fe$_3$O$_4$)/FeS globules. Scale = 0.1mm