separable processes in dimensionless form and tests how completely they accommodate the observations. Such an approach hopefully precludes inadvertent exclusion of relevant processes, *a priori*. It is first assumed that static lithostatic/atmospheric pressure alone controls crater scaling in order to compare the present experimental results with the previous results of *Holsapple* [1980] and *Herr* [1971]. Static atmospheric pressure effects are then isolated from possible dynamic pressure effects for a given target by examining data for a given event scale (initial impactor conditions) at low atmospheric densities. The derived scaling relations are used to correct the observations for static pressure in order to identify and characterize possible effects of aerodynamic drag through use of a wide range of targets and atmospheres. These empirical results are discussed in the context of scaling relations suggested by *Holsapple and Schmidt* [1987]. A systematic increase in cratering effeciency with increasing atmospheric pressure for dry sand, however, suggests that other atmospheric effects could be affecting crater scaling. Experiments designed to isolate the wake blast (disturbed air trailing the projectile) on loose particulate targets document the possible importance of this process. Consequently, corrections for static pressure and drag are made to examine the possible effects of such projectile-atmosphere interactions on cratering effeciency in different targets.

The goal of this study, then, is to first establish the dramatic effects of an atmosphere on impact excavation of particulate targets, in contrast with previous studies [*Holsapple*, 1980]. In this context, discussion emphasizes common trends and systematic differences for contrasting target types. The second goal is to reconcile the observed differences through identification of additional atmospheric effects and consideration of scaling relations.

Experimental Conditions

The impact experiments were performed at the NASA-Ames Vertical Gun Range (AVGR), Moffett Field, California. This is a national impact facility jointly operated by NASA-Ames and the Lunar and Planetary Institute, Houston, Texas, through NASA's Planetary Geology and Geophysics Program. Table 1 summarizes the variety of target types and properties used in this report. The primary target materials were compacted pumice and no. 140-200 sand, both with a bulk density of about 1.50 g/cm^3. The pumice target material has a median size of 80 µm with a bimodal distribution (primary concentration of sizes centered on 88 µm with a secondary concentration near 20 µm); the no. 140-200 sand (representing nearly 100% passing a U.S. no. 140 sieve while retained on a U.S. no. 200 sieve) exhibited a narrow range of sizes with both median and mode centered on 125 µm. Figure 1 and Table 1 provide more complete summaries of these and other targets. Uncompacted pumice exhibits a density near 1.2 g/cm^3 and first results indicated considerable dispersion in the data and clumping of ejecta while in ballistic trajectories. Subsequent experiments used compacted pumice with a measured bulk density of 1.5 g/cm^3.

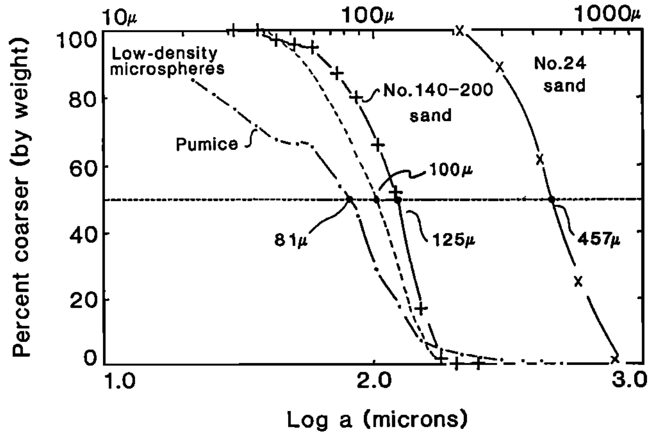

Fig. 1. Cumulative size distributions for particles comprising targets used in this study. Pumice targets were prepared by evacuation and compacting, thereby increasing density from 1.2 to 1.52 g/cm^3. Uncompacted pumice resulted in clumping of ejecta.

TABLE 1. Target Properties

Type	Grain Sizes*, µm			Bulk Density, g/cm^3	Internal Angle of Friction
	20%	50%	80%		
Pumice (compacted)	120	81	26	1.52	>80°
Microspheres	130	97	65	0.4	~20°
No. 140-200 Sand	145	125	89	1.55	~30°
No. 24	620	457	320	1.70	~30°

* Size of ejecta where cumulative fraction (by weight) is coarser than percentage given.

The use of compacted pumice was based on an extensive data base for parallel studies of atmospheric effects on ejecta emplacement [*Schultz and Gault*, 1981, 1984; *Schultz*, 1990, 1991]. Pumice, however, exhibits significant cohesion reflected in its high internal angle of friction (see Table 1). Consequently, crater growth may be controlled by material strength, rather than gravity, in addition to any atmospheric effects. Although fine-grained sand exhibits much lower internal friction, experiments revealed that craters formed in such targets at high atmospheric pressure undergo considerable collapse as well as possible interactions with the disturbed atmosphere accompanying the projectile. This study explores the response of these two very different target materials.

Two additional low-strength particulate targets were tested in order to examine possible extremes: coarse no. 24 sand and low-density microspheres. The coarse no. 24 sand has been extensively used in vacuum scaling studies [*Gault and Wedekind*, 1977] and exhibits low internal friction due to the rounded component quartz grains. The large size of the individual grains (see Table 1 and Figure 1), however, should minimize effects of aerodynamic drag at laboratory scales. In