The similarity in pressure effects on sand and pumice (Figure 4*a*) and the dependence with projectile size (Figure 4*b*) indicate that the atmosphere acts to modify gravity-controlled stages of crater growth. Although strength still must limit the last stages of growth in pumice (and even sand), this occurs after the velocity field has reduced to some critical value characteristic of the target, not the environment.

The appropriate gravity-scaling relation modified by atmospheric pressure from equation (10) now can be selected on the basis of the best fit to the data. Figure 5 shows the subset of low-density data selected to maximize atmospheric pressure effects while minimizing competing processes (helium data again shown in bold). Equation (10*c*) provides a significant improvement over past empirically derived relations: different impact velocities and different projectile sizes collapse into a single relation. Both sand and pumice exhibit parallel, but offset, effects. Nevertheless, different gas compositions and the higher impact velocities introduce

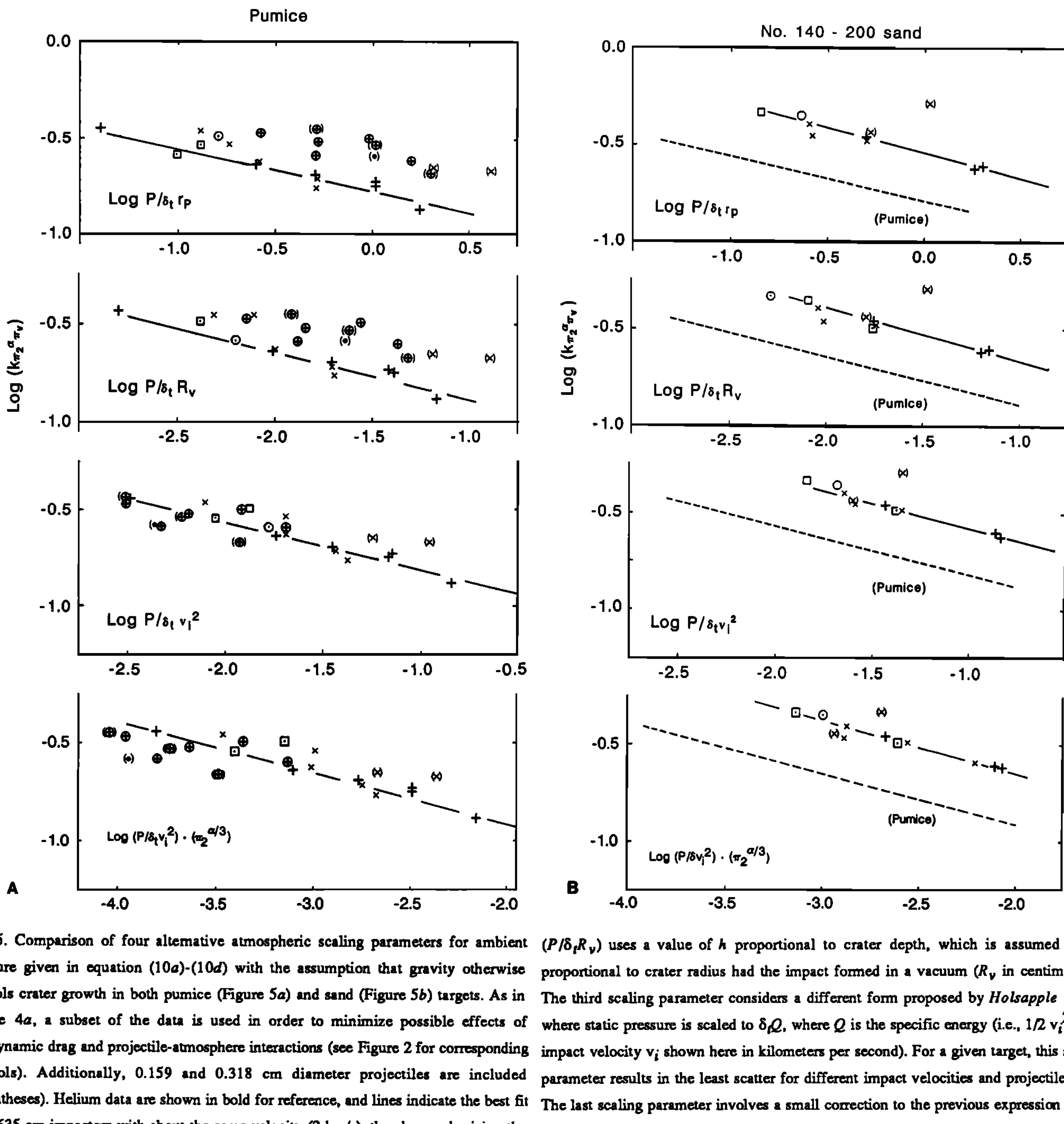

Fig. 5. Comparison of four alternative atmospheric scaling parameters for ambient pressure given in equation (10*a*)-(10*d*) with the assumption that gravity otherwise controls crater growth in both pumice (Figure 5*a*) and sand (Figure 5*b*) targets. As in Figure 4*a*, a subset of the data is used in order to minimize possible effects of aerodynamic drag and projectile-atmosphere interactions (see Figure 2 for corresponding symbols). Additionally, 0.159 and 0.318 cm diameter projectiles are included (parentheses). Helium data are shown in bold for reference, and lines indicate the best fit for 0.635-cm impactors with about the same velocity (2 km/s), thereby emphasizing the static atmospheric pressure dependence without introducing drag and wake blast effects. The top graph shows atmospheric pressure (in bars) divided by projectile radius (cm) and target density (g/cm^3); this is an abridged form of $P/\delta_t g h$ where $\delta_t g h$ is the lithostatic pressure (δ_t being target density, g is gravity, and h is a characteristic assumed to be proportional to projectile radius r_p) for a given target and density. The second parameter ($P/\delta_t R_v$) uses a value of h proportional to crater depth, which is assumed to be proportional to crater radius had the impact formed in a vacuum (R_v in centimeters). The third scaling parameter considers a different form proposed by *Holsapple* [1980] where static pressure is scaled to $\delta_t Q$, where Q is the specific energy (i.e., $1/2\ v_i^2$ with impact velocity v_i shown here in kilometers per second). For a given target, this scaling parameter results in the least scatter for different impact velocities and projectile sizes. The last scaling parameter involves a small correction to the previous expression on the basis of dimensional analysis and the coupling parameter approach of *Holsapple and Schmidt* [1987]. Figure 5*b* considers data for no. 140-200 sand using the same four scaling parameters. Figure 5*b* reveals that both sand and pumice exhibit a similar dependence on atmospheric pressure. Data for the two targets, however, are systematically offset.