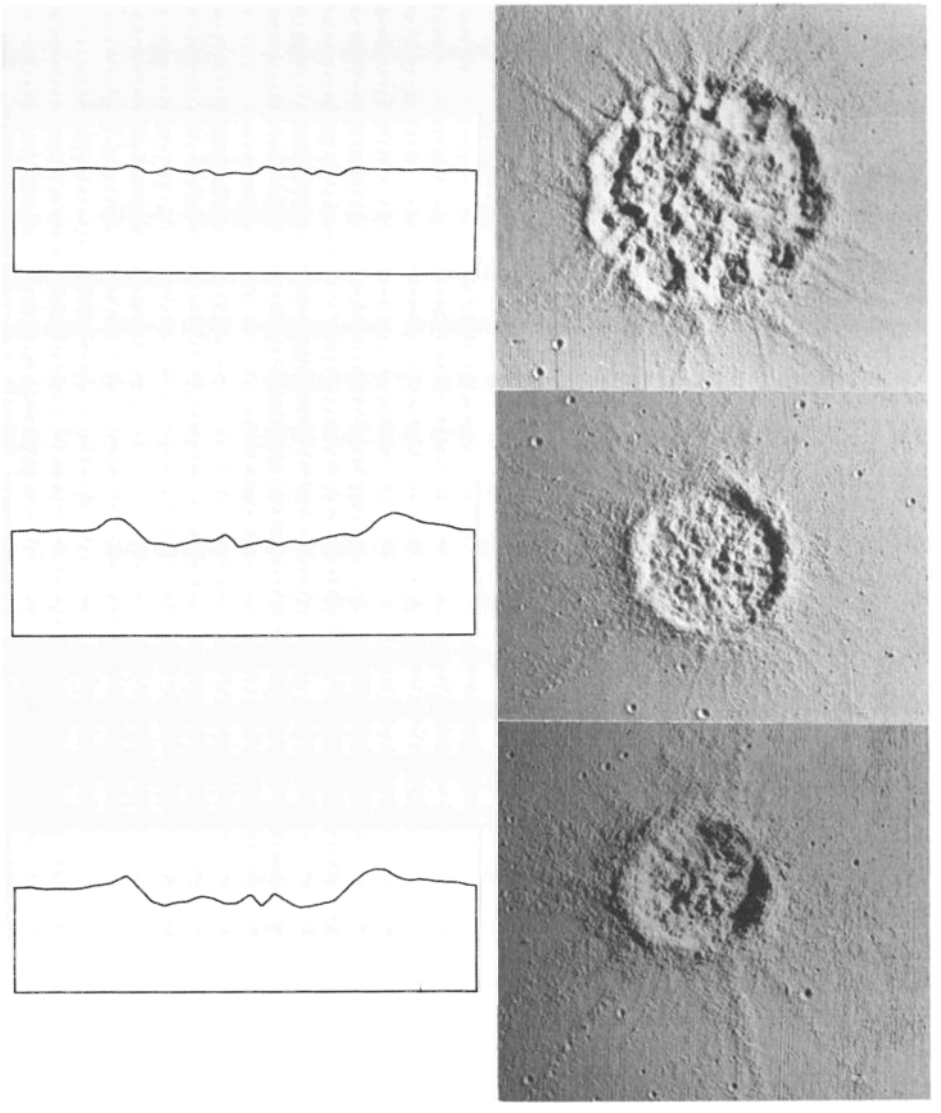

Fig. 9*b*

4.4. *Spoked and Herringbone Patterns*

A feature common to all low-velocity clustered impacts at normal incidence is the development of a spiked pattern of ridges extending radially and subradially from the crater rim. High-velocity clustered impacts do not produce this pattern. The number of spokes do not appear to depend on the number of impacting fragments in the cluster. Thousands of fragments produce about 20 well-defined spokes. High frame rate movies reveal that the spokes result from filamentary strings of ejecta that develop at relatively late times (see below).

For nonvertical impacts (Figure 16) the spokes form acute angles directed down range, thereby resembling the "herringbone" pattern of secondary impacts on the moon. Figure 17*a* illustrates the systematic change in this pattern and crater profile with impact angle, and Figure 17*b* illustrates the effect of cluster dispersion. Six distinctive features are observed. First, the herringbone pattern generally subtends smaller apex angles with smaller impact angle. Second, the herringbone pattern commonly bends downrange with increasing distance from the crater rim. Third, the zone of maximum ejecta deposits forms a downrange fan for modest impact angles (<60° from the horizontal) that does not occur for single impactors except for very low (<10°) impact angles as shown by *Gault and Wedekind* [1977]. Fourth, little ejecta are deposited uprange even at modest impact angles (<60°). Highly oblique (<15°) single-body impactors produce asymmetric butterfly wing ejecta patterns with little ejecta in the uprange and downrange (except for the fan) directions. Fifth, the crater rim becomes pronounced downrange and eventually absent uprange as cluster dispersion increases, and sixth, the crater floor is asymmetric with the deepest portion occurring uprange. Both of these latter features also occur for single impactors but require much lower impact angles [*Gault and Wedekind*, 1977]. The progressive change in crater morphology with cluster dispersion is shown in Figure 17*b* and underscores the contrast between single and multiple impactors.

Figure 18 quantifies the systematic change in the herringbone pattern with impact angle for two different types of clustered impacts. For low-velocity (100 m/s) aluminum shot in sand, the