litical science. It has become almost a platitude that the physical sciences have progressed, in recent years, at a rate astronomically greater than the rate of progress shown by the economic and political sciences. I believe one reason for this may be that the nonphysical sciences are too often taught as immutable truths, not subject to continuous re-examination and re-evaluation as a result of experimental tests—that is, research.

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May I comment on the statement of Sander Rubin about my "position" in the matter of teaching and research? He stated only half of it—and half a position is worse than none—when he noted that I claimed "any scholar not doing research simply cannot be a fully effective teacher." I also claimed—and neither half is complete in itself—that any scholar not immersed in teaching may have great difficulty in being a fully effective research worker. The point of my letter was not to take sides or to state an ideal but to propose that side-taking in this issue is tantamount to missing the point.

Some scholars prefer teaching, others research; some cannot make a sensible dichotomy. Whatever the case, to prefer one to the *exclusion* of the other may turn one aspect of scholarly activity into a mere technical competence like watchmaking or ghostwriting.

The deeper question is whether we want our universities and colleges (unlike our secondary and preparatory schools) manned by scholars or by Mr. Chipses. The original editorial and my letter [*Science* **131**, 71, 1282 (1960)] came down firmly on the side of scholars. The ultimate question may be whether a university should "give" an education by "good teaching" or create the kind of place in which an education is available to those who have sufficient interest and intelligence to take it.

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Shatter Cones and Their Origin

The shatter cones in fine-grained limestones and dolomites, described by Dietz [*Science* **131**, 1781 (1960)] are merely a much-magnified version of the cones of percussion well known to archeologists. It is this conical or conchoidal fracture in flints and cherts that made flint-working possible and started mankind on the technological exploitation of his environment.

Miniature cones of this kind are perhaps best seen in plate-glass doors and windows, where they have been produced by the impact of pebbles thrown up by passing cars, or bullets from air rifles or .22's in the hands of teen-agers. The apical angles of these cones are much blunter than in those shown by Dietz—well over 90° in all I have seen. This is presumably because of the lower impact velocity or lower energy of the pebbles, relative to that of a meteorite.

Cones of this perfection rarely if ever appear in worked flint, probably because man had no use for them. The impact of his hammerstone or flaking punch was deliberately localized near the edge of the flint block, so that a flake of controlled size and shape could be split off.

Surely somebody must have worked out the mathematical theory of shock waves in extended solids, such as a thick stratum of stone. Empirically, it can be seen that a greater impact produces sharper cones, that the conical wave penetrates deeper before being damped, and that at high velocities and energies the irregularities in the medium become a less controlling factor. Dietz speaks of shatter cones which have penetrated more than 12 meters in shale, a laminated stone, whereas impact cones are usually stopped by the layer of plastic in safety glass. Nevertheless, the phenomenon of conical fracture in stone cannot be considered one of great energies or velocities, except in so far as the size of the cone is concerned.

I do not recall having seen parasitic coning in flake surfaces in chipped flint. However, this is perhaps because of the distortion of the conical wave form and the different order of magnitude of the energies produced by a blow of a hammerstone and the impact of a meteorite.

The apex of the cone is ordinarily at the point of impact, and this cannot be the case with the parasitic cones. I presume that they develop where the main shock wave strikes some structural discontinuity in the stone, which initiates a new wave at that point. This suggests that where the apices of the presumed master cones are found below the surface of the rock strata, they may themselves be parasitic to a much larger cone with its apex at the surface, produced by the impact. Perhaps more logically, they may have been initiated at points along the front of some sort of spherical shock wave, if such forms exist.

I question Dietz' conclusion that volcanic explosions cannot initiate shatter cones, though they may not be able to produce cones as large or as sharp as those in his illustrations. In any case, cones of volcanic origin should be produced with their apices pointed downward, or at least toward the focus of volcanic shock, and not toward the surface. Dietz does not specify whether this was the case with the cones at the site of the underground nuclear bomb test.

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Formation of cones is a well-known common mode of failure both by percussion and by static loading. The point I make is that shatter cones are a *distinctive* type of percussion cone apparently related in nature to hypervelocity meteorite impact and a subsequent engulfment of the rock by an intense shock wave.

Conchoidal coning is *another* distinctive mode of coning. It is typical of glassy and isotropic cryptocrystalline solids. As the name implies, it is characterized by horizontal shell-like ribbing. Prehistoric man, and convicts working on the stone piles at Sing Sing for that matter, have produced uncounted millions of conchoidal fractures but never a shatter cone.

As I mentioned, artificial shatter cones are produced by nuclear detonations and high-*brisance* explosives. Just recently I have received from E. M. Shoemaker and D. Gault a plaster cast of the target crater produced in Kaibab limestone by a 3/16-in. glass pellet fired at 18,000 ft/sec at the Moffet Field laboratory of the National Aeronautics and Space Administration. At ground zero there is a beautiful nest of minute shatter cones.

The apex of a shatter cone is not the point of impact; rather, shatter cones are formed by the spherically spreading shock wave when it strikes some lithologic discontinuity. The spreading of the fracture is then limited by the next lithologic discontinuity, so that the cone may be either 1 centimeter long or many meters. The apex of the cone points toward the advancing shock-wave front. At the nuclear detonation site mentioned, jumbled and caved rocks had fallen into the explosion cavity. It was not possible to reconstruct the original orientation of the shatter-coned rock.

Shatter cones have never been reported from volcanic explosion sites. I don't believe they exist. Discovery there would be a simple and sufficient disproof of my thesis that shatter cones are a distinctive criterion for hypervelocity meteorite impact. I urge volcanologists to search for them. Science progresses not only by the discovery of new truths but also by discarding erroneous hypotheses.

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