is the average of three determinations and is given with the average deviation from the mean. Our results indicate that Buch and Gripenberg's (*3*) values for the pressure coefficient of K'_2 are too small, and that the dissociation of boric acid must be considered when studying the effect of pressure on the *p*H of seawater (*10*).

In Table 2 we have computed the effect of pressure on *p*H for a seawater with T(B) = 0.437 m*M* per kilogram of H_2O and TA = 2.57 meq per kilogram of H_2O. The *p*H decrease is linear with pressure and does not vary significantly with the variations in TA that occur in the ocean.

The main differences between our *p*H shifts and those calculated by Buch and Gripenberg (*3*) are due to the dissociation of boric acid under pressure, and to the fact that the effect of pressure on K'_2 is larger than Buch and Gripenberg estimated.

It is possible to use our measurements of the pressure coefficients at 22°C, in conjunction with Lyman's (*1*) values of the apparent dissociation constants at 1 atm and 2°C, to process oceanic data. However, we are presently measuring the pressure coefficients of carbonic and boric acids in seawater at low temperatures, and we feel that it would be best not to apply a pressure correction to deep-sea *p*H data until the temperature effect is known.

C. CULBERSON
D. R. KESTER
R. M. PYTKOWICZ
Department of Oceanography, Oregon State University, Corvallis

References and Notes

1. J. Lyman, thesis, University of California, Los Angeles (1957).
2. E. Brander, *Soc. Sci. Fennica, Commentationes Phy.-Math.* **6**, 1 (1932).
3. K. Buch and S. Gripenberg, *J. Conseil, Conseil Perm. Intern. Exploration Mer* **7**, 233 (1932).
4. R. M. Pytkowicz, *Deep-Sea Res.* **10**, 633 (1963).
5. A. Disteche and S. Disteche, *J. Electrochem. Soc.* **114**, 330 (1967).
6. A. Disteche, *Rev. Sci. Instr.* **30**, 474 (1959).
7. J. Lyman and R. H. Fleming, *J. Marine Res.* **3**, 134 (1940).
8. C. E. ZoBell and C. H. Oppenheimer, *J. Bacteriol.* **60**, 771 (1950).
9. H. S. Harned and B. B. Owen, *The Physical Chemistry of Electrolytic Solutions* (Reinhold, New York, 1958), p. 507.
10. Buch and Gripenberg's calculations were based on molar concentrations. We converted their pressure coefficients to molal concentrations by multiplying their values by d_1/d_P, the ratio of the density of pure water at 1 and at *P* atmospheres. Their *p*H shifts were corrected by adding the quantity $[-\log(d_1/d_{654})]/6.54$.
11. A. Disteche offered valuable advice throughout this research. This work was supported by NSF grant GA-301.

13 April 1967; revised 22 May 1967

Tektites That Were Partially Plastic after Completion of Surface Sculpturing

Abstract. *Among the 50,000 tektites collected over an 8-year period as part of a representative collection of the indochinities in an area near Dalat, South Vietnam, several individual ones have been found that show evidence of having been internally plastic after surface sculpturing was essentially completed. Two drops, which were bent after having formed a thin exterior skin or crust, exhibit surface breaks and stretching of their plastic interiors within the breaks. The lack of deep sculpturing in this interior stretched area, coupled with twisting within the break on one of them, indicates that the surface features on these tektites were formed in the atmosphere and not by etching by soil acids, as had been widely believed.*

The external features of tektites from southeast Asia have generally been considered to be the result of deep etching by soil acids. Evidence found in the surface features of several indochinites from an area near Dalat, South Vietnam, now indicates that this concept may be in error and that the general surface features are the result of aerial ablation. This evidence was discovered during the examination of field collections, totaling 50,000 specimens, made during an 8-year period beginning in 1958.

In inspecting the first 40,000 specimens, many shapes were found that indicated stretching: elongate drops, rods and straps that appeared to represent portions of the tails of drops that had been elongated to perhaps 6 inches (15 cm) or more, dumbbells, and discoidal shapes that showed whirlpool or swirling effects that had resulted from spinning. A large percentage of the elongate specimens also showed twisting and bending. Sixty-six percent of all specimens showed breakage, and an even larger percentage showed spalling. However, it was only during examination of the next 10,000 specimens that the full significance of these forms began to be realized.

As long ago as 1900, Suess (*1*) concluded that the surface sculpturing of tektites was due to aerial ablation and was "not due to some sort of corrosion process," because corrosion causes a matte appearance that is lacking on the surfaces of most tektites and that fails to account for the grooves and cupules found on tektite surfaces. Most students of the subject disagreed with this hypothesis, insisting that the present surfaces of tektites, particularly those of indochinites, were the result of deep etching by acids in soil.

Serious difficulties for the theory of attack by ground chemicals come from a study of the broken indochinites. Many indochinites have flattish surfaces that cut sharply across the rounded surfaces that seem to be part of the original shape, and these flattish surfaces are logically interpreted as breakage surfaces. The degree of pitting and sculpturing is much less on the broken surfaces than it is on the rounder original surfaces. In terms of the theory of attack by ground acids, this clearly implied that breakage had taken place after more than half the life of the tektites on the ground and that it had occurred simultaneously throughout the area strewn with indochinites. It was suggested (*2*) that this breakage might have resulted from an enormous tidal wave.

Doubts about these solutions to the problem were enhanced by the discovery of a number of onion-shaped tektites (Fig. 1) that look as though they had encountered either the surface of the ground or else the denser layers of the atmosphere while still in a molten condition.

The really decisive evidence was furnished, however, by two tektites (Fig. 2) that seem to have suffered sharp bending while the interior was still plastic. The exteriors of these had actually broken. Close inspection showed that breakage had occurred after cooling from the outside had produced a thin skin or crust over a plastic interior. The broken skin of the tektites had pulled apart, much as the skin of a cut finger would, while the plastic interior stretched but did not break. Thus, we conclude that although more than two-thirds of the indochinites were broken after more or less complete cooling had taken place, not all of them were cold rigid bodies at this point.

The internal plasticity of these tektites this late in flight is explained by the conclusion that tektites did not arrive at the earth's atmosphere as a

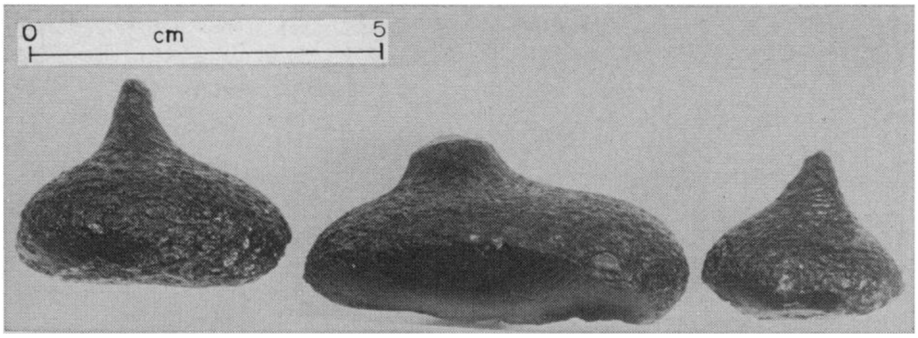

Fig. 1. Bulbous drops that show plastic flattening and external spallation after completion of aerial sculpturing.

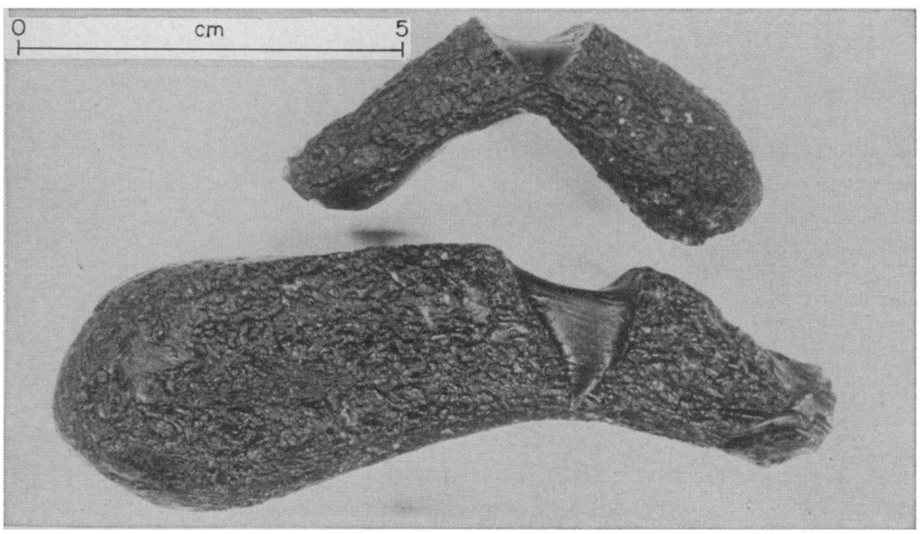

Fig. 2. Tektites that suffered surface breaks and interior stretching during plastic bending. Note lack of sculpturing within breaks.

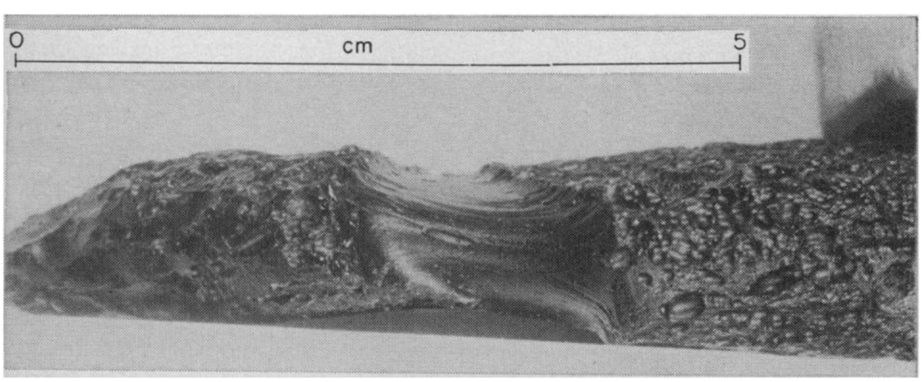

Fig. 3 Dorsal view of larger drop shown in Fig. 2, demonstrating twisting that accompanied surface separation and stretching.

swarm, but were spawned by a larger, semisatellite parent body (*3*) rotating rapidly within the confines of the atmosphere (*2*). Tektites were thrown off in all directions, up as well as down, and a very small percentage of them cooled in the act of plastic bending. Had they arrived at the atmosphere as individuals, there would have been little or no internal heating or plastic shaping and bending, but only surface ablation from atmospheric friction.

Some will argue that this bending occurred before the tektites encountered the atmosphere and that the breaks are not true breaks, but are only the result of much later spalling induced by the stress of bending, coupled with the action of soil acids. This argument might carry considerable weight were it not for the following considerations.

The interiors exposed by surface separations in the bent drops show only very slight etching, similar to the etching noted in the freshest of australites. These surfaces show no evidence of flight markings. They must, therefore, have been exposed, at the earliest, only after major aerial ablation had ceased to operate upon the exterior of the tektites.

The breaks thus exposed cannot be the products of spalling for they show no concoidal fracturing as do the normal spall markings. Many of the markings on either side of the separations would match if placed back together, showing that the specimen was completely formed and marked before bending and separation took place; and, most important, there is considerable twisting within the break in the larger specimen (Fig. 3). There is no conceivable manner in which such twisting could have occurred had not the specimen first been broken while in a partially or internally plastic state. The specimen must have been broken upon encountering strong aerodynamic resistance, or the soil, or by a collision with another individual very near the end of its terminal flight.

It seems evident, therefore, that the major features on the exterior of the indochinites from Dalat, Vietnam, were not formed by soil etching. Had they been, the areas of these breaks would have been as deeply etched as the exteriors of the specimens are widely thought to be. The major features had to be formed during their atmospheric flight. It is also evident that much of the breakage and the so-called spalling, which is widespread and shows the same etching age as the surfaces exposed by the skin fractures, also dates from the time of original fall and not from later breakage.

It is suggested that the forms and surface features of the indochinites be reevaluated in light of this new information and its relation to other known facts and to tektites of other areas.

H. H. Nininger

Meteorite Investigations, Sedona, Arizona

Glenn I Huss

American Meteorite Laboratory, Denver, Colorado

References and Notes

1. F. E. Suess, *Jahrb. Geol. Reichsanst.* **50**, 193 (1900).
2. H. H. Nininger, *J. Ariz. Acad. Sci.* **1**, 125 (1961).
3. J. A. O'Keefe and B. E. Shute, *Aerospace Eng.* **20**, 26 (1961).
4. We thank Dr. John A. O'Keefe for reading the manuscript and making valuable suggestions for its improvement.

28 April 1967