Meetings and Societies

Tektites

The growing scientific interest in cosmology and the relation of cosmic matter to the genesis of the elements has focused attention on all available samples of extraterrestrial matter. Inasmuch as meteorites are frequently seen to fall, their extraterrestrial origin is certain. Another class of objects, the tektites, may also be extraterrestrial, even though none has ever been observed to fall.

The tektites are glass objects that are found in several widely separated places on the earth (southern Australia, Texas, Czechoslovakia, the Philippine Islands, Java, the Ivory Coast, and the Libyan Desert). In each area many individual specimens, which weigh from 0.1 to 1000 grams each, have been found. They are often symmetrical in shape, and, in the case of the australites, their shapes are distinctly suggestive of "flow patterns." In bulk chemical composition they differ from obsidian and other volcanic extrusive rocks but resemble certain sedimentary rocks. That they cannot be of volcanic origin is shown by their distribution in areas where there is no associated volcanism. They are not associated with known meteorite craters, and they differ from the glassy "impactite" from such craters in their homogeneity and in the fact that they do not include nonfused local rocks. They all seem to be associated with sedimentary formations of Eocene to Pleistocene age.

Workers in the late 1890's proposed that these objects are of extraterrestrial origin. If this is so, tektites represent samples of cosmic matter different from that of the stony and iron meteorites. Even if they should be strictly terrestrial, their shapes, distribution, and occurrence pose problems of considerable interest.

The possibility of learning something more about the nature and origin of tektites by application of modern techniques has resulted in research on tektites by people in widely separated disciplines, including astrophysics, geology, geochemistry, and nuclear science. It was felt by some of these workers that a conference that would bring together a large group of persons actually engaged in tektite research, as well as other scientists who might be able to contribute to the various problems they pose, would be very useful. Accordingly, the Earth Sciences Division of the National Academy of Sciences–National Research Council requested and obtained support from the National Science Foundation for this purpose.

The Conference on Problems of Tektites was held at the National Academy of Sciences–National Research Council building in Washington, D.C., 17–18 June. Twenty scientists participated, and Irving Friedman served as chairman. Although several foreign scientists were invited, F. G. Houtermans, of Berne, Switzerland, was the only one able to be present. E. L. Krinov, of Moscow, sent a paper which was read at the conference, as were two lengthy letters from H. Otley Beyer, of Manila.

Technical discussion. The sessions started with the presentation of a paper, "Tektite localities in the United States," by Virgil E. Barnes (University of Texas), who summarized much of the present knowledge of tektites and their distribution. The only well-established occurrence in the United States is near a 120-mile length of the tilted sedimentary rocks of the Jackson formation, of late Eocene age, which crops out along a northeast-southwest line through Texas. Here the tektites seem to be eroding out of the Jackson formation, whose stratigraphic age is about 35 million years. A few specimens from Georgia suggest, but are insufficient to establish, an occurrence there. All other reported occurrences in the United States are now attributed to obsidian. The "americanites" of Colombia and Peru are also believed to be obsidian. Barnes favors a meteoritic origin for tektites; because of the close similarity of their chemical composition to that of terrestrial sedimentary rocks, he feels that similar rocks on another planet, later disrupted, might be the source of the material.

The hypothesis of a disrupted planet is also favored by William A. Cassidy (Pennsylvania State University), who reported on phase equilibrium investigations on tektites. He emphasized the double analogy between granites and tektites on the one hand and between mafic terrestrial rocks and stony meteorites on the other. He also noted that a recently discovered region of two-liquid immiscibility in molten mixtures of SiO_2, Al_2O_3, K_2O, and FeO corresponds to the gap in silicon content separating the tektites (more than 70 percent SiO_2) from the stony meteorites (less than 60 percent SiO_2). This suggests a differentiation between silicate groups with gravitational stratification in the parent planet, which would then have consisted of a metallic core, a crystalline mantle of mafic silicates, and an outer layer of sialic character. The latter may have been kept molten by its high concentration of radioactive elements up to the time of disruption, at which time the liquid presumably solidified into particles and the various sizes and shapes were caused by rotation. The surface features of those particles found on earth were caused by superficial heating during entry into the atmosphere.

Support for the meteoritic nature of tektites was given by studies of cosmic-ray-induced radioactivities in meteorites and tektites, reported by William D. Ehmann and Truman P. Kohman (Carnegie Institute of Technology). They found Al^{26} (half-life about one million years) in australites at about the same level as in chondritic meteorites, whereas this nuclide was absent in moldavites (Czechoslovakian tektites), in bediasites (Texas tektites), and in the terrestrial materials examined. This checks with the very fresh appearance of australites and indicates intervals, since fall, of at least several million years for moldavites and bediasites, which are highly weathered. A lower but definite level of Al^{26} in Libyan Desert silica-glass indicates that this material is to be classified as tektitic and meteoritic and that it fell about four million years ago. The occurrence of Be^{10} (half-life 2.7 million years) in some meteorites and tektites was indicated, but the levels of occurrence and the absence of Be^{10} in terrestrial materials were less well established.

The extreme unlikelihood that a swarm of particles could keep together in interplanetary space in such a way as to strike the earth in areas as small as the observed tektite-strewn fields was emphasized by Fred L. Whipple (Smithsonian Astrophysical Observatory). Whipple presented a paper, with Carlos Varsovsky, titled "Dynamical limits on a lunar origin for tektites." Certain considerations suggest that the collision of a large meteorite with the moon might eject molten matter in a right-circular hollow cone of rather narrow wall thickness, and that if this cone strikes the earth, its thickness might be reduced by a focusing effect of the earth's gravitational field. Calculations, now being programmed for the M.I.T.-I.B.M. computer, of orbits of particles leaving the moon from various points with various initial directions and velocities, may establish the validity or lack of validity of the "lunar impactite" hypothesis. Whipple also presented valuable summaries of present knowledge and theories concerning comets and meteors. Any connection between tektites and either of these classes of objects seems quite unlikely to him.

The assumption that tektites are formed from terrestrial materials was supported by several of the participants. A paper submitted by Krinov (scientific secretary of the Committee on Meteorites of the Academy of Sciences of the U.S.S.R.), entitled "Some considerations on tektites," was read. The findings of Soviet and other investigators seem to Krinov to support Spencer's theory that tektites are high-velocity impactites that were formed as a result of collisions of large meteorites with the earth. A paper, "Origin of Tektites" [*Nature* **179**, 556 (1957)], was submitted by H. C. Urey (University of Chicago) and read by the chairman. This paper described possible effects of collision of the head of a comet with the earth, which might include the fusing and scattering of terrestrial rock as tektites. Dynamics of collisions of large meteorites with the earth's surface were considered in detail by John S. Rinehart (Smithsonian Astrophysical Observatory) on the basis of controlled impact experiments and theory. His paper, "Impact effects and tektites," developed a mechanism by which the forms of tektites could result from the impact of a large crater-forming meteorite.

Several speakers presented information on various aspects of the physical and chemical composition of tektites. Alvin J. Cohen (Mellon Institute) described absorption spectra of tektites and showed that the principal light absorption feature is due to ferrous iron. No radiation effects were observed, evidently because of a built-in "radiation protection" mechanism. In contrast to tektites, most obsidians show water absorption bands and radiation-induced absorption. F. G. Houtermans (Physikalisches Institut, Berne, Switzerland) reported on studies of thermoluminescence of meteorites. Both chondrites and tektites show stored radiation-induced thermoluminescence, though in the case of tektites the irradiation is not necessarily attributable to cosmic rays because there is a fairly high content of radioelements.

Quantitative data on the content of radioelements in tektites were given by several speakers. John A. S. Adams (Rice Institute) reported extensively on the thorium and uranium contents of tektites. Most tektites have between 1 and 2 parts of uranium per million and have thorium-uranium ratios of about 7 to 1. Libyan Desert silica-glass has somewhat less than 1 part of uranium per million, whereas americanite has more than 18 parts per million. Similar results were obtained by Friedman (U.S. Geological Survey), whose paper is mentioned below. Adams found that most tektites have about 2.5 percent potassium. William H. Pinson (Massachusetts Institute of Technology) and Leonard F. Herzog (Pennsylvania State University) showed in their paper, also mentioned below, that the potassium and rubidium contents of tektites are remarkably constant at about 2.5 percent and 0.01 percent, respectively.

Friedman's paper, titled "Water, gas, and uranium content of some tektites," indicated that tektites have low water content, in contrast to other characteristics that indicate similarity to obsidians. Most tektites have between 20 and 100 parts of water per million whereas obsidians have from 800 to 3500 parts per million. The Libyan glass has somewhat higher water content (more than 700 ppm) and moldavites considerably lower (3 to 5 ppm) than the other tektites. Hydrogen and other noncondensable gases are lacking. The deuterium-hydrogen ratio of the tektite waters is in the range of that of terrestrial waters. The indications are that tektites were melted in the absence of water (this supports the assumption that they are of nonterrestrial origin) or were heated to a temperature in excess of 2000°C in a terrestrial environment.

Various age determination methods involving radioactivity are being applied to tektites. H. E. Suess (Scripps Oceanographic Institute) reviewed the potassium-argon work, which has given upper age limits of several million years. It may be possible to date the solidification of tektites as glass by this method. More sensitive methods now available might give actual values rather than limits for this age for various tektites. Pinson and Herzog, whose paper was titled "Rubidium-strontium ages of tektites," observed rather uniform radiogenic strontium-87 abundance in several tektites. Because the proportion of radiogenic strontium-87 to total strontium-87 is very small, the rubidium-strontium ages are highly uncertain and are very sensitive to the model chosen for the reservoir material from which the tektite specimen separated. For example, if the material of tektites was fractionated from average terrestrial material, their ages would be about 400 ± 200 million years. (Work done since the conference has revealed a systematic error in the strontium isotope results reported. Strontium-87/strontium-86 ratios in eight tektite samples from widely scattered localities are nearly identical, and equal to the ratio found in present day "common" strontium. The rubidium-strontium ages of all samples are thus in the range 10 ± 75 million years; in agreement with potassium-argon age data.) The isotopic composition of lead from tektites was discussed by George Tilton (Carnegie Institution of Washington). The lead from an australite was found to be almost identical with average modern terrestrial lead and totally unlike any meteorite lead.

Publication plans. The majority of the papers presented at the conference will be published in one issue of *Geochimica et Cosmochimica Acta,* to appear probably early in 1958.

General recommendations. H. Otley Beyer (University of the Philippines, Manila), in a letter to the chairman of the conference, pointed out that it is often difficult to learn the names and addresses of people currently engaged in tektite research. As a result, the conference approved his suggestion that a directory of those actively interested in tektites be compiled. It is expected that this directory will facilitate exchange of ideas, reprints, and specimens. All interested persons should write to E. P. Henderson, U.S. National Museum, Smithsonian Institution, Washington 25, D.C., describing their current work on, and interest in, tektites.

The conference chairman suggested that, in view of the difficulty most workers experience in obtaining specimens of tektites, a central clearinghouse for specimens be established to help serious students obtain material for their experimental work. The Smithsonian Institution is being asked to act as agent in these transactions. Several of those present felt that their respective institutions would be willing to subscribe funds for the purchase of specimens for this purpose, and it is hoped that a small research collection may be built up with such funds at the Smithsonian Institution. Through this arrangement experimental material could be used to full advantage, since several experiments can often be run on the same specimen if the sequence is "programmed" correctly. Those interested in obtaining tektite material for their work should write to E. P. Henderson, describing their needs and stating whether or not they could reimburse the institution or offer material in exchange.

Comments. The conference showed that definite progress is being made in solving some of the problems presented by tektites. However, the key problem—whether these objects are of cosmic or terrestrial origin—is not settled. Their chemical composition, the isotopic composition of their lead, and the difficulty of explaining their distribution on astronomical grounds make a terrestrial origin seem likely. On the other hand, their cosmic-ray-induced radioactivity, their low water content, and the difficulty of explaining their distribution on geological grounds make a cosmic origin seem equally likely.

Many of those present felt compelled to pursue further their investigations on tektites or to initiate work along new lines. In writing this report, we feel justified in stressing several avenues of investigation that seem particularly promising for future work.

Additional and more intensive field work on the occurrences of tektites would be valuable. Only in the case of the Libyan Desert silica-glass does the true size and shape of the strewn field appear to be known. Recoveries of material from the ocean bottom off southern Australia, in the Southeast Asia area, and off the Ivory Coast of Africa seem to be possible and would be of great interest. Any possible connection between the Libyan glass field and a group of craters, possibly of impact origin, some hundred kilometers south of the area of the glass field should be investigated.

Laboratory investigations of phase separations in cooling silicate melts of low water-content should be continued and extended to include the effects of pressure.

In connection with studies of cosmic-ray-induced radioactivity in tektites, much more extensive examination of terrestrial materials is needed to determine exactly what their rate of production is at the earth's surface as a function of altitude and geomagnetic latitude. In this connection, in addition to location, the altitude and probable amount of past overburden should be noted and recorded for all meteorites and tektites that are collected.

Various methods of determining age should be applied, with maximum possible sensitivity and precision, to as many occurrences of tektites as possible. Knowledge of the times of the different processes dated by the different approaches may help in understanding their history. Several specimens from each occurrence should be examined, to determine the extent of homogeneity or possible variability.

Quantitative astronomical studies of the behavior of swarms of particles in space should be extended to all possible conditions. Efforts should be made to learn more about the nature of the lunar surface and, in particular, to deduce or, preferably, physically sample its chemical composition.

The main result of the conference was to focus attention on tektite problems and to bring them to the attention of a wider group of scientists. The National Academy of Sciences, the National Research Council, and the National Science Foundation are to be commended and thanked for making the conference possible. It is hoped that in a year or two another conference of more international scope can be arranged.

IRVING FRIEDMAN
U.S. Geological Survey, Washington, D.C.

TRUMAN P. KOHMAN
Carnegie Institute of Technology, Pittsburgh, Pennsylvania

WILLIAM A. CASSIDY
Pennsylvania State University, University Park, Pennsylvania

Society Elections

■ American Society of Parasitologists: pres., Arthur C. Walton, Knox College; pres.-elect, Aurel O. Foster, U.S. Department of Agriculture; vice pres., Raymond M. Cable, Purdue University; sec., Paul E. Thompson, Parke, Davis & Co.; treas., Robert M. Stabler, Colorado College.

■ American Chemical Society: pres.-elect for 1959, John C. Bailar, Jr., University of Illinois; pres. 1958, Clifford F. Rassweiler, Johns-Manville Corp.

Regional directors reelected are: Wallace R. Brode, National Bureau of Standards, and William G. Young, University of California.

■ Medical Library Association: pres., Thomas E. Keys, Mayo Clinic Library; pres.-elect., Isabelle T. Anderson, Denver Medical Society Library; sec., Henrietta T. Perkins, Yale Medical Library; treas., Pauline Duffield, Texas Medical Association Library.

Forthcoming Events

February

1–14. Pan American Assoc. of Ophthalmology, Caribbean cruise cong., sailing from New York, N.Y. (L. V. Arnold, 33 Washington Sq. W., New York 11.)

3–4. Progress and Trends in Chemical and Petroleum Instrumentation, Wilmington, Del. (H. S. Kindler, Instrument Soc. of America, 313 Sixth Ave., Pittsburgh 22, Pa.)

3–7. American Inst. of Electrical Engineers, winter genl., New York, N.Y. (N. S. Hibshman, AIEE, 33 W. 39 St., New York 18.)

5–7. Biophysical Soc., Cambridge, Mass. (A. K. Solomon, Biophysical Lab., Harvard Medical School, Boston, Mass.)

10–14. American Soc. for Testing Materials, St. Louis, Mo. (F. F. Van Atta, ASTM, 1916 Race St., Philadelphia 3, Pa.)

13–15. National Soc. of Professional Engineers, spring, East Lansing, Mich. (NSPE, 2029 K St., NW, Washington 6.)

16–20. American Inst. of Mining, Metallurgical and Petroleum Engineers, annual, New York. (E. O. Kirkendall, AIME, 29 W. 39 St., New York 18.)

20–21. Transistor and Solid State Circuits Conf., Philadelphia, Pa. (J. H. Milligan, Jr., Dept. of Electrical Engr., New York Univ., New York 53.)

22–25. American Educational Research Assoc., St. Louis, Mo. (F. W. Hubbard, AERA, 1201 16th St., NW, Washington 6.)

24–28. American Soc. of Civil Engineers, Chicago, Ill. (W. W. Wisely, ASCE, 33 W. 39 St., New York 18.)

March

1. Junior Solar Symposium, Tempe, Ariz. (Association for Applied Solar Energy, 3424 N. Central Ave., Phoenix, Ariz.)

1–3. National Wildlife Federation, St. Louis, Mo. (E. F. Swift, NWF, 232 Carroll St., NW, Washington 12.)

3. Wildlife Soc., annual, St. Louis, Mo. (D. L. Leedy, U.S. Fish and Wildlife Service, Washington 25.)

5–6. Gas Conditioning Conf., 7th annual, Norman, Okla. (M. L. Powers, Extension Div., Univ. of Oklahoma, Norman.)

6–8. Fundamental Cancer Research, 12th annual, Houston, Tex. (W. K. Sinclair, M. D. Anderson Hospital and Tumor Inst., Univ. of Texas, Houston 25.)

6–8. Optical Soc. of America, annual, New York. (A. C. Hardy, Massachusetts Inst. of Technology, Cambridge 39.)

10–13. American Assoc. of Petroleum Geologists, annual, Los Angeles, Calif. (R. H. Dott, AAPG, Box 979, Tulsa 1, Okla.)

10–13. Society of Economic Paleontologists and Mineralogists, annual, Los Angeles, Calif. (R. H. Dott, Box 979, Tulsa, Okla.)

16–21. Nuclear Engineering and Science Cong., Chicago, Ill. (D. I. Cooper, *Nucleonics*, 330 W. 42 St., New York.)

17–21. National Assoc. of Corrosion Engineers, 14th annual, San Francisco, Calif. (NACE, Southern Standard Bldg., Houston 2, Tex.)

18–20. Amino Acids and Peptides, Ciba Foundation symp. (by invitation), London, England. (G. E. W. Wolstenholme, 41 Portland Pl., London, W.1.)

20–22. Michigan Acad. of Science, Arts and Letters, annual, Ann Arbor. (R. F. Haugh, Dept. of English, Univ. of Michigan, Ann Arbor.)

20–22. Pulmonary Circulation Conf., Chicago, Ill. (Wright Adams, Chicago Heart Assoc., 69 W. Washington St., Chicago 2.)

20–23. International Assoc. for Dental Research, annual, Detroit, Mich. (D. Y. Burrill, Univ. of Louisville, School of Dentistry, 129 E. Broadway, Louisville 2, Ky.)

23–26. American Assoc. of Dental Schools, annual, Detroit, Mich. (M. W. McCrea, 42 S. Greene St., Baltimore 1, Md.)

23–29. American Soc. of Photogrammetry, 24th annual, jointly with American Cong. on Surveying and Mapping, 18th annual, Washington, D.C. (C. E. Palmer, ASP, 1515 Massachusetts Ave., NW, Washington 5.)

24–27. Institute of Radio Engineers, natl. conv., New York. (G. W. Bailey, IRE, 1 E. 79 St., New York 21.)

27–29. National Science Teachers Assoc., 6th natl., Denver, Colo. (R. H. Carleton, NSTA, 1201 16 St., NW, Washington 6.)

29. South Carolina Acad. of Science, annual, Charleston. (Miss M. Hess, Dept. of Biology, Winthrop College, Clemson, S.C.)

29–30. American Psychosomatic Soc., 15th annual, Cincinnati, Ohio. (T. Lidz, 551 Madison Ave., New York 22.)

30–3. American College Personnel Assoc., annual, St. Louis, Mo. (L. Riggs, DePauw Univ., Greencastle, Ind.)

April

1–3. Corrosion Control, 5th annual conf., Norman, Okla. (M. L. Powers, Extension Div., Univ. of Oklahoma, Norman.)

2–4. American Assoc. of Anatomists, annual, Buffalo, N.Y. (L. B. Flexner, Dept. of Anatomy, School of Medicine, Univ. of Pennsylvania, Philadelphia 4.)

2–4. Instruments and Regulators Conf., Newark, Del. (W. E. Vannah, Control Engineering, 330 W. 42 St., New York 36.)

4–5. Southern Soc. for Philosophy and Psychology, annual, Nashville, Tenn. (W. B. Webb, U.S. Naval School of Aviation Medicine, Pensacola, Fla.)

7–11. American Assoc. of Cereal Chemists, annual, Cincinnati, Ohio. (J. W. Pence, Western Utilization Research Laboratories, Albany, Calif.)

8–10. Electronic Waveguides Symp., New York. (J. Fox, Microwave Research Inst., Polytechnic Inst. of Brooklyn, 55 Johnson St., Brooklyn 1, N.Y.)

9–12. National Council of Teachers of Mathematics, Cleveland, Ohio. (M. H. Ahrendt, NCTM, 1201 16 St., NW, Washington 6.)

9–14. Applied Psychology, 13th internatl. cong., Rome, Italy. (L. Meschieri, National Inst. of Psychology, Rome.)

10–11. American Inst. of Chemists, annual, Los Angeles, Calif. (L. Van Doren, AIC, 60 E. 42 St., New York 17.)

10–12. National Speleological Soc., annual, Gatlinburg, Tenn. (G. W. Moore, Geology Dept., Yale Univ., New Haven, Conn.)

10–12. Ohio Acad. of Science, annual, Akron, Ohio. (G. W. Burns, Dept. of Botany, Ohio Wesleyan Univ., Delaware, Ohio.)

11. Vitamin B-12 Symp., New York, N.Y. (Miss J. Watson, 451 Clarkson Ave., Brooklyn 3, N.Y.)

11–12. Eastern Psychological Assoc., annual, Philadelphia, Pa. (G. Lane, Dept. of Psychology, University of Delaware, Newark.)

11–18. Horticultural Cong., 15th internatl., Nice, France. (Secretariat General, 84, rue de Grenelle, Paris 7e, France.)

13–14. American Soc. for Artificial Internal Organs, Philadelphia, Pa. (G. Schreiner, Georgetown Univ. Hospital, Washington 7.)

13–18. American Chemical Soc., 133rd, San Francisco, Calif. (R. M. Warren, ACS, 1155 16 St., NW, Washington 6.)

13–19. Federation of American Societies for Experimental Biology, annual, Philadelphia, Pa. (M. O. Lee, FASEB, 9650 Wisconsin Ave., Bethesda 14, Md.)

14–16. Automatic Techniques Conf., Detroit, Mich. (J. E. Eiselein, RCA, Bldg. 10-7, Camden 2, N.J.)

14–18. American Assoc. of Immunologists, annual, Philadelphia, Pa. (F. S. Cheever, Graduate School of Public Health, Univ. of Pittsburgh, Pittsburgh 13, Pa.)

14–18. American Soc. for Experimental Biology, annual, Philadelphia, Pa. (J. F. A. McManus, Univ. of Alabama Medical Center, Birmingham.)

14–18. American Soc. of Biological Chemists, annual, Philadelphia, Pa. (P. Handler, Dept. of Biochemistry, Duke Univ. School of Medicine, Durham, N.C.)

15–17. Gas Measurement, 34th annual conf., Norman, Okla. (M. L. Powers, Extension Div., Univ. of Oklahoma, Norman.)

17–19. Association of Southeastern Biologists, annual, Tallahassee, Fla. (J. C. Dickinson, Jr., Dept. of Biology, Univ. of Florida, Gainesville.)

18. Iowa Acad. of Science, annual, Des Moines. (C. H. Lindahl, Dept. of Mathematics, Iowa State College, Ames.)

18–19. Arkansas Acad. of Science, annual, Little Rock. (L. F. Bailey, Botany Dept., Univ. of Arkansas, Fayetteville.)

19–21. American College of Apothecaries, Los Angeles, Calif. (R. E. Abrams, Hamilton Court, 39th and Chestnut St., Philadelphia, Pa.)

20–22. American Assoc. of Colleges of Pharmacy, annual, Los Angeles, Calif. (G. L. Webster, College of Pharmacy, Univ. of Illinois, 808 S. Wood St., Chicago 12.)

20–23. Chemical Engineering Conf., Canada-United States, Montreal, Quebec. (H. R. L. Streight, DuPont Company of Canada, P.O. Box 660, Montreal.)

21–23. American Oil Chemists' Soc., Memphis, Tenn. (Mrs. L. R. Hawkins, AOCS, 35 E. Wacker Dr., Chicago 1, Ill.)

21–28. American Industrial Hygiene Assoc., annual, Atlantic City, N.J. (G. D. Clayton, George D. Clayton and Associates, 14125 Prevost, Detroit 27, Mich.)

22–24. Electronic Components Symp., Los Angeles, Calif. (E. E. Brewer, Convair, Inc., Pomona, Calif.)

(See issue of 20 December for comprehensive list)