ORIGIN OF TEKTITES

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THE origin of tektites has been discussed for many years, and no satisfactory solution to the problem has been proposed. They definitely show flow patterns indicating travel at high velocity through gas such as the Earth's atmosphere. Their chemical composition shows that they are not obsidian and, in fact, they are similar in composition to sedimentary rocks without their water content. In particular, they contain several per cent of potassium oxide (K_2O), 1·5 p.p.m. of uranium and have very high silica and alumina contents. Spencer[1] and Barnes[2] list many analyses of these objects. Their chemical composition is produced on Earth by most complicated processes, including the weathering of granite and basalt and the removal of the alkaline earths and iron by the action of water. If they are extra-terrestrial in origin, then the question arises as to how their composition was produced elsewhere. Volcanic sources of heat are not sufficient to have melted them, and yet their arrival from space with the distribution found on Earth is not possible either, as I have pointed out[3].

Briefly, the argument is as follows: (1) If a large mass of glassy material arrived and broke up in the atmosphere, the parts should have distributed themselves over an area some tens of kilometres in dimension, as is observed for certain meteorite showers. The distribution over all southern Australia, for example, would be impossible. Hence, the compact-mass arrival is excluded. (2) If the tektites arrived as a swarm, its mean density must have been greater than 10^{-6} gm. cm.$^{-3}$, for otherwise solar gravitational forces at the Earth's distance from the Sun would break up the swarm and tektites would become distributed over the entire Earth. Yet a swarm of this density some 10^8 cm. in diameter would pile up tektites to a depth of 100 gm. cm.$^{-2}$ over southern Australia, and this is not the case. Arrival from the Moon raises similar objections. I know of no answer to these arguments.

Spencer[1] many years ago suggested that meteoritic falls may have been the source of melting of terrestrial materials; but no evidence for meteorite craters could be found in the neighbourhood of the various tektite areas. I suggested that a minor planet may have collided with the Earth and the enormous crater may have initiated some major plutonic effect which covered the crater. This was always regarded as a last resort type of suggestion.

The approach of the comet Arend-Roland stimulated a little further thought on this problem. What would happen if a comet collided with the Earth? A comet head consists of a very loose aggregate of small particles, and recently it has become evident that these particles consist of, or are mixed with, chemical compounds having large amounts of energy. In fact, the material is a high explosive which 'burns' quietly under excitation by high-speed particles from the Sun only because of its very loose structure and low density (see Donn and Urey[4] and references there given). Since comets move on nearly parabolic orbits, their velocity at the Earth's distance from the Sun is 42 km. sec.$^{-1}$. The heads are estimated to be 10–70 km. in diameter and their density may be 0·01 gm. cm.$^{-3}$. The kinetic energy of a spherical object 10 km. in diameter of this density and velocity would be 5×10^{28} ergs, which is equivalent to 5×10^7 atomic bombs of the old-fashioned fission type, or a half-million hydrogen bombs. The chemical energy would only be a fraction of this, perhaps 10^{27} ergs, or even somewhat more.

If an object of this kind entered the atmosphere at this high velocity, compression and heating of the material would occur. It would explode in a chemical sense, and most of its mass would be converted to gases at high temperature. The amounts of silicates expected to be present would be volatilized or scattered as fine dust. Such compaction would be effective at 60–100 km. above the Earth's surface and the explosive reaction should begin at this altitude. The high-temperature mass would continue to move towards the Earth, heat its surface quite easily to the melting point, produce a very compressed region of gas, and this would propel terrestrial material in all directions at high velocity. It is difficult to predict the type of crater to be expected. However, the explosion would resemble the high air burst of an atomic or hydrogen bomb; but the effects would be very much greater and somewhat different because of the great mass of gas both from the detonation of the comet head and from the compressed and heated air, and the much lower temperatures distributed throughout the mass. One would expect the general effect to be more that of a propellant than a detonating type of explosion. The mass would be stopped within one second and the maximum pressure would be about 40,000 atmospheres. Probably a very broad area would be involved and no deep penetration in a limited area would result.

If they are a by-product of a cometary collision, several puzzling features of tektites are explained. (1) Their material substance comes from the surface of the Earth, and hence varying compositions are to be expected; even the nearly pure silica of Libyan glass, and in fact the americanites, which are not usually included as respectable tektites because of their obsidian-like composition, could also owe their existence to this process acting upon granitic rock. (2) The high temperature required for melting is provided. (3) They were melted quickly and briefly and hence did not lose their alkalis, which are known to be very easily volatilized from melts. Also the presence of melted quartz particles, that is, lechatelierite, is understandable. (4) A mechanism for scattering over wide areas is available. (5) The flow marks could have been produced by the blast of hot gases over more slowly moving objects. (It has always appeared surprising to me that a small glass object, 1–2 cm. in diameter, would travel at high velocity through the atmosphere, keeping one orientation as is necessary in the case of the more 'button-shaped' tektites. A blast of high-temperature gas could

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produce this effect very quickly, and seems a more probable mechanism.) (6) Since more basic materials will crystallize rapidly even during cooling, it can be expected that only very acidic tektites will remain glassy and thus be observed. (7) The residual crater may be very difficult to identify; but it might well be looked for while keeping some flexible ideas as to what its properties may be.

The number of comets observed to arrive near the Sun is about 10 per year and the true number may be larger. Assuming completely random orbits, the chance of one hitting the Earth is $\frac{\pi a^2}{4\pi R^2} \times 2$, where a is the Earth's radius and R the distance of the Earth from the Sun. The factor 2 takes account of the chance of collision while the comet approaches the Sun and when it leaves again. There is a small increase in cross-section of the Earth because of its field. Approximately the factor is $\frac{a^2}{R^2}$ and this equals $1 \cdot 8 \times 10^{-9}$. With ten comets arriving per year, only one collision in 50 million years could be expected, and this is far too small to account for the many groups of tektites observed. Father P. J. Treanor has directed my attention to the strong probability that heads of comets may be loose aggregates that may break up during an approach to the Earth and separate masses may fall nearly simultaneously at widely separated points. In this case only one collision is required. It is interesting to note that many of the various kinds of tektites are Pleistocene in age and may be contemporaneous in origin. Only the Texas tektites appear to be of Eocene age and are thus about 50 million years old, and this is just the mean time between collisions calculated above.

The suggestion advanced in this article may appear to many as too hypothetical to deserve the light of day. However, the tektite problem has been, and is, one of the major puzzles to men "who pick up rocks and stop to think" even before the classical paper of Suess of 1900 [5] appeared, and conservative proposals have been found to be inadequate. It is often remarked that no tektite had even been observed to fall. If the present suggestion gives the true origin, all will agree that any demonstration of the process would cost far more than the scientific knowledge gained would justify. Yet such catastrophic events, some large and some small, should occur about once in 50 million years.

[1] Spencer, L. J., *Min. Mag.*, **25**, 425 (1939).
[2] Barnes, V. E., Univ. of Texas Publ. No. 3945, pp. 477–656 (1950).
[3] Urey, H. C., *Proc. U.S. Nat. Acad. Sci.*, **41**, 27 (1955).
[4] Donn, B., and Urey, H. C., *Astrophys. J.*, **123**, 339 (1956); also Seventh Liège Astrophysics Symposium on Molecules in Astronomical Objects (July 1956).
[5] Suess, F. E., *Jahr. Geol. Reichsanst. Urien.*, **50**, 193 (1900).

ORIGIN AND MODE OF FORMATION OF CERTAIN LOCAL STAINS ON SILVER TABLEWARE

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THE loss in brilliance of silverware is generally caused by the formation of a silver sulphide layer, which is easily removed by normal cleaning methods. In recent years, however, a different type of stain has appeared, usually taking the form of small local and often circular dark spots, which are most difficult to remove, the proprietary dip cleaners and the aluminium–soda process both being apparently ineffective. This modern malady of the silver-plating world has been frequently attributed to faulty electroplating, and many complaints have been received by manufacturers. It is the purpose of this article to show how such stains may be formed on any silver surface and why the phenomenon is more prevalent nowadays than it was in previous times.

Origin of Stains

Observation of many stains showed that they varied in colour from almost black to a pale straw, with some intermediate ones exhibiting colours due to interference. For some time there has been a general feeling in the plating trade that these stains were somehow connected with the use of detergents for washing up. A report published by the Master Silversmiths' Association confirmed this, stating that "stains are formed very rapidly when solid common salt is dropped on to the surface of the article when it is immersed in moderately hot water containing certain synthetic detergents. It appears that only detergents containing oxygenated compounds such as percarbonate, perborate and persilicate induce the salt to act on the silver in this way and the action does not occur when the salt is completely dissolved in the liquid".

Experiments were performed to confirm these statements, and it was found that stains could be produced by common salt particles when the silver was immersed in a dilute acid or alkaline solution or merely in water. This indicated that the oxygenated compounds and the detergents themselves were not necessary to produce the stains; but it was confirmed that a homogeneous salt solution would not cause staining. Reagents other than common salt were tested for staining properties. It was found that potassium chloride, ammonium chloride, potassium bromide and sodium iodide all produced stains under similar conditions, that is, on being dropped through water on to a silver surface, while sodium fluoride, sodium sulphate, sodium carbonate and sodium nitrate did not.

Five solid detergents were tested in a similar manner, and all but one produced stains. These detergents all contained halides, but the one which did not cause stains had the lowest halide content. Thus it became evident that the active agents of stain formation were probably those halide compounds which would give insoluble silver halides, that is, the chlorides, bromides and iodides.

From a practical point of view stains may be formed both by salt or detergent particles falling