the greying response, suggest the following scheme: Exposure of resting hair follicles to relatively high doses of x-rays results in the inactivation or destruction of a number of the radiosensitive zigzag follicles, leaving a greater proportion of the larger and less sensitive monotrich, awl, and auchene follicles. This phenomenon would increase the proportion of pigmented hairs within the exposed area and would result in variable greying responses, dependent upon the number of remaining zigzag follicles. Thus, the greater variability in number of active follicles within the 1300 r group (standard error of 0.33) in comparison with the variability for the control groups probably explains the greater variability of greying responses (60 to 100 percent) in that group.

DONALD B. GALBRAITH
HERMAN B. CHASE

*Department of Biology,
Brown University,
Providence, Rhode Island*

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18 August 1961

Metallic Spherules in Tektites from Isabela, Philippine Islands

Abstract. Iron-nickel spherules, as much as 0.5 mm in diameter, have been found completely embedded in some philippinites. The spherules consist mainly of kamacite with unidentified pink inclusions. The meteoritic origin of these spherules seems reasonable, suggesting that the tektites containing them were formed by asteroidal or meteoritic impact.

Fresh kamacite spherules have been found in five tektites from the Isabela district of Luzon, Philippines, and they supply strong physical evidence for the meteorite impact origin of tektites.

L. J. Spencer (*1*) reported "dark spots" in indochinites and australites that show metallic luster when viewed under the microscope. Additional description is not available and these "dark spots" were not identified. Recently Vorobev (*2*) described hollow spherules, 1 to 2 mm in diameter, that consist of "magnetite" and siliceous materials on the surface of some of the philippinites. It is possible, however, that the hollow spherules are similar to bubble cavities observed by us that have been filled with reddish, silty, terrestrial material after the tektite was buried. The spherules described by Vorobev are much larger and are not iron-nickel spherules of the type reported here.

The metallic spherules, from less than 0.1 mm to as much as 0.5 mm in diameter, have an average size of about 0.16 mm. They are completely embedded in the tektites, perfectly spherical, shiny, and fresh—without the slightest trace of oxidation or alteration. Under the metallographic microscope at high magnification, the surface of the spherules is seen to be covered by a network of a pink mineral (Fig. 1). This mineral is probably the same as the round inclusions within the spherules described below. The glass adjacent to the spherules shows no more evidence of strain than the tektite glass elsewhere.

The appearance, texture, bulk specific gravity, and index of refraction of the five tektite specimens containing metallic spherules fall within the normal range for tektites from Isabela. They show flow banding and contain small round bubble cavities, similar to those in any other tektite from this locality. As in other typical tektites, inclusions of low-index glass, presumably lechatelierite, are abundant. The magnetic susceptibility and specific magnetization of specimen P_I 73 were determined by our colleague, Arthur Thorpe, as 8.60×10^{-6} electromagnetic units per gram and 0, respectively, agreeing well with philippinites which Senftle and Thorpe (*3*) have already described. These data rule out the possibility that the tektites we studied could be obsidian or any other similar material.

Under the reflecting microscope, the major mineral phase is α-iron or kamacite, silver white and isotropic in reflected light, with no visible cleavage or grain boundaries even after the specimen has been etched. The spherules contain numerous round to elongate inclusions that are less than 5 μ in diameter (Fig. 2). They are pink in reflected light and "sparkle" as the microscope stage is rotated under crossed nicols because of their strongly anisotropic character. The etched spherules show the boundaries of these inclusions more clearly.

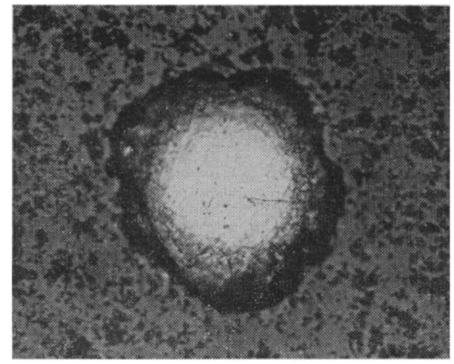

Fig. 1. Surface of a metallic spherule, 0.2 mm in diameter, with the overlying glass broken off, showing a network consisting probably of an iron phosphide.

The x-ray powder pattern obtained with Fe Kα radiation shows that the metallic spherules consist of two mineral phases. The major phase is kamacite as indicated by the petrographic study, with a unit cell, $a = 2.86_2$ A. The other phase, which is estimated to be less than 5 percent, is represented by the reflections indicated in Table 1. Reflections 1, 2, 3, and 4 possibly correspond to iron phosphide, FeP (ASTM card No. 3-1066), or schreibersite, Fe_3P (*4*). Further work will be necessary to identify this phase.

The chemical composition of the metallic spherules was obtained by electron-probe microanalysis. Three spherules from specimen P_I 73 were analyzed in a mount with a piece of pure nickel, a piece of pure iron, and a previously analyzed fragment of Canyon Diablo iron meteorite as standards. The spherules contain more than 95 percent iron and 1.2 to 3.2 percent nickel. We believe that nickel content determined by our analysis is in error by no more than approximately ± 5 percent of the amount present. Electron-probe

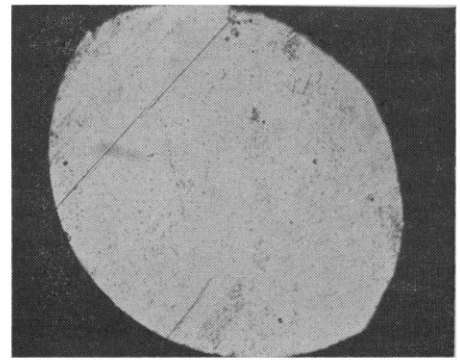

Fig. 2. Part of a metallic spherule about 0.5 mm in diameter, showing the radially distributed inclusions (possibly an iron phosphide).

Table 1. Weak to very very weak reflections in x-ray powder pattern of the minor phase in the metallic spherules. W, weak; VW, very weak; VVW, very very weak.

Line	d-Spacings (A)	Intensity
1	2.19	W
2	2.14	VW
3	2.11	VW
4	1.973	VW
5	1.600	VVW

analysis of the minute, pink inclusions proved difficult because of the small size of the inclusions. Preliminary results indicated only maximum values for iron (approximately 54 percent), and nickel was not detected. By use of non-dispersive x-ray optics, phosphorus was identified qualitatively and is considered to be a major constituent in the inclusions.

For comparison we have searched the literature for similar material. Terrestrial native iron that contains as much as 5 percent nickel (*5*) is not known to occur as spherules. "Cosmic" spherules rarely exceed 250 μ in size (*6*), whereas the tektite spherules are generally larger than 100 μ, with many greater than 300 μ and one as large as 500 μ in diameter. Castaing and Fredrikssen (*7*) showed that iron spherules from the Pacific Ocean red clay contain as much as 30 percent nickel. Smales *et al.* (*8*), using neutron irradiation technique, showed that the iron spherules from the Pacific Ocean are similar in composition to iron meteorites. As already reported, the tektite spherules contain more than 95 percent iron and only up to about 3 percent nickel.

Iron spherules found in the meteorite-impact glasses such as those of Wabar (*9*) compare favorably with those found in the tektites. Virgil E. Barnes, of the Bureau of Economic Geology, University of Texas, kindly allowed us to examine samples of Wabar glass which he and Donald Holm of the Arabian American Oil Company collected. The spherules in the Wabar glass are much more abundant than in the tektites, but none is larger than 250 μ, with most less than 70 μ. They show nearly identical spherical shape and shiny, highly reflecting surfaces. Polished sections of the spherules of the Wabar glass also show, besides kamacite, an unidentified pink, anisotropic mineral. X-ray identification shows these spherules to contain kamacite with unit cell $a = 2.862$ A as the major phase. The spherules which were analyzed by Max Hey and reported by Spencer (*9*) contain 8.8 percent nickel, greater in nickel content than the iron meteorite (7.3 percent) that formed the crater at Wabar.

The occurrence of nickel-iron spherules strongly suggests that tektites from Isabela originated by asteroidal or meteoritic impact in a siliceous medium. The next question is whether the impact took place terrestrially or extraterrestrially. This question can not be answered without presenting additional field and laboratory data. Based on our study of impact ejecta glass from terrestrial craters and the recent study of the aerodynamic features of tektites by Dean Chapman of the Ames Research Center (*10*), we favor the lunar or extraterrestrial origin advocated by previous workers (*11*) as a working hypothesis for the origin of tektites.

Detailed work on tektite spherules is continuing. It is possible that further study of the composition and mineralogy of the spherules may cast some light on the place of impact (*12*).

E. C. T. Chao, Isidore Adler, Edward J. Dwornik, Janet Littler
U.S. Geological Survey, Washington, D.C.

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Unit Responses of the Rabbit Lateral Geniculate Nucleus to Monochromatic Light on the Retina

Abstract. Seven unique wavelength responses, two inhibitory and five excitatory, with sensitivity maxima from 435 to 635 millimicrons, have been recorded from light-adapted, non-albino rabbits. Several combinations, usually one excitatory with one inhibitory response, often having characteristics suggesting mutual antagonism between them, were observed from single lateral geniculate cells.

Although hue discrimination in the rabbit has been investigated for many years by histological, behavioral, and gross electrical techniques, there remains considerable disagreement, not only about its characteristics, but its very existence. The approach used here, initiated in this animal by Dodt and Elenius (*1*) at the retinal level, was to record the responses of single cells to monochromatic light on the retina. In this study cells of the lateral geniculate nucleus were investigated to determine what wavelength information is transmitted centrally along the main visual pathway.

Eight non-albino Belgian hares were studied under urethan anesthesia and photopic conditions. After initial light-adaptation and localization of a responding cell from the contralateral geniculate body, by intermittent stimulation with white light (2 cy/sec; 1 : 1 light-dark ratio), monochromatic light (half-amplitude bandwidth of 10 mμ) was introduced. The pupil was dilated, and the eye was illuminated in Maxwellian view.

The monochromatic source, roughly equal quanta in composition (159 μ-watt/cm^2 at 500 mμ), was produced by a high-pressure xenon arc whose output passed through an automatic relay-controlled, motor-driven monochromator (*2*). The procedure was to record the response of a single lateral geniculate cell to repeated spectral scans from 400 to 700 mμ through increasing 0.5 log steps of neutral density filter over a four-log unit range. Stainless steel microelectrodes were used (*3*), permitting later verification of the recording site by the Prussian blue reaction.

The results were anaylzed graphically; discharges meeting the response criteria were plotted by direct inspection of the film records on a coordinate system of wavelength versus sensitivity.