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APPENDIX. — REPORT OF THE SUB-COMMITTEE ON METEORITES

(prepared by E. L. Fireman, President of the Sub-Committee)

Introduction

The past three years have not seen so important new discoveries nor so great technical advances in the science of meteorites as the previous three years. The period has rather been one of data accumulation by means of techniques developed earlier, and of more extensive investigations along previously begun lines. It has also been dominated by review articles, books, and symposia, rather than by original research, which is usually expressed in shorter publications. The more spectacular advances described in the previous report of Sub-Commission 22*a* are the bases for most of the recent work.

Schaeffer (**1**), Anders (**2**), and Arnold (**3**), wrote excellent review articles on isotopes in meteorites. Mason (**4**) wrote a splendid book on meteorites. Middlehurst and Kuiper (**5**) edited a collection of extensive articles on the Moon, meteorites, and comets. V. G. Fesenkov and E. L. Krinov (**6**) edited a monograph on the Sikhote-Alin meteorite fall and published a collection of papers on the dust of meteors and meteorites (**7**). O'Keefe (**8**) edited a collection of good articles on tektites. In addition, the proceedings of a number of conferences on meteors and meteorites and other collections of articles were published in book form (**9**). From the number of review articles and books written during the past three years, one might conclude that the origin and history of meteorites are known. This is not true. In fact, very few problems in meteorites can be considered solved.

Meteorite Falls, Finds and Craters

The Pribram meteorite fall, which occurred on 1959 April 7 is the only one for which rotating-shutter, double-station photographs of the flight through the atmosphere exist. This meteorite has a minor-planet-type orbit, as Ceplecha and his co-workers determined, with $a = 2{\cdot}434$ A.U.; $e = 0{\cdot}6742$; $q = 0{\cdot}7899$ A.U.; $\omega = 241^{\circ}35'$; and $i = 10^{\circ}25{\cdot}5'$ (**10, 11**). Tuček (**12**) studied the morphology and the mineral composition of Pribram — a crystalline chondrite whose principal constituents are olivine and enstatite. The spallation rare-gas isotopes, measured by Stauffer and Urey (**13**) are $\mathrm{He}^3 = 24{\cdot}0 \pm 1{\cdot}2 \times 10^{-8}\,\mathrm{cm}^3\,\mathrm{g}^{-1}$; $\mathrm{Ne}^{21} = 5{\cdot}40 \pm 0{\cdot}25 \times 10^{8}\,\mathrm{cm}^3\,\mathrm{g}^{1}$; and $\mathrm{A}^{38} = 0{\cdot}79 \pm 0{\cdot}04 \times 10^{-8}\,\mathrm{cm}^3\mathrm{g}^{-1}$. These values are within the range given in the extensive study of rare gases in chondrites by Kirsten, Krankowsky and Zähringer (**14**). The potassium in Pribram was not measured; a potassium-argon age of $3{\cdot}7 \times 10^9$ years was, however, estimated by assuming 0·087 per cent potassium. An exposure age of 12×10^6 years was estimated by assuming a helium-3 production rate. Fireman and DeFelice measured the tritium to be 210 ± 15 dpm/kg and the A^{39} to be 5·6 ± 0·4 dpm/kg (submitted to *Bull. astr. Inst. Csl.*). The radioactive isotope contents provide an improved value of the exposure age. The helium-3 to tritium age is $(29 \pm 3)\ 10^{6}$ years, and the argon-38 to argon-39 age is $36 \pm 4 \times 10^{6}$ years. Although the radioactivity content of Pribram is at the low end of the range for chondrites, it is not unusually low and indicates that the size of the body before it entered the atmosphere was not unusual compared to the other chondrites.

Following the fall of the Bruderheim meteorite in western Canada in March 1960, the Associate Committee on Meteorites provided national coordination in the identification, recovery, and study of meteorites and related phenomena. All major areas in Canada are represented on the committee, whose members come from various government departments, Canadian universities and scientific societies (**15**, **16**).

Nationwide programs for the reporting of bright fireballs, for the rapid recovery of newly fallen meteorites, and for public education in meteoritics, have been organized by the committee. Already this activity has resulted in the recovery of one new multiple fall (Peace River), the identification of a previously unlisted iron meteorite (Manitouwabing), and the location of some additional pieces of other Canadian meteorites. Four Canadian meteorites should be added to the 24 listed by Millman (*J. R. astr. Soc. Canad.*, **47**, 29, 92, 162; 1953). These are

Giroux (pallasite)	0965,496	Fd. 1954
Bruderheim (grey chondrite)	1129,539	Fl. 1960–3–4: 0106
Manitouwabing (coarse octahedrite)	0799,454	Fd. 1962
Peace River (grey chondrite)	1179,561	Fl. 1963–3–31: 0435

(The co-ordinate numbers and abbreviations used follow Leonard, F. C., and de Violini, R., *Univ. of Calif. Publ. in Astron.*, **2**, no. 1, 1956)

K. R. Dawson and others (**17**) have made extensive studies of Abee, while R. E. Folinsbee and his associates have begun a detailed study of Bruderheim and Peace River (**18–21**). Work on a number of other meteorites is being carried out, chiefly at the Geological Survey in Ottawa (**22**).

The study of fossil meteorite craters in Canada has continued as an active program of the Dominion Observatory. Much of this work has been summarized by Beals, Innes and Rottenberg (**23**); the application of gravity techniques to the study of craters has been described by Innes (**24**). Ten features, ranging from 2 to 60 km in diameter, have been studied sufficiently that a meteoritic origin is now suggested for them. These features, grouped by provinces, are:

Province	*Feature*	*Province*	*Feature*
Quebec	New Quebec (Chubb) (**25**)	Ontario	Brent
	Lac Couture		Holleford
	East Clearwater Lake	Manitoba	West Hawk Lake
	West Clearwater Lake	Saskatchewan	Deep Bay
	Manicouagan Lake		Carswell Lake

Diamond-drilling operations have been conducted at East and West Clearwater Lakes, Brent, Holleford and Deep Bay. Brecciated rocks have been recovered in the core from these features, and detailed studies of the rock are in progress (**26**). Coesite has been identified in the core from Holleford. Negative gravity anomalies have been found for New Quebec, both Clearwater Lakes, Brent, Holleford, West Hawk Lake and Deep Bay (**27**). Shatter cones have been found at West Clearwater Lake and near the center of the Carswell Lake feature. Brecciated material has been found exposed on the surface at Lac Couture, West Clearwater Lake, Manicouagan and Brent.

A study of the orbital stability of twin meteorites (**28**) capable of producing the two Clearwater Lakes, indicates that such a pair would be stable in the solar system under the action of planetary perturbations.

While an impact origin for these features is inferred from such studies as outlined above, some workers interpret the features in terms of tectonic events. K. L. Currie of the Geological Survey of Canada believes that the New Quebec, Clearwater Lakes, and Manicouagan features were formed by volcanic events or volcanic events possibly initiated by meteorite impact.

The committee for meteorites of the U.S.S.R. Academy of Sciences together with the Institute for Geochemistry and Analytical Chemistry of the U.S.S.R. Academy of Sciences sent an expedition in the region of the fall of the Tunguska meteorite-comet. The expedition confirmed earlier results on the scattering of magnetite and silicate balls in the soil in the vicinity of the fall (**29–49**).

Two iron meteorites, Bogou and Aroos, and three other stony meteorites, Hamlet, Harleton, and Ehole, were recovered and extensively studied by radio-isotope methods within three months of their fall (**50–61**).

Short descriptions of the new meteorite falls and finds are published in the Meteoritic Bulletins distributed by E. L. Krinov (**62**).

The number of new meteorite finds is somewhat smaller than the number of fresh falls. In view of the enormous demand for meteorite material in research, one of the most pressing needs of the future is a more extensive program for collecting meteorites. R. McCrosky and F. L. Whipple plan to complete in the early part of 1964 a network of cameras equipped with rotating shutters, which will cover the central region of the U.S.A. This network should determine the orbits of many fireballs and facilitate the systematic recovery of freshly fallen meteorites with well-determined orbits. Ceplecha (private communication) has proposed that the all-sky camera stations in Czechoslovakia be extended by placing similar stations in neighboring countries.

E. L. Krinov (**63**) and L. G. Kvasha (**64**) have updated the catalogues of meteorites and tektites in the collection of the U.S.S.R. Academy of Sciences through 1961 June 1.

Chao and co-workers (**65**) discovered both stishovite and coesite in the shattered sandstone in the floor of the Arizona meteorite crater. Stishovite is the polymorph of silica that is stable at extremely high pressures. Coesite has also been found in the neighborhood of several other craters (**66, 67**). Many regard it as the best criterion for a major meteorite impact. The presence of shatter cones (**68**) in the rocks is also regarded as evidence for a meteorite impact.

Mineralogy and Metallurgy of Meteorites

The possible occurrence of life forms, as originally reported by Claus and Nagy (**69**), caused a controversy (**70, 71**) that is not yet resolved.

Vdovykin (**72**) compared the bitumen of carbonaceous chondrites with the bitumens in terrestrial rocks. He also studied (**73**) the organic compositions of a number of carbonaceous chondrites and concluded that there is no reason to consider the inclusions contained in these meteorites as organic material of biogenic origin.

Lipshutz and Anders (**74, 75**) have given evidence that the diamonds in Canon Diablo were formed from the graphite on impact with the Earth. This hypothesis has received support from the laboratory transformation of graphite to diamonds by explosive shock (**76**). On the other hand, Kennedy (**77**) believes—on the basis of textural studies of the diamonds in Canon Diablo—that the formation of the diamonds preceded the formation of the graphite. Whether the diamonds in meteorites should be interpreted as formed by crystallization under high gravitational pressure or formed during impact with the Earth or by impact with bodies in space is another unresolved question.

Marvin (78) has reported the presence of cristobalite in the iron meteorite Carbo. Cristobalite is the form of SiO_2 that is stable under high temperature and low pressure.

Vronsky (79) and Pliashkevitch (80) investigated the iron meteorite Elga. This meteorite is interesting in that silicate inclusions consisting mainly of feldspar and pigeonite constitute between 10 and 15 per cent of the total mass. Ravitch and Revnov **(81)** describe the iron meteorite, Lasarev, which was found in 1961 in Antarctica. This meteorite is an octahedrite with surface peculiarities due to Antarctic weathering.

Diakonova and Kharitonova (82, 83) investigated the chondrules of the Nikolskoje and Saratov meteorites and found that the main difference of the silicates in the chondrules and in the whole rock was the greater content of SiO_2, MgO, and $A1_2O_3$ in the chondrules. Burkser *et al.* (84) investigated the germanium in stony meteorites and found the bulk of the germanium in the magnetic portion.

Kvasha and Viik (85) established that the carbonaceous chondrite, Staroye Boriskino, was altered by hydrothermal processes indicating that the meteorite was subjected to vapor and fluid solutions. Pochtarev and Gus'kova (86) from a study of the magnetic properties of 270 meteorites found that the magnetic susceptibilities of the stony meteorites fell into three groups. Kolomensky and Mikheeva (87) determined the X-ray parameters and the chemical composition of the hypersthene and olivine in the stony meteorite, Yurtuk. Yudin and Smishliaev (88) determined the quantitative amounts of nickel iron, troilite, chromite, copper, and ilmenite in the opaque minerals of the Okhansk meteorite.

Yavnel (89, 90, 91) by studying the phases, the structure and the content of the iron in the chondrites concludes that equilibrium conditions were absent during crystallization and that differentiation processes took place that divided the chondrites into the enstatite, bronzite-hypersthene, and carbonaceous groups.

Keil and Fredriksson (92) have applied to stony meteorites the electron-probe microanalyzer technique previously used on iron meteorites. They find an unusual association of minerals in the Norton County achondrite, which indicates that this meteorite was formed in a reducing environment. They have also applied the electron-probe technique to the investigation of the light and dark portions in the Pantar and Kapoeta meteorites (93), and find that the two portions have the same minerals with identical composition; the dark portion, however, consists of finer grains than the light portion. They attribute the finer grain size to shock brecciation.

Goldstein and Ogilvie (94) analyzed the phosphides and sulphides in metallic meteorites with an electron probe. They concluded that the very large troilite particles were formed directly from the molten state; the schreibersite nucleated in the 700 to 500 °C temperature range; and the rhabdite formed between 400 and 500 °C.

Lovering and Parry (95) analyzed the unusual 2γ-phase structure of the Santa Catherina meteorite, which contains 34 percent nickel, and obtained evidence that the material was subjected to pressures higher than 50 000 atmospheres during the cooling.

The chondrules, which are the characteristic textural feature of chondrites, have been the subject of some investigations. Merrihue (96) has given evidence that those in the Bruderheim meteorite are enriched in zenon-129. This evidence may support the view advocated by Wood (97), that chondrules were liquid silicate droplets that condensed from the solar nebula during the formation of the solar system. On the other hand, Fredriksson and Ringwood (98) support an ignimbritic (explosive volcanic) origin.

Isotope Research

Sensitive laboratory methods of mass spectrometry, radiochemistry, and low-level counting make it possible to measure the abundance of many stable isotopes and the presence of a few radioactive isotopes in meteorites. These measurements give us a great deal of information about the history of meteorites. An isotope in a meteorite has one of four origins: primordial, radiogenic, extinct radiogenic, and cosmogenic.

1. *Primordial*—If an isotope is fixed in the meteorite at the time of solidification and has remained unchanged in abundance since that time, it is called primordial. The principal elements (Fe, Si, O, Mg, and S) of a meteorite are primordial. An overwhelming fraction of the amounts of most isotopes of other elements are also primordial. The isotopic compositions of the principal elements in meteorites fall within the normal range of variation of the isotopic compositions of the same elements in terrestrial matter (**21, 99–101**). This suggests that meteoritic and terrestrial matter were produced in the same nucleosynthetic process.

The primordial isotopic compositions of the noble gases are difficult to obtain from measurements on terrestrial materials. The 1956 discovery by Gerling and Levsky of primordial helium and neon in the Pesyanoe meteorite was therefore of basic importance (**102**). Gerling and Levsky found much larger quantities of helium and neon than could be explained by radiogenic and cosmogenic sources. Zähringer and Gentner (**103**) found primordial gases in the enstatite chondrite Abee and the achondrite Kapoeta. Reynolds (**104**) observed them in the carbonaceous chrondrite Murray. Stauffer (**105**) confirmed the results for Murray and Pesyanoe and found primordial neon and argon in four other carbonaceous chondrites and two ureilites. König *et al.* (**106, 107**) found primordial helium and neon in the veined brecciated chondrites Pantar and Tabor, and Hintenberger *et al.* (**108**) found primordial helium and neon in the veined brecciated chondrite Breitscheid. Signer and Nier (**109**) have measured isotopic ratios and abundances for helium and neon in the Washington County iron meteorite, which Tilles (**110**) has interpreted as giving evidence for primordial gas in that meteorite. Primordial noble gas seems to be present in at least one meteorite of each of the major types; it is therefore associated with characteristics of the history of meteorites that are not distinguished in the usual classification.

Gerling and Levsky assumed that the primordial gas was simply dissolved in the silicates at the time of solidification. The partial pressure of the noble gases over the melt determined the amount of gas dissolved at solidification. They calculated that the gas pressure of helium would have to be greater than three atmospheres in order to account for the helium content in the Pesyanoe meteorite. They conclude that such a large helium pressure could only prevail in the atmosphere of a large planetary body. DuFresne and Anders (**111**) attempt to avoid a dense planetary atmosphere by having the primordial gas dissolve in a closed magma chamber, which has a temporary 'internal atmosphere'. They suggest that the primordial gases might be concentrated in the sulphide minerals.

Several groups (**102, 103, 106–108, 112, 113**) have found the primordial helium and neon to be concentrated in the dark phases of the Pesyanoe, Pantar, Kapoeta, and Breitscheid meteorites. The primordial xenon in at least one of these (Pantar) is also concentrated in the dark phase (**114**). Very few meteorites have dark and light phases. Fredriksson and Keil (**93**) found that the mineral composition of the dark phase is identical to that of the light phase; the color difference is a function of grain size, with the darker phase having the finer grains. They proposed that the primordial gas moved into the finer grains by shock. Zähringer and Gentner (**115**) and Jeffery and Reynolds (**116**) showed, by heating experiments on the Abee meteorite, that the primordial A^{36} and Xe^{132} are held more strongly than the radiogenic A^{40}. For this meteorite the primordial argon now present is held securely in a crystal lattice. Fireman and Schaeffer (**117**) showed that the primordial krypton in the Indarch meteorite is concentrated in the mineral tridymite (SiO_2), and not in the sulphide minerals. The tridymite fraction has the smallest Xe^{129} excess of any mineral fraction. This result may mean that the younger minerals trap more primordial gas than the older ones. The primordial gas in meteorites may be intimately connected with the solidification times of its minerals.

Much additional work has been done measuring the so-called secondary or general isotopic anomalies in meteoritic xenon (**20, 114, 118, 119**) but at present there is no generally accepted combination of mechanisms or sources to account systematically for these results.

2. *Radiogenic*—If an isotope results from the radioactive decay of a now-measurable primordial parent isotope, it is radiogenic. Sometimes it is difficult to decide whether an isotope is radiogenic. For example, helium-4 may result from the decay of uranium and thorium; it may be primordial; it may be produced by cosmic rays; or, as is typically the case, it may result from a combination of all 3 sources. Argon-40 is said to be radiogenic only when the A^{40}/A^{36} ratio exceeds the value 300 (the atmospheric ratio), in which case only the excess argon-40 is called radiogenic. The criteria for deciding whether the strontium-87 and the lead isotopes in meteorites are radiogenic are even more uncertain.

Kirsten, Krankowsky and Zähringer (**14**) determined the K^{40}-A^{40} ages of 48 stony meteorites. Their results showed that about two-thirds of meteorites had K^{40}-A^{40} ages between $3{\cdot}5$ and $5{\cdot}0 \times 10^9$ years and that the remaining meteorites had ages between $0{\cdot}5$ and $3{\cdot}5 \times 10^9$ years. All the measurements were made on whole-rock samples of the meteorites.

3. *Extinct radiogenic*—If an isotope results from the decay of a short-lived radioactive primordial parent isotope that is no longer present in the meteorite, it is said to have an extinct radiogenic orgin. The isotope xenon-129, which is thought to result from iodine-129, is the most famous isotope in this category (**118**). The important discovery of excess xenon-129 has now been checked in many laboratories. The report of a silver-107 excess has not been confirmed (**120**).

If the xenon-129 excess arises from iodine-129, which is formed in nucleosynthesis and incorporated in certain minerals or in other less distinct phases of the meteorites, there should be a correlation between the iodine-bearing minerals or phases and the xenon-129 excess. There should also be a correlation between the age of the mineral or phase and the xenon-129 excess. Jeffery and Reynolds (**121**), by heating experiments on the Abee meteorite, obtained a correlation in the release pattern of xenon-129 and that of the xenon-128 formed in a nuclear reactor from iodine-127. The heating experiment, although suggestive, is not so direct as would be desirable, and does not give any information on the age correlation.

Merrihue (**96**) found the xenon-129 excess in chondrules of Bruderheim to be larger than that in the whole-rock samples. He suggests an earlier origin for the chondrules. Fireman and Schaeffer (**117**) found the xenon-129 excess in the enstatite mineral fraction of Indarch to be larger than in the whole-rock samples. They also found that the xenon-129 excess in the tridymite mineral fraction was lower than in the whole-rock samples of Indarch and that the xenon-129 excess was not concentrated in the calcium-sulphide and calcium-phosphate, where it has been suggested (**122**) the iodine is located. The location of the iodine in the Indarch meteorite or in other meteorites has not yet been determined.

4. *Cosmogenic*—If an isotope is produced by the interaction of cosmic rays with the meteoritic material, it is called cosmogenic. All radioactive isotopes present in meteorites with half-lives less than 10^7 years are cosmogenic. Many isotopes lighter than iron and present in concentrations of less than 10^{-8} are also produced by cosmic rays. Radiochemical measurements of the radioactive isotopes H^3, A^{37}, A^{39}, C^{14}, and Cl^{36} have continued (**56–58, 123–133**). Gamma-ray measurements of Mn^{54}, Al^{26}, Na^{22}, and the cobalt isotopes have greatly increased during the past three years (**60, 61, 134–137**). Measurements of cosmic-ray-produced rare-gas isotopes have also increased (**14, 109, 138–140**). If we assume that cosmic rays are constant, we can define a time of exposure to them. This time is called the exposure or radiation age. The subject of exposure ages of meteorites has been reviewed by Schaeffer (**1**), by Anders (**2**), and by Arnold (**3**). The exposure age is usually determined from a radioactive and stable isotope; the pairs of isotopes Cl^{36}-A^{36}, A^{39}-A^{38}, H^3-He^3, Al^{26}-Ne^{21} and K^{40}-K^{41} have been

used. The exposure ages of special meteorites can be determined from two radioactive isotopes of different half-lives (**123**). Most stony meteorites have exposure ages between one and 50 million years. The Norton County achondrite has the oldest exposure age, between 200 and 400 million years. The Farmington chondrite has the youngest, between 7 and 25 thousand years (**123**). The exposure ages of iron meteorites center about 500 million years, which is an order of magnitude more than most stony meteorites. The exposure ages indicate that the size of the body in space must have been reduced in the not-too-distant past.

The mean collisional time with the Earth of a body in an orbit similar to that of Pribram is about 300 million years (**141**). If a body has to be perturbed from an asteroidal-type orbit into a Pribram-type orbit, the collisional time is even longer. If stony meteorites came from the asteroidal belt, we need a mechanism to reduce the size of the body shortly (a few million years) before it strikes the Earth. Two such mechanisms—collisions between meteoroids in space and space erosion—have been proposed; a third, the Yarkowsky-Radzievskii effect, may also be significant.

a. Collisions—Very little is known about collisions between meteoroids in space. In order to explain the exposure ages of stony meteorites, a collisional time of a few million years is necessary. If the frequency of collisions were constant, then the stony meteoroids had approximately a thousand collisions during the history of the solar system. The last collision before striking the Earth removed more than one meter of shielding from the body and left fragments of approximately one-half meter size exposed to cosmic rays. If previous collisions were similar in character to the last collision, that is, reduced the size of the object by several meters, then the size of the stony meteorites would have been enormous a billion years ago. Such a high frequency of strong collisions in space leads to a size distribution of stony meteorites that disagrees with observations. This collisional mechanism is, however, favored in a recent report (**142**). It is possible that the collisional frequency of meteoroids was much lower in the distant past. If the collisional frequency between objects in asteroidal orbits is higher than that of objects in Pribram-type orbits, the difficulty is accentuated.

b. Space Erosion—The erosion of surface material from a body in space by the action of fine dust and by ions was proposed (**143–145**) to account for the exposure ages of meteorites. Experiments by Heymann and Fluit (**146, 147**) indicate that ion bombardment erodes iron meteorites and chondrites at comparable rates. This experiment eliminates the possibility of erosion by ions but not by dust. The amount of dust a body encounters in space depends upon its orbit. The dust is thought to be concentrated in the plane of the ecliptic and toward the Sun; therefore space erosion for a body in a Pribram-type orbit would be more rapid than for one in an asteroidal orbit. The erosion rate of stony meteorites by fine dust should be much more rapid than that of iron meteorites. The soft matrix material in which the hard grains of a stone are embedded would erode very rapidly, and then the unsupported harder grains would fall away from the body. Space erosion could also account for the discrepancy between the K^{40}-K^{41} and the Cl^{36}-A^{36} exposure ages in iron meteorites (**148**). The amount of dust in space, however, is uncertain.

c. Yarkowski-Radzievskii Effect—This effect (**149, 150**) is caused by the action of solar radiation. If the resultant vector of the radiation pressure does not pass through the center of inertia, the rotation is accelerated. If the rotation period of a stony object several meters in diameter is approximately one second, it will fly apart. Iron objects are less likely than stony ones to do this. This mechanism has the advantage of being more effective for objects in Pribram-type orbits than for objects with asteroidal orbits.

The study of cosmogenic isotopes seems to raise more problems than it solves.

Tektites

Much additional work has been done on tektites in recent years, and most investigators now agree that they result from hypervelocity impact. However, the nature of the impacting body (cometary, meteoritic) and the location of the impact (Earth, Moon) are not yet agreed upon.

Chao *et al.* (**151**) found that tektites contain nickel-iron spherules similar to those found in terrestrial impactites, but much larger. O'Keefe *et al.* (**152**) demonstrated the presence of neon, helium, and oxygen in tektite bubbles. The neon and helium appear to have diffused there, and the oxygen may have been trapped. Zähringer (**153**) demonstrated the presence of atmospheric air in tektite bubbles. Chapman (**154**) extended his calculations of tektite velocities from ablation and concluded that they are of lunar origin.

Vorobjev (**155**) found that philippinites contained magnetite spherules with nickel. He concludes that the formation of tektites requires such exceptional thermal conditions that they could not be formed on the Earth. He also measured the beryllium content of tektites (**156**) and found it to be remarkably constant compared to strong variations in the beryllium content of terrestrial rocks.

Adams and Huffaker (**157**) recalculated the ablation data and concluded that tektites cannot be the result of ground impact and are probably ablation droplets from natural Earth satellites.

Zähringer (**153**) confirmed and extended the earlier studies of Reynolds and Gentner and Zähringer on the K-A ages of tektites and showed all North American tektites to be of one age, all Pacific and Australasian tektites to be a second age, and all moldavites a third age.

Gentner, Lippolt, and Schaeffer (**158**) have obtained K-Ar ages on impact suevite from around the Rieskessel which are identical, within errors, to the moldavite ages.

Von Koenigswald (**159**) found that in Java and the southern Philippines are found tektites that are transitional between the australites (whose forms are clearly derived by ablation) and other tektites.

Pinson and Schnetzler (**160**) showed by the rubidium-strontium measurement that tektites appear to have differentiated from a parent magma about 300 million years ago, and the apparent Sr^{87}/Sr^{86} ratio of the parent material is very uniform.

Tilles (**99, 161**) measured isotopic abundances of stable isotopes of silicon in several tektites and found the isotopic ratios covered a very small interval compared with the much larger total variations observed among all measured terrestrial samples.

Taylor and Epstein (**162, 163**) measured oxygen isotopic abundances and also found that all the tektites studied were very uniform in isotopic composition compared to a much wider range for most of the terrestrial rocks suggested as parent material. The oxygen isotope data are inconsistent with fusion of soil, sediments, or most igneous rocks as parent material, and suggest fusion of either highly silicic granite rocks or of extraterrestrial material.

The second international symposium on tektites was held in Pittsburgh, Pennsylvania, U.S.A., in 1963, and the proceedings will be published in *Geochimica et Cosmochimica Acta*.

Viste and Anders (**164**) showed by careful counting that Al^{26}, a radioactive isotope, is found in tektites from the Far Eastern strewn field in abundances less than would be expected if they had been in space for as much as 100 000 years. This apparently excludes any extraterrestrial source more remote than the Moon.

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