22. COMMISSION DES METEORES ET METEORITES

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La Commission a deux Sous-Commissions: 22 *a*, 22 *b*.

The Report of Commission 22 is printed on page 557.

22*a*. SOUS-COMMISSION DES METEORITES

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MEMBRES: Astapovich, Harrison Brown, Krinov, Leonard†, Levin, Link, Nininger, E. W. Salpeter.

INTRODUCTION

The marked acceleration in meteoritic research during the past few years is truly gratifying. Such research is an important prelude to vehicular exploration of the Moon and planets. In it may lie the vital key to the problem of solar system origin and evolution.

Because of the large number of diversive contributions in the field of meteorites, the present report must be both incomplete and sketchy. Hopefully the references included will assist students and investigators in making further progress in understanding our only samples of extra-terrestrial matter. Much research has been done in related fields of high-velocity phenomena, ion sputtering, physics and dynamics of meteorites in space and in other fields. No report is made here of such research.

GENERAL INFORMATION

The late Professor F. A. Paneth has left his collection of meteorites for experimental study in which portions of the material may, if necessary, be destroyed. Qualified investigators desiring to make use of this opportunity should apply to the Secretary of the Paneth Meteorite Trust, Dr. H. Wänke, Max-Planck-Institut für Chemie, Mainz, Germany. The collection may be augmented by later additions, and those in a position to do so are recommended thus to increase the facilities for the experimental study of meteorites which is in general not possible with specimens located in museums.

In Canada a program for the routine reporting of all bright fireballs is being organized on a national basis. Standard fireball report forms are being widely distributed, and a central co-ordinating agency has been established in Ottawa with the address: Meteor Centre, National Research Council, Ottawa 2, Ontario. Travelling exhibits of meteorites will be used in a general educational campaign. The above activities are being organized by the recently formed Associate Committee on Meteorites of the National Research Council of Canada, which will also serve as an international liaison office on meteorites.

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SPECIAL METEORITICAL PUBLICATIONS

The Committee on Meteorites of the U.S.S.R. Academy of Sciences published the monograph *The Sikhote-Alin Iron Meteorite Shower* written by a group of authors and edited by V. G. Fesenkov and E. L. Krinov (**1**). Issues XVII to XXI of *Meteoritika*, contain collected articles edited by V. G. Fesenkov and E. L. Krinov (**2**).

Pergamon Press Limited (London, England) published the book *Principles of Meteoritics*, 1955, by E. L. Krinov in English translation edited by H. Brown (**3**).

The Permanent Commission on Meteorites of the International Geological Congress issued the *Meteoritical Bulletin* nos. 9 through 21 edited by E. L. Krinov (**4**).

METEORITE FALLS, FINDS, AND CRATERS

The first and very significant double-station photographs of a meteorite fall were made on 1959 April 7, at the Ondřejov Observatory. Since three of the ten plates were taken with rotating shutters, 241 breaks at a frequency of about 48/sec were obtained, and the first precise trajectory velocity and orbit of a meteorite were measured. With a beginning height of 97·8 km at a velocity of 20·886 km/sec, the meteorite had a minor-planet type orbit with $a = 2{\cdot}424$ A.U., $e = 0{\cdot}6742$, $q = 0{\cdot}7899$ A.U., $\omega = 241°35'$, and $i = 10°25'\!{\cdot}5$. With motion inclined to the Earth's surface at 43°, the separation of 17 individual bodies was photographed between the heights of 44 and 23 km. The end height of the main body was 13·3 km. The maximum luminosity reached -19^m at 55 km. A predicted point of impact was calculated before a search was made and one of the four meteorites, of masses 4·48, 0·80, 0·42, and 0·105 kg, was found only 12 m from the calculated position. The main trajectory belongs to a body of approximately 100 kg weight which has not yet been found. The meteorites are chondrites mainly of enstatite, and olivine with some nickel-iron. Detailed results will be published in *B.A.C.* No. 2, 1961.

The Russian fall Yardymlinsky (Aroos) has been thoroughly studied, both in Russia and abroad (**5, 6**).

B. I. Vronsky writes on the discovery of the Susuman iron (18·8 kg found in 1957), (**7**), U.S.S.R. The Elga meteorite, 28·8 kg, was discovered in Yakutia, U.S.S.R. in 1959.

Two North American stony falls, Hamlet on 1959 October 13, and Bruderheim on 1960 March 4, were studied immediately by several investigators (see below) for short-lived radioactive isotopes, particularly A^{37}. Short-lived radioactive isotopes have also been measured in the iron meteorite, Yardymlinsky (Aroos) which fell in Azerbaijan, U.S.S.R., on 1959 November 24.

C. Hoffmeister discussed the puzzling circumstances surrounding the Rainsdorf fall of 1958 July 26 (**8**).

G. S. Hawkins (**9**) and Harrison Brown (**10**) have independently studied the mass distribution among meteorite falls. Whereas Hawkins finds that the number of meteorites with a mass greater than m varies as $1/m$, Brown finds a slower change in mass with frequency of fall. The former relationship is consistent with the distribution derived from bright fire-balls and for asteroids and with the comminution law of rock crushing.

A study of the fall of the Tunguska meteorite was continued. A final map was made of the region of the fall on a precise cartographic basis with indication of the boundaries, shape, and area of the region of the radial fall of trees; the direction of the large axis of ellipse of this area was determined and it closely coincides with the direction of the trajectory of the meteorite; in the soil magnetite, silicate and intermediate types of globules were discovered; the region and southern boundary of the distribution of anomalous optical phenomena in the atmosphere observed after the fall of the meteorite were determined. A number of theoretical studies have been made of the conditions of the movement and explosion of the meteorite. The combination of all these data leads to the conclusion that the Tunguska meteorite was of the nature of a comet. Investigation is being continued. (K. P. Florensky, Y. M. Yemelyanov, I. T. Zotkin, O. A. Kirova, and B. I. Vronsky (**11**): preliminary results of 1958 Tunguska expedition. I. T. Zotkin (**12**): anomalous optical phenomena in atmosphere during fall. O. A. Kirova (**13**): mineralogy of soil samples. V. G. Fesenkov (**14, 170**): the nature of the Tunguska meteorite. M. A. Tsikulin (**15**): parameters of fall deduced from destruction of forests. K. P. Stanyukovich and V. P. Shalimov (**16**) and V. A. Bronshten (**17**): the movement of meteoritic bodies through the Earth's atmosphere) and others (**171-173**).

Kaalijarv craters on Saarema Island, Estonia, were further studied by A. O. Aaloe (**18, 19**) and meteoritic matter collected. E. L. Krinov (**20, 21**) has classified meteorite craters as impact, explosion, and impact-explosion. He found regularities of elliptical fall-areas; groups of craters will occur in the front of the ellipse, and buried, intact meteorites will be found in the rear.

E. C. T. Chao and E. M. Shoemaker (**22**) have made the important discovery of coesite in the shattered sandstone in the floor of the Arizona meteorite crater. Coesite is the polymorph of silica which is stable at very high pressures (**23**), and not previously found to occur naturally on the Earth. Coesite is now regarded as a criterion for major meteorite impact in geologic basic structures of uncertain origin. The formation of this phase during impact also suggests a means of formation of diamond in meteorites without resorting to pressures in the center of a hypothetical moon-sized parent meteorite planet.

R. S. Dietz (**24**) studied shatter cones (percussion fracture cones) in rock; these are less than one meter in size, and are known to occur in only 4 geologic structures, all of which are suspected to be meteorite craters. Possibly we have here another criterion for meteorite impact.

C. S. Beals' studies (**25**) of fossil meteorite craters in Canada have established practical criteria of importance for the identification of large geological formations of possible meteoritic origin. His important discovery of a probable Precambrian meteorite crater at Holleford, Ontario, Canada, demonstrates the power of his techniques and adds a vital chapter to our understanding of meteorite impacts.

E. Opik (**26**) has continued his important theoretical studies of high-velocity impact phenomena.

MINERALOGY, METALLURGY, AND PHYSICAL PROPERTIES OF METEORITES

H. C. Urey, A. Mele, and T. Mayeda (**27**) searched for diamond in a number of chondrites, with negative results. They verified, by X-ray, that Goalpara (a ureilite) does contain diamond, in very fine grains (about 100 Å). A. E. Ringwood (**28**) similarly verified that Novourei (a ureilite) contains diamond and (**29**) demonstrated the presence of coehenite $(FeNi)_3C$ in 9 irons; this indicates they crystallized under pressure.

W. Nichiporuk and A. A. Chodos (**30**) measured the concentration of V, Cr, Co, Ni, Cu, Zn, Fe in the sulfide nodules from 12 irons and 2 stones by X-ray fluorescence.

H. C. Urey and T. Mayeda (**31**) studied metallographically the metal particles in 11 chondrites and 1 achondrite; they find curious Ni-rich borders on the taenite particles.

W. Nichiporuk (**32**) studied by wet chemical methods the partition of Ni, Ga, Ge, Co, Cu between kamacite and taenite phases in iron meteorites.

L. G. Kvasha (**33, 176**) described petrographically a number of stony meteorities, including several rare types, and presents interesting photo-micrographs and petrochemical diagram of achondrites.

K. N. Alexeyeva (**34**) has studied physical properties of meteoritic material. Meteorites have higher specific gravity, thermal and electrical conductivity and lower elasticity and strength, than terrestrial rocks of similar composition.

G. P. Vdovykin (**35**) studied the bitumens in 4 carbonaceous chondrites, and found that they differed qualitatively and quantitatively.

Basic measurements by mineralogical and X-ray techniques have been made by I. A. Yudin (**36**), of the stone Nikolskoye; by I. A. Yudin and N. F. Obotnin (**37**), of the carbonaceous chondrites, Migei, Staroye Boriskino, Groznaya; by V. D. Kolomensky (**38**), of the stones Kunashak and Nikolskoye (**39**); and by N. M. Stulov (**40**).

A new and better method for analyzing iron in silicate and metal phases confirms the existence of three groups among the chondrites in the work of A. A. Yavnel and M. I. Dyakonova (**41**), and M. I. Dyakonova and V. Y. Kharitonova (**42, 174**).

Gallium-germanium groups in the irons have been correlated with nickel content and with conditions of crystallization by A. A. Yavnel (**43, 44**).

L. G. Kvasha (**45**) studied the inter-relationship of Ni, metallic Fe, and silicate Fe content in chondrites. She agrees with Urey that the metal particles in chondrites are fragments.

An electron microprobe analyzer has been used on iron meteorites and the iron-nickel-cobalt-rich borders on taenite bands demonstrated by A. A. Yavnel, I. B. Borovsky, N. P. Ilyin, and I. D. Marchukova (**46**). (See M. Feller-Kniepmeyer and H. H. Uhlig of M.I.T. (**47**)).

One of the exciting new fields of research is the search for remnant magnetism in meteorites. J. Duchesne and J. Depireux (**48**) detected ferro-magnetic resonance in 3 carbonaceous chondrites, which they attributed to magnetite. F. D. Stacey and J. F. Lovering (**49**) found marked natural magnetic moments, over and above that induced by the Earth's field, in 3 chondrites. The planet(s?) on which these chondrites formed must have possessed a substantial magnetic field (possibly in a molten iron core?). J. F. Lovering (**50**) also finds remnant magnetism in the Moore County euchrite. This stone has a pronounced layered structure, and its attitude in the parent planet can be inferred. Measuring the angle between magnetic moment and pole to the mineralogical layering, it is inferred that the rock came from either 10°N. or 10°S. latitude, relative to the magnetic pole. Another interesting result is that the stone, an igneous rock, must have cooled to below 560°C. (the Curie point of magnetite) while the planet's core was still hot and molten, in order to have retained a magnetic moment; hence, Moore County must have come from near the surface of the planet; Lovering estimates about 10 km. The intensity of magnetization is approximately equal to the weakest magnetization observed among terrestrial cenozoic basic igneous rocks.

RADIOACTIVITY AND ISOTOPE RESEARCH

Uranium-lead and lead-lead dating methods continue to be exploited by I. E. Starik, E. V. Sobotovich, and M. M. Shats (**51**), I. E. Starik and M. M. Shats (**52**), I. E. Starik, E. V. Sobotovich, and G. P. Lovtsyus (**53**), I. E. Starik, E. V. Sobotovich, G. P. Lovtsyus, M. M. Shats, and A. V. Lovtsyus (**54**), E. S. Burkser (**55**), V. I. Baranov and K. G. Knorre (**175**). Ages calculated by the U-Th-He^4 method, *e.g.*, by P. Eberhardt and D. C. Hess (**56**) for seven chondrites, are subject to the suspicion that He^4 has diffused away because the K^{40}-A^{40} ages are almost always older than the He^4 ages in the same fall. Futhermore, direct diffusion studies by

J. Reynolds (**57**) and W. Gentner, H. Fechtig and G. Kistner (**58**) indicate that both A and He diffusion is serious in 4×10^9 years.

With regard to the extremely high K^{40}-A^{40} ages of iron meteorites work by M. Honda (**59**) and H. Voshage and H. Hintenberger (**60, 61**) shows that the Carbo meteorite contains the expected amount of K^{40} and K^{41}. The result has a small effect on the K^{40}-A^{40} age of the Carbo meteorite and demonstrates that in the case of the Diablo meteorite spallation has no effect on the K^{40}-A^{40} age. Voshage and Hintenberger (**61**) used K^{40} and K^{41} to arrive at cosmic ray exposure times for two irons; Carbo, $(1{\cdot}05 - 1{\cdot}40) \times 10^9$ yrs.; Treysa $(0{\cdot}50 - 0{\cdot}67) \times 10^9$ yrs. A better exposure age is obtained by the A^{39}-A^{38} method for Treysa and by the Cl^{36}-A^{36} method for Carbo.

Great interest in isotope work centers about the measurement of cosmic ray induced isotopes and the calculation of cosmic-ray exposure ages. The latter tend to lie in the range $(4 - 40) \times 10^6$ years for stones (except Norton County) and 30×10^6 to $2{\cdot}1 \times 10^9$ years for irons. Some of the recent work on cosmic ray produced isotopes in meteorites are in the following references:

Reference	What measured	In what
Ebert and Wanke (**62**)	He^3	5 irons
J. Geiss (**63**)	He^3	2 chon, 3 achon
Wanke and H. Hintenberger (**64**)	He, Ne	irons
F. Begemann, Eberhardt, and D. C. Hess (**65**)	H^3, He^3	Abee (achon)
J. Geiss, Oeschger, and P. Signer (**66**)	He^3, H^3	Monte das Fortes (chon)
F. Begemann, J. Geiss, and D. C. Hess (**67**)	H^3, He^3	Norton County (achon)
E. L. Fireman (**68**)		
E. L. Fireman (**69**)		
P. Signer and A. O. Nier (**70**)	Distribution of A^{38}, A^{36}, Ne^{22}, Ne^{21} Ne^{20}, He^4, He^3.	explores inter-relationships of these isotopes thoroughly.
E. L. Fireman (**71**)	Distribution of He in the Grant meteorite.	Draws contour map.
A. P.Vinogradov, I. K. Zadorozhnyi, and K. G. Knorre (**72**)	A	
L. K. Levsky (**73**)	noble gases	2 irons
W. Gentner and J. Zahringer (**74**)	H^3, A^{36}, A^{38}	irons
E. L. Sprenkel, R. Davis, Jr., and E. O. Wiig (**75**)	Cl^{36}, A^{39}	4 irons
K. Goebel and P. Schmidlin (**76**)	H^3	7 stony meteorites
D. O. Fisher and O. A. Schaeffer (**77**)	He^3, He^4, Ne^{21}, Ne^{22}, A^{36}, A^{38}	7 iron meteorites
O. A. Schaeffer and J. Zahringer (**78**)	He^3, He^4, Ne^{21}, Ne^{22}, A^{36}, A^{38}	7 iron meteorites
E. L. Fireman and J. DeFelice (**79**)	A^{39}, A^{38}, H^3	3 irons, 1 chon, 1 achon (A^{38}-A^{39} exposure age)
E. K. Gerling and L. K. Levsky (**80**)	Cosmic ray exposure age of	Sikhote Alin iron
E. Anders (**81**)	Al^{26}	Plainview (chon)

J. Hoffman and A. O. Nier (**82**) and P. Signer and A. O. Nier (**70**) in Carbo and Grant have obtained cross-sectional contours in noble gas spallation isotopes giving levels of equal cosmic-ray intensity. The contour shape reflects the shape of the meteorite in space to provide a measure of entry mass loss. Whipple and Fireman find that ages measured by cosmic-ray argon in iron meteorites can be interpreted to provide an upper limit to the total etching rate in space. A typical maximum etching rate is $1 \cdot 5 \times 10^{-7}$ cm/yr for the Sikhote Alin iron.

There had been some doubt whether Washington County (iron) is a genuine meteorite, as it contains voids and has the appearance of a metal casting; but O. A. Schaeffer and D. E. Fisher (**83**) have removed doubt by demonstrating the presence of cosmogenic noble gases.

Cosmogenic isotope work on meteorites has yielded some valuable information on cosmic-ray flux in the solar system. E. L. Fireman and J. DeFelice (**84**) measured A^{39} ($\frac{1}{2}$ life 325 years) and A^{37} ($\frac{1}{2}$ life 35 days) in two newly-fallen meteorites, Hamlet, a stony meteorite, and Aroos, an iron meteorite. The former is dependent on the average cosmic ray flux over the whole orbit, the latter on the cosmic-ray flux near 1 astronomical unit. They concluded that the cosmic-ray flux is somewhat higher near 1 A.U. than near 3 A.U. R. W. Stoenner, O. A. Schaeffer, and R. Davis, Jr. (**85**) performed the same experiment on the Hamlet meteorite, and within the accuracy of their measurements found the cosmic ray flux to be constant.

The newest and a most promising field of research is the search for primordial noble gases—isotopes neither radiogenic nor cosmogenic. The first work was done by J. Reynolds (Letter to Editor, *Phys. Rev.* (**86**). Also see work by J. Zahringer and W. Gentner in *Zeits. fur Naturforsch.* (**87**)). H. Stauffer (**88**) measured the abundance and isotopic composition of A and Ne in 5 carbonaceous chondrites; they have retained 10–100 times more of their primordial noble gases (relative to abundance of Si) than has the Earth. J. H. Reynolds (**89**) has done detailed work on the isotopes of xenon in carbonaceous chondrites, and has attempted to break the abundances down into components—primordial, radiogenic, contamination, etc. He measures Xe^{129}, estimates the amount of I^{129} originally present, concludes that about 120×10^6 years elapsed between nucleogenesis and the time the planet began to retain Xe^{129}.

The discovery of meteoritic xenon and its anomalous isotopic composition in some meteorites is of great importance. The presence of primordial noble gas in some meteorites and the evidence for the effects of extinct radioactive nuclides should be very useful in unraveling the origin of the solar system. The discovery of the anomalous isotopic composition of meteoritic silver is also of great importance.

H. Fechtig, W. Gentner and J. Zahringer (**90**) measure precisely the diffusion of A in various Ca minerals at temperatures down to 25 °C. This permits estimates in the error in K^{40}-A^{40} ages due to A leakage and gives us a better idea of just what a K^{40}-A^{40} age means. S. F. Singer (**91**) shows that the application of cyclotron cross-sections to spallation isotope work may lead to too high values for the cosmic-ray ages of meteorites; however, it is well known that a cosmic-ray age is only experimentally determined when a radioactive and stable spallation isotope are measured in the same sample.

CHEMICAL RESEARCH

Investigators	Elements	Methods	Meteorites
J. Geiss, and D. C. Hess (**92**)	K	isotope dilution-mass spectrometer	7 chons
B. M. Gordon, E. L. Friedman, and G. Edwards (**93**)	Cs	mass spectrometer	3 stones
P. W. Gast (**94**)	Rb, K, Cs	isotope dilution-mass spectrometer	5 chon 5 achon
G. L. Bate, H. A. Potratz, and J. R. Huizenga (**95**)	Sc, Cr, Eu	neutron activation	5 chon
J. F. Lovering, W. Nichiporuk, A. Chodos, and H. Brown (**96**)	Ga, Ge, Co Cr, Cu	spectrograph (emission)	88 irons 9 stony irons

Investigators	Elements	Methods	Meteorites
U. Schindewolf (97)	Se, Te	neutron activation	4 chon
A. DuFresne (98)	Se, Te	colorimetry	22 meteorites
J. W. Winchester, and A. H. W. Aten, Jr. (99)	Sn	colorimetry	8 irons
H. Onishi, and E. B. Sandell (100)	Sn	colorimetry	19 irons, mixtures of chondrites
U. Schindewolf, and M. Wahlgren (101)	Rh, Ag, In	neutron activation	5 chon
W. D. Ehmann, and J. R. Huizenga (102)	Bi, Tl, Hg	neutron activation	6 stones
G. W. Reed, K. Kigoshi, and A. Turkevich (103)	Ba, Hg, Tl, Pb, Bi, U	neutron activation	4 chon, 2 achon, 2 irons, 3 carb chon
E. A. Vincent, and J. H. Crockett (104)	Au	neutron activation	4 chon
I. E. Starik, E. V. Sobotovich, and G. P. Lovtsysus (105)	Pb		irons
G. L. Bate, H. A. Potratz, and J. R. Huizenga (106)	Th	neutron activation	2 irons
G. L. Bate, J. R. Huizenga, and H. A. Potratz (107)	Th	neutron activation	5 chon, 2 achon
H. Hamaguchi, G. W. Reed, and A. Turkevich (108)	U, Ba	neutron activation	4 chon, 1 achon
G. W. Reed, H. Hamaguchi, and A. Turkevich (109)	U	neutron activation	7 irons 1 stony-iron
I. E. Starik, and M. M. Shats (110)	U		meteorites

ON THE ORIGIN OF METEORITES

The enormous progress in measurements of meteorites and in the background understanding of physical, chemical, and nuclear processes helps us reconstruct detailed evolutionary steps for meteorites. At the moment, however, the subject is in an extremely interesting state of uncertainty. H. C. Urey's early catalytic thinking on the subject has led to great progress, but has resulted in heavy opposition to his detailed processes. His concept of two generations of parent bodies seems unnecessarily unwieldy to most investigators, and his proposal (111) that the Moon is the secondary source body for chondrites has been attacked by G. G. Goles, R. A. Fish, and E. Anders (112) and repulsed to the satisfaction of all, including Urey.

Fish, Goles, and Anders (113) have perhaps made the greatest attempt to take all the data into account in meteorite evolution. They propose one generation of parent meteorite planets; small, less than 250 km. These are heated fiercely but briefly by short-lived radionuclides which were present immediately after nucleogenesis, but naturally are absent today (*e.g.* Al^{26}). This brought about central melting, formation of irons and achondrites; and vulcanism, the ejecta of which (ash, etc.) formed chondrites.

A. P. Vinogradov, E. I. Dontsova, M. S. Chupakhin (114) indicate a difficulty with a simple model. They have measured oxygen isotope ratios in 3 pallasites, 4 chondrites, 5 achondrites, and 4 carbonaceous chondrites. They find the ratios in all except the carbonaceous chondrites very nearly identical. From this, they argue persuasively that it is impossible for the array of meteorites to have formed by process of melting, phase differentiation, fractional crystallization, etc., for such a history would be bound to produce isotope fractionations, such as are observed in terrestrial rocks. This observation is in further support of an earlier work (115) in which Vinogradov reviews work on Pb, A, Ne, He, O, C, Xe, Kr, and S isotope ratios in meteorites, points out the lack of isotope fractionations, and arrives at the same conclusion. The variations in the Xe isotopic composition in some stony meteorites and the anomalous isotopic composition of the silver in the Toluca iron meteorite pose an additional problem.

Beginning earlier in the evolutionary process, B. Y. Levin (**116**) postulates a (O. J. Schmidt) nebular disk of gas and dust about the Sun. The dust grains are vaporized by proximity to the Sun; this vapor, moving out from the Sun, soon cools and becomes oversaturated. It condenses from gas directly into solid, forming tiny balls of amorphous material (proto-chondrules). These accrete into planets of chondritic composition; radioactive heating causes central melting, irons, achondrites. The amorphous chondrules gradually 'devitrify', and grow crystals or crystallites, such as we see in them today.

J. F. Lovering (**117, 118**) requires a parent meteorite planet model, equivalent to one of Urey's 'primary bodies', but of lunar or greater dimensions. H. C. Urey (**119, 120**) has attacked Lovering's work heavily, with a counter-attack by Lovering.

A. E. Ringwood (**121**) also pictures a planet, Moon-sized or larger, accreting at low temperatures with material in a highly oxidized state. H. C. Urey (**122**) also attacks this hypothesis. Ringwood is preparing a monograph (**123**) to elaborate his concept and to present a great amount of (very much needed) petrographic and X-ray data on chondrites.

B. Mason (**124**) proposes that chondrites were original condensations about as small as they are now. Originally they were all carbonaceous chondrites, but an unspecified heat source altered most of them to what we see today, and drove off the carbon. He requires a supplementary parent meteorite planet, with radioactive heating to account for irons and achondrites.

Data on the chemical composition of meteorites have been generalized by A. A. Yavnel (**125**) in connection with the problem of the origin of meteorites and other problems of meteoritics.

E. Anders and C. M. Stevens (**126**) find that meteoritic thallium has the same isotopic composition as terrestrial thallium; from this he suggests that Canyon Diablo solidified at least 10^8 years after the isolation of the solar system, if the latter was formed according to the 'continuous synthesis' model.

TEKTITES

An increasing interest in tektites bodes well for an early solution to the puzzling problem of their origin (or origins). At present, however, the numerous investigations do not seem to *prove* whether tektites are terrestrial or extra-terrestrial in origin. Hence no critical summary account of the results will be attempted in this report.

E. L. Krinov (**127**) reviews tektite work in U.S.S.R., including discussions of viscosities, major and minor elements, and K^{40}–A^{40} dates. He believes tektites are impactite glass.

A. J. Cohen (**128**) discusses the new tektite discovery area in Georgia (U.S.A.).

F. E. Senftle and A. Thorpe (**129**) made magnetic susceptibility studies of tektites, showing that they were heated above 1400 °C and that all Fe is in solution. If extra-terrestrial, they probably were glass before they entered the Earth's atmosphere.

W. D. Ehmann (**130**) measured Ni in tektites by activation analysis. The Ni/Fe ratio is perceptible, but only $\frac{1}{2}$ to $\frac{1}{10}$ of that in known meteorite impact glasses.

Papers by J. A. O'Keefe, C. M. Varsovsky, and T. Gold (**131**) arguing for a lunar origin for tektites were heavily attacked by V. E. Barnes, Z. Kopal, and H. C. Urey (**132**).

J. A. O'Keefe (**133**) reviews the properties of tektites and presents a strong argument for their extra-terrestrial origin, specifically a lunar origin.

D. R. Chapman (**134**) concludes that the shapes and surfaces of tektites show definite re-entry characteristics. See also I. Friedman and T. P. Kohman (**135**) and for javites, v. Koenigswald (**136**).

I. Friedman, A. Thorpe, and F. E. Senftle (**137**) melted rocks in a solar furnace. To fuse a tektite takes 20 min at 2500°C. or else a higher temperature. The ferric/ferrous iron ratio in tektites indicates they formed under a lower oxygen pressure than that in the Earth's atmosphere. Magnetic susceptibility studies show tektites could not be formed from the rock in which they are found lying.

S. R. Taylor and L. H. Ahrens (**138**) found the Rb/Sr ratio in tektites the same as in most undifferentiated terrestrial rocks, and concluded that an origin at least within the solar system is strongly indicated.

R. D. Cherry and S. R. Taylor (**139**) think that the Be^{10} and Al^{26} reported by Ehmann and Kohman (**140**) in tektites was formed in the silicate portion of comets, which then collided with the Earth. But E. Anders (**81**) made a careful and unsuccessful measurement for Al^{26}.

H. C. Urey (**141**) defends his earlier proposal that tektites are formed by comets striking the Earth.

S. R. Taylor (**142**) measured K, Na by flame photometry, and Rb, Cs by emission spectrograph in tektites and found the same abundances as in terrestrial sedimentary rocks.

R. D. Cherry, S. R. Taylor, and M. Sachs (**143**) show that 3 parts terrestrial shale plus 1 part SiO_2 (sand) = tektite. See also S. R. Taylor and M. Sachs (**144**).

J. H. Reynolds (**145**) measured K, atmospheric A, radiogenic A, atmospheric Ne, possibly cosmogenic Ne in tektites, and derived a short upper limit for their lifetime in space. $K^{40}-A^{40}$ ages of tektites are the same as the ages of the geological strata in or on which they lie.

An important series of papers on the composition of tektites was presented in the U.S.S.R.: G. G. Vorobyev (**146**) a study of indochinites, (**147**) a study of moldavites, (**148**) probes of tektites and silica glasses, (**149**) emission spectrographic study, and (**150**) chemical composition and origin of tektites; L. G. Kvasha and G. S. Gorshkov (**151, 177**) chemical composition of tektites versus terrestrial lavas; and I. E. Starik, E. V. Sobotovich, M. M. Shats, G. P. Lovtsyus (**152**) U and Pb in tektites. This series of papers prompts the assumption that tektites are either of a cosmic origin or were formed by the fall of crater-forming meteorites.

METEORITIC DUST

The acoustical detection of small meteorites in space by rockets, satellites and space probes has now been accomplished in a number of vehicles: for Satellite 1959 η (Vanguard III) by H. E. LaGow and W. M. Alexander (**153**); for Satellite 1958 δ (Sputnik III) by O. D. Kamessarov, T. N. Mayarova, L. N. Neugodeov, S. M. Poloskov and L. Z. Rusakov (**154**); for 1958 α (Explorer I) (**155**); for Pioneer I by M. Dubin (**156**); for Sputnik III and space rockets by T. N. Nazarova (**157**); and others (**158**). F. L. Whipple (**158**) finds from these measures that the impact rate near the Earth ($\sim$ 140 km) for particles of mass greater than 10^{-10} gm is 10^4 to 10^5 times as great as expected from zodiacal cloud calculations and falls off as approximately $h^{-1\cdot 4}$, where h is the height above the Earth's surface. The zodiacal cloud value is reached some distance beyond $h = 10^5$ km. A. Hibbs (**159**) confirms this result. D. B. Beard (**160**) anticipated the Earth's dust belt; he presents a theory of Earth capture of zodiacal particles from nearly circular orbits by the aid of solar attraction. Whipple (**161**) cannot confirm this theory, and, after discussing a number of possible mechanisms to produce the dust belt, favors a lunar origin for the particles, where meteorites falling onto the Moon eject dust into circum-terrestrial orbits. If indeed the particles near the Earth are moving largely in long-lived circum-terrestrial orbits instead of circum-solar orbits, the accretion rate on the Earth falls from the order of 10^4 tons/day to less than 10^3 tons/day, with only a few per cent of this input contributed by particles in circum-terrestrial orbits.

At the Ondrejov Observatory, I. Zacharov (**162**) has made a long series of meteorite dust collections at three stations with rain gauges equipped with Tretjakov filters. From spectroscopic evaluation of meteoritic content from the Ni/Fe ratio in the solids recovered, Zacharov finds that the accretion is maximum after the Perseid shower and averages 10^{-13} to 10^{-12} gm/cm²/sec. This rate of fall is even higher than that obtained similarly by H. Pettersson (**163**), 10^4 tons/day on the Earth or 2×10^{-15} gm/cm²/sec. Pettersson (**164**) further investigates the presumably meteoritic rate of fall as evidenced in deep-sea deposits.

P. Hodge, F. W. Wright, and E. L. Fireman (**165**) at the Smithsonian Astrophysical Observatory and C. E. Junge, C. W. Chagnon, and J. E. Manson (**166**) at the Geophysical Research Division of the Air Force Cambridge Research Center have separately been utilizing high-altitude jet aircraft and occasional balloons to collect stratospheric dust at altitudes from 13 to 30 km. E. L. Fireman and G. A. Kistner (**167**) have analyzed individual particles of the high altitude collection for eight elements to determine the composition of the possible meteoritic dust. P. Hodge (**168**) finds about 0·2 spherule per m³, with a large statistical uncertainty occurring at 15 km altitude. The corresponding rate of fall on the Earth is only 20 tons/day.

D. W. Parker and W. Hunter (**169**) find black or silvery magnetic spherules of $(5\text{-}35)\mu$ diameters in melt water from the West Greenland Crevass and on gelatin-coated slides from high-flying aircraft. These they identify 'undoubtedly' as meteoritic dust.

By means of an airborne impact particle collector flown at an altitude of 20 km over the Arctic on 15 November 1960, C. L. Hemenway, E. F. Fullam and L. Philips (*Nature*, **190,** 897-8, 1961) find "enormous numbers of ultra-small, high-density particles of the order of 75 Å in size, in addition to the solid and 'fluffy' particles larger than 0.2μ normally seen." The authors call these new particles, observable only in an electron microscope, *nano-meteorites*, since they are three orders of magnitude smaller than micrometeorites.

All of these terrestrial methods of collecting meteoritic dust show great promise, but the uncertainties in identifying particles as of cosmic origin leave the conclusions extremely doubtful at the moment. Much more research is urgently required, particularly in the precise analysis of composition to clarify the problem.

N. Richter determined by experiment the optical properties of iron and stony meteorites. The investigation contains absolute reflection coefficients in two spectral ranges ($\lambda 4200$ and $\lambda 5250$), the polarization power of the surfaces depending on phase angle and the phase curves of reflected light between 6° and 173° phase angle. The experiments show as well as possible the optical characteristics of actual interplanetary surfaces of known iron meteorites. The size of the pieces was in the order of one cm.

PROPOSALS

The vital importance of meteorite studies to space sciences, the increasing interest in the subject generally, the continuing development of new and more powerful methods of analysis, and the increasing number of meteorite investigators combine in demanding an increased effort and coordination in observing, reporting, finding, analyzing, and cataloging meteorite falls, meteorites and the results of meteorite studies. The following proposals represent a positive attempt towards meeting the above requirements.

1. It should be recommended that all astronomical and geophysical groups watch carefully for new falls, discoveries of meteorites, and detonating bolides that might lead to the discovery of new falls. It is further recommended that organizations be set up wherever possible, either by countries or in convenient geographical areas, for the systematic reporting of falls, finds, and detonating bolides, with organized search procedures and organized efforts to make new finds. (Whipple and Krinov).

2. It should be recommended to meteoritic centers and groups studying meteorites that serious attention be devoted to the development of equipment and methods of instrument observing of bright bolides and their dust trains so that highly reliable data can be obtained on the atmospheric trajectories and the orbits of meteoric bodies as well as the discovery of meteorites when possible (due consideration must be given to the experience gained during the photographic observations of the fall of the Pribram/Luhy meteorite in Czechoslovakia on 1959 April 7). (Krinov).

3. The major data of all new falls and discoveries of meteorites should be reported immediately to the Permanent Commission on Meteorites of the International Geological Congress (E. L. Krinov, Committee on Meteorites of the Academy of Sciences of the U.S.S.R., Osipenko, 52, Moscow, zh-127, U.S.S.R.) for publication in the *Meteoritical Bulletin*, the data to include: name of meteorite; place of fall or discovery; date of fall or discovery; class and type; number of individual specimens, their size and weight; circumstances of fall or discovery (brief data). (Krinov).

4. Considering the exceptional importance of the 'Bibliography on Meteorites' edited by Harrison Brown (Pasadena, U.S.A.) issued in 1953, Dr Brown should be asked to prepare for publication additions and corrections to the above book. Meteoritic centers should be requested to assist Dr Brown in this work by providing various types of information; the Sub-Commission should collaborate in publishing the addition. (Krinov).

5. The Sub-Commission should be instrumental in organizing the compilation of a catalog, verified and unmistakable elements of the atmospheric trajectory and orbit of bright bolides and meteorites. (Krinov).

6. It should be recommended that for each large meteorite fall, meteoritic dust (magnetite, silicate, and other globules) should be collected over a considerable area in and about the fall or crater, giving due consideration to the experience of similar investigations made in the U.S.A. and the U.S.S.R. It is recommended that the Institute of Meteoritics (Albuquerque, New Mexico, U.S.A.) undertake such a search in and around the area of the Norton County stony meteorite shower that fell on 1948 February 18. (Krinov and Whipple).

7. It should be recommended that greater attention be paid to the study of meteorite craters, particularly Henbury, Wabar, Odessa, and Gran Chaco to obtain more precise data on morphological properties of the explosive craters, on the one hand, and impact craters, on the other. It is especially important to search for large individual specimens in the rear section of each of the above group of craters. (Krinov).

8. The methods used by Carl S. Beals in finding old craters by aerial surveys and in investigating the nature of suspected meteorite craters and the questionable geological features of possible meteoritic origin should be extended and applied wherever possible by investigators throughout the world. (Beals, Krinov, Whipple).

9. It should be recommended that as complete as possible a study be made of the morphological properties of meteorites for the purpose of investigating the mechanism of the break-up of meteoric bodies during their movement through the Earth's atmosphere to determine the loss of mass and also to determine their original shape and mass, study of dust trains, and so forth, with due consideration for the experience of similar investigations undertaken in the U.S.S.R. (Krinov).

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10. It should be recommended that the method used by the Smithsonian Astrophysical Observatory to study the distribution of cosmogenic isotopes in large iron meteorites be applied whenever possible with a view to determining their pre-atmospheric shape and mass. (Krinov).

11. It should be recommended that the methods of collection and analysis of meteoritic dust in the atmosphere, at the surface of the Earth, in glaciers, and in deep-sea deposits, be vigorously improved and applied for the purpose of determining the nature of the micro-meteorite material falling on the Earth, as well as the rate of fall and possible variations in the rate of fall over past ages. (Whipple).

12. It should be recommended that the studies of meteoritic material by space vehicles be improved and continued for the purpose of determining as much information as possible about the nature, orbits, and abundances of such material in free space. (Whipple).

13. It should be recommended that the Sub-Commission assist in every way possible in the systematic and uniform analysis of meteorites wherever possible, and specifically, that assistance be given to Harrison Brown (Pasadena, U.S.A.) in his thorough and systematic effort to analyze meteorites uniformly by non-destructive methods.

F. L. WHIPPLE
President of the Sub-Commission

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