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## 22b. SOUS-COMMISSION DES CARTES STELLAIRES

PRÉSIDENT: P. M. Millman.

MEMBRES: MM. Bećvář, Olivier, Prentice.

### GENERAL

The past triennium has been characterized by further developments in meteor astronomy, and the following results have been obtained:

(1) The majority of meteors, whether photographic and visual or radar and telescopic, show a strong preference for direct motion near the ecliptic inside the solar system.

(2) Meteors are connected with comets and their orbits have the same distribution as those of comets.

(3) Meteorites are connected with the system of minor planets; micro-meteorites with the zodiacal light.

(4) The structure of a few showers and their ages have been determined.

These results are based on improved observational methods (photographic, radar and telescopic observation in connexion with visual observations).

Great progress has also been made in the physical theory of meteors, although many unknown parameters permit different interpretations of the new theories. I.G.Y. measurements directly in the 'meteor surroundings' (artificial satellites and meteors) will contribute to the removal of the fundamental discrepancies which exist today. We shall then know even better the interaction between the atmosphere and meteors.

The detailed description of results obtained is presented below.

### OBSERVATIONAL METHODS

Radar observations of meteors were made in the following countries:

*Australia.* Radio-echo rates for both shower and sporadic meteors have been systematically measured from 1952 at Adelaide with the 27 Mc/s C.W. equipment. Meteors above limiting brightness in the range $M_R+7{\cdot}5$ are regularly registered. A. A. Weiss discusses the sporadic background [1], shower meteors [2] and the influx of meteor particles over the whole surface of the Earth and their density in space [3]. The results are in good agreement with those obtained at other radio stations.

*Canada.* A new meteor observatory was erected in 1957 at Springhill (20 miles south-south-east of Ottawa) where the programme of meteor research using a combination of radio, photographic and visual techniques was transferred from Metcalf Road Field



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Station. A 32 Mc/s meteor radar with peak power of 400 kW and single-dipole antenna system has been built specially for the I.G.Y. meteor programme. In addition to this a special 32 Mc/s I.G.Y. meteor radar with peak power near 20 kW and omni-directional antennas is operated continuously throughout the I.G.Y. [4].

*Czechoslovakia.* The first Czechoslovak radar was finished in 1957. It works on a frequency of 37·5 Mc/s with peak power of 25 kW and with a rotating antenna system ($14\times 6$ m; the beam-width to the half-power points is $\pm 16°$ in the horizontal plane and $\pm 27°$ in the vertical plane) at an elevation of 45°. The radar is now being tested.

*Great Britain.* The radio survey of meteor activity has been continued at the Jodrell Bank Station of the University of Manchester with the same equipment as before. Important results on meteor physics have been obtained.

*U.S.A.* A system of megawatt transmitter and six receiving stations are proposed to be operated during the I.G.Y. by Harvard College Observatory in order to obtain reliable information on the radiant, velocity and acceleration of individual meteors down to 12th magnitude. [5]

*U.S.S.R.* Regular radar observations began in June 1955 at the Astronomical Observatory at Kazan, where automatic registration equipment was developed for use during the I.G.Y. Regular radar work at Stalinabad (Academy of Sciences of Tadjic S.S.R.) began in 1956, and at Ashkhabad (Academy of Sciences of Turkmenistan S.S.R.) in 1957. Regular I.G.Y. work began in U.S.S.R. in June 1957 at the following radar-meteor stations: Kazan, Ashkhabad, Stalinabad, Kiev and Odessa on 4·2 m band and at Tomsk and Kharkov on 8·4–10 m band. Observation of individual orbits was started at the last two stations in October 1957. Summaries of the results have been published [6, 7, 8].

The Canadian radio-physicists have elaborated the project JANET which shows how meteor trails can be used for radio communication over large distances [9–20].

## PHOTOGRAPHIC OBSERVATIONS

The Super Schmidt cameras are in regular operation in U.S.A. [21] for double meteor photographs, in England in combination with radar observations [22], and in Canada. Methods of reduction of meteors photographs were summarized by F. L. Whipple *et al.* in a paper on 'Reduction Methods for Photographic Meteors' [23].

A new patrol system of unguided meteor cameras was constructed in U.S.S.R. in Odessa by E. N. Kramer with four cameras, *f.* 2·5, f.c. 25 cm and with a special rotating shutter which permits the determination of the precise time. The patrol-system works quite automatically for double-station photography and timing data, together with the number of rotations, are registered by a printing chronograph. The rotating shutter has two systems of arms moving slowly one against the other that makes possible the determination of the time from the measurements of breaks with precision of 1 in $10^8$ [24]. Similar instruments were already in use some years ago at Stalinabad and Ashkhabad. The same instruments as in Odessa are used for double-station photographs in Kiev during the I.G.Y. Results are published in [25–28] and descriptions of the methods in [29–32].

The meteor base Ondřejov-Prčice was further developed; as well as ten unguided cameras at each station with rotating shutters, at one station a new patrol system of thirteen guided cameras was put into operation. Also experiments with two 'long focus' cameras with f.c. = 50 cm, *f* 4·5, field $32°\times 26°$ with special rotating shutter in the focal plane (Ceplecha) were made. The operation of six small spectrographs (J. Rajchl) was continued. This system of many cameras is in operation on every clear moonless night. Some amateur stations collaborated with this system. The reduction method for meteor negatives was studied by E. Chvojková [33]. The results obtained by the Ondřejov equipment were used (Z. Ceplecha [34]) for studies of the great showers (Perseids, Geminids) and for some critical studies about the physical theory of meteors (Fritzová [35]).

H. Hirose and K. Tomita of Tokyo Observatory have continued photographic observations of meteors, and have obtained important material about the Quadrantids [36, 37]. Valuable photographical results were obtained by English [38] and Dutch [39] amateurs.

VISUAL OBSERVATIONS

*Canada.* Group observations of great showers are made [40]. A combined programme of radio and visual observations has been prepared for the I.G.Y.; besides many amateur stations the following took part on this programme: Bakr Lake, Meanook-Newbrook, Ottawa, Resolute, Saskatoon and Springhill. At the second station these observations are supplemented by photographic observation (Super-Schmidt cameras) and by spectral photography. Stations from other countries also take part in this programme.

*Czechoslovakia.* Observers at public observatories and in astronomical circles under the direction of the People's Observatory at Brno have observed not only visual but also telescopic meteors using binocular telescopes of 3° and 8° field of view. Visual observations on Regular World Days and during the activity of great showers are part of the programme of the observatory of Ondřejov, in order to complement the photographic and radar observations. Meteor expeditions are organized every year to co-ordinate all observations done in the country. The comparison of U.S.S.R. and Czechoslovak observations has been made by I. S. Astapovich and Z. Ceplecha [41]. The reduction of visual observations was done by A. Hruška by means of his nomograms [42]. The reduction methods of group observations were studied by Z. Kviz [43].

*Japan.* Visual observations in Japan have been made by amateur groups, especially by the main group of the Oriental Astronomical Association and the Japanese Astronomical Study Association. From the beginning of the I.G.Y. the observations have been concentrated on the Regular World Days and are carried out by some thirty amateur observers under the leadership of Köjiro Komaki.

*The Netherlands.* The Dutch group of observers publishes its results in the periodical *De Meteoor.* Individual observations in a limited area of 40° diameter is the programme of this group. Attention is paid to 'twin' meteors. Time, magnitude, shower, train and its duration are the only data estimated. The number of all stars in a small area gives the magnitude limit.

*U.S.A.* It is estimated that about half a million meteors have been reported to the A.M.S. C. P. Olivier continuously directs the observations. The position of the radiants and hourly rates are published in the periodical *Meteoritics.*

*U.S.S.R.* Visual observations are organized in parallel with the radar observations (Ashkhabad, Kiev, Odessa, Charkov, Kazan, Sverdlovsk, Moscow). The group observations of the Simpheropol division of VAGO (Soviet Astronomical-geodetic Society) included together with other observations of the VAGO meteor stations under the direction of V. V. Martynenko; observations of telescopic meteors are in the programmes of Ashkhabad, Stalinabad and Simpheropol. The results of Perseids 1956 were published by A. P. Savruchin [44].

*Other countries* (England, South Africa, etc.). The observational material of hourly frequencies obtained in 1937 and 1938 by C. Hoffmeister on his visit to South Africa has now been published [45]. This important observational material obtained by an experienced observer in the southern hemisphere could be used for investigations into different theories about daily variation of meteor numbers.

ASTRONOMICAL RESULTS

M. Plavec has a special publication [46] on the theory of the origin and on the early stages of meteor streams. The cause of the origin of meteor showers is studied: (*a*) from comet bursts, (*b*) from slow ejections, (*c*) from gravitational disturbances. The mass and density of meteor streams is determined. These theoretical considerations are applied to the Draconid shower.

L. Kresák has criticized the Guigay theory of comet decay by collisions [47]. It is shown that the approaches of several cometary orbits to those of the Perseids do not support the opinion of their common origin being fully explainable by pure chance. A general theory of the random distribution of known cometary orbits around an arbitrary point in space is outlined and the corresponding numerical results are derived. L. Kresák has also shown a probable connexion between the meteor streams of 1925 and 1935, November 21 and the comet 1944 I [48].

*Known showers* (most substantial results only)

*Quadrantids.* The double-station orbits were calculated by H. Hirose and K. Tomita [49]. L. Sehnal has used these results for the study of secular perturbations [50].

*Aquarids.* The orbits on the basis of radar observations were computed by D. W. R. McKinley [51]. One double-station orbit was determined by Babatshanov [52] and two orbits by Z. Ceplecha [53].

*June-Draconids.* The first part of the investigation into this stream, dealing with the secular perturbations of the mother comet Pons-Winnecke, has been published by V. Guth [54].

*Capriconids.* Twelve double-station orbits have been calculated by F. W. Wright, L. G. Jacchia and F. L. Whipple [55] from Harvard material.

*Perseids.* The extensive study of radiant velocity, orbits and 'colour index' was carried out by Z. Ceplecha [53] on the basis of twenty double-station Perseids of the Ondřejev material and twelve double-station Perseids of the Harvard material. A further ten double-station meteors of Ondřejov material are in the same paper. L. Fritzová and J. Rajchl [56] have analysed the dependence of the light-curves on the height and velocity of photographic meteors. Combined visual and radar observation was carried out by a Swedish group under the direction of B. A. Lindblad [57]. The question of the origin of telescopic Perseids was solved by M. Kresáková [58]. A detailed analysis of the spectrum of a bright Perseid was published by A. F. Cook and P. M. Millman [59]. Visual observations were made in England, Bulgaria, Canada, Czechoslovakia, the Netherlands and U.S.S.R.

*Draconids.* The surprising phenomenon of the year 1952 and its cause were studied by J. G. Davies and A. C. B. Lovell [60]. A few Draconids were detected by radar in 1956 at Jodrell Bank. The radar investigations in Kazan in 1955 were negative [61]. L. G. Jacchia [62] has pointed out some physical characteristics of the shower on the basis of two Draconids in 1953. Z. Ceplecha has studied the difference in the composition of the matter of these meteors on the basis of Canadian photographical results [63]. The very extensive theoretical paper of M. Plavec applied to this stream is mentioned above.

*Orionids.* These were observed visually and telescopically (U.S.S.R. Canada) and by radar (Jodrell Bank) indicating a connexion with the orbit of Halley's comet similar to that of the Aquarids.

*Geminids.* Good weather at Ondřejov at the maximum activity in 1955 has enabled double-station Geminids to be obtained during two nights. This material was used by Z. Ceplecha [64] together with the older Harvard material for calculation of precise elements of this shower and for a revision of some physical processes in the meteor phenomena. The spectrum of a Geminid was analysed by J. A. Russel, M. S. and C. D. Sadovski and G. F. Wetzel [65]. I. S. Astapovich [66] has detected on wave-length 33 m 6000 meteors at the height of 50–100 km with the hourly rate of 100–120; the magnitudes of these meteors could be 9–10. The shower was observed visually (Canada, Czechoslovakia, U.S.S.R.) and telescopically (Czechoslovakia, U.S.S.R.). Geminids have had 50% greater activity in 1954 at Jodrell Bank as compared with 1953. The hourly rate has lasted on the higher level in 1955 and 1956.

*Ursids.* Six radio orbits were obtained in 1954 at Jodrell Bank. These measurements confirm the association of this stream with Comet Tuttle.

*Day-time streams.* A number of $\delta$ Aquarid orbits (Jodrell Bank) and day-time Arietid orbits have been computed, confirming the close similarity between these orbits. Orbits of meteors from the day-time $\psi$ Perseids and Piscids have also been computed. Work on all these streams is continuing.

*New streams.* A new shower was detected at Jodrell Bank between 1957 January 16, 19 with a radiant in Bootes. The rate was about thirty per hour and check of previous records indicates similar activity in 1951.

On 1956 October 5 a very remarkable meteor shower was observed by J. Nakamura [67] on board the Japanese Antarctic expedition ship *Soya* ($\lambda$ 72° 10′ E., $\phi$ 11° 0′) with radiant $\alpha=356°$, $\delta=43°$; the maximum rate was some 300/hour about $16^h 30^m$ U.T.

On the evening of 1956 December 5 between $18^h 15^m$–$22^h 45^m$ U.T. a new shower of sixty meteors was detected by S. C. Venter (South Africa). The radiant was situated in Phoenix: $\alpha=1^h$, $\delta=-50°$. There were many bright meteors observed from the same radiant [68]. The same shower has been detected in Eastern Australia using radio methods [69].

*Sporadic meteors.* Sporadic meteors were studied by different methods. The very extensive material obtained by members of the British Astronomical Association during 1930–49 was analysed by G. S. Hawkins and J. P. M. Prentice [70]. It was found that sporadic meteors observed in the northern hemisphere are more numerous in the summer months and that the radiants show a concentration to the ecliptic with two concentrations of radiant points, at the Earth's apex and at the anti-helion, due to direct orbits with low inclination and large eccentricity. It was found that the ratio of direct to retrograde meteors was 50:1 for slightly inclined orbits. The same result was obtained previously by G. S. Hawkins [71] from a radio-echo survey of sporadic radiants at Jodrell Bank between 1949–51.

T. Murakami from the Hiroshima University also studied the theory of the annual variation of sporadic meteors [72]. He obtained the same result as C. Hoffmeister: excluding the regular showers, the sporadic meteors show an annual rate with the maximum in August and a minimum in spring. The celestial distribution of radiants of minor or transient showers is quite random, without any elliptical concentration.

An analysis of the orbits of 2400 sporadic meteors obtained at Jodrell Bank in the magnitude range +7 to +8 is now complete. 40% of the radiants lie within 15° of the ecliptic. About 15% of the meteors move in rather circular orbits with inclinations near 60°, or in the range 110° to 150° which class of orbit is unknown in the orbits of photographic meteors. In the magnitude range +4 to +6, preliminary results show these circular orbits are less common. As J. G. Davies and K. R. R. Bowden [73] and R. E. McCrosky [74] have shown, radar meteors of various magnitude ranges show no tendency to cluster in the sizeable groups that are sometimes (Astapovič) reported for visual meteors.

A. Hruška has studied the annual variation of hourly rates on the basis of the material of the Czechoslovak Astronomical Society from the years 1948–50 [75], the annual variation is obscured by different disturbing influences. The luminosity function was derived from the same material (1014 meteors) [76].

## PHYSICS OF METEORS

The physical theory of meteors has undergone great development in the past few years. J. Hoppe has revised his theory and has published [77] a theoretical foundation of the physical theory with the aim of including the whole range of meteor phenomena. The first part of the theory dealing with the 'shooting star' state was published in [77]. The energy and impulse transport is considered as the effect of individual collisions of atoms with the solid meteor surface. B. J. Levin [78] has studied thoroughly all physical problems of meteors and has criticized the Hoppe theory; his book contains one of the most complete monographs on the physical theory of meteors. Levin has derived, in the second part of this book, the great influence of geocentric velocity on the visibility of meteors; sporadic meteors are shown to be the dominant part of meteor matter. The density of meteor particles in the solar system is in agreement with the cosmogonical theory of O. J. Schmidt.

One of the first to study meteor physics, E. J. Öpik has discussed the physical problems of meteors in a series of papers [79, 80]. P. M. Millman has surveyed meteor physics [81]. A certain change in the conventional suppositions about meteor particles was realized by L. G. Jacchia [82], F. L. Whipple [83] and E. J. Öpik [84]. The density of particles 0·05 g/cm³ seems to point to the 'fragmentation' structure of the meteors. J. Hoppe [85] is of another opinion, that the classical theory can explain the weak-meteor anomalies. He [86] confutes the criticism of Levin and states that his theory can be used for the 'shooting-star' state. Z. Ceplecha [87] has calculated the influence of the changes of the new revised Hoppe theory on the changes of the calculated initial velocity of the meteor, with the result that no substantial changes are present; he has investigated [88] the revised Hoppe theory by means of photographic observations, with the result that the coefficient of the mass equation is constant and the drag coefficient linearly dependent on velocity. This means the revised Hoppe theory is not in agreement with photographic observations. J. Hoppe has published [89] a further revised theory which is in agreement with Ceplecha's results. Using Levin's theory, Ceplecha [63] has published a distribution of photographic meteors in groups of different material composition. This rough composition (iron, stony and porous meteors) is computed from the beginning height from the heat conductivity. Different compositions were found for different showers (Geminids: 44% iron; Perseids, Taurids: 12% iron; and sporadic meteors 40% iron). Exceptional are Draconids with 32% porous, 64% stony and 4% iron meteors. On the other hand Öpik [141] gives only 1·75% of iron meteorites and 0·08% of iron micro-meteorites. It is evident that in meteor physics there are many unknown parameters which make it difficult today to combine different observations and ideas about meteors in one theory. These parameters may be determined by experimental results from artificial satellites.

## RADIO-METEOR PHYSICS

(The following survey is by A. C. B. Lovell: references [90–110] are not indicated individually.)

A review of the current situation in this field has been published by Lovell (1957) under the title *Geophysical Aspects of Meteors.*

*Scattering of radio waves by meteor trails.* The results of the investigation of the polarization effects in the radio echoes from meteor trails have been published by Billam and Browne (1955, 1956). The results are in good agreement with the predictions, namely (i) for short-duration echoes plasma resonance is observed when the electric vector is transverse to the ionized column but not when it is longitudinal; (ii) for long-duration echoes, which occur when the radio wave cannot penetrate the ionized column, the reflexion coefficient is independent of the polarization of the incident wave. Atmospheric turbulence is shown to reduce the duration of these echoes.

The effects of wind-sheer on the scattering of radio waves from an ionized column have been discussed by Kaiser. This effect is of particular practical importance in the determination of trail direction by the three-station orbit apparatus.

*Atmospheric pressures and scale heights.* The work on atmospheric pressure and scale height has been continued (Evans, 1955). The results do not differ significantly from those obtained by the rocket and photographic meteor techniques in New Mexico and geographical variations therefore appear to be small. Seasonal variations in the height of a given pressure level are of the order $\pm 1$ km which is a little greater than the probable error. Possible diurnal variations with an amplitude of about $\pm 1$ km have been found. More detailed investigations of these effects are being made.

*Meteor mass distributions.* A study of the magnitude and mass distributions of the sporadic and certain shower meteors has been made by using three radio-echo methods (Brown, Bullough, Evans and Kaiser, 1956): (i) observations of the total echo-rate of short-duration echoes; (ii) observations of the height-distribution of homogeneous velocity groups; (iii) distribution of long-duration echoes. For sporadic meteors the mass distribution is found to be an inverse square law over the magnitude range 0 to $+10$. The mass distribution of the daytime Arietid shower can be represented by an inverse power law with an exponent greater than 2, indicating that the faint meteors are most plentiful. In the case of the Perseids, Quadrantids and Geminids the exponent is less than 2 for the faint meteors and greater than or equal to 2 for the bright meteors. This result indicates that the main contribution to the meteoric mass in these three showers comes from meteors in the magnitude range $+2$ to $+5$.



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*Meteor ionization.* Preliminary studies of the meteor ionizing and luminous efficiencies have been made by simultaneous visual and radio observations (Evans and Hall, 1955). The ratio of the efficiencies appears to be almost independent of velocity. There is evidence that the ionizing efficiency approaches unity and has only a small velocity-dependence. Work is now in progress on a combined radio-echo and photographic programme using specially constructed Schmidt meteor cameras from which it is hoped to obtain more precise results over a wide range of meteor velocities.

Kaiser (1955*b*) has deduced the meteoric ionization contribution to the ionosphere from the radio-echo measurements of line densities without introducing the somewhat uncertain factor of the ionizing efficiency. He concludes that sporadic meteors should produce $2\cdot3\times10^{-4}$ electrons/c.c./sec independent of height. If the normal E region value for the recombination coefficient of $10^{-8}$ applies, then the equilibrium electron density will be about 150 electrons/c.c. On the other hand the recombination rate in meteor trails is believed to be only $10^{-11}$ or $10^{-12}$ and if this value applies then the equilibrium electron density will be $10^4$ electrons/c.c. The general effect will be to produce a continuum of ionization from about 130 to 115 km, but below this height the individual trails will not join up to form a continuum. If the recombination rate is near the lower value quoted above, then the sporadic meteor ionization may be a significant factor in the maintenance of the nocturnal region. The calculations show that the intense day-time streams will not make a significant contribution to the summer day-time E region ionization. The major night-time showers will make a contribution similar to that of the sporadic meteors, but at a lower height, for example, 100 km for the Perseids and 93 km for the Geminids.

*Diffusion coefficients.* The coefficient of diffusion as a function of height has now been measured by Greenhow and Neufeld (1955*a*). The results apply to the height range of 80–110 km for which $D$ varies from $10^4$ cm$^4$/sec at 80 km to $10^5$ cm$^2$/sec at 100 km. These values are very close to the theoretical calculations using the rocket panel values for the air densities in the height range.

*The variation of ionization along a meteor trail.* In view of the anomalies observed in the light curves of faint photographic meteors, Greenhow and Neufeld (1957) have investigated the ionization curves experimentally. The technique consisted of the observation of the radio echoes from the same trail at two widely spaced stations. The results show that the mean ionization curves for faint meteors in the magnitude range +6 to +8 are much shorter than predicted by theory and that the rise to maximum electron line density is more rapid than expected. Evidence is obtained that individual meteors may depart considerably from this mean curve, for example, in some cases the electron density increases from zero to its maximum value in a trail length of less than 800 m. Evidence for fragmentation and irregular ionization is also obtained and, in general, the anomalous behaviour is similar to that of the light curve.

This work was completed by explorations of D. W. R. McKinley from Canada [114, 115].

## MISCELLANEOUS OBSERVATIONS AND DISCUSSIONS

*Meteor spectra.* The number of spectra is increased by results from Canada, Czechoslovakia and U.S.S.R. [142]; the total number of spectra is 200–250. A very complete record has been obtained by P. M. Millman [116] of a Perseid in 1952 using a camera *f* 2, f.l. = 20 cm with a replica grating (200 lines per mm), emulsion Eastman Super XX. 100 lines are present in this spectrum: sixty-six multiplets of nine neutral elements and of four ionized elements have been identified.

*Trains.* C. P. Olivier has published [117] the third catalogue on enduring meteor trains (575) by which his catalogue now contains 2073 objects. The orbital elements of the bolides, from which the train arose, are also given. V. V. Fedynsky [118] has studied the drift of meteor trains obtained by visual and by radio methods; good agreement was obtained. Ch. D. Gulmedov [119] has published the results of Ashkhabad observations in 1955–6. This method is in use during the I.G.Y. at observatories Ashkhabad, Kiev, Stalinabad for all meteors, the orbits of which are photographed.

The method of reflection of electromagnetic waves from the ionized meteor trails is used at Jodrell Bank. A combination of pulse and a continuous wave method has been used from the year 1954 for these observations [111]. The prevailing component of the wind is towards the north in winter and towards the south in summer. The prevailing east-west components are stronger and are towards the east in winter and summer and towards the west in spring and autumn (mean height 90–95 kW). Recently the height variation of these winds has been studied [113]. It is shown that the observed variations in amplitude and phase are compatible with the theory that these winds are the result of thermal and tidal effects of the Sun increased by resonance at the height under discussion.

G. S. Hawkins and later W. E. Howard and A. F. Cook [120] pointed out the inadequacy of recombination as the source of light from enduring meteor trains, for the theoretical brightness is 200 times less than the observed one.

*Fireballs.* C. P. Olivier has published a series of bolide orbits in Leonard's *Meteoritics* [121]. The list of 125 bolides is included together with orbits in his third catalogue. J. S. Astapovič has published a catalogue of fifty-five bolide-orbits [122]. The following are specially mentioned: 1948 September 28, mass 250 kg; 1952 July 13, the great exploding bolide with height of 16 km [124]; Canadian bolide [125]; Czechoslovak bolide 1957 January 9 [126]; 1955 May 8 [127]; 1956 February 1 [128]; 1956 February 12 [129]. The well-known 'Canadian Procession of 1913 February 9' was studied [130, 131]. The University Observatory of Vienna undertook the organization of information about bolides. Prof. Thomas is preparing a book on methods of calculation of bolide orbits according to V. Niesl. J. A. Russel [132] has discussed the calculation of the bolide end-point, using least-squares.

*Telescopic meteors.* Observations of telescopic meteors were made in U.S.A., by I. S. Astapovič [133], A. M. Bacharev [134], A. K. Terentevoj [135] and V. E. Stepan [136]. Telescopic observations were analysed by I. S. Astapovič [137] on the basis of many experiments. M. Kresáková [138] has reduced the material of the telescopic Perseids with the results that no differences between visual and telescopic Perseid are present in the time of maximum and the position of the radiant. Z. Kvíz [139] has reduced statistical observation of telescopic Orionids and Leonids of 1955 in Brno and has deduced a new telescopic radiant. L. Kohoutek and J. Grygar [140] have studied the influence of an extended field of view on the estimated magnitude of telescopic meteors and have deduced corresponding correction factors.

It seems that if the increase of the number of very weak meteors is to be proved to be real, it would be desirable to find the connexions and relations between different magnitude groups of meteors.

*Meetings.* Meetings of the Commission for Comets and Meteors of the Soviet Academy of Sciences were held in Odessa in November 1955, and May 1957, and in Moscow in November 1956, and June 1958. The first international symposium on interplanetary matter was held in Jena in October 1957. The meetings of amateur meteor astronomers were in Brno in 1956 and 1957. Three expeditions to make visual and telescopic meteor observations were organized for the summers of 1956, 1957 and 1958 in Czechoslovakia.

## RECOMMENDATIONS

(1) More work on theoretical investigations of meteor spectra; mechanism of production and on evaluation of the relevant cross-sections; problem of air density dependence on the excitation process (R. N. Thomas).

(2) Standardization of notations in meteoric physics (J. Hoppe).

(3) Commission 22 is asked to use its influence with all proper organizations and individuals to see that the journal *Meteoritics* continues in publication (C. P. Olivier).

(4) To urge upon all persons interested in astronomy that they report fireball observations promptly to the nearest centre for such work (C. P. Olivier).

(5) To urge upon active observers, particularly those working on variable stars and using medium-size telescopes with large fields, to keep records of all telescopic meteors seen—

including at least time, magnitude and the field in which they appear—and report them annually to the nearest centre desiring such data (C. P. Olivier).

(6) For telescopic meteor observations a net for satellite observations to be used (V. Guth).

(7) In view of the great increase in radar and photographic data, proper steps should be taken to insure that amateurs do not become discouraged or indifferent to the phases of visual work on meteors which remain important (C. P. Olivier).

(8) To make use of panchromatic material with Super-Schmidt cameras to gain telescopic meteors (Z. Ceplecha).

V. GUTH

*President of the Commission*

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## 22*a*. SUB-COMMISSION ON METEORITES

J. D. Buddhue has published an important book, *The Oxidation and Weathering of Meteorites* [7]. The collected works of Academician A. N. Zavaritsky, *Work in Meteoritics*, was published by the U.S.S.R. Academy of Sciences [101]. The Committee on Meteorites of the U.S.S.R. Academy of Sciences regularly published two bibliographies on meteoritics [56], and K. Tuchek published a catalogue of meteorites at the Prague National Museum [85].

A valuable record of new meteorite finds and falls is the *Meteoritical Bulletin*, edited by E. L. Krinov, and published by the Permanent Commission on Meteorites of the International Geological Congress, in Moscow. This bulletin describes all currently published finds and falls. Investigations on meteorites in the eastern hemisphere are included also in *Meteoritika* published by the Soviet Academy of Sciences. Data on meteorites in the western hemisphere appear in *Meteoritics*, published by the Meteoritical Society and the Institute of Meteoritics of the University of New Mexico, and in Canada in the *Journal of the Royal Astronomical Society of Canada*. The journal *Meteoritics* has unfortunately been discontinued and the loss is evident.

We may mention some of the many interesting papers. Studies of the orbits, structure and morphology of the great Sikhote-Alin fall have appeared in *Meteoritika*, by V. G. Fesenkov, A. A. Javielja, E. L. Krinov and S. S. Fonton. Krinov [43] has summarized the results. The uncertainty of the trajectory of the great Tungusska meteorite has been studied by N. N. Sytinskaya [84], and the place of its fall was described by K. P. Florensky [30]. K. P. Staniukovich [80] has studied the origin of the ballistic wave that occurs when a meteor body penetrates the atmosphere. The morphology of meteorites has been studied by E. L. Krinov in the monograph *Osnovi Meteoritiki* [42]; he reaches the following conclusions: (1) meteorites do not lose as much matter as would be expected from the physical theory of meteors; (2) the fragments of a meteorite are very similar in shape to its original shape; (3) the original shape of meteorites is polyhedral. F. C. Leonard [49] and F. C. Leonard and R. G. Rowland [50, 51] have dealt with the classification of meteor falls and their distribution on the Earth's surface [52]. F. C. Leonard is also preparing a geographical catalogue of the meteoritic falls of the world, and a study of their *f*, *n*, *m*, and *t* ratios.

E. W. Salpeter has published a catalogue of the Vatican collections of meteorites [78].

From the chemical composition and structure of meteorites, A. A. Yavnel has evolved a new classification which divides meteorites into six sub-classes with five families in each [96]. A few falls of meteorites are also described in *Meteoritics* [48, 37]. H. C. Urey [86] W. A. Cassidy [11] and R. Šimon [79] have studied the origin of tektites.

Papers by C. S. Beals, G. M. Ferguson and A. Landau [3] and by M. J. Innes [39] contain studies of unusual interest on the identification of 'fossil' meteorite craters of great dimensions in Canada. P. M. Millman [58] has published a detailed study on the profile of the New Quebec Crater.

Papers by V. G. Fesenkov [21], E. J. Öpik [62] and H. C. Urey [87] have dealt with meteorites as they relate to the origin of the solar system. The age of meteorites, as derived from isotopes of P-6, U, He and other inert gases, was the subject of a study of R. D. Russell [77], G. W. Reed and A. Turkevich [67], G. Bost [4], and F. K. Gerling and L. K. Levski [33].

E. J. Öpik [63] points out that the theory of a cosmic origin for the meteor dust on the bottom of the sea must be regarded with caution. F. Link [55] in a paper discussing the dimensions of dust particles refutes the criticisms of Z. Švestka [82]. I. Zacharov [99] deals with the influence of dust particles on twilight measurements during Perseid activity.

The relation between meteors and rainfall has been studied by E. G. Bowen [5, 6], who finds a greater amount of rainfall 30 days after the maximum of great showers. A. A. Dimitriev reaches a similar conclusion. This relation has been criticized by F. L. Whipple and G. S. Hawkins [91].

The launching of artificial satellites by the U.S.S.R. and by the U.S.A. makes possible the direct obtaining of micrometeorites from above the Earth's atmosphere.

An Aerobee rocket of the Air Force Cambridge Research Center, on 1957 October 16, released artificial meteors (brightness −2 magnitude) in the form of aluminium pellets at an altitude of 87 km over New Mexico. Observations of artificial meteors are likely to be useful for determining the density of the Earth's atmosphere at great heights [61], but more important for determining luminous efficiencies and masses of meteoroids.

The Smithsonian Astrophysical Observatory has established a long-range research program in meteoritics, which will attempt to integrate various aspects of the science, and includes problems of ablation and ultra-velocity ballistics, the distribution of meteoritic dust from crater formation and from atmospheric sampling at high altitudes. E. L. Fireman is studying cosmic-ray spallation products in meteorites. F. B. Riggs, Jr. is designing and constructing an electron fluorescent X-ray micro-analyser to study iron meteoritic dust on a micron scale.

The ablation and flow of meteorites as they enter the Earth's atmosphere have been studied by J. S. Rinehart, D. B. Williams, and E. P. Henderson [94], from the flow markings in a number of iron meteorites. Some of the characteristics of high velocity meteoritic ablation have been simulated under experimental conditions. Similar effects were obtained in projectiles by H. O. Morrison and W. A. Allen [60].

The morphological properties were studied of a number of meteorites, primarily from the multitude of samples of the Sikhote-Alin iron meteorite shower, to discover the mechanism of the destruction of meteoric bodies moving in the Earth's atmosphere at cosmic speed. Four forms of extra-terrestrial dust were observed and suggestions made for their classification. The classification of the surface structure of fusion crusts was elaborated. An experiment was made to determine the original form of meteoric bodies at the moment of entrance into the atmosphere [43, 45].

In 1956 J. S. Rinehart [76] led an expedition to the Arizona meteorite crater, and determined the nature and distribution of small bits of meteoritic debris in the soil around the crater. The results suggest strongly that the meteorite approached the crater from a direction slightly to the south or west, and that its mass could not have been less than 10,000 tons.

A. A. Yavnel [95] discovered meteoric and meteoritic dust in the soil samples brought in 1929 to 1930 by Kulik from the region where the Tungusska meteorite fell. The Committee on Meteorites of the U.S.S.R. Academy of Sciences sponsored an expedition to the region of the fall of the Tungusska meteorite [30], to investigate the nature, extent, and limits of the felling of trees, and collected soil samples to study the presence of dispersed meteorite matter.

Astapovich [1], Zotkin and Krinov [102], Fedynsky [19], and Fesenkov [20, 22] made a systematic study of the atmospheric trajectories and orbits of a number of meteorites that fell recently. The circumstances of the fall of the Sikhote-Alin meteorite were studied by Divari [14], Krinov [45], and Fesenkov [20].

Mean velocities of fireballs and meteorites were derived by Whipple and Hughes [92] on the basis of H. A. Newton's method involving the elongation of radiants.

A complete study of the composition, structure, and physical properties of the Sikhote-Alin meteorite was made by Dyakonova [16], Kvasha [46], Kharitonova, Yavnel and Fonton [97]. A number of other meteorites that fell recently were studied by Dyakonava [15], Kvasha [47], Kharitonova and Yudin [98]. The average chemical composition of meteorites was determined by Dyakonova and Yavnel [17], Kozlovskaya and Levin [41], and Levin, Kozlovskaya and Starkova [54]. The metamorphism and breccia structure of meteorites was studied by Kvasha [47].

Harrison Brown, C. R. McKinney and Carleton Moore have applied X-ray fluorescence to a study of the distribution of Cr, Mn, Fe, Co and Ni in a large number of stony meteorites, primarily chondrites. They have found that the Cr/Mn ratio is nearly constant in all 'ordinary' chondrites, but varies widely in the carbonaceous chondrites and the achondrites. Their work indicates the existence of specific families of chondrites which differ from each other in iron, cobalt and nickel contents. Precise average values have been obtained for the ratios Cr/Mn and Ni/Co in ordinary chondrites. In addition, the Ti/Mn ratios have been determined for these same meteorites.

In recent years the chemical analyses of meteorites for rare elements have been greatly improved so that it is possible to have confidence in the abundances of the elements. Such analyses have recently been made for He, Ag, Se, Te, In, Co, Pb, Bi, Tl, U, Th. It is interesting that the lead, bismuth and thallium abundances are very low. The indium abundance in the meteorites is very low also and does not agree with the Suess-Urey abundance curves. Urey [87] has observed that the metal particles of the chondrite meteorites consist of both kamacite and taenite and that these must have been produced elsewhere than in the chondrites. He has drawn conclusions in regard to the origin of meteorites from these facts.

A. A. Vinogradov, I. K. Zadorozhnyi and K. P. Florensky [89] investigated the influence of cosmic irradiation on the formation of helium isotopes in the Sikhote-Alin meteorite.

The argon and helium age of meteorites was systematically measured by Burkser [10], Gerling and Rik [34], Starik and Shats [81].

E. L. Fireman has set up a laboratory to measure radioactive isotopes in meteorites by low-level counting techniques, and stable isotopes by neutron activation techniques. He measured for the first time the tritium $H^3$ and $A^{39}$ in recently fallen iron meteorites, and obtained a measure of the intensity of the cosmic ray influx on the meteorites, and of the time of exposure [23, 24]. This flux is greater than that striking the polar regions of the Earth. The $H^3$–$He^3$ exposure times range from $0{\cdot}5 \times 10^9$ years and upward for iron meteorites, and have smaller values for stone meteorites. The argon exposure age is $0{\cdot}5 \times 10^9$ years for two iron meteorites. Measurements of $He^3$ and $Li^6$ in several iron and stone meteorites show lack of proportionality between these isotopes and indicate that slow neutrons in space did not contribute significantly to the high helium-3 content [27]. $He^3$ content measured in iron meteorites varied by more than a factor of $10^4$. The $A^{39}$ and $A^{38}$ combine to give a value of $5 \times 10^8$ years for the time the Sikhote-Alin meteorite was exposed to cosmic rays and an equal value for the Pitts meteorite, which fell on 1921 April 20. Fireman finds that the argon exposure age is subject to fewer uncertainties than the tritium-helium-3 exposure age, and that the hydrogen content of some iron meteorites is extremely large and of terrestrial origin. The terrestrial hydrogen in the form of water apparently exchanges with the cosmic hydrogen in the iron meteorite, and diffuses through the nickel iron structure. In stony meteorites the loss of tritium which is in the combined state is much smaller but the diffusion loss of helium-3 is large. Apparently, therefore, the tritium-helium-3 ages of iron meteorites are too great and those of the stone meteorites are too low.

Targets designed to simulate meteorites were exposed to high energy protons and the tritium and $A^{37}$ and their depth variation were measured [29]. Fireman [25] measured the contours of the constant helium-3 in slices of the Carbo and Grant Meteorites and concluded that Carbo had a non-spherical shape in space and had lost a significant amount of material by ablation or fragmentation in its passage through the atmosphere.

The Grant Meteorite was sectioned, through the courtesy of the Battelle Foundation, through the assistance of E. P. Henderson; E. L. Fireman [26] measured the distribution of helium-3. The contours of variations with depth indicate that the average energy of the cosmic radiation was close to 6 Bev. These measurements suggest that the Grant Meteorite, before it struck the Earth's atmosphere, was a pear-shaped object, with a mass of approximately 880 kg, which lost 400 kg by ablation, in its plunge through the atmosphere.

Experimenters are beginning to use the potassium-argon method to measure solidification ages. Ages of $1{\cdot}0 \times 10^9$ years for an achondrite, of $4{\cdot}5 \times 10^9$ years for several chondrites [32] and of $10^{10}$ years for several iron meteorites [100] have been obtained by this method. The lead-lead and the uranium-lead methods have given ages in the neighbourhood of $4{\cdot}5 \times 10^9$ years for several stony meteorites. For only one meteorite, however, Nuevo Laredo, is the lead-lead measurement consistent with the uranium content. Recently Reed and Turkevich [67] have been applying activation methods to determine the lead isotopes in iron meteorites; they find extremely great ages of about $10^{10}$ years, in agreement with the Zähringer and Stoenner measurement of potassium-40-argon-40. If the extremely high solidification age for iron meteorites receives further confirmation, our ideas on the origin and evolution of the universe will have to be revised.

H. Pettersson [66] has collected airborne meteoritic dust in Hawai and the Pacific Islands and, on the assumption of 2·5 % nickel in the cosmic source, obtains a total dust concentration of 572 $\mu$g per 1000 cubic meters of air. The total for the Earth, to the height of 100 km, is then $28{\cdot}6 \times 10^6$ tons. If the time of fall is taken as two years, the yearly rate is $14{\cdot}3 \times 10^6$ tons; or, for the entire year, some 40,000 tons per day. This value is somewhat higher than the estimates of Öpik [64] and F. L. Whipple [90], which run close to 2000 tons per day for the entire Earth.

P. Hodge [38] at the Smithsonian Astrophysical Observatory has developed equipment that will allow aircraft to collect meteoritic dust at high altitudes. Preliminary results indicate probable particle densities of the order of ten particles larger than 3 $\mu$ in diameter per cubic meter, above an altitude of 15,000 m. Preliminary studies by C. Hemenway and E. F. Fullam [36] with an electron microscope suggest that some of the large particles (10 $\mu$) may be porous in structure, as indicated by the Harvard meteoritic studies and the icy conglomerate models for comets. There is tentative evidence, however, for a concentration of high-density magnetic particles with a frequency distribution mode of about 0·3 $\mu$.

W. D. Crozier [12] has collected meteoritic dust from cores in dry lake deposits and from mountain tops, in the south-west U.S.A.

Important contributions to the problems of the zodiacal cloud have been made by H. Elsasser and H. Siedentopf [18]. In the theoretical relationships between cometary meteors and the zodiacal cloud, U. Haug [35] has carried out calculations on the distribution of orbital elements for the small particles of the zodiacal cloud.

*Tektites.* A conference of tektites was held under the auspices of the U.S. National Academy of Sciences, and reported by I. Friedman, T. R. Kohman and W. A. Cassidy [31]. H. C. Urey [88] contributed to the discussion, although he could not be present at the conference. The question of the terrestrial or non-terrestrial origin of tektites has not yet been answered.

In this symposium [83] new and significant data were contributed by J. A. S. Adams, W. H. Pinson, I. Friedman, H. E. Suess, V. E. Barnes, J. S. Rinehart, W. A. Cassidy, W. D. Ehmann, T. P. Kohman and C. M. Varsavsky. F. G. Houtermans took part in the discussion, and E. L. Krinov and H. O. Beyer could not be present but sent papers. The extremely low water- and gas-content of tektites, as measured by Friedman, was of particular interest. A limitation in age since solidification was calculated by the potassium argon method, by Suess. Ages by the rubidium-strontium method were computed by Pinson and Herzog (M.I.T.); these were not upper limits but actual ages. Continuing studies on tektites may be expected to clarify the nature and source of their origin.

F. L. WHIPPLE
*President of the Sub-Commission*

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## 22*b*. REPORT ON MAPS FOR METEOR PLOTTING AND REDUCTION

Because of the variety of the meteor programmes being carried out in different countries, it has been found difficult to decide upon one or two series of meteor maps which will satisfy all users. Prentice has called attention to the necessity for distinguishing between maps for meteor plotting and maps for meteor reduction.

The uses of meteor plotting maps may be summarized under two chief headings:

(*a*) the plotting of meteor paths to an accuracy better than one degree and the graphical determination of radiants and heights by visual methods alone;

(*b*) the less accurate plotting of meteor paths for the purpose of determining the general position of the meteor trail when visual work is carried out in co-operation with photographic and radio programmes.



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The projections used in meteor maps, almost universally, have been either the gnomonic or the stereographic. With the former, meteor paths (i.e. great circles) are straight lines, and radiants can easily be determined, but the distortion of star groups is serious and the change of scale is large. The hemisphere cannot be represented on one map on the gnomonic projection. The stereographic projection, on the other hand, has no distortion and a much smaller variation in scale, but great circles project as arcs of circles and radiant determination is not so simple as with the gnomonic. With the stereographic there is no difficulty in representing the hemisphere on one map sheet. The gnomonic has been applied more generally to use (*a*), the stereographic to use (*b*).

The details of various series of meteor maps, used in the past, have been listed in the following Table.

Notes on preferences regarding meteor maps have been received from J. P. M. Prentice, England; C. P. Olivier, United States; and C. de Jager, Netherlands. There is unanimous agreement on reproducing all stars as filled-in black circular dots of graded sizes, and on omitting the constellation and Milky Way boundaries from plotting maps. The majority favours no co-ordinate lines on the plotting maps themselves but merely co-ordinate marks around the borders of all maps, and the production of transparent grids for reading off co-ordinates of meteor plots. Opinion is about equally divided on the subject of including the Greek letter designations of bright stars. The Japanese maps have these in red so that they are invisible under red illumination.

## SERIES OF METEOR MAPS

### (*a*) *Descriptions*

1. 'A Meteor Star Atlas', by R. K. Young, *Publ. Dom. Obs. Ottawa*, vol. II, no. 7, 1915.
2. 'Gnomonic Star Maps for Visual Meteor Observers', by M. Huruhata. Published by the Japanese Astronomical Society, Tokyo, 1950.
3. Produced by the Meteor Section of the Netherlands Astronomical and Meteorological Society.
4. Photographic reproductions, of charts by T. W. Backhouse, prepared by J. P. M. Prentice for the British Astronomical Association. Very few copies printed.
5. 'Gnomonický Atlas Hvězdné Oblohy', by R. V. Guth, Vydala Česká Astronomická Společnost, V. Praze, 1940.
6. Produced by P. M. Millman of the Stellar Physics Division of the Dominion Observatory, Ottawa; stereographic projection.
7. Used by V.A.G.O. and produced by E. M. Proskurina, Moscow, 1951, edited by I. S. Astapovich.

(Nos. 1, 2, 3, 4, 5 and 7 are all based on a gnomonic projection.)

### (*b*) *Details*

| No. | No. of maps in series | Approx. size (cm) | Approx. scale 10° at centre (mm) | Total coverage in Dec. | Limiting star mag. | Co-ordinate lines $\alpha$ | Co-ordinate lines $\delta$ | Star designations | Lines joining stars |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 18×23 | 24 | +90° to −90° | 5·0 | 15° | 10° | Numerous | None |
| 2 | 12 | 20×24 | 17 | +90° to −40° | 5·0 | 10° | 10° | Numerous (in red) | None |
| 3 | 6 | 18×26 | 17 | +90° to −30° | 5 | None | | None | Numerous |
| 4 | 14 | 75×75 | 52 | +90° to −90° | 6·4 | 5° | 5° | Numerous | — |
| 5 | 14 | 50×50 | 35 | +90° to −90° | 6·5 | Two on each map | | None | None |
| 6 | 4 | 30×30 | 13 | +90° to −40° | 4 or 5 | None | | None | A few |
| 7 | 4 | 70×90 | 30 | +90° to −27° | 4 – 5 | Every degree | | Yes | A few |

Most users favour a plotting map size with dimensions between 20 and 30 cm and stars included down to about magnitude 5. The scale should be small enough to make it possible to plot at least 80 or 90 degrees of sky across the map. Using faint lines to connect up stars forming important configurations in the constellations is considered to be a help by most observers. The English group uses no maps at all in plotting (see B.A.A. *Handbook*, 1954, p. 36) but large-scale gnomonic maps for the reduction of observations.

It would appear from the above that at least four series of meteor maps are required to satisfy all users:

1. Gnomonic maps, small scale, for plotting.
2. Gnomonic maps, large scale, for reduction.
3. Stereographic maps, small scale, for plotting.
4. Stereographic maps, large scale, for reduction.

In recent years, increased quantities of instrumental meteor data have become available. For example, large numbers of Super-Schmidt meteor photographs have been secured in the U.S.A. and Canada, and radar meteor echoes are being recorded at a number of stations in various parts of the world.

As a result of these new trends, the accurate reduction of visual meteor plots and the determination of meteor radiants from visual observations are of less importance than they were some years ago. The need for maps covering this phase of the work is not as great as before.

On the other hand, there will be a continuing demand for maps designed for plotting the approximate positions of meteors and for the study of bright fireballs. In the Canadian programmes of combined radio, photographic and visual meteor observation, the stereographic projection has been used almost exclusively for both plotting and reduction.

PETER M. MILLMAN
*President of the Sub-Commission*

### *Report of Meeting of Sub-Commission 22a.* 18 August 1958

PRESIDENT: F. L. Whipple.

SECRETARY: L. G. Jacchia.

The President presented a report on meteorite research in the U.S.A. since the time of the last I.A.U. meeting and Krinov presented the U.S.S.R. report. As some members had not sent reports, the President asked all members to send in any additional information which may be deemed useful.

Millman asked whether work on meteor craters should be reported to Sub-Commission *22a*; the opinion was that it should.

Leonard submitted a proposal for a new standard nomenclature in meteoritic research. The President thought that the proposal should be referred to the suggested new Sub-Commission *22b* (Notations).

Leonard also called the attention of the members of the Commission to the international character of the Meteoritic Society.

Before asking Harrison Brown to submit his proposed resolution the President pointed out that, with the limited meteorite material available all over the world, we are the custodians of precious information from outer space. The problem is to make the best possible scientific use of this material for the benefit of the human race. The question of the chemical composition of meteorites is of paramount importance, and we should try to see how all analyses could be made on a uniform basis, to utilize the material in the most economical way.

Harrison Brown presented his report, which contained specific recommendations concerning the question raised by the President. Krinov said that the problem of standardizing chemical analyses of meteorites was raised once before, in 1948, when the Permanent Commission on Meteorites was set up in the International Geological Union; a similar resolution was passed but was never implemented. Krinov thought that such a resolution is vital and that it should be adopted in a form to be binding. The President questioned whether it was appropriate for the I.A.U. or the I.G.U. to pass such a resolution. Krinov surmised that perhaps it would be better to have the resolution presented at the 1960 meeting of the Geological Union in Copenhagen, since the samples affected are preserved in geological museums. Levin, on the other hand, thought that, since the geologists had failed to take any action once before, and since astronomers have more international contacts, the resolution should be approved in the I.A.U. Krinov suggested that a firm recommendation should be considered. Several representatives (Levin, Millman, Plavic, Davies, Whipple, Hoppe and Guigay) spoke briefly about conditions in their respective countries concerning meteorites and co-operation with geologists. The Commission then voted to establish a working group for the study and revision of the Brown resolution and for drafting recommendations to be formally presented to the I.A.U. for Sub-Commission 22*a*. The working group consisted of Brown, Krinov, and—for the duration of the meeting only—Davies and Millman.

## RESOLUTIONS

(*a*) To establish under the control of Sub-Commission 22*a* a program of international collaboration for the chemical analysis of meteorites. The objective of this program will be to obtain an exact chemical analysis of the abundance of elements in meteorites, for which the need is urgent.

(*b*) It is urgently requested, as an essential part of this program, that geological and mineralogical museums or other museums or institutions which possess collections of meteorites collaborate in furnishing specimens of meteorites for analysis when they are so requested by the President of Sub-Commission 22*a*.

(*c*) As a second essential part of this program, it is urgently requested that laboratories which are competent in carrying out precision analyses of meteorites and which possess the necessary means to do so collaborate in furnishing these analyses when the President of Sub-Commission 22*a* so requests.

(*d*) We respectfully request the International Congress of Geology to collaborate with the International Astronomical Union in carrying out this essential program.

The President raised the question whether tektites should be considered as within the scope of the Commission. Krinov thought that since, according to some theories, tektites might have originated from the impact of gigantic meteorites, which caused the remelting of quartz rocks, there might be a relation between tektites and meteorites. Dubin (not a member of the Commission) said that, on the basis of isotope tests, Paneth has proved that tektites are of terrestrial origin. Kuiper (not a member of the Commission) thought that, as long as the origin of tektites is not definitely known, they should come within the scope of the Commission. The President agreed and proposed that tektites continue as a proper subject for the Commission without the drafting of any resolution on the subject.

The President sounded out the Commission, with an eye to a possible resolution, on the subject of meteoritic dust, about which international co-operation is obviously important. Krinov agreed on the problem and expressed the opinion that in connexion with the subject the morphological study of meteorites should be encouraged; he did not see, however, any necessity for a resolution. The President agreed, pointing out that international co-operation on meteoritic dust already exists.

In regard to the morphological study of meteorites, the President informed the Commission about the slicing of the Carbo and Grant meteorites and their analysis by Fireman at the Smithsonian Astrophysical Observatory.

A few reports on meteoritical subjects were presented briefly and the meeting adjourned.

### *Report of Meeting of Sub-Commission 22b.* 15 August 1958

At this meeting the Report of the Sub-Commission was approved after some minor amendments. A recommendation that the Sub-Commission be dissolved was approved for passing on to Commission 22; it was felt that the duties assigned to the Sub-Commission no longer warranted its continued existence.



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