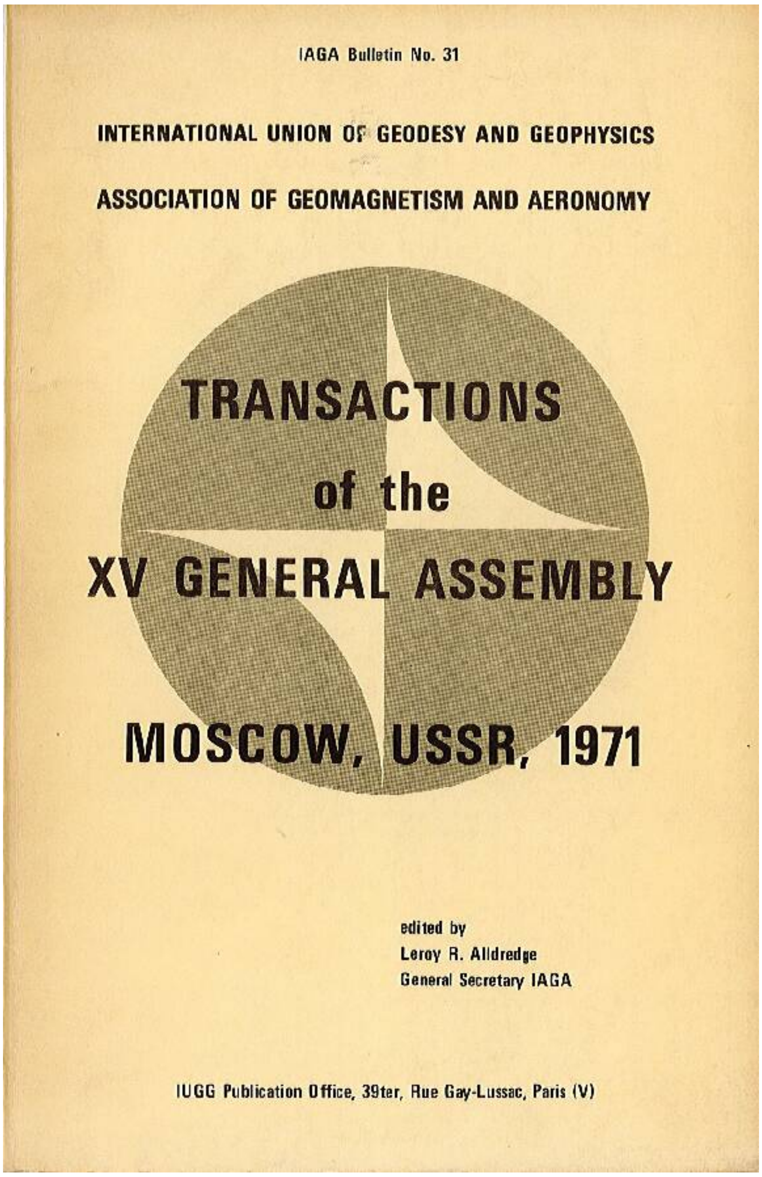


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IAGA Bulletin No. 31

INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS

ASSOCIATION OF GEOMAGNETISM AND AERONOMY

# TRANSACTIONS of the XV GENERAL ASSEMBLY

# MOSCOW, USSR, 1971

edited by
Leroy R. Alldredge
General Secretary IAGA

IUGG Publication Office, 39ter, Rue Gay-Lussac, Paris (V)

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# INTRODUCTION

The XV General Assembly of IUGG was held at the Moscow State University, Moscow, USSR, from 2 August to 14 August 1971. IAGA was provided with excellent quarters and facilities for lecture halls and for the President and Secretariat. The local committee did an excellent job in reproducing a 506 page program and abstract booklet containing the complete IAGA program for the Assembly.

Appreciation is extended to the Local Organizing Committee for their work. Special thanks is given to Dr. B.S. Volvovsky, general secretary of the Geophysical Committees; Dr. K. Yu. Zybin, who was specifically responsible for the Geomagnetism and Aeronomy arrangements and to Mrs. N. A. Beloussova who was in charge of the ladies program.

Two hundred and eighty scientists registered for the meetings from outside the USSR and approximately 200 Soviet scientists attended the meetings.

Full scientific sessions and business meetings were held by each IAGA Commission and by the two joint IAGA/IAMAP Committees. The program and abstracts for most of these sessions were published and distributed at the assembly. All of the available copies of this publication were distributed at the assembly. It is still hoped that additional copies of this publication can be made available at a later date as an IAGA Bulletin.

IAGA News No. 10, which included the new organization, new officers, resolutions, and minutes of the Executive Committee meeting, was published immediately following the Assembly. This publication gives a more complete account of the XV Assembly.

# FIRST IAGA PLENARY SESSION
# MOSCOW ASSEMBLY

The first IAGA Plenary Session was called to order at 4:00 p.m. on Monday 2 August, in the Central Auditorium of the Physical Faculty Building, by President T. Nagata.

## WELCOME BY SOVIET OFFICIAL, DR. V. A. TROITSKAYA

Mr. President, Ladies, Gentlemen, dear Colleagues:

Allow me to welcome the delegates and the guests of the IAGA on behalf of the Soviet Organizing Committee of the XV Assembly of the IUGG.

The Organizing Committee has no doubt but that the numerous symposia of the Association as well as the scientific session of its working groups will be successful and fruitful. The work of those present will be devoted to the most important problems of the physics of the magnetosphere, of the Sun-Earth interrelation, of aeronomy, of the main geomagnetic field, and of paleomagnetism. We shall also discuss important problems dealing with the development of automatic methods of retrieval and processing geomagnetic data and many other problems.

It is for the first time that IAGA meeting is convened in our country, and it is for the first time that such a great number of Soviet scientists can take an active part in the scientific, methodological and organizational work of the Association.

According to the preliminary figures scholars of 40 countries will participate in the Assembly activities.

The Organizing Committee sincerely hopes that an exchange of scientific information, personal contacts and discussions at this representative gathering of specialists will form a good basis for a successful solution of many difficult scientific problems which have not yet been solved, for preparation and carrying out international scientific projects which require concerted efforts of scientists of many countries. Our meetings are certain to help us in establishing friendly contacts and mutual understanding which are of paramount importance for carrying out any work.

We also hope that in spite of the brevity of your stay here and of the very busy scientific program you will be able to find time for excursions, visiting museums, theaters, for getting acquainted with Moscow. We sincerely hope that you will like it.

The Organizing Committee and I personally note with pleasure that among the delegates and guests there are many ladies who will be able to take part in various activities planned by the Ladies' Committee. It will give them a chance to get a better picture of different aspects of life in our country than that which the gentlemen who will take part in the official business meetings will be able to get.

We hope that on returning to your respective countries you will share your experiences with other people.

The Organizing Committee wishes all of you success in your further work and a pleasant stay in Moscow.

## INTRODUCTORY STATEMENT BY PRESIDENT T. NAGATA

Ladies and Gentlemen:

On behalf of the International Association of Geomagnetism and Aeronomy, I would like to express our sincerest thanks for the warm welcoming words which were just given by Madame Troitskaya.

It is indeed our great pleasure to have our XVth General Assembly here in Moscow, in USSR, where, for example, the world's well known journal, specifically named "Geomagnetism and Aeronomy", is regularly published. As typically symbolized by this journal, USSR is one of the most important centers for research in geomagnetism and aeronomy in the world at present.

I would like to remind you further that, in 1931, the first meeting to prepare for the Second International Polar Year, 1932-33, was organized in Leningrad in the Soviet Union. As you know very well, the Second International Polar Year was indeed the dawn of the international cooperation for coordinated observations and research of geomagnetism and aeronomy. I believe that the global research of the geomagnetic variations and the ionospheric phenomena were substantially initiated by this Second Polar Year program.

Since that time, we have had the International Geophysical Year for 1957-58, in which the Soviet Union took one of the major parts of the program, particularly by setting up the World Data Center B.

In 1958, we had here, in this building of the University of Moscow, a great scientific symposium on the IGY results, and we decided here to continue such fruitful international cooperation in geophysics one more year, under the name of the International Geophysical Cooperation 1959.

Since then, we had IQSY for the quiet sun period, and IASY for the active sun year. Thus, not only the ionospheric regions, but the earth's magnetosphere also have become our territory for our extensive research. People now say, "we are in the space age".

As for the physics of the earth's interior, the *Upper Mantle Program,* which was initiated by Prof. Beloussov, has opened a new world for us in understanding physics of the earth's crust and mantle. I do not need to emphasize how much geomagnetism has contributed to establishing the new concepts such as the *ocean floor spreading* or the plate tectonics.

American Apollo Missions and Soviet Lunar Spacecraft have now placed in our hands the genuine lunar materials. We are studying every detail of these materials. Thus, the interior of the Moon also is going to be physically understood.

Ladies and Gentlemen, I am convinced that this Assembly Meeting, here in Moscow, USSR, will be fully successful and fruitful; because of the memorable contributions of this country and of this city in the history of development of our Geomagnetism and Aeronomy program.

## BUSINESS ITEMS

Professor T. Nagata announced the appointment of Ad Hoc Committees for this Assembly as follows:

| | |
|---|---|
| Resolutions Committee: | A. J. Dessler, chairman<br>R. Schlich<br>Y. D. Kalinin<br>J. O. Cardus |
| Nominating Committee: | T. Nagata, chairman<br>A. J. Zmuda<br>J. O. Cardus<br>N. P. Benkova<br>A. P. DeVuyst |
| Finance Committee: | O. Schneider, chairman<br>R. B. Leaton<br>M. Fukushima |

A proposal from the United Kingdom to abolish National Reports in favor of one prepared by IAGA each four years was referred to the Executive Committee for consideration.

A proposal from Canada regarding cooperation in making magnetic surveys in the Arctic was referred to Commission II for action.

A proposal from the United States to require screening of papers by National Committees prior to submission for an Assembly program and the use of a standard format for abstracts was referred to the Executive Committee for consideration.

President Nagata encouraged each Commission Chairman to review needed organizational changes in their business meetings and to be prepared to make recommendations on this subject later during the Assembly to the Executive Committee.

President Nagata indicated that the Japanese National Committee for Geodesy and Geomagnetism has asked their Government through the Science Academy for official approval to invite IAGA to hold its Second Scientific Assembly in Kyoto from 10 September to 21 September 1973. He indicated that adequate facilities had already been reserved in Kyoto.

## REPORT OF THE GENERAL SECRETARY

The Secretary reported that for this Assembly Dr. F. J. Lowes was acting as Chairman of Commission III for T. Rikitake who could not attend.

A. J. Zmuda was acting as Chairman of Commission IV for J. A. Jacobs who could not attend.

A. Egeland was acting as Chairman of Commission VI for A. Omholt who could not attend.

The Secretary very briefly gave his report which is reproduced in complete form below. It covers the period between the XIV General Assembly and the XV General Assembly.

During the above four year period the secretariat published *IAGA News* Nos. 6 through 9 as follows: No. 6, October 1967; No. 7, July 1968; No. 8, September 1969; No. 9, November 1970.

Since these publications include most of the activities of IAGA during this period they can be considered as part of the General Secretary's report, permitting this report to be very short. Only the highlights will be reiterated here. Material for each *IAGA News* was solicited from all IAGA officials. Copies were mailed to nearly 1,000 people including National Committees, IAGA officials, and others who have expressed an interest to the General Secretary. Additional copies of the *IAGA News* Nos. 6-9 are available at the Secretariat's Office for those who do not have copies. Persons wishing to have their names added to the distribution list, should notify the General Secretary.

## ORGANIZATION

There were several changes made in the organization of working groups of some commissions at the XIV General Assembly but they were very minor compared to the major restructuring that occurred in Berkeley in 1963. All of these changes have been fully documented in the *IAGA News* series and in *IAGA Bulletin* No. 25. Every elected officer and all commission chairmen were able to serve throughout the entire four year term except for Dr. T. Rikitake, chairman of Commission III, who asked Dr. F. J. Lowes to help prepare for the XV General Assembly and to act in his place at that assembly because of an added work load at home.

Several commission chairmen have indicated that there is a need to reorganize their working groups. This will be given close attention at the XV General Assembly. Working groups that have not performed any useful function should be eliminated.

## FIRST GENERAL SCIENTIFIC ASSEMBLY, MADRID 1969

The new IUGG rules adopted in Zurich at the XIV General Assembly suggested that each Association alone or in combination with others should hold scientific assemblies between the IUGG General Assemblies.

The highlight of the four year period was the General Scientific Assembly which IAGA held together with IASPEI in Madrid, Spain, in September 1969. We are grateful to the Spanish Government and the local organizing committee led by Rev. Fr. A. Romana, S.J. for an extremely profitable assembly in which only scientific topics were allowed. All administrative items were postponed to a later date. The report of this scientific assembly is covered in *IAGA Bulletin* No. 27. Four hundred and sixty scientists registered in Madrid for this assembly. There were 483 papers presented by 625 authors. These figures include 57 papers presented in the three symposia which were jointly sponsored by IAGA and IASPEI.

## PREPARATION FOR THE XV GENERAL ASSEMBLY, MOSCOW, 1971

The IUGG Executive Committee met in Madrid in September, 1969 where they approved 31 interdisciplinary symposia which according to the new IUGG rules were the only scientific sessions to be allowed as an official part of the XV General Assembly. This list of symposia included eight to be convened by IAGA and eight more which IAGA was to cosponsor.

In spite of the new rules regarding IUGG General Assemblies, IAGA was encouraged (unofficially) to hold a more or less full scientific assembly as a part of the XV General Assembly. Consequently, *IAGA Bulletin* No. 30 requiring 617 papers to describe the program and abstracts was delivered to the local arrangements committee in Moscow during the first week in April 1971.

Thanks are given to Dr. B.S. Volvovsky, general secretary of the Soviet Organizing Committee, many members of his staff and especially Dr. V.A. Troitskaya, vice president of IAGA, for the hospitality shown to me and for the work they did in preparing for the assembly during the week I was their guest in Moscow.

## EXECUTIVE COMMITTEE

The Executive Committee met on the following occasions: St. Gall, Switzerland, September 1967; Tokyo, Japan, May 1968; Washington, D.C., October 1968; Madrid, Spain, September 1969; Leningrad, USSR, May 1970.

## FINANCE AND BUDGET

A brief summary of the income and expenses of IAGA is shown on page 6. The books have been audited by Helen R. Machin, Finance Officer for the NOAA Environmental Research Laboratories, U.S. Department of Commerce. This auditor has verified that the money has been spent as indicated. A certified statement to this effect is on the Summary Sheet.

A proposed budget for the next four year period 1971-1974 is shown on page 7. In the proposed budget more money is allocated for the support of General Scientific Assemblies than in the past. This is in keeping with the new IUGG rules which suggest that Associations should hold scientific assemblies between Union General Assemblies. The problem of finding money needed for travel for Association officials and contributing young scientists is becoming more acute.

## WORLD MAGNETIC SURVEY BOARD (WMS)

The Board held a meeting on October 4, 1967 at St. Gall, Switzerland.

The WMS Board also sponsored an IAGA Symposium on the "Description of the Earth's Magnetic Field" on October 22-25, 1968 in Washington, D.C. One of the main successes of this symposium was the adoption of an International Geomagnetic Reference Field (IGRF) in the form of the 8th degree coefficients for both the field itself and its secular change.

Dr. E.H. Vestine, who had served as Secretary to the Board since its inception, died on July 13, 1968. Dr. A.J. Zmuda was appointed to fill that vacancy. Dr. Zmuda has worked very hard to complete the final report for the World Magnetic Survey. It is anticipated that the final report, *IAGA Bulletin* No. 28, will be distributed about the time of the Moscow Assembly.

*IAGA Bulletin* No. 29, Grid Values for the IGRF 1965.0, has already been distributed.

The Board was officially discharged on 21 January 1970, but Dr. Zmuda is continuing on to complete the final Report. The IUGG has already provided $6,000 to help pay publication cost of the final report.

## SYMPOSIA

IAGA sponsored or cosponsored the following Symposia as indicated:

Sponsored: The Fourth International Conference on the Universal Aspects of Atmospheric Electricity, 12-18 May 1968, Tokyo, Japan

Sponsored: Laboratory Measurements of Aeronomic Interest, 3-5 September 1968, Toronto, Canada

Sponsored: Description of the Earth's Magnetic Field, 22-25 October, Washington, D.C., USA

Cosponsored: Solar Flares, 9-16 May 1968, Tokyo, Japan

Cosponsored: International Symposium on Solar Regular Daily Geomagnetic Variations, 23-29 April 1970, Potsdam, GDR

Cosponsored: Third Equatorial Aeronomy Symposium, 3-10 February 1969, Ahmedabad, India

Cosponsored: Solar-Terrestrial Physics, 12-20 May 1970, Leningrad, USSR

## PUBLICATIONS

*IAGA News* No. 6 – October 1967
*IAGA News* No. 7 – July 1968
*IAGA News* No. 8 – September 1969
*IAGA News* No. 9 – November 1970

## INTERNATIONAL ASSOCIATION OF GEOMAGNETISM AND AERONOMY

### Financial Report for the Period 1967 to 1970

Amount in USA dollars Exchange rate . . . . .

| RECEIPTS | IUGG | | GRANTS & CONTRACTS |
|---|---|---|---|
| 16 IUGG ALLOCATION | 40,000.00 | | X |
| 2 UNESCO GRANTS | X | | 5,000.00 |
| 3 OTHER GRANTS | X | | . . . . . . |
| 4 CONTRACTS WITH UNESCO, etc. | X | | . . . . . . |
| 5 SALES OF PUBLICATIONS | 5,038.00 | | X |
| 6 MISCELLANEOUS | 1,997.62 | (1)(2) | X |
| SYMPOSIA REFUNDS | 606.39 | | X |
| SPECIAL SPANISH ACCOUNT | 1,140.45 | | X |
| 7 TOTAL RECEIPTS | 48,782.46 | | 5,000.00 |
| 8 CASH ON HAND AND IN BANKS Jan. 1, 1967 | 17,073.90 | | |
| 10 TOTAL | 65,856.36 | | 5,000.00 |

| EXPENDITURES | IUGG | GRANTS & CONTRACTS |
|---|---|---|
| 11 ADMINISTRATION | | |
| 11.1 Personnel | 1,034.41 | X |
| 11.2 Quarters (rents, etc.) | 0 | X |
| 11.3 Supplies & Equipment | 136.53 | X |
| 11.4 Communications | 2,364.43 | X |
| 11.5 Travel (administrative) | 8,067.55 | X |
| 11.6 Miscellaneous | 34.98 | X |
| 12 PUBLICATIONS | | |
| 12.1 C.R. Assemblies, Transactions | 9,364.57 | . . . . . . |
| 12.2 C.R. Symposia | 11,839.59 | . . . . . . |
| 12.3 Periodicals, IAGA News | 3,584.05 | . . . . . . |
| 12.4 Others | 635.64 | . . . . . . |
| 13 ASSEMBLIES | | |
| 13.1 Organization | . . . . . | . . . . . |
| 13.2 Travel | . . . . . | . . . . . |
| 14 SYMPOSIA | | |
| 14.1 Organization | 3,500.00 | . . . . . . |
| 14.2 Travel | 1,558.00 | . . . . . . |
| 15 SCIENTIFIC MEETINGS | | |
| 16 GRANTS (Permanent Services) | 500.00 | . . . . . . |
| 18 CONTRACTS WITH UNESCO, etc. | 442.00 | . . . . . . |
| 19 MISCELLANEOUS | 137.82 | . . . . . . |
| LOSS IN DEVALUATION OF £ | 686.46 | . . . . . . |
| 20 TOTAL EXPENDITURES | 43,886.03 | |
| 21 CASH ON HAND AND IN BANKS Dec. 31, 1970 | 26,970.33 | |
| 23 TOTAL | 70,856.36 | |

(1) Includes interest in the amount of $393.18 earned for 1966.
(2) Closeout of Spanish Sub-Account

Audited and certified correct

Helen R. Machen

Finance Officer,
NOAA Environmental Research Laboratories

February 24, 1971
Date

## INTERNATIONAL ASSOCIATION OF GEOMAGNETISM AND AERONOMY

### Estimate of Income and Expense for the Period 1972-1975

**Amounts in USA dollars Exchange rate . . . . . .**

| | **RECEIPTS** | **IUGG** | | **GRANTS & CONTRACTS** |
|---|---|---|---|---|
| 16 | IUGG ALLOCATION ............... | $56,000. | (1) | |
| 2 | UNESCO GRANTS ................ | X | | . . . . . . |
| 3 | OTHER GRANTS ................. | X | | . . . . . . |
| 4 | CONTRACTS WITH UNESCO, etc. .... | X | | 2,000. |
| 5 | SALES OF PUBLICATIONS .......... | . . . . . | | X |
| 6 | MISCELLANEOUS ................ | 4,000. | | X |
| 7 | TOTAL RECEIPTS ................ | 60,000. | | 2,000. |
| 8 | ESTIMATED CASH ON HAND AND IN BANKS JAN. 1, 1971 ........... | 26,970. | (2) | . . . . . . |
| 10 | TOTAL | $86,970. | | 2,000. |

| | **EXPENSES** | | | |
|---|---|---|---|---|
| 11 | ADMINISTRATION ................ | $15,000. | | X |
| 12 | PUBLICATIONS .................. | 25,000. | (2) | . . . . . . |
| 13 | ASSEMBLIES ..................... | 22,970. | | . . . . . . |
| 14 | SYMPOSIA ...................... | 5,000. | | . . . . . . |
| 15 | SCIENTIFIC MEETINGS ............ | . . . . . | | . . . . . . |
| 17 | GRANTS (Permanent Services, etc.) .... | 5,000. | | . . . . . . |
| 18 | CONTRACTS WITH UNESCO, etc. ...... | . . . . . | | . . . . . . |
| 19 | MISCELLANEOUS ................ | 2,000. | | X |
| 20 | TOTAL EXPENDITURES ........... | 74,970. | | . . . . . . |
| 21 | ESTIMATED CASH ON HAND AND IN BANKS Dec. 31, 1974 ............... | 12,000. | | . . . . . . |
| 23 | TOTAL ......................... | $86,970. | | . . . . . . |

(1) This implies IUGG must raise its present allotment from $8,500/yr. to $14,000/yr. Note that this is the goal IUGG is striving for (See *IUGG Chronicle* No. 80, July 1970, pp. 72 & 73). This larger amount is badly needed to support the IAGA General Scientific Assemblies held between IUGG General Assemblies. Much of the increase will go for travel expenses to get young scientists to attend.

(2) This includes an amount between $8,500 and $10,000 which is being held for cost of the final WMS Report which is at the printers.

*IAGA Bulletins:*

No. 12v1, Geomagnetic Data 1967, Indices K and Ci, 1969
No. 12v2, Geomagnetic Data 1967, Rapid Variations, 1969
No. 12w1, Geomagnetic Data 1968, Indices K and Ci, 1970
No. 24, Program and Abstracts for St. Gall Meeting, 1967
No. 25, Transactions of XIV General Assembly, 1967
No. 26, Program and Abstracts for Madrid Meeting, 1969
No. 27, Transactions of the General Scientific Assembly, Madrid, 1969
No. 28, World Magnetic Survey Final Report
No. 29, Grid Values for the IGRF 1965.0, 1971
No. 30, Program and Abstracts for Moscow Meeting, 1971

*IAGA Symposia:*

No. 6, The Birkeland Symposium on Aurora and Magnetic Storms, 1967
No. 7, Proceedings of the Symposium on Upper Atmospheric Winds, Waves and Ionospheric Drifts, 1967
No. 8, Proceedings of the Symposium on Laboratory Measurements of Aeronomic Interest, 1969
No. 9, Proceedings of the Symposium on Multidisciplinary Studies of Unusual Regions of the Upper Mantle, 1969

## RELATION WITH OTHER ORGANIZATIONS AND FUTURE STRUCTURE

IAGA continued its contacts with many other ICSU bodies. IAGA has representatives in SCAR, IUCSTP, SPARMO, COSPAR, SCOR, two Joint Committees with IAMAP and UMP.

There is an obvious overlap in some areas covered by IAGA, URSI, COSPAR and IUCSTP. This problem has been under continuous study for several years. In September 1969, the IUGG Executive Committee established a small committee to investigate the future structure of the Union. The committee was instructed to examine, in particular, relations with URSI and to maintain contact with a similar committee established from URSI. This committee has issued a preliminary report (See *IAGA News* No. 9, page 56) and is seeking further advice. This matter will be an important one for the XV General Assembly. Members of the IAGA Executive Committee are working with the IUGG officials in formulating this important policy.

## ACKNOWLEDGEMENT

The General Secretary wishes to thank the great number of scientists worldwide who have cooperated to help IAGA achieve its goals. The support of the Environmental Research Laboratories of National Oceanic and Atmospheric Administration has permitted the secretariat to be operated at a minimal cost to the Association.

# AUSTRAL SUBSTORMS

A Scientific Paper by
Takesi Nagata, President of IAGA

## ABSTRACT

Simultaneous observations of the Austral aurora phenomena with the use of a H$\beta$ tilting-filter scanning photometer and a multi-color scanning photometer for $\lambda$4278, $\lambda$5577, and $\lambda$6300 auroral lines have led to a clear distinction between the proton auroras from the electron auroras. In the proton auroras, the ratio of I(H$\beta$)/I(5577) is about one tenth, which is in agreement with the theoretical estimate, while the ratio is zero ($<10^{-3}$) in the electron auroras.

Studies in detail of the substorms of electron aurora by means of all-sky cameras and scanning photometers have shown that an auroral substorm consists of (i) the breakup phase and (ii) the post-breakup phase. The breakup phase can be further divided into (a) the prestage which is represented by a sudden intensification of auroral arc(s) or band(s) and (b) the main stage which is characterized by the poleward movement of the intensified aurora(s) with speed of 1 km/sec. on average. The post-breakup phase is defined as diffused or patchy auroras which still remain after the intense aurora(s) passed away poleward in the breakup phase. Generally, the post-breakup auroras move towards the equator-side.

An electron auroral breakup is accompanied by a sharp negative magnetic bay while a post-breakup phase is accompanied by a broad negative bay. It seems that the sharp negative bay moves polewards together with the moving breakup aurora, while the broad negative bay stays with the associated post-breakup aurora(s). Thus, the auroral electrojet also can be classified into (i) AEJ-1 which is an intense and narrow electrojet moving together with the breakup aurora and (ii) AEJ-2 which is a comparatively broad and weak electrojet associated with the post-breakup aurora(s).

The breakup phase of electron auroras is accompanied not only by a sharp magnetic bay but also by VLF hiss emissions, ULF emissions of PiB type and a sharp CNA phenomenon, while the post-breakup phase is accompanied by a broad magnetic bay, VLF chorus emissions, ULF emissions of PiC type and a broad but weak CNA. The proton auroras are not accompanied by VLF hiss emissions, as theoretically expected, but accompanied by weak ULF emissions and broad positive magnetic bays.

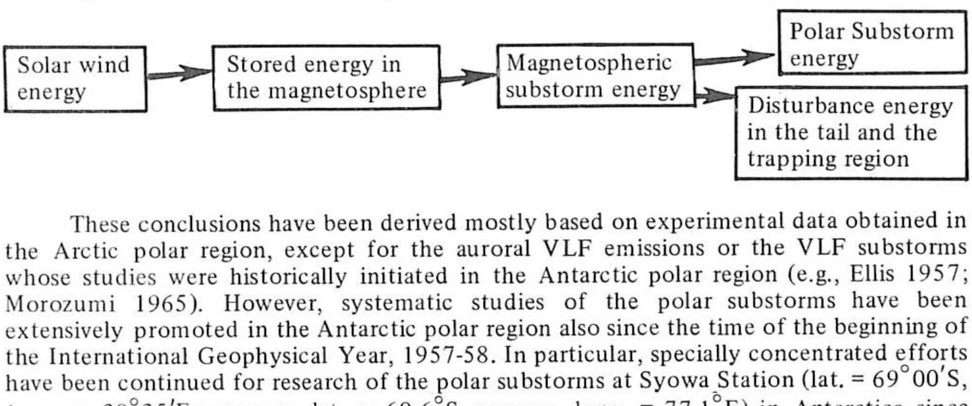
About 2 hours before the breakup of an electron substorm, the intensity of the polar two-vortex electric current system (SP field or DP-2 field) starts to gradually grow, and almost simultaneously the intensity of the equatorial ring current and its asymmetricity, which is represented by the maximum southward field at midnight, also begin to grow. These remarkable changes can be considered to represent the growth phase of the polar substorm.

## 1. INTRODUCTION

Physics of the polar substorms has been one of the most exciting research subjects for geomagneticians and space physicists recently. Therefore, the general assemblies and the general scientific assembly of our International Association of Geomagnetism and Aeronomy have devoted much time to discussing this extremely interesting topic. Since numerous observed data of physical states within the magnetosphere and in the solar wind on both quiet and disturbed conditions have recently been accumulated, in addition to the ground-based, balloon-borne and rocket-borne observations of the polar substorm phenomena in the polar regions, the complicated physical processes in the magnetosphere which result in the polar substorms have gradually been clarified, and the concept of the "magnetospheric substorm" has newly been proposed.

The polar substorms are typically represented by bursts of auroras, which may be called the *auroral substorms* or the *auroral flares*. It has been well known since the time of Celsius (1746) that the auroral substorms are associated with the simultaneous *magnetic substorms*. The ionosphere in the auroral active zone also is highly ionized at the same time, thus the *ionospheric substorms* accompany the auroral and magnetic substorms. VLF and ULF waves also are strongly emitted when the auroral and magnetic substorms break up, the bursts of VLF and ULF emissions being named the *VLF substorms* and the *micropulsation substorms* respectively, or the auroral VLF and the auroral ULF respectively.

The source of these polar substorms has been detected by balloon-borne, rocket-borne and satellite-borne measurements to be precipitating electrons and protons, though detailed characteristics of the proton auroras have not yet been sufficiently known. The electron polar substorms are considerably different from the proton polar substorms in regard to their characteristics as well as their geographical distributions. Characteristics of precipitating electrons in the auroral zone have been quite well observed and analyzed with respect to their energy spectra, precipitation geography, and their emissions of visible auroras, Brehmstrahrung x-rays and radio waves. Particularly, the x-ray bursts caused by precipitating auroral electrons have been studied in some detail, and have been even named the *x-ray substorms*. All these aspects of the magnetospheric substorms and the resultant polar substorms have been well summarized by Akasofu in his book *"Polar and Magnetospheric Substorms"* (1968). Thus, the energy flow diagram chart starting from the solar wind energy and ending at the energy of the earth's polar substorms has been expressed as




These conclusions have been derived mostly based on experimental data obtained in the Arctic polar region, except for the auroral VLF emissions or the VLF substorms whose studies were historically initiated in the Antarctic polar region (e.g., Ellis 1957; Morozumi 1965). However, systematic studies of the polar substorms have been extensively promoted in the Antarctic polar region also since the time of the beginning of the International Geophysical Year, 1957-58. In particular, specially concentrated efforts have been continued for research of the polar substorms at Syowa Station (lat. = 69°00′S, long. = 39°35′E; geomag. lat. = 69.6°S, geomag. long. = 77.1°E) in Antarctica since 1957. Research disciplines at this station are, for example, the magnetic substorms (e.g., Oguti 1963; Nagata *et al* 1966), the auroral substorms (e.g., Kaneda *et al* 1968; Hirasawa and Kakinuma 1970), the VLF substorms (e.g., Kokubun *et al* 1969; Nishino and Tanaka 1969), the ULF substorms (e.g., Fukunishi 1969, Fukunishi and Hirasawa 1970, Kokubun 1970) and the substorm effect on cosmic rays (Kodama and Inoue (1970). The observing instruments for the polar substorm research at Syowa Station at present are:

(a) Aurora: ($a_1$) all-sky camera, ($a_2$) auroral photometer for rapid variation of λ4278Å, ($a_3$) meridian scanning multicolor photometer λ4278Å, λ5577Å, λ6300Å), ($a_4$) meridian scanning H$\beta$ photometer, ($a_5$) VHF auroral radar, ($a_6$) video-recording of ultra-sensitive auroral television cameras.

(b) Geomagnetism: ($b_1$) 3-component flux-gate magnetograph, ($b_2$) 2-component induction magnetograph, ($b_3$) absolute magnetometer.

(c) Ionosphere: ($c_1$) vertical ionosonde (f = 0.4 - 15MH$_3$), ($c_2$) riometer (f = 10, 20, 30, 40, and 70 MH$_z$).

(d) VLF emission: ($d_1$) narrow band intensity recorder (f = 0.75, 1, 2, 4, 8, 12, 32, 64, and 128 $KH_z$), ($d_2$) chorus recorder (f = 0.2 - 4 $KH_z$)

In addition to these ground-based observations, the balloon-borne measurements of auroral x-rays and the electric field and the rocket-borne measurements of various elements of the auroral and magnetic substorms also have been conducted as the regular programs. In the neighborhood of Syowa Station, magnetogram records are available from Mouson (geomag. lat. = 73.1°S, geomag. long. = 102.9°) and Plateau Station (geomag. lat. = 77.2°S, geomag long. = 52.5°). Using these Antarctic data of the polar substorms and when necessary, referring to the simultaneous Arctic data, particularly those in the geomagnetically conjugate area in the North, and the magnetospheric data also, we can discuss the morphology and physical mechanism of the *Austral substorms* in fair detail. As a matter of fact, many of the characteristics of the austral substorms are essentially the same as those of the Boreal substorms which have been studied by a large number of workers. However, new observing techniques such as the multi-color scanning photometer and the tilting-filer H$\beta$ scanning photometer, which have been operated on the routine base in Antarctica, have given us much clearer morphology of the electron and proton auroras separately. Further, a synthetic physical picture of the polar substorm phenomena is now available in Antarctica through the simultaneous observation of auroras, geomagnetic variations, ionospheric variations, VLF emissions, and ULF emissions. This report is a summary of recent studies on the Austral substorms.

## 2. SPECIAL INSTRUMENTATIONS FOR THE POLAR SUBSTORM RESEARCH IN SYOWA STATION.

In this summary report, the auroral substorms and the magnetic substorms will be considered as the two kinds of basic data for representing the polar substorms, while the other substorm phenomena in the ionosphere, VLF, ULF, etc., will be regarded as the associated phenomena with these two basic substorms.

In regard to the instrumentations for observing the ionospheric variations and the VLF emissions, (c) and (d) in the previous section, no particular explanation may be needed (see, however, Kokubun *et al* 1969). The magnetographs, ($b_1$) and ($b_2$), and the magnetometer ($b_3$) also may not need to be described. In the auroral observations, at Syowa Station, however, outlines of the instrumentations will be briefly described here except for the well known VHF auroral radar ($a_5$). The all-sky camera ($a_1$) took an all-sky photograph every 30 seconds with the exposure time 15 seconds during the southern dark times. The zenith auroral photometer for rapid variation of λ4278Å ($a_2$) was designed specifically for observing the auroral pulsations. The field of view of its zenith telescope is 5° in angle, and the variations in the observed intensity of λ4278Å aurora are recorded through three bandpass filters of f = 0.01 ∿ 0.1 $H_3$, f = 0.1 ∿ 2 $H_z$ and f = 2 ∿ 30 $H_z$ in frequency ranges (Hirasawa and Kakinuma 1970).

Fig. 1 illustrates the block diagrams of ($a_3$) the meridian scanning multi-color photometer (bottom) and ($a_4$) the meridian scanning H$\beta$ photometer (top). All the photometer components for 4 different spectral lines can scan through 180° in angle along the geomagnetic meridian. The multicolor photometer which is operated at present scans the whole range of angle with a period of 5 seconds. The old type of the scanning photometer, which had been used until 1969, had a 12 second scanning period.

The meridian scanning H$\beta$ photometer is attached specifically to a tilting filter which can sweep from the standard wave length 4866.4 Å through 80Å toward shorter wave length with 2.1Å in the band-pass width and 2 seconds in period. The scanning period for the whole angle along the geomagnetic meridian is 45 seconds in this special scanning photometer.

The purpose of this H$\beta$ tilting-filter scanning photometer is to observe the Doppler shift of the H$\beta$ line in order to estimate the energy of precipitating protons for the proton auroras. In the case of electron auroras, on the other hand, a mutual comparison of the intensities of the three spectral lines, i.e., 4278Å, 5577Å, and 6300Å, can indicate an approximate value of the energy of precipitating electrons.

In the present summary report, data obtained by these meridian scanning photometers will be taken as the most basic ones for representing the auroral substorms.

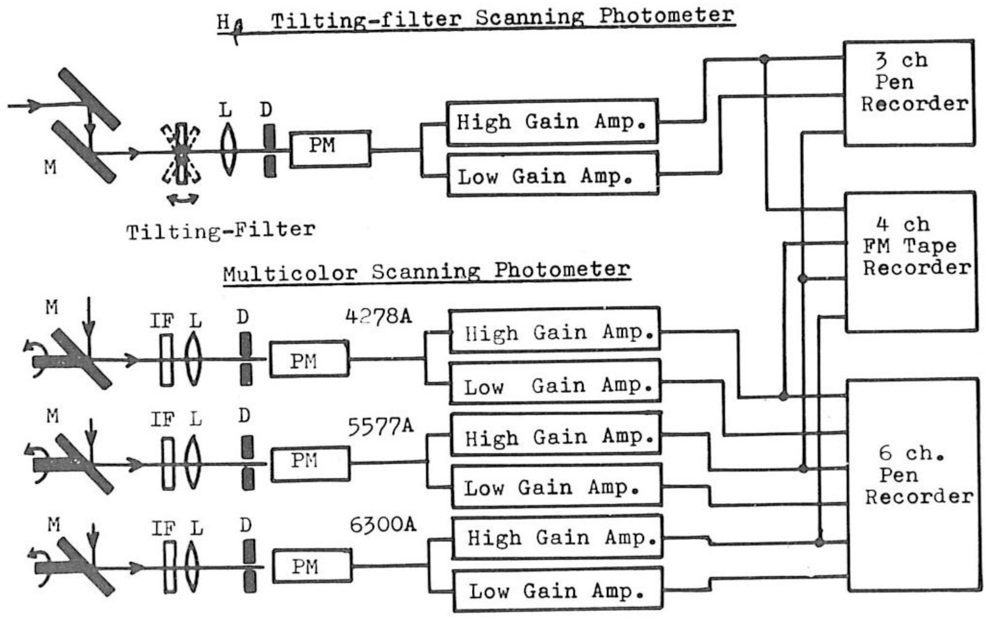



Fig. 1. Block diagrams of the $H_\beta$ tilting-filter scanning photometer and the multi-colour scanning photometer.

Since the scanning photometers can measure the auroral luminosity of respective spectral lines, at least, between zenith angle $\chi = 80^\circ$ toward the north and $\chi = 80^\circ$ toward the south along the geomagnetic meridian, the photometers can observe aurorals displaying from $-\Delta\varphi$ to $^+\Delta\varphi$ in latitude difference from the observing point, where

$$\Delta\varphi = 80^\circ - \text{Arcsin}\ 0.985\ \frac{R}{R+h}$$

with R = the earth's radius and h = average height of auroral emission. If h is assumed to be 120 km, $\Delta\varphi$ becomes $4{\cdot}8^\circ$, whence the photometers can observe auroras from 520 km north to 520 km south. This range of coverage at Syowa Station (geomag. lat. = $69{\cdot}6^\circ$S) will permit observation of almost all auroras in the midnight sector.

The auroral photometric data thus obtained can provide a practically continuous time sequence of the distribution of auroral luminosity of a selected spectral line along the geomagnetic meridian, such as shown, for example, at the top of Fig. 2. Such a diagram to represent the distribution of auroral luminosity along a geomagnetic meridian (in abscissa) as a function of time (in ordinate) will be called the *meridian-time diagram of auroral luminosity*. An important merit of this diagram is its high time resolving power, which can practically correspond to that of the continuous magnetogram data. Thus, analyses in detail of both auroral substorms and the simultaneous magnetic substorms have become possible.

However, the meridian-time diagrams of auroral luminosity obtained at a station can provide time changes of the auroral intensity only along a meridian, and cannot show the auroral changes along the latitude circles. To fulfill this shortness, the video-recording of an ultrasensitive auroral television camera ($a_6$) is operated at Syowa Station for selected cases of auroral activity. It may be desirable in the future to set up an appropriate network of the meridian scanning auroral photometers in Antarctica to cover the whole sky of the midnight sector to obtain continuous routine observations.

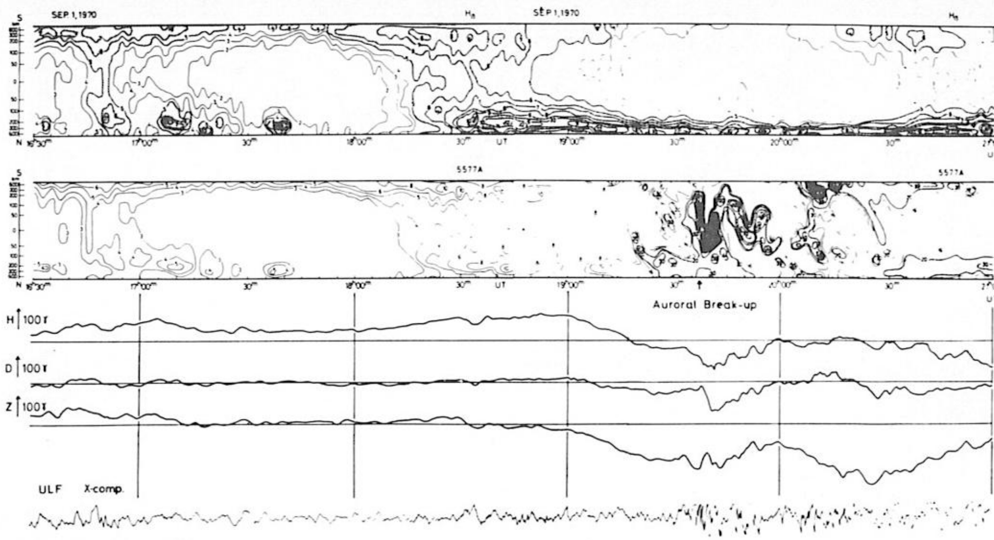


Fig. 2. Example of proton auroras and an electron aurora. (All observed at Syowa Station.) From the top to the bottom:
(1) Meridian-time diagram of $H_\beta$ aurora.
(2) Meridian-time diagram of λ5577Å aurora.
(3) Variation of geomagnetic H, D and Z components.
(4) X-component of ULF.

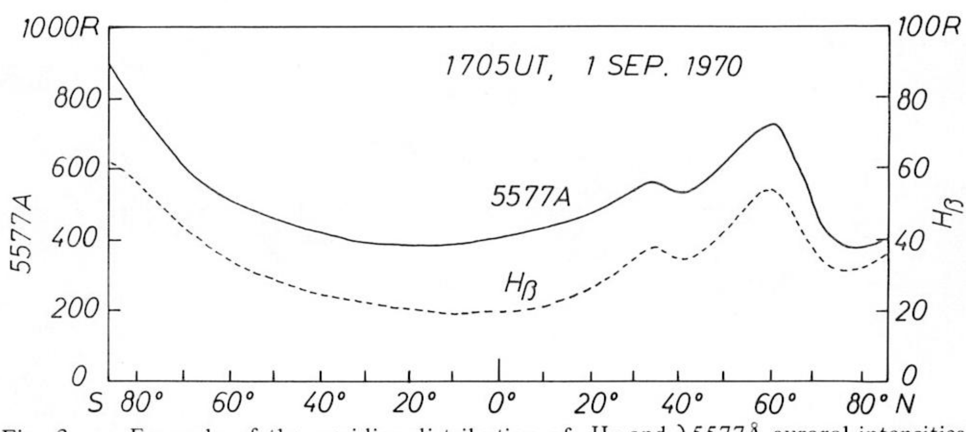



Fig. 3. Example of the meridian distribution of $H_\beta$ and λ5577Å auroral intensities.

## 3. ELECTRON AURORAS AND PROTON AURORAS

Fig. 2 shows an example of a set of the meridian-time diagram of $H\beta$ aurora (top), that of λ5577Å aurora (second), three components of geomagnetic variations (third) and geomagnetic micropulsations, simultaneously observed at Syowa Station. (Note that the numeral of figures for the contours in the $H\beta$ diagram is in unit of 8R, while the λ5577Å diagram is in unit of 100R.) Comparing the $H\beta$ diagram with the λ5577Å ones it is clearly seen that the breakups of $H\beta$ aurora around $16^h50^m$ and $18^h30^m$ are associated with the simultaneous breakups of λ5577Å auroras. On the other hand, however, a sequence of intense breakups of λ5577Å aurora from about $19^h20^m$ through $21^h15^m$ are not associated at all with $H\beta$ aurora. In the previous two cases, the ratio of the intensity of λ5577Å aurora to that of $H\beta$ aurora, i.e., $I(5577)/I(H\beta)$, amounts to $8 \sim 15$, the average ratio being about 10. Fig. 3 shows an example of the distributions of $I(H\beta)$ and $I(5577)$

along the geomagnetic meridian at a particular instant during the case, where I(5577)/I(H$\beta$) = 14 ~ 15. The ratio, I(5577)/I(H$\beta$) for the λ5577Å and H$\beta$ auroras caused by precipitating protons of various different energies has been theoretically estimated by Eather (1967) to range from 4 to 12. One may conclude therefore that the auroral breakups around $16^h50^m$ and $18^h30^m$ are attributable to *the proton aurora events.*

The breakup of λ5577Å aurora at about $19^h40^m$ reached about 20KR in its zenith luminosity, but there was no enhancement of H$\beta$ aurora in the zenith at the same time, the ratio, I(5577)/I(H$\beta$), for this case being larger than $10^3$ at least. It may be concluded therefore that the auroral breakup around $19^h40^m$ is certainly attributable to the *electron aurora event.* A long time sequence of such simultaneous meridian-time diagrams of H$\beta$ and λ5577Å has been obtained at Syowa Station. These data have clearly indicated that the polar auroras can be definitely classified into either the electron aurora or the proton aurora in most cases. As will be discussed later with observed examples, a breakup of electron aurora in the midnight sector is always associated with a characteristic sharp magnetic substorm (i.e. a sharp negative magnetic bay) and emissions of auroral VLF hiss and auroral ULF of PiB type (see Section *6-3*). In Fig. 2 also, a breakup of a negative magnetic bay and emissions of characteristic ULF waves are observable only in association with the electron aurora event. Corresponding to the two proton aurora events in the dusk time, on the other hand, broad positive magnetic bays are observable. The correlation between the proton auroras and the positive magnetic bays in the dusk sector has generally been established in their statistics.

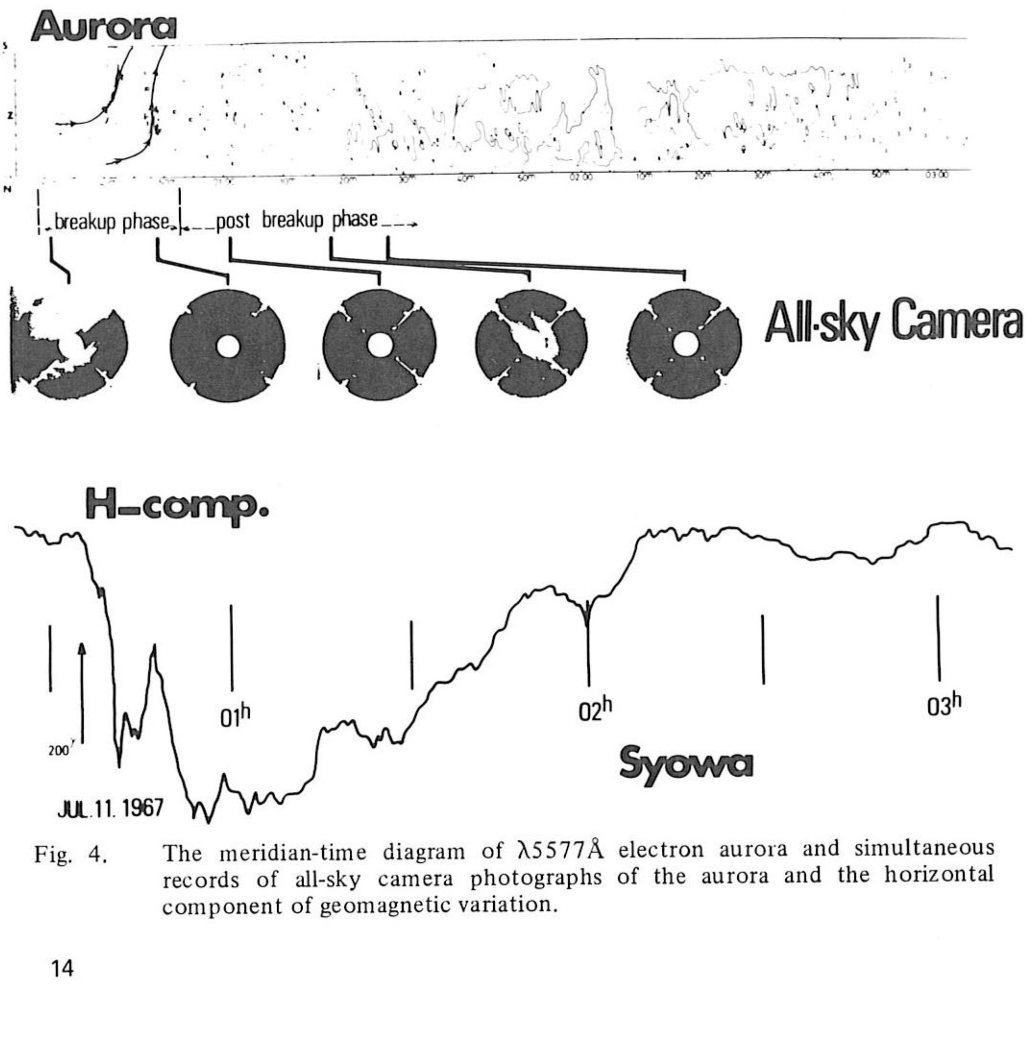



Fig. 4. The meridian-time diagram of λ5577Å electron aurora and simultaneous records of all-sky camera photographs of the aurora and the horizontal component of geomagnetic variation.

The Balmer lines of the hydrogen atom, $H_\alpha$, $H_\beta$ and $H_\gamma$, have been observed in the auroral spectra since the time of the first discovery of these lines by Vegard (1939). Later works have shown that the intense auroras of λ4278Å and λ5577Å are exclusively caused by precipitating protons. (See a summary of Akasofu, 1968, pp. 126-139). However, the morphology in detail of the proton auroras has not yet been sufficiently clarified even in the Arctic region. In Syowa Station, in Antarctica, the routine observations of the proton auroras by means of the $H_\beta$ tilting-filter scanning photometer were started in the Antarctic winter of 1970. Statistical studies on the proton auroras will therefore be reported elsewhere in the future.

## 4. BREAKUP AND POST-BREAKUP PHASES OF ELECTRON AURORAS

Fig. 4 illustrates an example of simultaneous data of the meridian-time diagram of λ4278Å auroral luminosity (top), all-sky camera photographs (middle) and variations in the geomagnetic H-component (bottom). As seen in the auroral data, two auroral arcs were suddenly intensified at about $0^h30^m$, and the intense poleward-side arc began to move polewards at about $0^h40^m$ while the equatorward-side one also began to move polewards at about $0^h48^m$. After the intense auroral arcs had passed away polewards, comparatively weak auroras in forms of diffused aurora or auroral rays still remained for a long time. These weaker auroras move generally equatorwards. The above-mentioned characteristics of a time sequence of an auroral substorm is always the same for all auroral substorms which take place in the midnight sector. For example, Figures 5 and 6 show the meridian-time diagrams of λ4278Å auroras observed at Syowa Station for various different magnitudes of simultaneous magnetic substorms, which are represented by $\bar{K}_p$ indices. These λ4228Å auroras are certainly due to precipitating electrons.

The general characteristics of electron-auroral substorms derived from these data are the following: an auroral arc or band is suddenly intensified, and from 5 to 20 minutes later the intensified aurora moves polewards with an average speed of about 1 km/sec. This phase of an auroral substorm may be called *the breakup phase.* The breakup phase can be further divided into *the prestage ($B_1$-stage),* in which the intensified aurora does not move along the geomagnetic meridian, and *the main stage ($B_2$-stage)* which is characterized by the poleward movement. As already pointed out by Akasofu (1964), however, the auroral arcs or bands move westwards or eastwards even in the prestage.

The auroral activity, which remains for a comparatively long time after the main stage of breakup phase and which moves equatorwards in general, may be named *the post-breakup phase* of an auroral substorm. Frequently breakups of two or more auroral arcs or bands take place almost simultaneously as shown in examples in Figures 4 and 8. Summarizing these observed results, one may express the structure of an electron auroral substorm observed at a station in or near the auroral zone by the following diagram:

| Auroral Substorm | = | Breakup Phase ($B_1$-stage) + ($B_2$-stage) | + | Post-Breakup Phase |
|---|---|---|---|---|

Statistical results of 65 examples of the electron auroral substorms have shown (a) that the duration time of the $B_1$-stage of the breakup phase ranges from 2 to 25 minutes where the duration time is the shortest around midnight and the longest at the dusk time; (b) that the duration time of the $B_2$-stage ranges from 5 to 30 minutes, the median value being 10 minutes, and (c) the speed of the poleward movement of auroras in the $B_2$-stage ranges mostly from 0.5 to 1.5 km/sec., as shown in Fig. 7, the median value being about 1 km/sec. Characteristics of the breakup and post-breakup phases of the Austral auroral substorms summarized here are in general agreement with those of the Boreal auroral substorms summarized by Akasofu (1968), except for Akasofu's pre-breakup phase which will be discussed later.

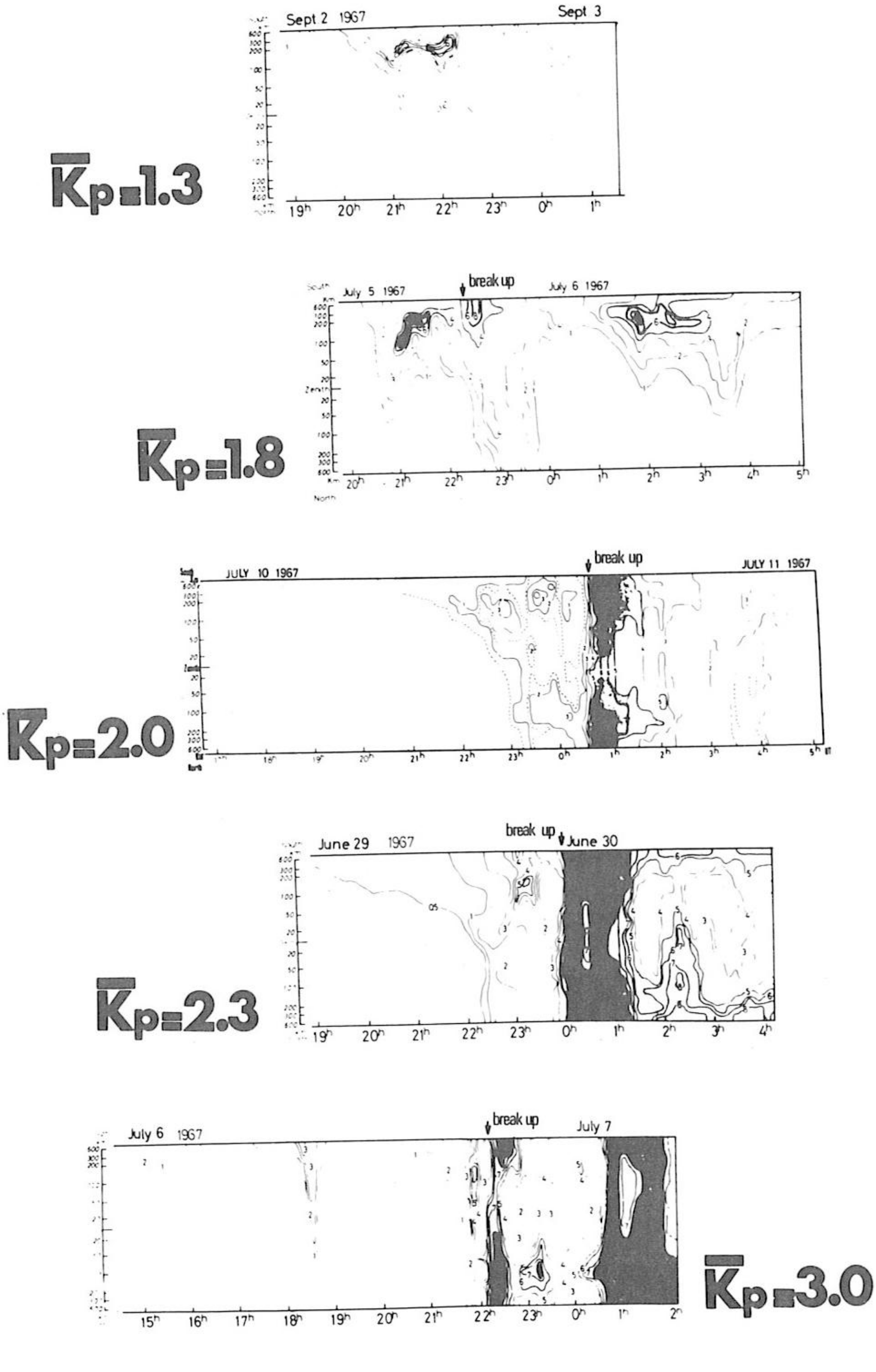



Fig. 5. Examples of the meridian-time diagrams of λ4278Å auroras for different values of Kp index. (I). Kp = 1.3 - 3.0.

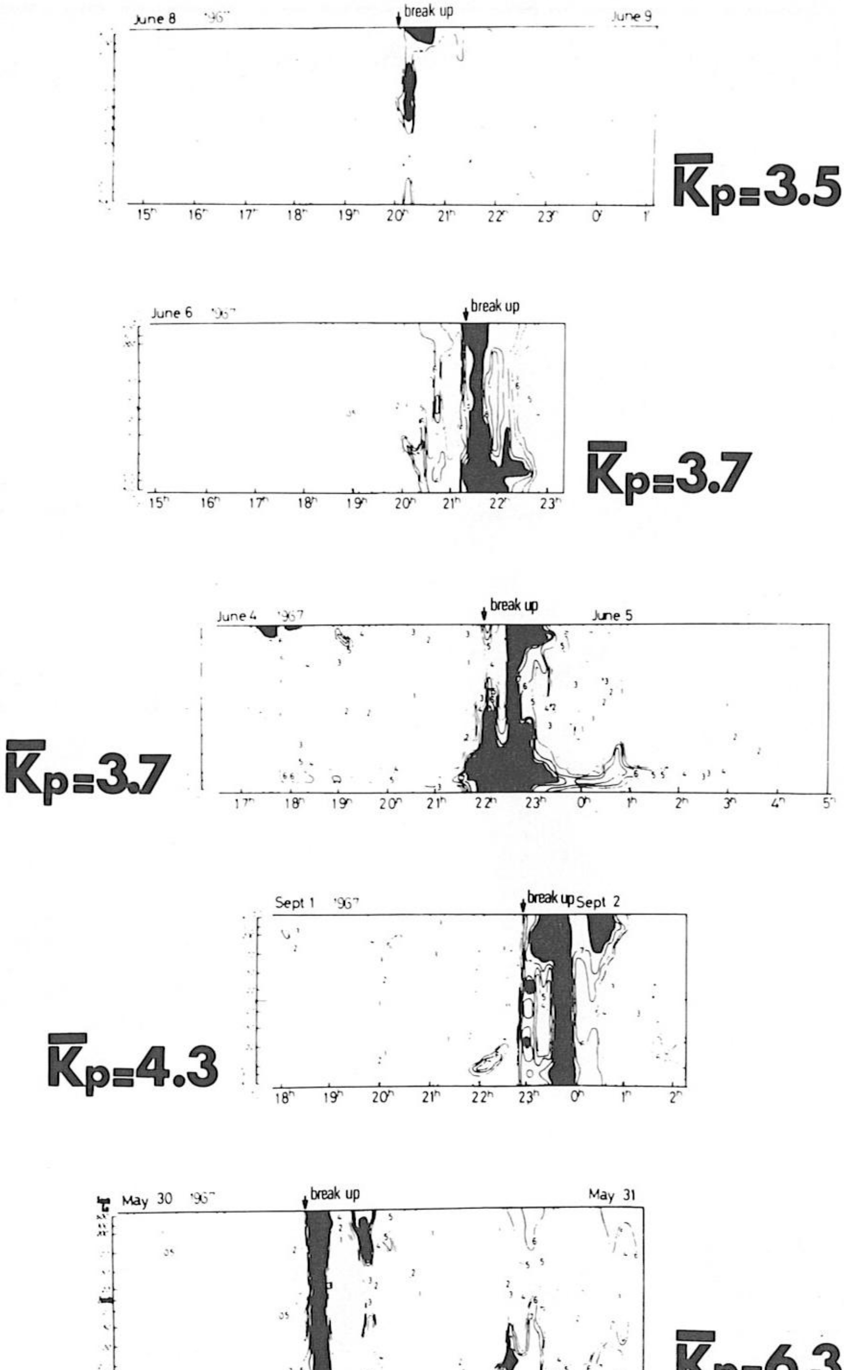



Fig. 6. Examples of the meridian-time diagrams of λ4278Å auroras for different values of Kp index. (II). Kp = 3.5 - 6.3.

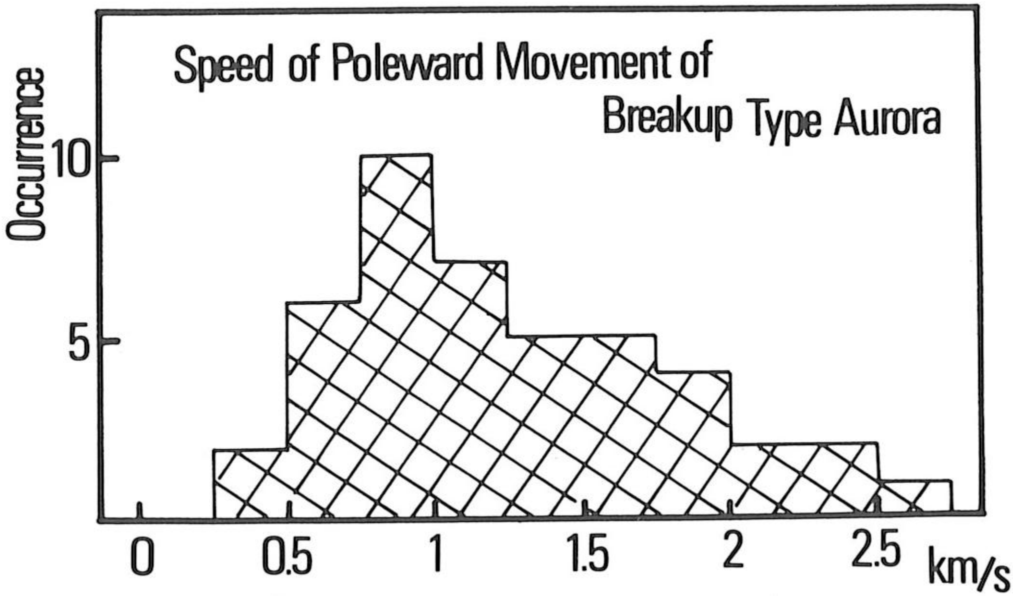


Fig. 7. Histogram of the speed of poleward movement of the breakup type aurora.

## 5. STRUCTURE OF MAGNETIC SUBSTORMS – AURORAL ELECTROJETS

Simultaneously with an electron auroral breakup, a breakup of a magnetic substorm takes place as illustrated, for example, in Fig. 4. In this figure, two sharp negative magnetic bays occurred during 20 minutes after $0^h40^m$, corresponding in time to the two intense auroral arcs passing one by one through the zenith of the magnetic observation site. Corresponding to the post-breakup phase of a comparatively long life, a broad magnetic bay of the nearly same duration is observed , and whenever a relatively intense post-breakup type aurora passes through the zenith equatorwards, the ground magnetogram shows a small corresponding peak of negative magnetic bay. The above-mentioned correspondence between the auroral substorms and the magnetic substorms holds generally with no exception throughout the examined 65 examples. It seems thus that the auroral electrojet associated with the breakup aurora has a considerably different characteristic from that of the electrojet corresponding to the post-breakup aurora.

Fig. 8 shows another example of the correlation between the auroral and magnetic substorms. It seems in this case that the onset of magnetic breakup propagates polewards together with the breakup aurora, the speed of the apparent poleward propagation of magnetic breakup being about 0.6 km/sec. Similar studies on other examples have given almost the same results. It has thus been concluded that a magnetic breakup (an onset of the initial sharp magnetic bay) of a magnetic substorm moves polewards together with the corresponding breakup aurora. The poleward movement of a sharp magnetic bay observed in the northern polar region has already been pointed out by Oguti (1969), who concluded that the average speed of poleward movement is about 0·6 km/sec. Recently, Rostoker (1971) has shown that the auroral electrojet of the Arctic magnetic substorms consists of, at least, two components; one is the poleward border peak of the electrojet which moves polewards with a growth of intensity with time, while the other is the equatorward part of the electrojet which is less intense than the poleward border peak and which remains at the initial breakup latitude and fills up the equatorside ionosphere behind the poleward moving component, thus the total width of the auroral electrojet being broadened with a growth of a magnetic substorm. In the results of Rostoker's study, the speed of the poleward movement of the poleward border peak is also 1 km/sec. in the order of magnitude. These results are in good agreement with the conclusions obtained in the present study.

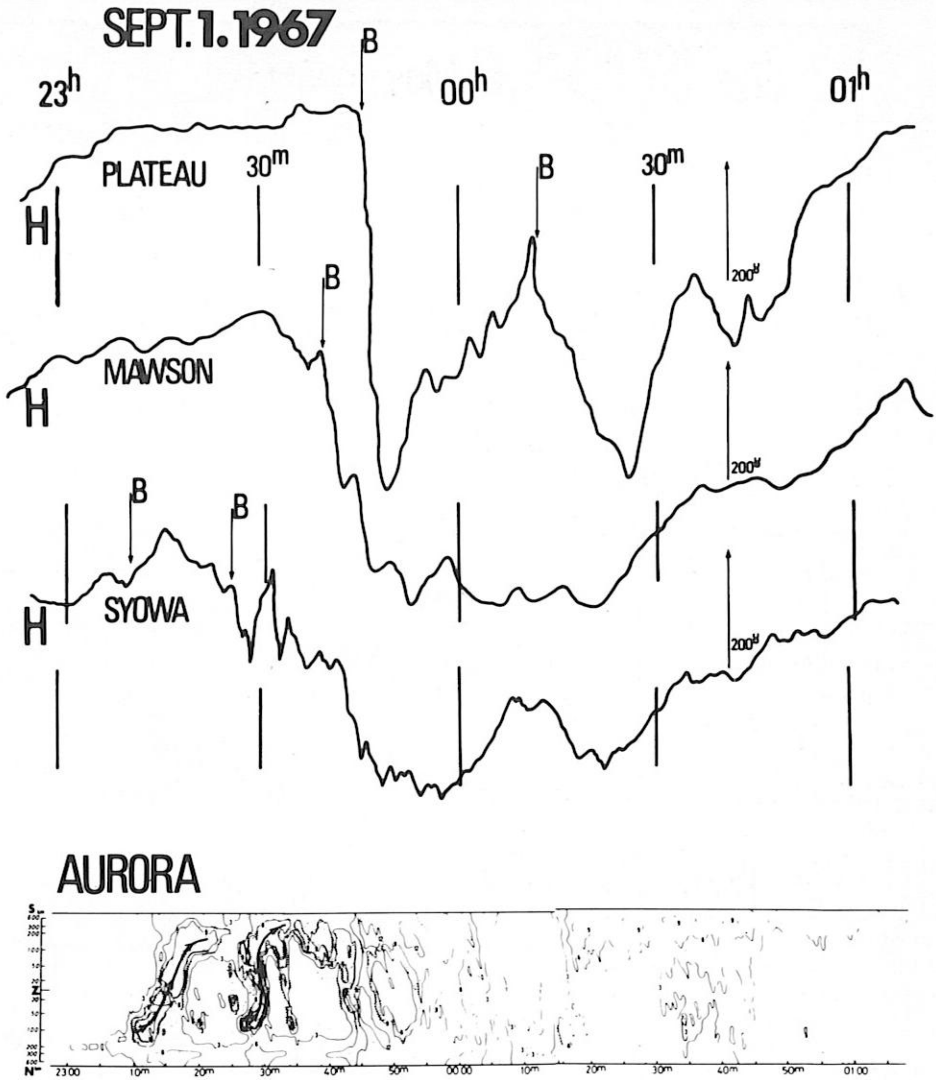



Fig. 8. Example of the poleward movement of the breakup type magnetic substorm and the meridian-time diagram of λ4278Å aurora observed at Syowa Station.

Another observed fact to suggest a difference in characteristics between the breakup electrojet and the post-breakup is as follows: Fig. 9 shows an example of the breakup and post-breakup phases of an auroral and magnetic substorm. The bottom of the figure shows changes with time of the horizontal disturbance magnetic vector of the auroral electrojet. The horizontal disturbance magnetic vector (H) considerably changes its direction during the breakup phase, while it is quietly southwards in the post-breakup phase, indicating a quasi-steady westward electrojet for the latter case. For the purpose of emphasizing this characteristic, time-changes of the horizontal geomagnetic disturbances are decomposed into the short period component (less than 10 minutes in period) and the long period one (larger than 10 minutes in period) by the numerical filtering technique.

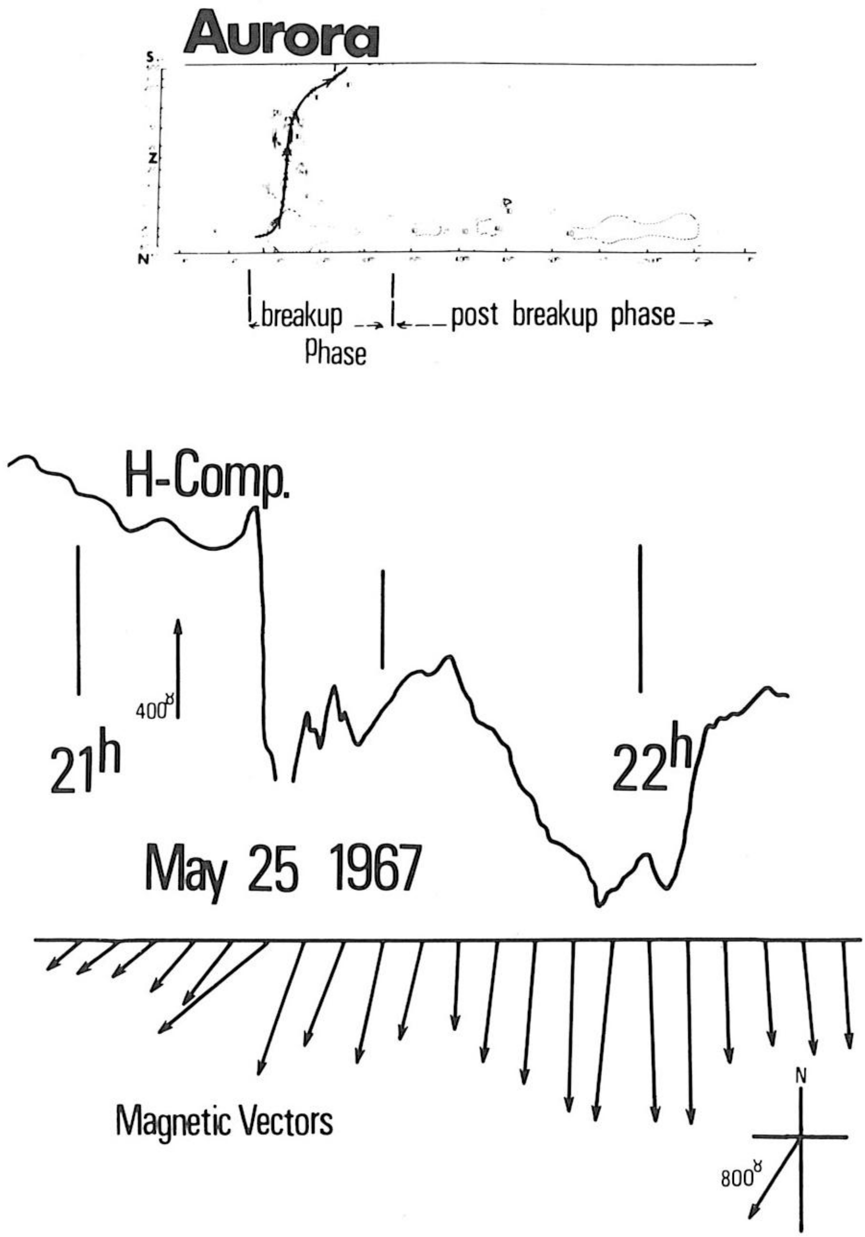



Fig. 9. Example to show different characteristics between the breakup type magnetic substorm and the post-breakup type magnetic substorm.
From the top to the bottom:
(1) Meridian-time diagram of λ4278Å aurora.
(2) Variation of geomagnetic H - component.
(3) Horizontal magnetic disturbance vectors.

As shown in Figures 10 and 11 for example, the horizontal disturbance vector of the short period component rotates either clockwise or counter clockwise with about 10 minutes in a rotation period, while that of the long period component keeps its direction practically invariant. In the breakup phase, the direction-changing short period component is dominant or at least comparable with the long period component, while the quasi-steadily directed long period is absolutely dominant in the post-breakup phase. Thus the breakup phase is characterized by the rapid change in the direction of the short period component while the post-breakup phase by the quasi-steady westward electrojet.

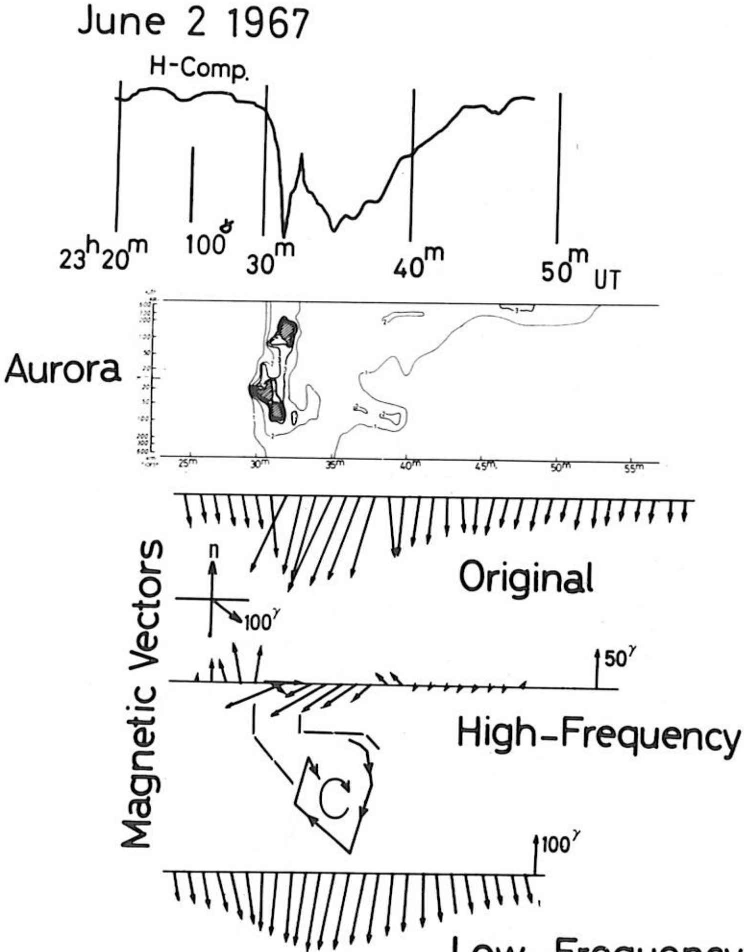



Fig. 10. Example to show characteristics of the high frequency component (period < 10 min.) and the low frequency component (period > 10 min.) of the magnetic substorm and the simultaneous meridian-time diagram of λ4278Å aurora.

From the top to the bottom:

(1) H-component of original magnetogram.
(2) Meridian-time diagram of λ4278Å aurora.
(3) Original horizontal disturbance vectors.
(4) Horizontal disturbance vectors of the high frequency component.
(5) Vector diagram of a part of (4).
(6) Horizontal disturbance vectors of the low frequency component.

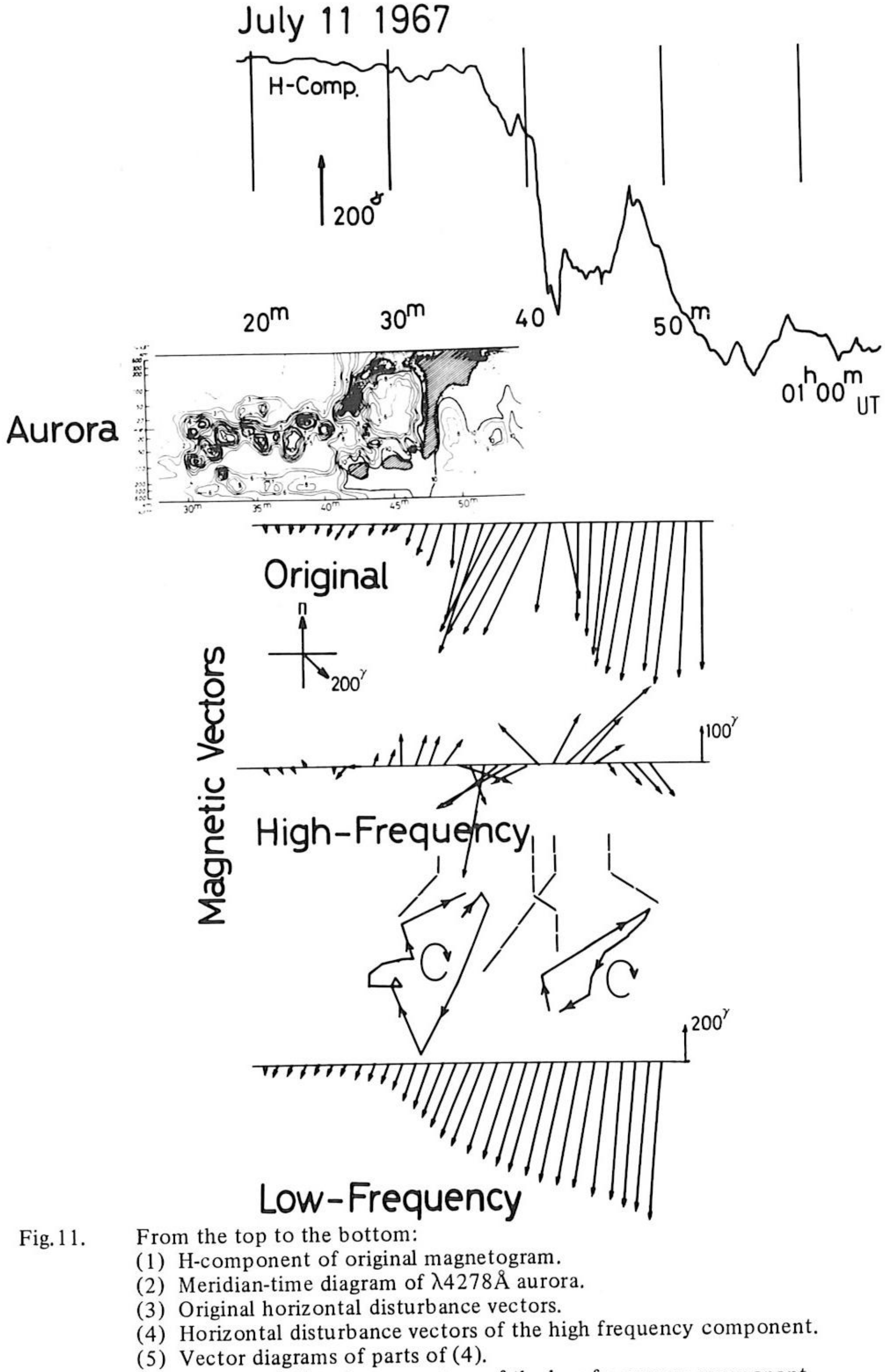



Fig. 11. From the top to the bottom:

(1) H-component of original magnetogram.
(2) Meridian-time diagram of λ4278Å aurora.
(3) Original horizontal disturbance vectors.
(4) Horizontal disturbance vectors of the high frequency component.
(5) Vector diagrams of parts of (4).
(6) Horizontal disturbance vectors of the low frequency component.

Fig. 12 shows the histogram to represent the statistical dependence of the sense of rotation of the short period horizontal disturbance vector upon the geomagnetic local time. As seen in the diagram, the counterclockwise rotation is dominant in the dusk-midnight sector while the clockwise rotation is dominant in the midnight-dawn sector. It seems very likely that the rotation of the short period horizontal disturbance vector is due to the poleward motion of the breakup auroral electrojet.

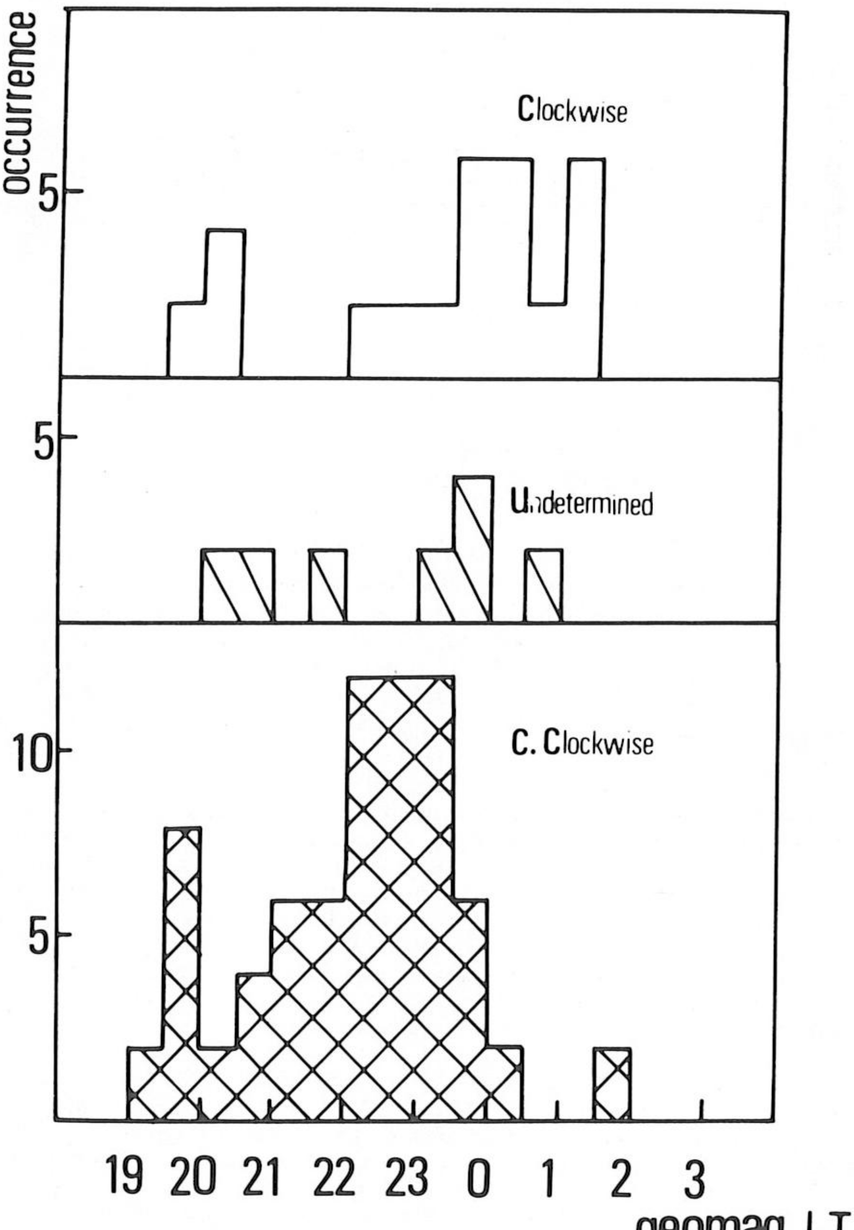



Fig.12. Histogram to show the dependence of the geomagnetic local time of the clockwise and counter-clockwise rotations of the horizontal magnetic disturbance vectors of the high frequency component.

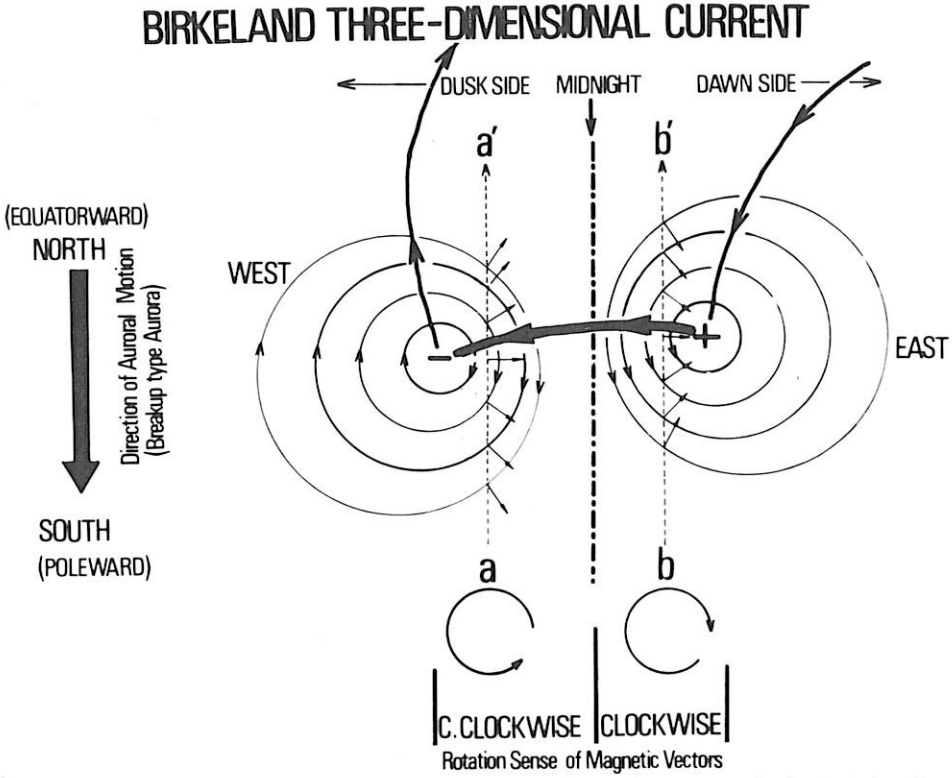



Fig.13. Schematic representation of the breakup type auroral electrojet whose poleward movement can result in the counter-clockwise and clockwise rotations of the ground horizontal disturbance vectors on the dusk and dawn sides respectively.

A simple possible interpretation of the magnetic vector rotation characteristics would be such as illustrated at the right hand side of Fig. 13, where the breakup type auroral electrojet is assumed to consist of incoming and outgoing field aligned currents and the strong horizontal westward electrojet flowing through the ionosphere (i.e., Fukushima 1969). As shown in the figure, the Hall current caused by the electrostatic charge impressed on the ionosphere by the incoming field aligned current is counterclockwise around the eastern edge of the electrojet, while that caused by the outgoing field aligned current is clockwise around the western edge of the electrojet. When the breakup type auroral electrojet moves polewards and passes through the zenith of an observing point from the equatorward side to the poleward side, a horizontal magnetic disturbance vector observed on ground between the middle and eastern edge of the electrojet rotates clockwise (in the southern polar region) as represented by arrows on b-b′ line in the figure, and that observed on ground between the middle and the western edge of the electrojet rotates counterclockwise, as shown by arrows on a-a′ line. On the other hand, the horizontal magnetic disturbance on the ground caused by the westward electrojet is continuously southwards throughout the period of the poleward motion of the electrojet, and it may considerably contribute to the quasi-steady southward magnetic disturbance of the long period. Since the breakup type auroras appear mostly around $23^h$ in local time (mostly from $19^h$ to $02^h$), the dusk and dawn sides in the auroral zone may statistically be covered by the western half and eastern half respectively of the breakup type electrojet. Thus, the statistical characteristics of the dominant counterclockwise rotation in the dusk-midnight sector and the dominant clockwise rotation in the midnight-dawn sector of the short period horizontal magnetic disturbance vector can naturally be explained.

As previously described, the post-breakup type auroral electrojet is represented mostly by a quasi-steady westward electrojet, which is accompanied by diffused surface or rayed arcs of comparatively weak auroras and which is extended across the entire width of geomagnetic meridian width which the breakup aurora has passed polewards in the breakup phase. It seems likely therefore that the post-breakup type auroral electrojet is mostly due to the Cowling current flowing through the electrically high conductive zone which is continuously ionized by the post-breakup auroral electrons. The electromotive force to drive the Cowling current would be due to the polar DP-2 field which also is intensified by the magnetospheric substorm activity, as will be discussed later (Section 8). We may thus conclude that the auroral electrojet is composed of the breakup type electrojet (AEJ-1) and the post-breakup type one (AEJ-2), whose behaviors and origins are basically different from each other.

Fig. 14 schematically illustrates the behaviors and origin of AEJ-1 and AEJ-2. On the left side, the top figure represents a composition of an elemental auroral substorm which consists of the breakup type aurora on the poleward side border and the post-breakup type aurora extending equatorwards from the edge of the breakup aurora; in actual cases, two or more elemental auroral substorms often appear successively in the midnight sector of the auroral zone, as schematically illustrated at the bottom.

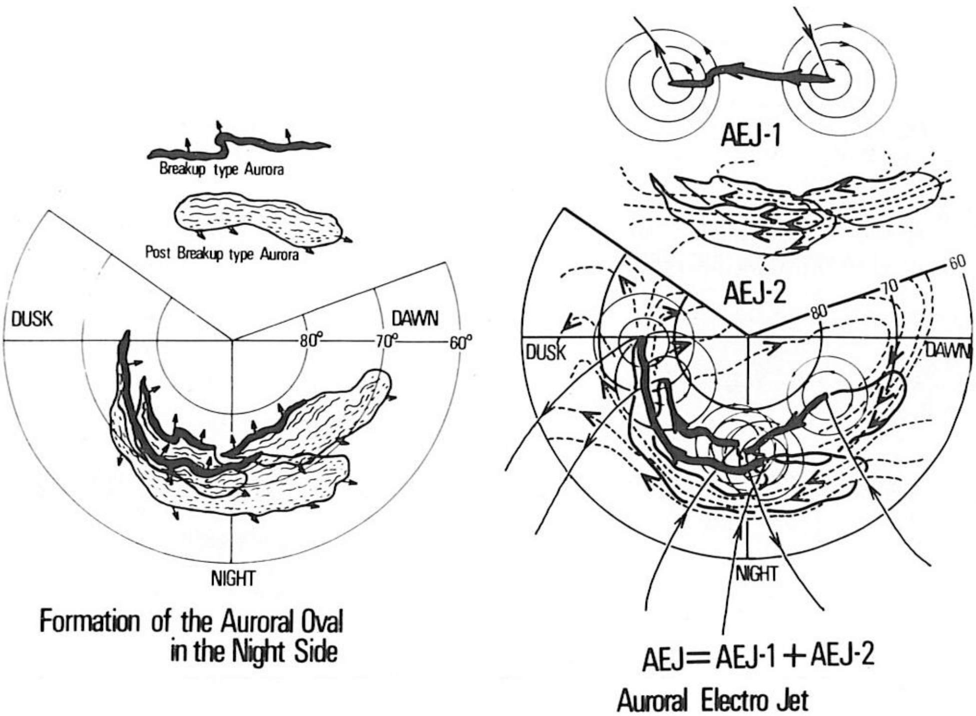



Fig.14. Schematic representation of the structure of the auroral electrojet.
The breakup type electrojet = AEJ-1.
The post-breakup type electrojet = AEJ-2.

Left top: Form and movement of a breakup type aurora.
Left middle: Form and movement of a post-breakup type aurora.
Left bottom: Structure of multi-auroras.
Right top: Electric current of AEJ-1 and field aligned current.
Right middle: Electric current of AEJ-2.
Right bottom: Electric current systems corresponding to the multi-auroras on the left side.

On the right side in the figure, the current systems of AEJ-1 and AEJ-2 which accompany the breakup and post-breakup auroras respectively are illustrated at the top, while the bottom figure represents the electric current systems which correspond to the multi-occurrence of auroral substorms shown on the left and which are responsible for magnetic substorms consisting of the three pairs of AEJ-1 and AEJ-2. (Note that Fig. 14 represents the breakup and post-breakup substorms in the northern polar region.) Summarizing these characteristics of the breakup and the post-breakup auroras with AEJ-1 and AEJ-2, one may express the structure of a polar magnetic storm by the following diagram.

| Polar Magnetic Substorm | = | AEJ-1 associated with Breakup Aurora | + | AEJ-2 associated with Post-Breakup Aurora |
|---|---|---|---|---|

## 6. VLF AND ULF EMISSIONS AND CNA ASSOCIATED WITH AURORAL AND MAGNETIC SUBSTORMS

(6-1) Auroral Hiss and Auroral Chorus

It has already been established (e.g., Morozumi 1965, 1967; Harang *et al*, 1967) that the emissions of the *auroral VLF* hiss are associated with the breakup phase of the auroral and magnetic substorm. Fig. 15 shows an example of a high correlation between the luminosity of λ4278Å aurora and the intensities of auroral VLF hisses of 40,60 and 80 $KH_z$ in frequency. Figures 16 and 17 also show examples of VLF hiss (4 $KH_z$ and 12$KH_z$ bands) whose strong emissions are associated only with the breakup phase of the auroral and magnetic substorms. It must be emphasized here that the auroral VLF hiss emissions occur only with the breakup phase of the electron aurora, and not with the breakup of the proton aurora; definitely suggesting that the auroral VLF hiss is caused by precipitating electrons.

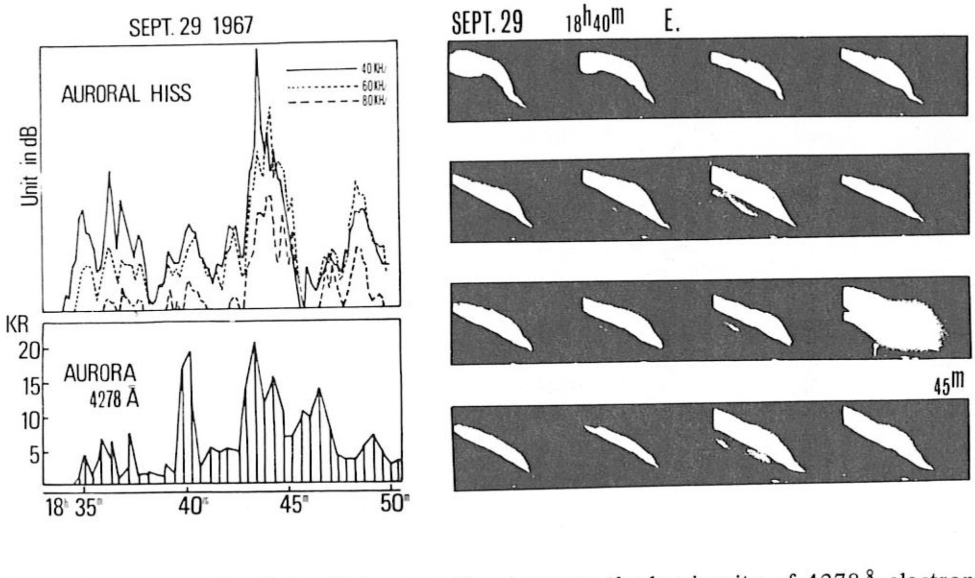



Fig. 15 Example of the high correlation between the luminosity of 4278Å electron aurora and the intensity of auroral VLF hiss of 40, 60, and 80 KHZ bands.

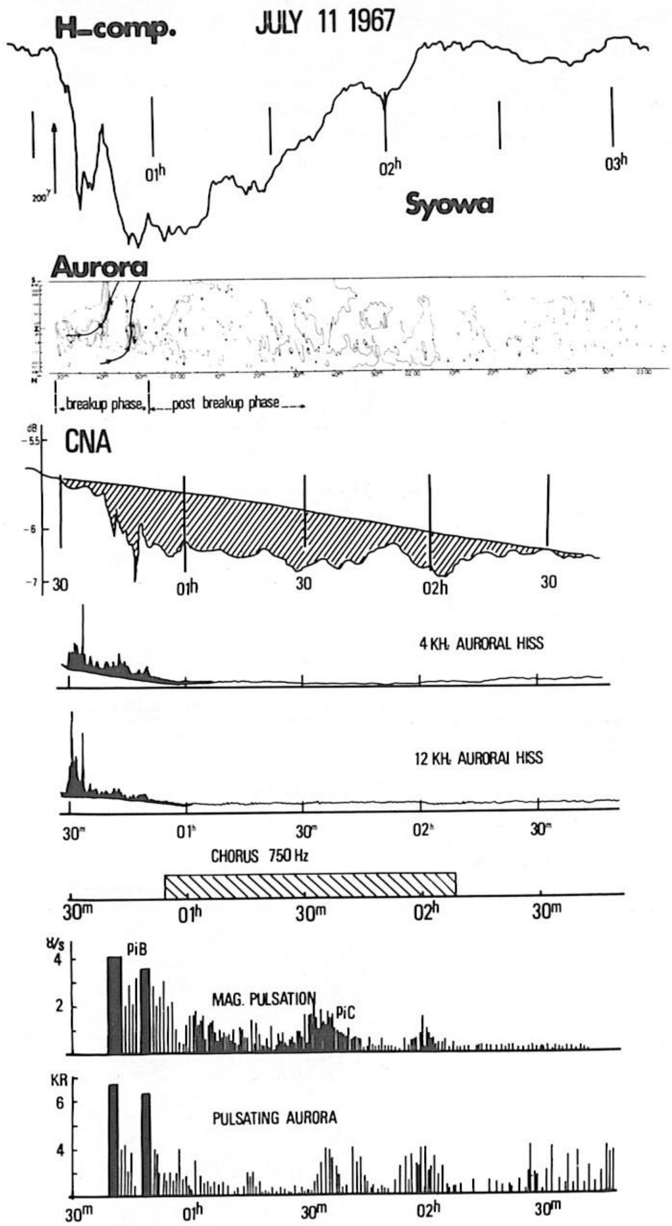



Fig.16. Auroral and magnetic substorms and associated phenomena. From the top to the bottom:

(1) H-component of magnetogram.
(2) Meridian-time diagram of $\lambda 4278$ Å aurora.
(3) Cosmic noise absorption (CNA).
(4) Intensity of VLF hiss emission (f = 4 KHz).
(5) Intensity of VLF hiss emission (f = 12 KHz).
(6) Approximate intensity of VLF chorus (f = 750 Hz).
(7) Amplitude of magnetic pulsation.
(8) Amplitude of auroral pulsation in the zenith.
(All observed at Syowa Station.)

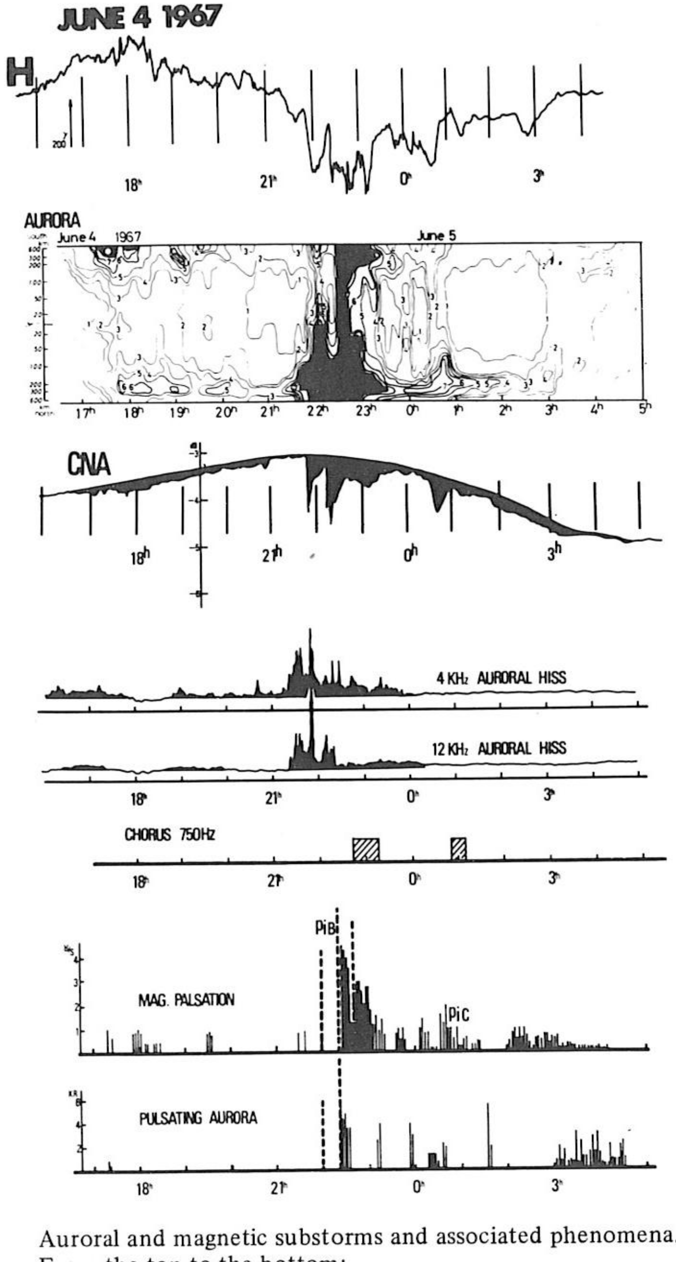



Fig. 17 Auroral and magnetic substorms and associated phenomena. From the top to the bottom:

(1) H-component of magnetogram.
(2) Meridian-time diagram of λ4278Å aurora.
(3) Cosmic noise absorption (CNA).
(4) Intensity of VLF hiss emission (f = 4 $KH_z$).
(5) Intensity of VLF hiss emission (f = 12 $KH_z$).
(6) Approximate intensity of VLF chorus (f = 750 $H_z$).
(7) Amplitude of magnetic pulsation
(8) Amplitude of auroral pulsation in the zenith.
(All observed at Syowa Station.)

As for the VLF chorus observed at Syowa Station, an extensive report has already been published (Kokubun *et al,* 1969), dealing mostly with the polar chorus which is emitted in the daytime sector in high latitudes. As observed in Figures 16 and 17, however, the post-breakup auroras in the midnight sector are almost always accompanied by the VLF emissions of the chorus type. This type of VLF chorus emitted in the night sector was noted by Morozumi (1965) and Morozumi and Helliwell (1966), and its characteristics have recently been studied in detail by Hayashi and Kokubun, it being called by them the *auroral chorus.* The dynamic spectrum of the auroral chorus consists of fine discrete-risers of 0.1 ~ 0.3 seconds in duration and a very weak hiss background. The duration time of a group of these risers is usually several seconds, and such groups of risers take place intermittently with a time interval from several to 10 seconds. A remarkable difference of the auroral chorus from the auroral hiss is in regard to their relationship with the auroral breakup: the auroral hiss always takes place simultaneously with the breakup of electron aurora, while the occurrence of the auroral chorus has a systematic time delay from the breakup phase of substorm, depending on local geomagnetic time. The result of a statistical study on the time lag of an occurrence of auroral chorus from the electron aurora breakup seems to suggest that the emission source of high energy electrons for the auroral chorus is drifting eastwards with speed of about 800 m/sec. from the electron aurora breakup area.

### (6-2) CNA (the Ionospheric Substorm)

The breakup phase is associated simultaneously with a sharp cosmic noise absorption (CNA) phenomenon, as shown in Figures 16 and 17. The post-breakup phase also is accompanied by the CNA phenomenon of smaller magnitude, and each intensification of the post-breakup aurora and the corresponding peak of the post-breakup magnetic bay correspond to a peak of the post-breakup CNA, as illustrated in the figures.

Studies on the auroral CNA phenomena have been fairly extensively conducted for the Arctic substorms, and their results are well summarized by Akasofu (1968) under the subject of "ionospheric substorm." The auroral CNA phenomena in the Antartica have essentially the same characteristics as those in the Arctic. The auroral CNA phenomena have been classified into (a) *N-type CNA* which is characterized by a sharp onset and a poleward movement, (b) *E-type CNA* which is related to the so-called westward travelling surge of aurora, and (c) *M-type CNA* which is related to the eastward drifting bands or patches of aurora. The N-type CNA is so closely associated with the auroral and magnetic breakups that it is undoubtedly a result of the strong ionization of the ionosphere by precipitating electrons which are responsible for the sharp onset of the breakup aurora, and for the auroral VLF hiss emissions. It is very likely, on the other hand, that the M-type CNA is closely related to the post-breakup phase and the auroral VLF chorus emissions. It seems however that the ionospheric substorms must be more extensively studied with a reasonably good network of CNA observations in the future in the Antarctic region.

### 6-3 Auroral ULF Emissions

The magnetic micropulsations (ULF emissions) of Pi types are also associated with the auroral and magnetic substorms. Fig. 18 shows an example of the simultaneous records of an onset of magnetic substorm breakup and an enhancement of the ULF emissions in the horizontal N-S component. As pointed out by Heacock (1967), the wave forms of irregular ULF emissions associated with the breakup phase are clearly different from those in the post-breakup phase. Adopting Heacock's terminology, Pi-bursts (PiB in Fig. 18) are emitted in the breakup phase while PiC pulsations are emitted in the post-breakup phase, as illustrated in Figures 16, 17 and 18. Particularly in Fig. 16, two bursts of PiB take place separately in simultaneous correspondence to each of two auroral breakups.

The wave form of PiB type ULF can be characterized by its apparently long period and large burst-like amplitude so that it belongs to Pi-2 category in the IAGA official classification. On the other hand, the wave form of PiC type ULF can be represented by

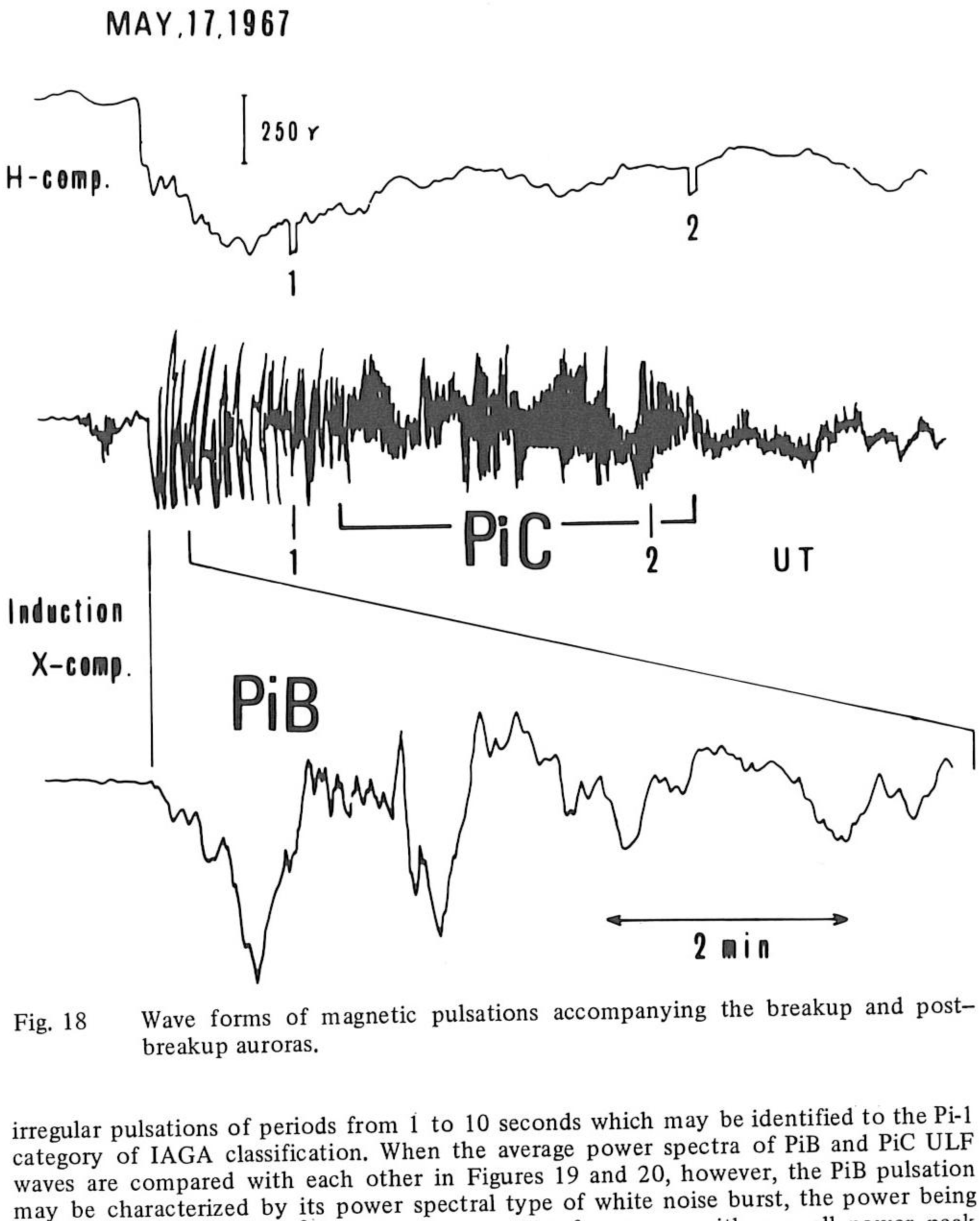



Fig. 18 Wave forms of magnetic pulsations accompanying the breakup and post–breakup auroras.

irregular pulsations of periods from 1 to 10 seconds which may be identified to the Pi-1 category of IAGA classification. When the average power spectra of PiB and PiC ULF waves are compared with each other in Figures 19 and 20, however, the PiB pulsation may be characterized by its power spectral type of white noise burst, the power being almost proportional to $f^{-2}$ where f denotes the frequency, with a small power peak around 5 seconds in period, while the PiC pulsation can be represented by a dominant power peak around 10 seconds in period. In other words, the PiB type ULF is mostly a white noise burst, while the PiC type ULF is characterized by a rather periodic wave of about 10 seconds in period.

It has been concluded in comparison of the auroral ULF emissions with the auroral substorms from 56 examples that the PiB pulsations associate only the breakup aurora and the breakup geomagnetic bay, while PiC pulsations are closely related to the post-breakup auroras and magnetic bays, and changes of amplitude of PiC pulsations are approximately parallel to those of the zenith auroral luminosity, negative peaks in the north component geomagnetic bay and CNA.

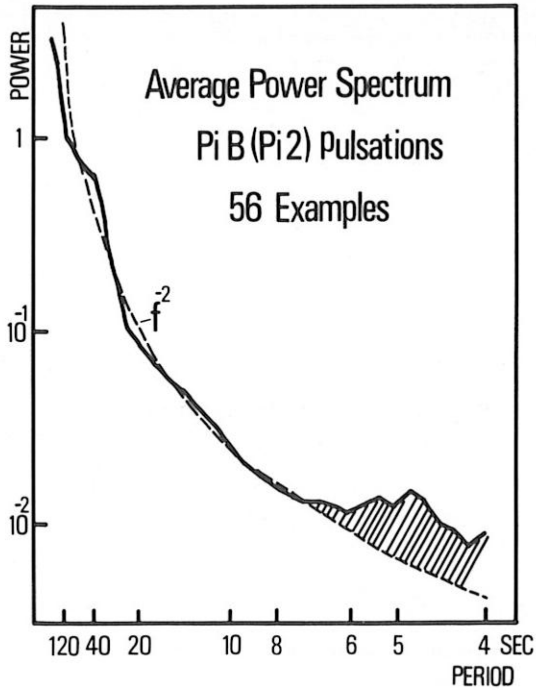



Fig. 19 Power spectrum of magnetic pulsation of PiB type which is in association with the post-breakup phase of substorm.

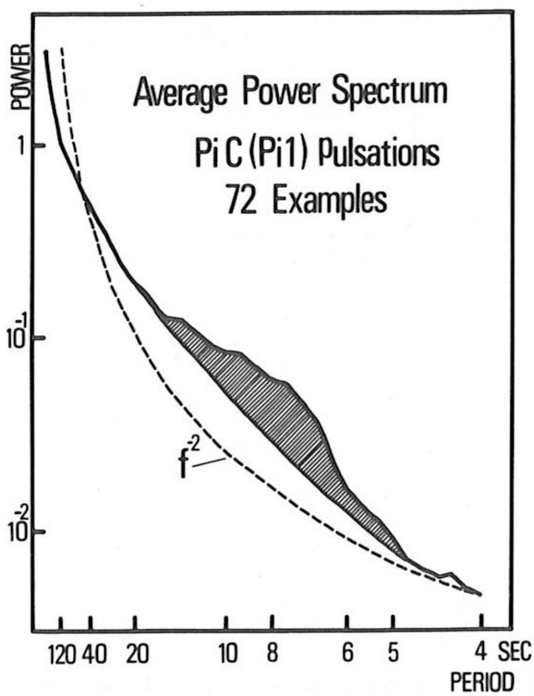



Fig. 20 Power spectrum of magnetic pulsation of PiC type which is in association with the post-breakup phase of substorm.

### (6-4) Auroral Pulsations

At the bottoms of Figures 16 and 17, the auroral pulsations observed with the λ4278Å zenith auroral photometer for special observation of rapid variation (a2 instrument in Section 1) are shown. The pulsations of zenith λ4278Å aurora change their types (periods) and amplitudes approximately in parallel to the magnetic pulsations in most cases but not always. As seen, for example, in the parallel records from $17^h$ to $21^h$ in Fig 17, magnetic perturbations, weak VLF hiss and PiC type magnetic pulsations can be emitted from the auroral activities which are not located in the very neighborhood of the observing point but in either poleward or equatorward sides of a fair distance. No enhancement of λ4278Å aurora nor pulsating aurora were observed in the zenith for this period. As shown in parallel records around $01^h30^m$ and $02^h$ in Fig. 16, on the other hand, the zenith auroral pulsations can correspond to the magnetic pulsations, negative peaks in geomagnetic bay and CNA peaks when the auroral substorm activities (the post-breakup type activities in this case) are located near the zenith.

### (6-5) Overall Morphology Of The Polar Substorms

In Fig. 21, simultaneous data of the meridian-time diagram of the electron auroral substorm, the magnetic substorm, the auroral CNA phenomenon, the auroral VLF hiss, the auroral VLF chorus, the auroral geomagnetic pulsations (ULF emissions) and the zenith luminosity of aurora are schematically summarized. These are the representative modes of variations in respective phenomena observed at a station in the southern auroral zone. At the top of the figure, the geomagnetic variations observable at a station in higher latitudes are schematically shown. The meridian-time diagram of electron aurora (λ4728Å aurora) covers the auroral activities not only in the neighborhood of the observing station but also in higher and lower latitudes less than 600 km in distance from the station.

With respect to the auroral substorms near the zenith area and the associated phenomena, one may summarize the conclusions of the foregoing discussions from Section 3 through Section 6 by the following table.

| *Phase of auroral substorm* / *associated phenomena* | *Breakup Phase aurora* | *Post-Breakup Phase Aurora* |
|---|---|---|
| Geomagnetism | Sharp breakup type bay | Broad post-breakup type bay |
| ULF | PiB emission | PiC emission |
| VLF | Auroral hiss | Auroral chorus |
| Ionosphere | Sharp CNA (N-type) | Broad CNA (M-type) |

As shown in Fig. 21, auroral breakups at a higher latitude, which are frequently observable at the poleward horizon in the meridian-time diagram of aurora, are accompanied by the breakup type magnetic substorms at the higher latitude. However, the VLF hiss and the geomagnetic pulsations emitted by the higher latitude substorms can be observed at the station which we are concerned with. The figure further shows that only the post-breakup auroras and the associated broad geomagnetic bay, broad CNA's, VLF chorus, PiC pulsations and auroral pulsations are observable at our station when the breakup auroras take place at higher latitudes.

## 7. CONJUGATE RELATIONSHIP OF POLAR SUBSTORMS

The geomagnetically conjugate relationship between Austral and Boreal auroras has recently been studied in detail by Belon *et al* (1967, 1969) and Davis (1971). One of the most interesting results obtained recently by Davis is that the bright auroral arcs of the breakup type in the beginning stage of an intense auroral activity are almost exactly subjected to the geomagnetically conjugate relationship between the Arctic and the Antarctic, while the locations of the broader auroras in the later stage in the North and the South are deviated by several hundred kilometers from their geomagnetic conjugacy. The reported characteristics of the conjugate pairs of the bright auroral arcs, which move polewards, are essentially identical to those of the breakup phase of auroral substorms summarized in the present report. It may therefore be considered that, in case of the

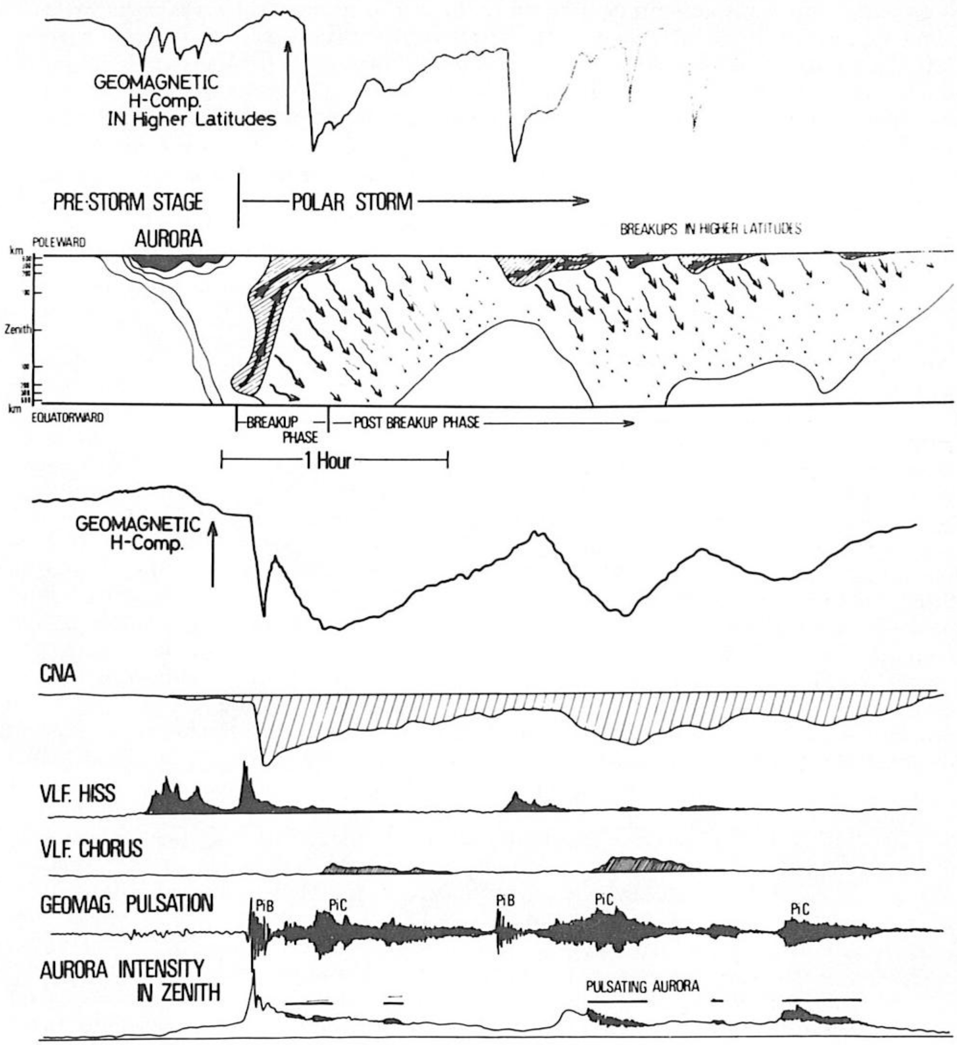



Fig. 21 Schematic summary of polar substorms and associated phenomena.
From the top to the bottom:

(1) H-component of magnetogram at higher latitudes.
(2) Meridian-time diagram of λ4278Å auroras.
(3) H-component of magnetogram at the same station as (2).
(4) CNA observed at the same station as (2).
(5) Intensity of auroral VLF hiss observed at the same station as (2).
(6) Intensity of VLF chorus observed at the same station as (2).
(7) Magnetic pulsations (ULF emission) observed at the same station as (2).
(8) Intensity of aurora at the zenith of the same station as (2).

breakup aurora, large fluxes of auroral electrons precipitate along the same lines of geomagnetic force towards both the northern and southern polar ionospheres. The observed deviation from the geomagnetic conjugacy for the weaker and broader auroras in the later stage would be due either to possible distortions of the line configuration of geomagnetic force caused by the preceding breakup of the magnetospheric (and polar) substorm, or to individual eastward drifts of high energy electrons.

A similar discrepancy between the breakup type magnetic bay and the post-breakup type in regard to the geomagnetic conjugacy has also been noticed in comparison of Syowa Station magnetograms with those at Reykjavik (geomag. lat. = 66.7°, geomag. long. = 71.2°) which is a very good conjugate point of Syowa Station (Nagata *et al.*, 1966). The correlation coefficient of X-component of geomagnetic variation between Syowa Station and Reykjavik is always larger than 0.9 for the breakup magnetic bays, but it is less than 0.8, ranging form 0.6 to 0.8, for the post-breakup type magnetic bays.

## 8. GROWTH PHASE OF POLAR SUBSTORMS

A time sequence of an auroral substorm phenomenon is divided by Akasofu (1968) into three phases; namely, (i) the pre-breakup phase, (ii) the breakup phase and (iii) the post-breakup phase. The results of the present studies on the Austral substorms strongly support Akasofu's concepts of the breakup and post-breakup phases. As shown in Figures 5 and 6, the auroral breakup phase is almost always preceded by an apparent pre-breakup phase phenomenon which is represented by the equatorward expansion of weak and patchy auroras before an onset of the breakup phases of an electron aurora substorm. The characteristic of the apparent pre-breakup phase is in agreement with Akasofu's definition of the pre-breakup phase. As schematically shown in Fig. 21, however, an auroral breakup associated with a breakup type magnetic bay and auroral VLF hiss emissions was frequently observed at a higher latitude before the auroral breakup observed at the auroral zone station. In such a case, the apparent pre-breakup phase could be identified to the equatorward moving post-breakup phase of a breakup aurora which took place previously at a higher latitude. One might say, then, that an intense auroral breakup at the auroral zone latitude is statistically preceded by a smaller auroral breakup at higher latitudes. Actually, Oguti (1969) has shown that the magnetic substorm breakup in the midnight sector is preceded by precursory magnetic perturbations which start in high latitudes (about 80° in geomagnetic latitude) in the midday sector 20 or 30 minutes before the substorm onset in the midnight sector, and the precursory perturbations propagate towards the midnight auroral zone. Unfortunately, however, the existing networks of the auroral observations in the polar regions are not sufficiently dense to definitely identify the suggested pre-breakup phase or the precursory disturbance in the auroral substorms. This problem seems to deserve extensive studies in the future.

Even if the definite observational identification of the pre-breakup phase of the polar substorms has not yet been sufficiently achieved, several precursory magnetospheric phenomena have been found in advance of the breakup phase of the polar substorms. For example, the southward orientation of the solar wind magnetic field has been pointed out by a number of investigators as the primary cause of the magnetospheric substorm and consequently that of the polar substorm. Ness (1971) has recently shown a definite statistical conclusion that the northward magnetic field in the solar wind begins to decrease about 2 hours before an onset of a polar magnetic storm and the field direction is kept reversed since about one hour before sunset. Nagata and Iijima (1970) have reported that, after the southward reversal of the solar wind magnetic field, (a) the polar two-vortex current system (DP-2 field) is gradually enhanced, indicating a growth of the magnetospheric convection of the low energy plasma, and (b) the Dst-field and its asymmetric feature also grows, indicating a growth of the equatorial asymmetric belt of the energetic plasma. This phase in the magnetosphere to prepare for a breakup of the polar substorm (auroral and magnetic) has been called the *growth phase* of the polar substorm. Fig. 22 shows an example of the polar equivalent current systems before and after a breakup of a polar magnetic substorm; in the growth phase on the left, the polar two-vortex current system (DP-2 field) is considerably strengthened, and in the expansion phase (which covers the breakup phase and the initial part of the post-breakup phase) on

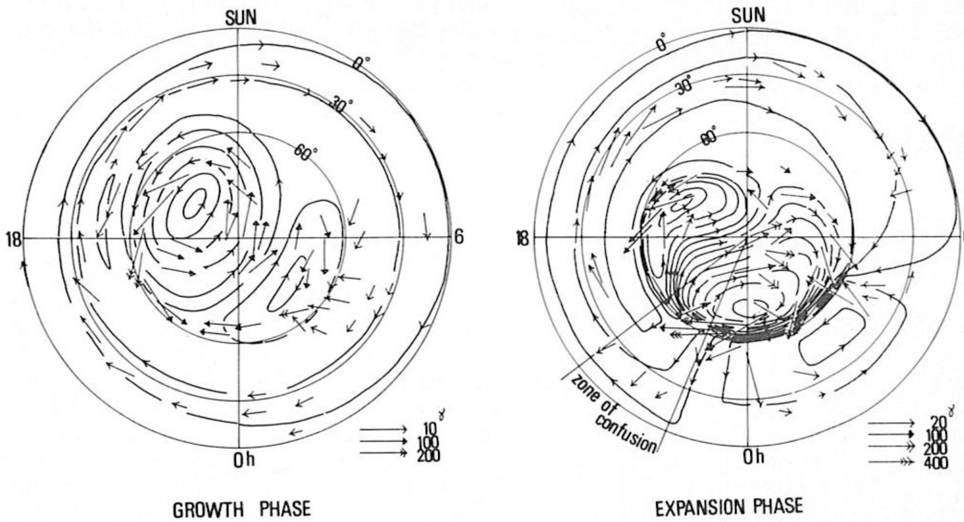



Fig. 22 Polar equivalent current systems in the growth and expansion phases of a polar substorm.
Left: Intensified DP-2 field in the growth phase (before the auroral breakup).
Right: Intensified DP-2 field superposed by AEJ field in the expansion phase (after the auroral breakup).

the right an intense auroral electrojet current system (AEJ-field) comes out in addition to the intensified DP-2 field.

The strength of DP-2 field can be represented by the intensity of the parallel equivalent current in the vicinity of the center of the polar cap or its resultant magnetic field, namely the polar cap magnetic variation field (PCN). At the top of Fig. 23, an example of time changes of Austral PCM and Boreal PCM before and after a breakup of polar substorm is illustrated. AU and AL indices (Davis and Sugiura 1966) which have been derived from 10 magnetogram data in the auroral zone, shown in the second diagram in Fig. 23, can represent the activity of the auroral electrojet. An abrupt increase of the negative value of AL index represents an onset of the breakup of a polar magnetic substorm (i.e., a sharp negative bay). It is clearly seen in Fig. 23 that PCM begins to gradually increase about 2 hours before the breakup of a polar substorm. The increased intensity of PCM in the expansion phase is partly due to the return current of the auroral electrojet represented by AL index.

The third diagram in Fig. 23 represents the intensity of the symmetric Dst field and the amplitude and the phase of a superposing asymmetric component of the ring current, which are derived from 8 low latitude magnetograms; the northward component of the disturbance geomagnetic field $D(t,\lambda)$ at t in time and $\lambda$ in longitude in low latitudes is approximated by

$$D(t, \lambda) = D_{st}(t) + C_1(t) \sin(\lambda + \epsilon_1) \quad ,$$

where Dst, $C_1$ and $\epsilon$ are named Dst, first harmonic and phase respectively in Fig. 23. As shown in the figure, the Dst - component, whose negative value represents the westward ring currents, begins to grow up about one hour before the substorm breakup. The asymmetric component, $C_1(t)$, begins to gradually increase at approximately the same time when the DP-2 field starts to increase, namely about 2 hours before the breakup. In

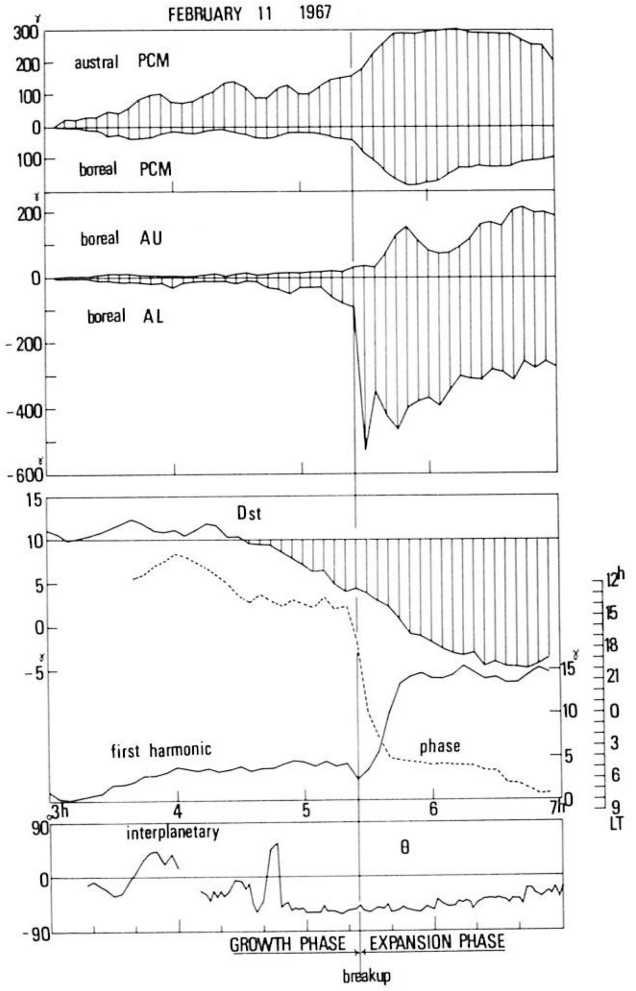



Fig. 23 Example to show the precursory phenomena for a breakup of polar substorm in the growth phase.

From the top to the bottom:

(1) Austral PCM to represent the strength of DP-2 field in the southern polar cap.

(2) Boreal PCM to represent the strength of DP-2 field in the northern polar cap.

(3) Boreal AU index which represents the positive magnetic bays in the northern polar region.

(4) Boreal AL index which represents the negative magnetic bays in the northern polar region.

(5) Dst field which represents the symmetric component of the equatorial ring current.

(6) Amplitude and phase of the first harmonic of the asymmetric component of the equatorial ring current, where phase = $12^h$ means the southward maximum of the asymmetric magnetic field at midnight.

(7) Direction of the interplanetary magnetic field where +90 and -90 represent the northward and southward fields respectively.

the growth phase, the phase of the asymmetric component of the ring current is kept approximately around $12^h$ in local time: that is, the westward ring current is enhanced in the midnight sector and reduced in the midday (sunward) sector. Summarizing these characteristics of the equatorial ring current in the growth phase, it may be said that the equatorial westward current is gradually intensified, particularly in the midnight sector, one or two hours in advance of a breakup of polar substorm.

After the breakup, Dst still increases and $C_1$ abruptly increases while the phase is almost reversed, thus the equatorial westward current becoming markedly reduced in the midnight sector and markedly intensified in the sunward sector in the expansion phase. This expansion phase structure of the equatorial ring current indicates that the electric current circuit is almost cut off in the midnight sector. Combining the structure of the auroral electrojet described in Section 5 with this result, it may naturally be concluded, as Akasofu has suggested (1969), that the electric current in the magnetosphere makes a new closed circuit through the field aligned current and the auroral electrojet in the polar ionosphere in the midnight sector in the expansion phase. At the bottom of Fig. 23, the direction of the interplanetary magnetic field observed on Explorer 33 is shown, where $+90^\circ$ and $-90^\circ$ represent the northward and southward directions respectively. As already well known and summarized by Ness, the interplanetary magnetic field direction has been kept southwards since one or two hours before the breakup of a polar substorm.

The above-mentioned precursory phenomena for the substorm breakup, i.e., the growth of DP-2 field and the growth of the asymmetric ring current, are generally observed in a number of other analyzed data also (Iijima and Nagata, 1971).

## 9. CONCLUDING REMARKS

Many characteristics of the Austral substorms (auroral and magnetic) are substantially the same as those of the Boreal substorms which have been studied by a large number of workers. Particularly, a full agreement is obtained between Arctic and Antarctic substorms in regard to the breakup and post-breakup phases. In addition, new techniques of the tilting-filter scanning photometer and the multicolor scanning photometer have been developed for studying the morphology of Austral auroras in detail, and the meridian-time diagrams of H$\beta$, $\lambda$4278Å and $\lambda$5577Å auroras are newly introduced in the present report. Thus, the space-time distribution of the proton auroras can now be observed separately from that of the electron auroras. It has been confirmed then that the typical polar magnetic substorms in the midnight sector, which are characterized as sharp magnetic bays, are associated only with the electron-auroral substorms.

The breakup phase of the electron aurora is strongly characterized by the poleward movement of the intense auroral arc or band with 1 km/sec. in the average speed during the main stage ($B_2$ stage), and this poleward movement of the breakup aurora is accompanied by a poleward movement of a sharp magnetic bay of the breakup type. Further, the breakup phase of auroral and magnetic substorm is simultaneously accompanied by burst-type emissions of VLF hiss and PiB type emissions of ULF, which are caused by precipitating auroral electrons.

On the other hand, the post-breakup phase of the electron aurora is characterized by patchy and weaker auroras which generally expand equatorwards, and the associated post-breakup phase of the polar magnetic substorm is represented by a quasi-steady westward electrojet of a longer life, which is broader in the meridianal width and which results in observed broad negative bays. No appreciable VLF hiss is associated with the post-breakup phase, and ULF emissions caused by the post-breakup phase electrons are of the PiC type, which are associated with the auroral pulsations of the same period.

It is concluded thus that the auroral electrojet (AEJ) which is responsible for the polar magnetic substorm consists of two components: namely, AEJ-1 which moves polewards together with the breakup phase aurora in the main stage, and AEJ-2 which is the quasi-steady westward jet current fulfilling the remaining path of the breakup aurora which has passed away polewards. AEJ-1 shows evidence that this electrojet is caused by the incoming and out-field aligned currents which connect the earth's polar ionosphere and the outer magnetosphere. On the contrary, the comparatively quiet and steady AEJ-2 seems to be derived mostly by the intensified DP-2 electric field through the high conductive electrojet belt which is still continuously ionized by the post-breakup type auroral electrons.

About two hours before an onset of the breakup of auroral and magnetic substorms, the interplanetary magnetic field changes its direction for two hours or more. The field line connection between the geomagnetic field and the southward solar wind field seems to result in intensifying the magnetospheric convections of the low energy plasma, or in other words, to make the solar wind electric field penetrate into the magnetosphere. As a result of this effect, the polar two-vortex current system (DP-2 field) is gradually intensified during the growth phase of the polar substorm. At the same time, the asymmetric equatorial ring current of high energy plasma grows up with the progress of the growth phase, resulting in no appreciable current in the sunward sector but a considerably strong westward current in the midnight sector.

A trigger effect to break down the growing precursory stage of the growth phase seems to be due to the earthward invasion of the plasma from the plasma sheet which is thinned by the electric field penetrating into the geomagnetic tail, as suggested, for example, by Hones and others (1970). As suggested, the plasma gas invading into the ring current belt from the plasma sheets may cut off the intensified ring current in the midnight sector, thus the in-coming and out-going field aligned currents and AEJ-1 in the polar ionosphere forming a new electric current circuit. This would be the breakup phase of auroral and magnetic substorm. Fig. 23 in the present report clearly shows that the ring current in the midnight sector diminishes or disappears with an onset of the breakup phase of the polar substorm.

It has been hopefully planned in Antarctica that analyses of energy spectra of precipitating auroral electrons and protons will be continuously carried out with the aid of the H$\beta$ tilting-filter scanning photometer as well as the multicolor scanning auroral photometer, and that direct measurements of auroral electrons and protons by means of the rocket-borne probes will be regularly carried out on a routine basis at Syowa Station.

In writing this report, I am much indebted to my colleagues in Tokyo, T. Oguti, S. Kokubun, T. Hirasawa, E. Kaneda, H. Fukunishi and K. Hayashi who spent a long time at Syowa Station in Antarctica to carry on extensive observations of the Austral substorm phenomena and also to T. Iijima who made various analyses of the northern substorms at my disposal. My thanks are due also to Miss J. Sitko for her help throughout the course of preparing this report.

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# ORIGIN OF THE GEOMAGNETIC FIELD AND ITS SECULAR CHANGE

A Scientific Paper by
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## OSCILLATION SPECTRUM OF THE TERRESTRIAL DYNAMO

The origin of the main geomagnetic field and the origin of its secular variations should be treated together. There are two reasons for this: the first–terrestrial hydromagnetic dynamo (HD) is essentially non-stationary; and the second–it is just the study of secular variations that provides the main body of information on the dynamo of the earth.

The terrestrial dynamo is a complicated auto-oscillating system. Investigations of geomagnetic variations show that the so-called "constant field" varies with time in a fairly complicated fashion. Theoretical study of HD also reveals several possible oscillation mechanisms. Both experiment and theory indicate that the spectrum of these oscillations contains three markedly different frequencies:

1) the fundamental frequency, corresponding to a period approximately $9 \times 10^3$ years;

2) a number of oscillations of "medium" frequencies, corresponding to a period of $\sim 10^3$ years (period of the westward drift);

3) high-frequency oscillations with periods of $\sim 10^2$ years or less.

Along with distinct frequencies, which form a line spectrum, HD oscillation also contains a random component of the noise type, i.e., continuous spectrum. Besides, the behavior of the HD during periods very long in geological scale shows some specific features, of which quick changes of the main field polarity is the most prominent one.

Fig. 1 shows a schematic picture of the spectrum of geomagnetic field variations.

The above complex temporal behavior should obtain a quantitative explanation by the HD theory–such that the number of measurable values exceeds that of the parameters in the theory. Only in this case can the HD theory be a theory and not just the hypothesis of magnetohydrodynamic origin of the main geomagnetic field.

## THE GOAL OF THE THEORY OF THE EARTH'S DYNAMO

The principal possibility of the field (roughly resembling that of the earth) generated by a HD has been demonstrated by the kinematic theory of the HD. This theory admits, however, an arbitrary choice of velocities. In order to eliminate this arbitrariness all respective forces and specific causes of the convective motions should be taken into consideration which requires a hydromagnetic theory of the HD.

It should be emphasized that the hydromagnetic theory widely differs in its goal from the kinematic one. Today we are not concerned with the demonstration of the possibility of the HD being created by some probable forces: this is now beyond any doubt. Since Cowling (1934) established his famous theorem and Bullard and Gellman (1954) constructed the first model of the terrestrial dynamo, which has served as a prototype for further models, the kinematic theory has gone a long way. Namely, many motions of very different natures capable of generating a field have been analyzed, and though there are no general theorems on the possibility of the HD, known examples make us sure that almost any motion which is not too symmetrical

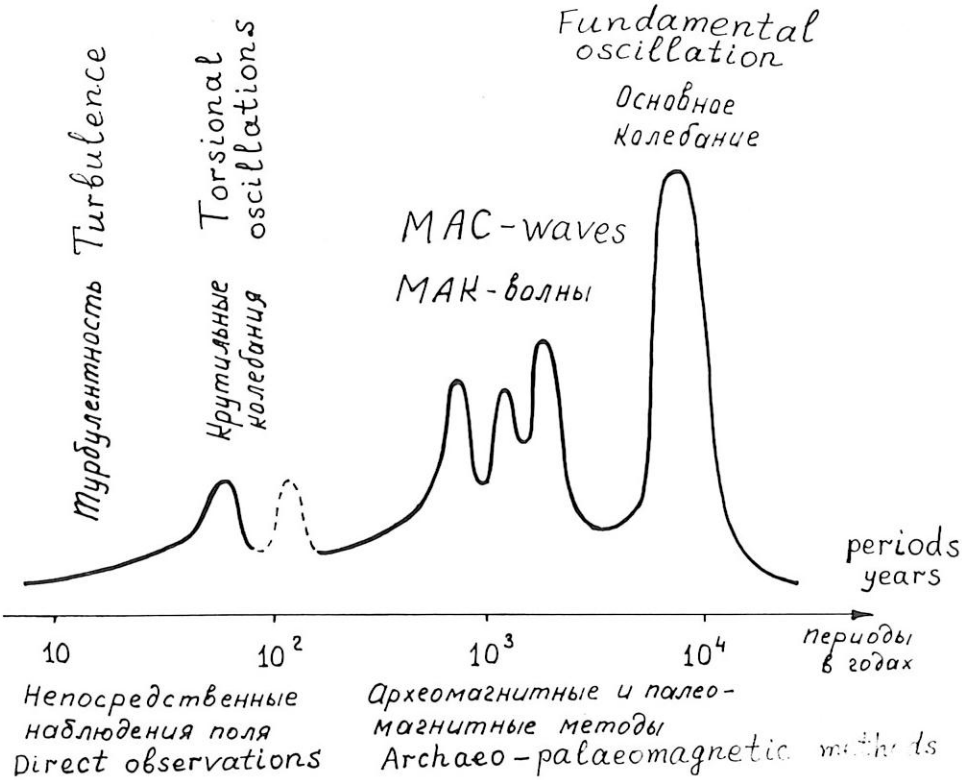


Fig. 1 – Schematic picture of the spectrum of geomagnetic field variations.

can generate a planetary field. Therefore, almost any assumption about the forces in the core implies motions capable of generating the earth's field. Practically, in all cases where the Coriolis forces play an important part and the dynamo mechanism has no large reserve of excitation, the main component of such a field will be, as the observations show, an axial dipole since the dipole mode is a mode with the least Joule damping and, what is more, it weakens less than other modes geometrically from the core to the earth's surface. Hence, the goal of the theory needed is now naturally conceived of as establishing the motions and fields really existing inside the core and real connections of these with properties of the earth's deep interior.

The problem of a realistic HD theory is far from trivial, because our knowledge of the earth's deep interior is rather scanty. A certain amount of optimism is obviously needed if we are to believe in the feasibility of such a theory. At present it does not exist, yet much has been done by many authors and particularly a large body of evidence has been collected which shows that the construction of the theory is now possible. This paper attempts to outline roughly a possible approach to the hydromagnetic theory of the HD which seems to the author the most plausible one.

## INITIAL EQUATIONS

As initial equations describing the main motions and fields in the core we can take the convection equations of an incompressible fluid where the fluctuation of density is accounted for buoyancy force only as well as both the equations of heat and admixture transfer and the induction equation of magnetohydrodynamics for homogeneous fluid. These equations in the coordinate system rotating with the earth take the form

$$\operatorname{div} \mathbf{B} = 0, \quad \operatorname{div} \mathbf{v} = 0 \tag{1.1}$$

$$\partial \mathbf{B}/\partial t = \operatorname{rot} (\mathbf{v} \times \mathbf{B}) + D_m \nabla^2 \mathbf{B} \tag{1.2}$$

$$d\mathbf{v}/dt = -\nabla P - 2\Omega \times \mathbf{v} + \operatorname{rot} \mathbf{B} \times \mathbf{B}/4\pi\rho + \mathbf{g}C + \nu\nabla^2 \mathbf{v} \tag{1.3}$$

$$d\xi_1/dt + \operatorname{div} \mathbf{i} = -\dot{\xi}_{\circ} \tag{1.4}$$

$$dT_1/dt + \operatorname{div} \mathbf{i}^T = \Sigma \tag{1.5}$$

Here $\mathbf{v}$ is velocity, $\mathbf{B}$ – magnetic field, $\rho$ – density, $\mathbf{P}$ – effective pressure divided by density, $\mathbf{g}$ – gravity acceleration, $\Omega$ – angular rotation velocity of the earth, $C = -\alpha T_1 - \bar{\alpha}\xi_1$ relative change of density as a consequence of the deviation of the temperature $T_1$ and admixture concentration $\xi_1$ from the static values $T_{\circ}$, $\xi_{\circ}$ ($\alpha$, $\bar{\alpha}$ are expansion coefficients); $\Sigma$ – sum of all heat sources divided by heat capacity; $\mathbf{i}$, $\mathbf{i}^t$ admixture and heat fluxes divided by density and heat capacity respectively; $\nu$ - kinematic viscosity coefficient; $D_m = c^2/4\pi\sigma$ coefficient of magnetic field diffusion. The application of homogeneous fluid convection equations (1) to the earth's core calls for an explanation; the problem is discussed in the author's paper (Braginsky, 1964*a*).

## TWO APPROACHES TO THE HD THEORY

The first question which arises when we attempt to solve the equations (1) is: should we consider laminar or turbulent motion? In particular, what kind of motion is responsible for generating the main field? There are two kinds of generative motions analyzed by many authors. The first suggested by E. Parker (1955) is large-scale field generation by small-scale turbulent motions, the second field generation by large-scale regular motions. One may ask which of the two has more advantages when explaining the earth's HD. The following consideration outlines a possible solution of this question.

The most important parameter of the HD is the magnetic Reynolds number

$$R_m = vL/D_m \tag{2}$$

where v and L are characteristic velocity and linear dimension. This parameter gives the order of the quotient of the values entering in induction and diffusion terms of the induction equation. If $R_m \ll 1$, then the Joule damping highly exceeds induction effects, but if $R_m \gg 1$, then the converse is possible. There exists a critical value of $R_{mc}$ of this parameter (depending on the velocity distribution), and when $R_m = R_{mc}$ the excitation of the field and its Joule dissipation are balanced, so that the field does not grow nor damp with time. Even when $R_m$ is large there exists, as shown by Cowling in 1934, the forms of the velocity field with corresponding symmetry such that the magnetic field cannot be generated. The estimates for the earth's core give $R_m \sim 10^3$ which is rather a large value.

Already in his monograph of 1957, when discussing the origin of the sun's magnetic field, Cowling has noted the fact that for the sun the magnetic Reynolds number is very large and that the problem seems to consist rather in explaining why the sun's magnetic field does not achieve enormous values than in finding the cause of its existence. In effect to know the form of the fluid motion necessary to ensure the same order of magnitude of the field generation and its Joule damping is an essential problem of the HD theory. As a particular case, $R_m$ can have its critical value $R_{mc}$ when these effects are balanced, but it seems more natural to consider the general case $R_m \gg 1$ (if $R_m \ll 1$ then the field is absent). Here we can imagine two main possibilities: the first, the motion assumes the character of fully developed turbulence, so that the mixing of the magnetic field lines increases the Joule damping which becomes of the same order as the excitation; the second, the velocity field assumes a form near to the sufficiently symmetrical one which makes impossible the self-excitation. It seems more probable that the first possibility is characteristic of the sun, stars and perhaps Jupiter with its strongly asymmetrical field, i.e. for systems of enormous size where $R_m$ is extremely large; on the other hand the earth's core having a modestly large $R_m$ gives an example of the second possibility which will be discussed below.

In any event, the question what is the role played by turbulence in the earth's core and what is the interrelation between determinacy and chance, between mechanical and stochastic elements in the terrestrial HD is one of the most important questions which should be answered by a full-fledged hydromagnetic theory of the earth's dynamo.

## GENERATION EQUATIONS

The second of the above approaches underlines the author's theory of "generation equations" for the dynamo with small deviations from axial symmetry when the magnetic Reynolds number is very large: $R_m \rightarrow \infty$. In this case velocity $\mathbf{v}$ and the magnetic field B can be represented in the form of a sum with an axially symmetrical term and a small nonsymmetrical one.

$$\mathbf{v} = \bar{\mathbf{v}}_p + \mathbf{1}_\varphi \bar{v}_\varphi + \mathbf{v}' \;, \quad \mathbf{B} = \bar{\mathbf{B}}_p + \mathbf{1}_\varphi \bar{B}_\varphi + \mathbf{B}' \tag{3}$$

where the subscript p denotes the meridional component of the vector, such as, for example, $\mathbf{v}_p = \mathbf{1}_z v_z + \mathbf{1}_s v_s$; $\mathbf{1}_i$ is the unit vector of the i-th axis; and z, s, $\varphi$ are cylindrical coordinates. The superior bar refers to "average" values, independent of the azimuth $\varphi$ and changing slowly, with times of the order of fundamental period; the primes refer to values that are purely variable with respect to $\varphi$ and to values which are independent of $\varphi$, but vary rapidly with time. The self excitation of the field is examined in Braginsky (1964b) for the case $R_m \gg 1$ and when the following relationships hold for the orders of the quantities:

$$\bar{v}_p/\bar{v}_\varphi \sim \bar{B}_p/\bar{B}_\varphi \sim (v'/\bar{v}_\varphi)^2 \sim (B'/\bar{B}_\varphi)^2 \sim R_m^{-1} \tag{4}$$

It is shown that in this case the "average" fields $\bar{B}_\varphi$ and $\bar{\mathbf{B}}_p = \nabla sA \times \mathbf{1}_\varphi/s$ are determined by the generation equations [5]

$$\text{div}\, \mathbf{B}_{ep} = 0 \;, \quad \text{div}\, \mathbf{v}_{ep} = 0 \tag{5}$$

$$\partial A_e/\partial t + s^{-1}\mathbf{v}_{ep}\cdot\nabla(sA_e) = D_m(\nabla^2 - s^{-2})A_e + D_m\Gamma\bar{B}_\varphi \tag{6a}$$

$$\partial\bar{B}_\varphi/\partial t + s\mathbf{v}_{ep}\cdot\nabla(s^{-1}\bar{B}_\varphi) = D_m(\nabla^2 - s^{-2})B_\varphi + [\nabla\zeta \times \nabla(sA_e)]_\varphi \tag{6b}$$

where $\zeta = \bar{v}_\varphi/s$. The quantity $\Gamma$, called the coefficient of generation, is expressed in a definite manner in terms of quadratic combinations of velocities $v'$ ("generating velocities") averaged over $\varphi$. The quantities $A_e$ and $v_{ep}$ also differ from A and $v_p$ because of the average quadratic combinations of $\mathbf{v}'$. It is demonstrated by Tough (1967) that in the next approximation, $A_e$ and $v_{ep}$ contain in addition to quadratic, also cubic combinations of $\mathbf{v}'$ but the form of eqs. (6a,b) does not change.

The mechanism of self excitation of the main geomagnetic field functions in two steps: the poloidal field $\bar{B}_p$ is stretched to produce the field $\bar{B}_\varphi$ which is $R_m$ times as large as $\bar{B}_p$; then the weak $\sim R_m^{-1}$ generation mechanism regenerates the field $\bar{\mathbf{B}}_p$.

It is shown in Braginsky (1964*a*) that relations (4) are in agreement with the equation of rotating fluid motion. Tough and Roberts (1968) suggest a theory of a nearly axial symmetrical HD, assuming, as known, external forces rather than velocities and writing, besides the generation equations, the motion equation developed according to small deviation from axial symmetry.

## TYPES OF VARIATION MECHANISMS

It should be noted that the approximation $R_m \to \infty$ is quite rough as applied to the terrestrial HD, as is the classification of frequencies given above. But these rough approximations help to bring some order in the general, very complex picture of the change of the fields and separate, although roughly, the individual mechanism for various types of HD oscillations. In this case the variations of the "averages" are responsible for the fundamental frequency, while the more rapid variations of velocities $\mathbf{v}'$ and of the fields $\mathbf{B}'$ are associated with medium and high frequencies. The mechanisms of generation of high frequency oscillations are at present not clear and we shall abstain from discussing them here. Velocities and fields corresponding to medium frequencies arise, as shown by the author (Braginsky, 1964*a*, 1967) in the form of waves (called MAC-waves), as a result of instability of axially symmetrical distribution of nonbalanced density C and the field $\bar{B}_\varphi$ in the core. The excitation of the MAC-waves is caused by Archimedes buoyancy forces. The possibility of such waves was independently shown by Hide (1966); these waves were discussed also by Rikitake (1966), Malkus (1967) and Stewartson (1967).

The MAC-waves create large-scale velocities $\mathbf{v}'$ necessary for generating the poloidal field in the dynamo and it is the same MAC-waves which create the fields $\mathbf{B}'$; the latter penetrating from the core to the earth's surface brings about the secular variations in planetary scale with periods of the order of $10^3$ years. Therefore, the generation of the main field and of its secular variations are strongly interrelated. A consistent theory of the HD requires simultaneous examination of slowly changing mean quantities and a set of much more rapidly changing MAC-waves interacting among themselves and with mean quantities. Here lies the principal mathematical difficulty of the HD-theory. So it seems more natural to begin with separating these problems, even if roughly. Let us consider first the changing of "mean" quantities.

## THE FUNDAMENTAL FREQUENCY

It is quite remarkable that even the average geomagnetic field (axial dipole) is not stationary, but oscillates with a period of about $9 \cdot 10^3$ years (Bucha, 1969; Kitazawa, 1970), although all the external conditions at the boundary of the core remain constant for at least hundreds of thousands of years. The mechanism that maintains the field is probably such that the field cannot be stationary, but fluctuates about some non zero value, even when the external conditions remain unchanged The reason of this oscillation can be the absence of the factor that would stop the development of the MAC-waves at the level where the generation coefficient $\Gamma$ is just that as required for stationarity. The excitation of MAC-waves is caused by buoyancy forces; they are counteracted by the stabilizing effect of quasi-elastic magnetic forces, proportional to $\bar{B}^2_\varphi$. If the field $\bar{B}_\varphi$ is small, then MAC-waves develop to the larger amplitudes and this leads to an increase in $\Gamma$ and to the growth of the field $\bar{\mathbf{B}}_p$. As a result of inhomogeneous rotation, the field $\bar{B}_\varphi$ extends from the field $\bar{\mathbf{B}}_p$, but the large $\bar{B}_\varphi$ interferes with the excitation of MAC-waves and causes their attenuation. Consequently, the generation of the field $\bar{B}_p$ weakens and the field begins to attenuate. This is followed by the attenuation of the field $\bar{B}_\varphi$, and when this field has become sufficiently small, MAC-waves are excited again, the generation of the field $\bar{B}_p$ intensifies, etc. As a result, the velocities $v'$ and the coefficient of generation are sometimes greater and sometimes smaller than necessary for stationarity, and the average field changes periodically. The real process is much more complicated, of course, because other quantities also participate in the oscillations, while the coefficient of generation and the effective velocity depend not only on the amplitudes, but also on the velocities of MAC-waves that change during the oscillations. It seems, however, natural that the two-stage mechanism of the HD self-maintenance($B_p \to \bar{B}_\varphi$, $\bar{B}_\varphi \to \bar{B}_p$) is not fixed on a constant level but oscillates about it, because the field $\bar{B}_p$ is determined by the generation mechanism depending on the larger field $\bar{B}_\varphi$.

## NONSTATIONARY KINEMATIC MODEL OF THE HD

To illustrate the phenomena described and to estimate the period of the fundamental oscillation the model of the HD was examined (Braginsky, 1970) having the following simple relationship between the coefficient of generation and the average field: if $\bar{B}_\varphi^2$ averaged over the volume of the core is smaller than some constant, then $\Gamma$ is equal to the given function of the coordinates; otherwise $\Gamma = 0$. With the proper selection of parameters in this model the evolution from arbitrary initial conditions, according to the equations of generation, leads to the establishment of periodic oscillations, where all the quantities vary about some average nonzero values. The Figs. 2, 3, 4 from Braginsky (1970) show the temporal variation of the dipole moment d and mean square field $b^2 = \langle \bar{B}^2_\varphi \rangle A_V$ with different meridonal circulations (proportional to the coefficient $\alpha$) and with the value of $\Gamma$ (proportional to the coefficient $\beta$) chosen to ensure strong oscillation of the dipole.

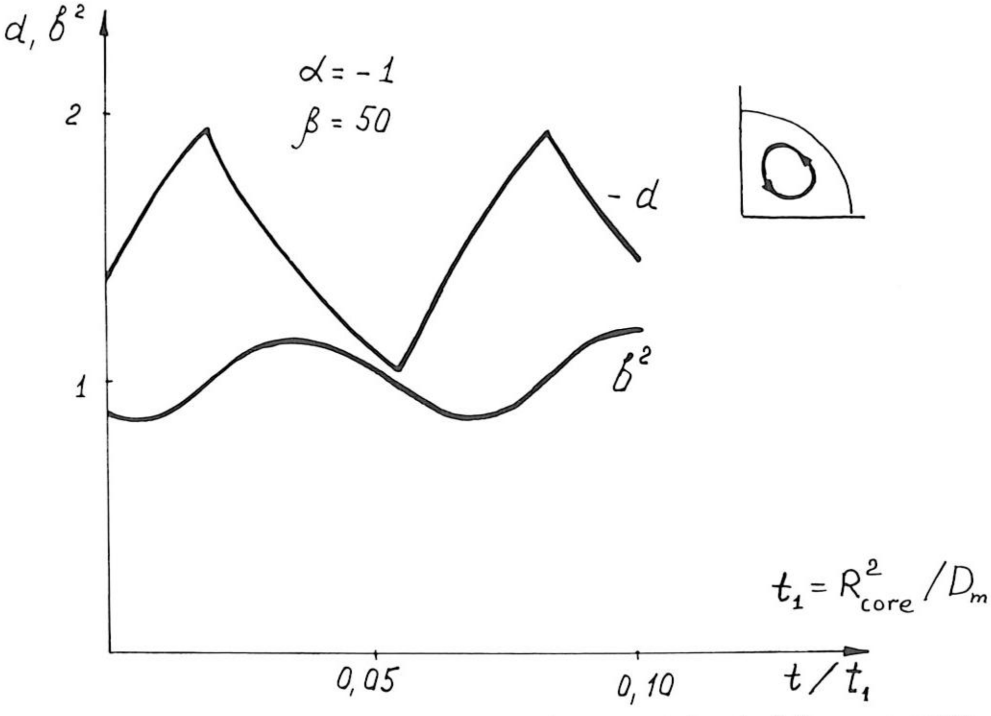


Fig. 2 – Temporal variation of the axial dipole moment d and of the mean square toroidal field $b^2$ for $a = -1$ and $\beta = 50$. ($a$ is proportional to the meridional circulation and $\beta$ is proportional to the generation coefficient.)

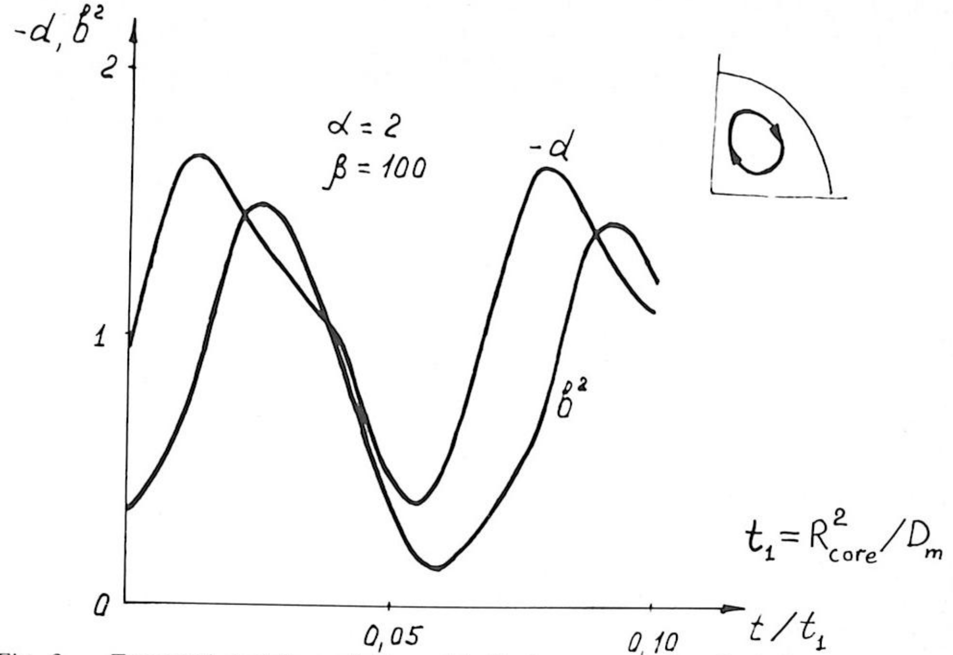


Fig. 3 – Temporal variation of the axial dipole moment d and of the mean square toroidal field $b^2$ for $\alpha$ = 2 and $\beta$ = 100. ($\alpha$ is proportional to the meridional circulation and $\beta$ is proportional to the generation coefficient.)

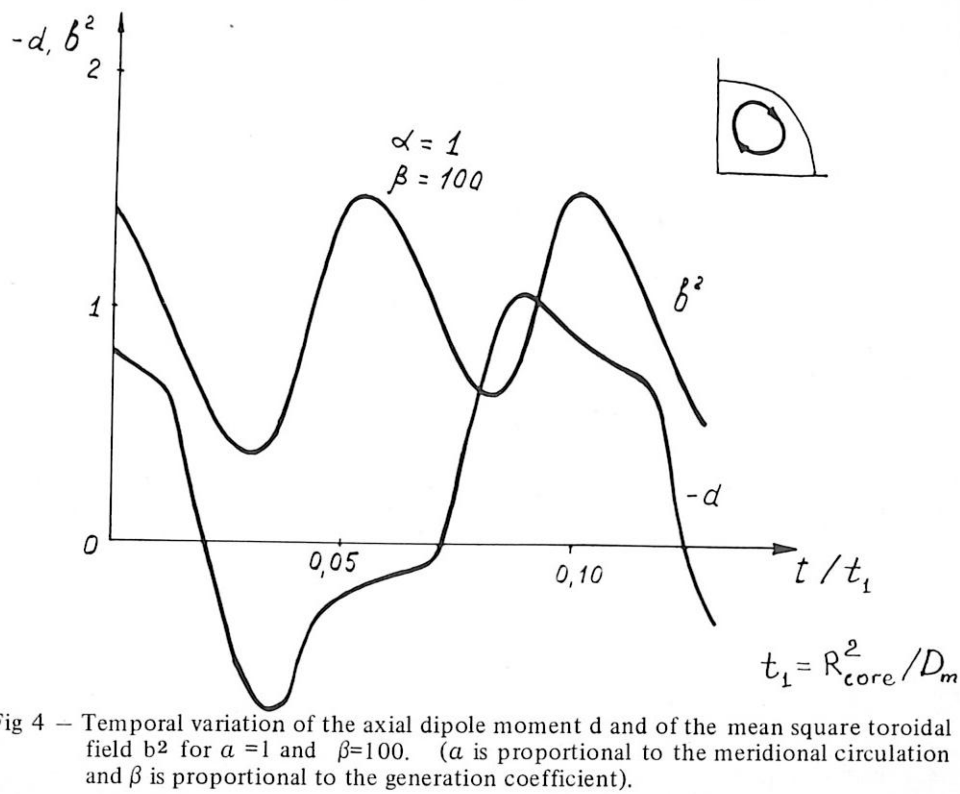


Fig 4 – Temporal variation of the axial dipole moment d and of the mean square toroidal field $b^2$ for $\alpha$ =1 and $\beta$=100. ($\alpha$ is proportional to the meridional circulation and $\beta$ is proportional to the generation coefficient).

The important parameter of the earth's core is its conductivity. In Braginsky (1964*c*) the estimation of conductivity $\sigma \sim 6 \cdot 10^{15}$ $sec^{-1}$ is obtained by means of extrapolating experimental data on the conductivity of liquid iron and on the influence on it of a silicon admixture. Being aware of the period $T_{\odot}$ of the fundamental oscillation of the earth's dynamo we can estimate $\sigma$ according to the results of the solution of the dynamo non-stationary model. If we assume $T_{\odot} = 9 \cdot 10^3$ years we obtain $\sigma = 2.5 \cdot 10^{15}$ $sec^{-1}$. This estimate is probably too low, since the presence of the inner core reduces the period because of the decrease of the free volume where convection takes place and of the increase in the gradients of the magnetic field. In what follows we shall assume $\sigma \sim 3 \cdot 10^{15}$ $sec^{-1}$. If in order to estimate the velocity $\bar{v}_{\varphi}$ we use the velocity of the "westward drift" then we shall be able by means of the kinematic model to estimate the field $\bar{B}_{\varphi}$ as well as the quantitv of Joule heat $Q_j$ released in the dynamo. These rough estimates are $\bar{B}_{\varphi} \sim 2 \cdot 10^2$ gauss and $Q_j \sim 0.5 - 1 \cdot 10^{19}$ erg/sec respectively; such a $Q_j$ is dozens of times less than the complete heat flux from the earth's interior. However the complete heat release in the dynamo must exceed $Q_j$ with a non-thermal convection mechanism by a few times and with a thermal convection mechanism by a dozen times, which seems too much.

## THE HD-EQUATIONS

In order to pass from the kinematic theory to the hydromagnetic theory we have to make use of the complete equations system including the motion equation and the equations of admixtures and heat transfer. By analogy with the theory of generation equations we can break each of these down into an equation for slowly changing average quantities and that for "deviations" of oscillating nature.

When dealing with large-scale motions in the core we can disregard viscosity and inertia. Then the motion equation becomes the equilibrium equation of the following forces: magnetic, Coriolis and buoyancy. Let us assume as in (4), $C = \bar{C} + C'$ where $C' \ll \bar{C}$ and analogously for $T_1$ and $\xi_1$. Averaging the equations (1.3-5) and making use of first-approximation equations for $\mathbf{B}'$, $C'$ (as in the generation equations theory) we obtain:

$$\frac{\partial}{\partial z}(2\Omega \bar{v}_{\varphi} - \frac{\bar{B}_{\varphi}^2}{4\pi\rho s}) = (\mathbf{g} \times \nabla\bar{C})_{\varphi} \tag{7}$$

$$2\Omega v_s = \frac{1}{4\pi\rho s} \operatorname{div} (s\bar{B}_{\varphi}\bar{B}_p + s\overline{B'_{\varphi}B'_p}) \tag{8}$$

$$\frac{\partial\bar{C}}{\partial t} + \mathbf{v}_{ep} \cdot \nabla\bar{C} + \operatorname{div} \mathbf{i}^c = Q^c \tag{9}$$

The equation (7) determines the largest-azimuthal-component of average velocity. It corresponds to the so-called "thermal wind equation" in meteorology. The term $(\mathbf{g} \times \nabla C)_{\varphi}$ in (7) represents the convective nature of the dynamo motor. It can be shown that the HD model under analysis cannot work without this term.

The second equilibrium equation (8) describes the balance of azimuthal projections of forces and determines the effective velocity of meridional circulation. This equation contains averaged terms $\overline{B'_{\varphi}B'_p}$ depending on oscillations. The velocity of meridional circulation is $\sim R_m$ times less than $\bar{v}_{\varphi}$ but it is highly relevant since the work of gravitation forces

$$A = \int \rho\bar{C} (\mathbf{g} \cdot \mathbf{v}_{ep})\, dV$$

is the main source of the dynamo energy. This work is not zero because of the derivative $\partial\bar{C}/\partial\vartheta \neq 0$. The velocity $\mathbf{v}_{ep}$ is also present both in generation equations (6) and in transfer equation (9).

The explicit formulation of (9) is, however, far from easy because the conditions in the earth's core are insufficiently known.

It seems probable (Braginsky, 1964*c*) that the main cause of convection is gravitational differentiation rather than the heat release in the core. If so, $Q^c$ can be assumed constant, $Q^c = -\bar{\alpha}\dot{\xi}_0$. This constant is one of the main dynamo parameters because it is just $Q^c$ that determines the convection intensity. Yet certain difficulty arises in obtaining the expression for an average flux $i^c$. The transfer of admixtures in the core is obviously carried out by turbulent pulsations rather than by molecular diffusion mechanism too weak for this. Small-scale turbulence of convective type in the core can be demonstrated by simple estimates (Braginsky, 1964*a*). This turbulence is not necessarily relevant for field generation but it is decisive in transfer phenomena. To make the expression for $\mathbf{i}^c$ exact enough it is necessary to study in detail turbulence properties when rapid rotation and magnetic field are both present. Till then the simplest method of accounting $\mathbf{i}^c$ can be to use for $\mathbf{i}^c$ a phenomenological expression based on common concepts of mixing length and of turbulent (anistropic) diffusion.

## VISCOSITY ROLE

The solution of HD equations is strongly dependent on the earth's core viscosity. Though in the equations (7) and (8) describing the equilibrium inside the volume viscosity can be safely ignored, near the core-mantle interface it is, however, very important. A boundary layer is formed here, having the thickness $\delta_v \sim (v/\Omega)^{1/2}$ of the same nature as the known Eckman layer. Equation (7) determines $\overline{v}_\varphi$ up to an arbitrary function $v_{\varphi 1}$ (s) not depending on z. This function can be determined, as shown by Tough and Roberts (1968) from the boundary condition linking $\overline{v}_\varphi$ and $\overline{v}_\vartheta$ on the boundary layer by methods familiar in the theory of the rapidly rotating fluid. However, the result obtained depends on viscosity. It can be shown by estimates that if $\nu \sim 10^8$ cm$^2$/sec then the conditions in the boundary layer give the function $v_{\varphi 1}$ of the same order of magnitude as the rest of terms in $\overline{v}_\varphi$; the meridional circulation velocity lines are closed in part inside the core and in part in the boundary layer. If $\nu \ll 10^8$ cm$^2$/sec then the boundary layer is too thin and the whole circulation is closed inside the core. To obtain this, however, some specific distribution of magnetic forces in the core should be established, as was shown by Taylor (1963). The couple exerted by the magnetic forces on any annular cylinder of fluid co-axial with the axis of rotation must vanish. In the contrary case the condition on the Eckman layer determines a very great velocity $v_{\varphi 1}$, which produces in a short time the field $\overline{B}_\varphi$; the process runs until the cylindrical shells equilibrium condition is satisfied.

The viscosity in the core is strongly dependent on the pressure, since as the pressure grows the relaxation time for atomic self-diffusion is rapidly decreasing. As Zharkov (1962) has shown, if the relaxation time corresponding to the "effectively solid" behavior for seismic waves is achieved just at the inner core depth, then at the core-mantel interface we obtain the viscosity $\nu \sim 3 \cdot 10^4$ cm$^2$/sec. This value which can be considered an upper estimate is much inferior to $10^8$ cm$^2$/sec, so that the Eckman layer is very thin indeed here.

Still another registration point for estimating the core viscosity can be obtained from the study of the core-mantle couple. The common viewpoint is that this interaction is completely ensured by electromagnetic forces estimated as $\sim \sigma_m(\overline{B}_r^2/c^2)\overline{v}_\varphi L_m$, where $\sigma_m$ is conductivity of the mantle and $L_m$ thickness of its conducting layer. But the viscous friction force having the order of $\sim \rho\nu\overline{v}_\varphi/\delta_\nu$ increases because of the Eckman layer and the mantle conductivity as well as the magnetic forces in the mantle are by three orders less than those in the core. Therefore while the viscous forces inside the core are much inferior to the magnetic ones when $\nu \ll 10^8$ cm$^2$/sec, the ratio of forces of magnetic vs. viscous interaction between the core and the mantle equal to $\sim \sigma_m(B_r^2/c^2)L_m/\rho(\nu\Omega)^{1/2}$ becomes of the order of unity already when $\nu \sim 10^2$ cm$^2$/sec. Accordingly, for the estimates of the core viscosity the study of effects connected both with torsional oscillations in the core-mantle system and with length-of-day variations may prove helpful.

## ON THE POLARITY REVERSALS MECHANISM

The above properties of the terrestrial HD, namely smallness of the azimuthal forces $\sim R_m$ times inferior to the main (meridional) forces and smallness of viscosity, bring about a state where the breaking of the azimuthal equilibrium can be produced by relatively small perturbations. It seems natural to assume that just these properties underlie the polarity reversal mechanism of the terrestrial dynamo. In a steady state the azimuthal equilibrium condition for coaxial cylindrical shells is satisfied, but if it is violated because of a rapid chance perturbation, then there appear immediately great changes in the azimuthal velocity $v_\rho$ and the azimuthal field $\overline{B}_\rho$ so that the state of the dynamo is completely perturbed. After it is restored, the main dipole can be of the opposite sign, since the HD equations admit equally both senses of the dipole. The said chance perturbations may be caused by certain sudden external actions, e.g. if the convection source is the sinking of heavier material from the mantle to the core, then it may be sharp fluctuations in the quantity of this material. The perturbations may also be produced by internal instabilities and fluctuations in the core. It is to be expected that the number of external perturbations and, consequently, the number of polarity reversals increases in epochs of enhanced geological activity.

## MAIN RELATIONS IN THE HD

Estimating the order of magnitude of terms in the HD equations system we obtain the following similarity relations holding between main quantities in the terrestrial HD:

$$R_m \sim \overline{v}_\varphi L/D_m \sim (Lg/2\Omega D_m)\overline{C} \tag{11.1}$$

$$\overline{B}_\varphi \sim B_\circ R_m^{1/2} \tag{11.2}$$

$$\overline{B}_p \sim B_\circ R_m^{-1/2} \tag{11.3}$$

$$B' \sim B_\circ \tag{11.4}$$

$$\overline{v}_\varphi \sim (g/2\Omega)\overline{C} \ , \quad \overline{v}_p \sim D_m/L \tag{11.5}$$

$$B_\circ = (4\pi\rho 2\Omega D_m)^{1/2} \tag{11.6}$$

The field in the HD is determined by the quantity $B_\circ$ which increases according to the rotation velocity of the planet. For the earth, when $\sigma = 3 \cdot 10^{15}$ $sec^{-1}$ we have $B_\circ = 21$ gauss.

The quantity $\overline{C}$ increases when the intensity of the convection sources $Q^c$ increases, but slower than the latter, since the intensifying of convection entails the increase of the admixture turbulent diffusion coefficient. The magnetic Reynolds number $R_m$ and the field $\overline{B}_\varphi$ inside the core increase with $\overline{C}$ as (11.1) - (11.3) show.

As for the field $\overline{B}_p$ observed on the earth's surface it decreases as $\overline{C}^{-1/2}$. It is natural to assume that in earlier stages of earth's development ($\sim 10^9$ years ago) gravitational differentiation and other relaxation processes were more (in any event, not less) intensive than at present. It seems plausible that the convection in the core had been then more intensive and according to (11.3) the average field on the earth's surface had in that remote epoch been weaker than now. Palaeomagnetic data available do not contradict this conclusion. The quantity $B'$ does not by (11.4) depend on $\overline{C}$. Only its small part $B'_{ext} \sim B' R_m^{-1}$ decreases with the increase of $\overline{C}$ (Braginsky, 1964*b*) and penetrates to the surface. The ratio $B'_{ext}/\bar{B}_p$ is proportional to $\bar{C}^{-1/2}$ so that in the past the average surface field was more like the field of the axial dipole than at present. Note that if the radius of the inner core is smaller (just the common assumption for the remote past) then L and $R_m$ are larger, which effect is analogous to the increase of $\bar{C}$.

To sum up: The geomagnetic field of remote geological epochs can be represented by the field of the axial dipole not worse than the actual field can; this result is of importance in the interpretation of paleomagnetic data.

## THE INTERMEDIATE MODEL

In order to construct a consistent theory of the HD we have to solve a system of averaged equations together with complicated equations for waves which determine the coefficient of the generation $\Gamma$. Since this problem is hard enough it seems natural to try a preliminary model approach, i.e., to build up a model intermediate between kinematic and hydromagnetic theories. Doing so we shall assume $\Gamma$ (depending on $\mathbf{v}'$) to be a simple prescribed function of coordinates. In the simplest case we can take (8) in the form

$$2\Omega v_{es} = \frac{1}{4\pi\rho s} \operatorname{div} (s\bar{B}_\varphi B_{ep}). \tag{8'}$$

The amplitude of the function $\Gamma$ is determined as in kinematic models by the condition of finite solution when $t \to \infty$. We hope that such an "intermediate" model permits us to consider some interesting effects, in particular, the fundamental oscillation and changes of polarity. This model seems to be less arbitrary than the kinematic one: average velocities are not prescribed here but are determined from the equations for rapidly rotating fluids taking into consideration magnetic and buoyancy forces.

The next step should be to solve the problem of MAC-waves and then to examine both problems together. However, the elaboration of a quantitative theory of MAC-waves, which would allow us to determine the wave set in the core, meets with serious mathematical difficulties and, most probably, with non-uniqueness too. So it seems advisable first to determine the wave spectrum from experimental data.

## MEDIUM FREQUENCIES

Paleomagnetic and archeomagnetic investigations reveal that the geomagnetic field varies with periods of $\sim 10^3$ years. The spectral analysis carried out by Yukutake (1962) on the basis of declination measurements in sedimentary rocks in Japan and England has revealed the periods of 700, 1200, 1800, and 7000 years. The spectral analysis of archaeomagnetic data on the magnitude and inclination of the field show periodicity as well (Burlatskaya *et al.*, 1960). The time-averaged archeomagnetic data on inclination for various points on the earth satisfy the relationship $\operatorname{tg} I_{AV} = 2 \operatorname{tg} \theta$ ($I_{AV}$ is the average inclination and $\theta$ is the latitude of the observation point), which is characteristic of the field of the axial dipole (Burlatskaya *et al.*, 1968). This fact indicates that all the other field components mainly have an oscillatory character. The above results need corroboration and more accurate analysis, yet the existence of the periods found by spectral analyses seems extremely important. It is just the discrete frequencies in the spectrum of variations that show these variations to be not a random process but a result of a regular mechanism. Such a mechanism may be supposed to be underlain by the aforementioned MAC-waves. For the time being we can give but an estimate of the order of magnitude for the frequency of these waves

$$\omega \sim \bar{B}_\varphi^2 \, (4\pi\rho 2\Omega L^2)^{-1/2} \tag{12}$$

If $2\pi/\omega \sim 10^3$ years, $\rho \sim 10 g/cm^3$, $L \sim 10^8 cm$ then we have $\bar{B}_\varphi \sim 2 \cdot 10^2$ gauss in accordance with the estimate of the kinematic dynamo model. To elaborate a quantitative MAC-waves theory we need to know average fields and velocities in the core. The development of MAC-waves is limited by the dissipation and some non-linear effects difficult to account for. It seems likely that the pattern of a group of steady waves interacting between themselves may be, generally speaking, non-unique. The elicitation of that pattern may be substantially helped by the analysis of experimental data on secular variations of "medium" frequencies.

In order to quantitatively represent the secular variations it is desirable to have a set of spherical analyses of the geomagnetic field in the past. Some analyses in the dipole approximation (n=1) for a time interval of 2000 years have been carried out on archaeomagnetic data by Marton (1970). An attempt to represent the secular variations as the result of the dipole motions has been made also by Kawai and Hirooka (1967). However, the harmonics n=2 have the same order of magnitude as the transverse dipole. The archaeomagnetic data available at present are too scanty, far from accurate and even sometimes contradictory, which impedes spherical analyses for remote epochs.

The author (1970) has tried to approximate secular variations by a set of travelling waves using the spherical analysis results for epochs 1600-1965. In order to approximate MAC-waves adequately we have to consider a longer time interval and we need to use the archaeomagnetic data for earlier epochs.

It should be emphasized that a considerable extension of archaeomagnetic studies seems highly desirable. We may hope that such kind of studies can largely facilitate the construction of an analytical expression for a reference geomagnetic field of the past, which would be of obvious use both for the HD-theory and for archaeomagnetic dating.

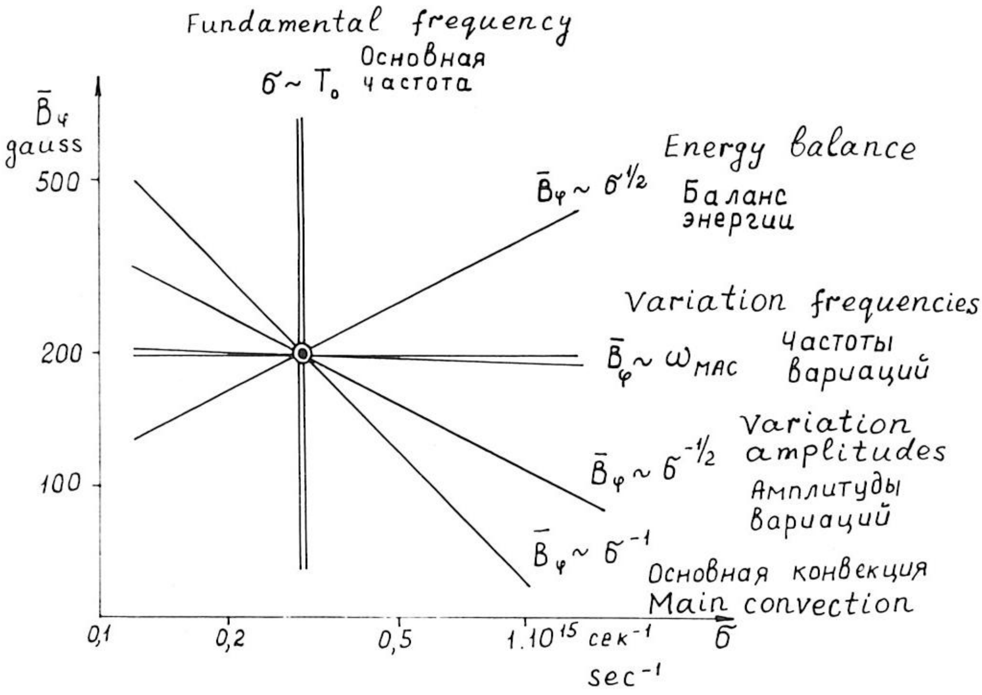


Fig. 5 – Diagram illustrating various relationships between the mean toroidal field, $\bar{B}_\phi$ and core conductivity.

**DIAGRAM $\sigma - \bar{B}\varphi$**

A graphical method of checking the consistency of the different results of the HD-theory on the main field and its variations may consist in plotting the corresponding relationships on the diagram $\sigma - \bar{B}_\varphi$ on a logarithmic scale (Fig. 5). In order to obtain quantitatively the coefficients of these relationships we need a further development of the theory. Now the coefficients can be estimated according to the order of their magnitude only; therefore our diagram is idealized so that the consistency is checked only according to the order of magnitude.

The theory of main convection permits one to determine the conductivity from the magnitude of the fundamental period as well as from the duration of the polarity reversals. This gives us the vertical line on the $\sigma - \bar{B}_\varphi$ diagram. Besides, the theory permits one to express $\bar{B}_\varphi$ according to (11.2), (11.3) so that with the fixed known values of $\bar{B}_p$ we have the relation $\bar{B}_\varphi \sim B_\odot^2 \sim \sigma^{-1}$; it gives the line at the angle of -45°. The intersection of the two lines determines the point corresponding to the real parameters in the HD of the earth. The rest of the relationships must pass through the same point. The MAC-wave frequencies are proportional to $\bar{B}_\varphi^2$ and are weakly dependent on conductivity. Therefore, the comparison of a quantitative MAC-waves theory to the results of secular variations analysis must give a bundle of almost horizontal lines passing through the same intersection point. The amplitude of secular variations observed is determined by $R_m \sim \bar{v}_\varphi L/D_m$. Since $\bar{v}_\varphi \sim \bar{B}_\varphi^2$, we have the line $\bar{B}_\varphi \sim \sigma^{-1/2}$ on the diagram. Joule heat released in the dynamo is proportional to $\bar{B}_\varphi^2/\sigma$. If geophysical considerations permit us to estimate the power Q of the dynamo energy source, and the HD-theory, its efficiency $\eta$, then we can draw on our diagram the line of the form $\bar{B}_\varphi =$ const $\sigma^{1/2}$. The indeterminacy of this constant is somewhat reduced by the fact that it depends on the square root of $\eta$Q. In addition we can hope to obtain further relationships from theoretical and experimental study of high-frequency variations not discussed here. As the theory develops, the quantity and accuracy of the relationships we can represent on the diagram can be expected to grow. Ideally, proceeding in this manner we must be able to achieve such a state of affairs in the HD theory so that the number of the measurable quantities exceeds the number of parameters introduced in the theory.

In conclusion I would like to express my hope that a quantitative theory of the earth's HD will be really constructed in the foreseeable future. It must help to understand better both the nature of the geomagnetic field and the structure of the earth's deep interior.

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# FINAL PLENARY SESSION

The final plenary session was held Thursday, 12 August at 10:00 a.m.

## REPORT OF RESOLUTIONS COMMITTEE

It was noted that Chairman A.J. Dessler and his committee had considered 38 resolutions and that 27 of these had survived the review by the resolutions and executive committees.

Great enthusiasm was shown for a resolution of thanks to the local organizing committee and their helpers who made this meeting so successful. Twenty-six scientific resolutions were approved. All of these resolutions are reproduced elsewhere in these transactions. One resolution proposing the adoption of the S.I. Units (MKSA) in expressing geomagnetic terms was not adopted because of some objections from the floor. The subject of this resolution will be further studied by a new Ad Hoc Committee made up of representatives from the first five Commissions.

## FINANCE COMMITTEE REPORT

Chairman O. Schneider read the report of the Finance Committee which was identical to that reproduced in the minutes of the Executive Committee. This report was accepted.

## SECOND IAGA GENERAL SCIENTIFIC ASSEMBLY

President Nagata confirmed the invitation from Japan to IAGA to hold its Second General Scientific Assembly in Kyoto from 10 September to 21 September 1973. He indicated this had been approved by the Executive Committee. The delegates at the Plenary Session also accepted this invitation unanimously.

## OTHER ACTIONS OF THE EXECUTIVE COMMITTEE

Other actions taken by the Executive Committee on items submitted by National Delegations, and Internal Reorganization of IAGA, were called to the attention of the delegates (see minutes of the Executive Committee).

## REPORT OF HIGHLIGHTS OF COMMISSIONS

The Commissions, and Joint Committees, summary highlight reports as recorded below were given.

### COMMISSION I
**A. P. DeVuyst--Reporter**

During the XV General Assembly of IUGG the Scientific Session, Review and Business meetings of Commission I of IAGA were held on Wednesday, 4 August 1971.

Highlights of these meetings were: on one hand, the progress made in the routine operation of digitally recording magnetometers and progress in very sensitive sensors for rapid and normal variations, and on the other hand, the progress in proton magnetometers improving in this manner the magnetic standards.

After the business meeting it was obvious that many members of IAGA were interested in the performance and reliability of various automatic and semi-automatic systems. Because of this, two recommendations were submitted to the Executive Committee:

1. To hold at the next General Assembly of IAGA in 1973 a special scientific session on, "Modern Magnetic Observatory Techniques" (in 3 parts: review, contributed papers and panel discussions).
2. Setting up a new Working Group I-4: "Processing Techniques of Observatory Data."

## COMMISSION II
## REPRESENTATION OF MAIN MAGNETIC FIELDS
**B. R. Leaton–Chairman**

The Commission held two scientific sessions, incorporating in one of them its review and business meeting. Each of the working groups met separately, though one of them only briefly. There was also a meeting of the joint ad hoc working party of Commissions I and II set up in Madrid to consider the use of S.I. Units in IAGA. This meeting is reported elsewhere.

Twelve papers were read at the first session. They comprised papers II-1 through II-10 (see Program and Abstract book), and an appropriate part of II-19, plus an extra paper. They covered such topics as the relationship between gravity and magnetic fields on a global scale, the location of global magnetic anomalies, various aspects, both theoretical and practical, of methods of analyzing the field, the application of one of these methods to paleomagnetic data and evaluation of the present IGRF and suggestions for its improvement. This session was extended to become an open forum on the IGRF. Several of the papers of the immediately preceeding session had been on this topic. A suggestion was made to use a new preliminary field as a basis for adjustment to the secular change coefficients of IGRF to bring the forecasts for 1975 from the two fields into agreement. This suggestion got only minority support. As evaluations so far indicate that the present IGRF is satisfactory for its intended purpose, to act as an anomaly base and for particle trajectory analysis, it was decided to recommend the continued use of the present IGRF at least until 1973.5. It is recognized that researchers into rapid time variations in satellite data may need to use a model to higher order and degree, derived from their own or similar data.

At the second scientific session, five papers were presented, namely numbers II-15 through II-18 plus the first part of II-19. The first four concerned aspects of surveying and the last a definitive field for 1950.0. The business part of this session agreed that Working Group II-5 on Planetary Magnetic Fields, was presently serving very little useful purpose due to a dearth of much new data on planetary magnetic fields and recommended a transfer of its function to Commissions V or VIII. All other Working Groups are active and reviews were given by their reporters. A suggestion, in agreement with Commission III, that the part of that Commission's work concerning recent secular change be transferred to Commission II was supported. Highlights of the discussion both in this session and in working groups were the recognition of data shortage in particular areas and for the determination of time changes, deficiencies in the IGRF, particularly its secular change, the need for a low level satellite survey in about 1976, the non-availability of much marine data and the incompleteness of the World Magnetic Archive. Recommendations were made for six resolutions on these topics.

## COMMISSION III
**F. J. Lowes–Reporter**

Work in the very wide field of this Commission continues to increase rapidly.

During 10 Scientific Sessions at the XV General Assembly over 100 papers were presented.

Particularly in fields like archeomagnetism and paleomagnetism the emphasis has been on the acquisition of further data, and although preliminary attempts are being made to apply to the data spatial and temporal analysis analagous to that applied to modern data, it is clear that these preliminary results must be treated with caution.

It was proposed that the present work (compilation of observatory data) of Working Group III-2, "Secular Variation," be transferred to Commission II, and that the Working Group with new membership, would then concern itself with wider aspects of secular variation.

Several Symposia were proposed for the 1973 meeting.

## COMMISSION IV
**A. J. Zmuda–Reporter**

The Commission on Magnetic Variations held 12 sessions containing a total of 133 papers. The following summaries are from the contributions of the various Working Groups.

### Working Group 1–Morphology and Indices

C-figures of individual stations are to be discontinued.

K-indices of individual stations will be put in machine readable form.

A tentative scheme was established for a yearly survey of magnetic storms.

Studies were made of the variation of the magnetic indices with sunspot activity, direction of the earth's dipole axis, and the asymmetry of the magnetospheric ring current.

Method of selection of international quiet and disturbed days was discussed.

### Working Group 2–Daily Variations

Many new morphological results were obtained describing local as well as global characteristics.

In the dynamo theory, atmospheric motions, varying ionospheric conductivity and daily variations are to be connected. The atmospheric winds are the least well determined of these variables.

Some progress has been made in calculations of the models of the daily variation current systems. Recent rocket measurements confirm that the major part of the current system flows in the E region.

Much attention has been concentrated in the last few years on the possible contributions to the daily variations from sources in the magnetosphere: currents in the magnetopause and neutral sheet, as well as the ring current.

### Working Group 3–Equatorial Electrojet

A comprehensive list of workers interested in the equatorial electrojet has been compiled. Information is exchanged in order to avoid duplication of effort.

An International Equatorial Aeronomy Symposium is being planned for September 1972 in Nigeria. It is expected that at least one session will be devoted to the interrelationship between the surface observations and those of the POGO satellites.

### Working Group 4–Special Disturbances Events

Twenty-two storms in the period 1967-1970 have been analyzed and the results published in *Solar-Geophysical Data*.

All the available magnetic DP-2 events have been scaled and digitized, and will be distributed in a few weeks.

A preliminary glossary of the nomenclatures and motions for the polar magnetic disturbances has been prepared. The ultimate aim is standardization in this area of activity.

### Working Group 5–Micropulsations

Special attention was given to new indices of activity based on pulsations due to their potential value in the general problems in magnetospheric physics and especially in the diagnostics of magnetospheric parameters from surface observations.

Most members are in favor of reconsidering the existing classification of micropulsations. However, this is a very serious problem which has to be treated very carefully and it was suggested that a small commission be set up to investigate this problem and to report on it at the 1973 IAGA Assembly.

### Working Group 6–Magnetospheric Field Variations

Dst indices have been recalculated for the years 1957-1970. The primary purpose of deriving the Dst index is for diagnosis of magnetospheric activity. We still do not have a complete understanding of the quiet-time magnetospheric field. Some progress, however, has been made through analysis of OGO 3 and 5 magnetic observations during quiet times: the quiet-time ring current is much different from what has been usually considered and the ring current is found to be active even under quiet conditions.

## COMMISSION V
**J. G. Roederer–Reporter**

This Commission organized a Review Session on Outstanding Problems in Solar-Terrestrial Research, a series of Sessions with contributed papers on Solar-Terrestrial Physics, and co-sponsored a Symposium on Electric Fields in Space and their Connection with Atmospheric Effects (with IAMAP), and on Magnetospheric Models (with IAGA Commissions III and IV).

As on previous occasions, the Review Session was a success and proved again that a series of lectures on selected topics of current interest, delivered by a group of carefully selected speakers, is an essential ingredient to an international meeting. The program developed as planned with only one withdrawal.

The scientific sessions on Solar Terrestrial Physics were overcrowded with contributed papers – to the point that one additional session had to be introduced and the program rearranged (there was only one withdrawal out of 18 papers!). Such last-minute alterations are annoying to the participants and must be avoided in the future. A series of 15 cosmic ray papers that, by their nature, had only marginal relation to current Commission V interests, were condensed into 4 "quasi-reviews" given by the corresponding group leaders.

The Symposium on Electric Fields was quite successful from the point of view of quality of scientific papers presented. However, it fell short of its main goal, the study of the connection with the atmosphere. Indeed, only 3 reviews (out of 9) and 1 contributed paper (out of 12) dealt specifically with the troposphere. This is probably the most eloquent proof that the connection – if any – is only a very weak one! A few minor changes of the program replaced absentee papers with late submissions.

The session on Magnetospheric Models consisted of presentation of papers and an informal discussion.

The Commission V Business Meeting was devoted mainly to an informal discussion on reorganization, focusing particularly on the problem of how to attract more solar-terrestrial scientists to IAGA. The hope was expressed that the new Executive Committee would give due consideration to the problem of how to attract more solar-terrestrial scientists to IAGA.

## COMMISSION VI
**A. Egelund and G. G. Shepherd–Report submitted on behalf of A. Omholt**

The Commission has four working groups: Morphology, Spectroscopy and Excitation, Radio Aurora, and Particles and Fields. Of these, the Morphology working group still has much to discuss, the Radio Aurora working group has virtually completed its work on nomenclature, and the other two groups have been concerned with reviewing the progress in their respective fields.

At the XV General Assembly, one symposium comprising seven sessions was organized in conjunction with Commission VII. Of these, four had some emphasis on aurora: radio aurora, auroral particles, a case study of the March 6-9, 1970 event, and low energy electrons. The sessions were well attended and well subscribed in terms of contributed papers. Indeed, some of the sessions had insufficient time for proper discussion because of the number of papers. However, it is gratifying to see the amount of work being done and the interest in this field.

## COMMISSION VIII
**A. J. Dessler Reporter**

In the four scientific sessions of Commission VIII, a total of 48 papers were presented. Joint symposia were also arranged. The attendance to hear these papers was good, varying from about 50 to over 100.

At a business meeting attended by approximately 40 members of Commission VIII, four resolutions were adopted. Other organizational matters were discussed.

The scope of the scientific papers demonstrated that we are now able to describe in some detail the time dependent behavior of variations in the terrestrial atmosphere. However, theoretical understanding is still lacking in several vital areas. Study of other planetary atmospheres can undoubtedly be of aid in obtaining theoretical insight into the behavior of the earth's atmosphere. And, a fundamental understanding of the earth's atmosphere will be vital to the development of theories of the atmospheres of other planets.

At the time of this general assembly, three separate spacecraft are on their way to Mars. It seems reasonable to expect that the atmosphere of Mars will be a focal subject at the 1973 meeting of IAGA in Kyoto.

## JOINT IAGA / IAMAP COMMITTEE ON LUNAR VARIATIONS
**O. Schneider - Reporter**

The review presented by the Committee Chairman at the business meeting comprised 86 titles of papers on lunar subjects mainly published in the interval since the Madrid Assembly, and covering tidal and other lunar effects in all domains of aeronomy, geomagnetism and the neutral atmosphere. An increasing emphasis has become evident in this work, on the study of partial tides and interaction phenomena, especially with the oceans.

Twenty-two new papers, including three initial lectures, were presented either as scientific communications at the Committee Business Meeting or the interdisciplinary Symposium on Lunar Effects in Geophysical Phenomena, convened by the Committee Chairman. The symposium showed that there is more common ground shared by tidal theory and methods in the diverse fields of geodesy and geophysics than has generally been recognized.

The Committee has six working groups convened by Committee members but including other colleagues, on the following subjects:

1 . Theoretical problems of atmospheric oscillations;
2. Internal (lithospheric and hydrospheric) aspects of geomagnetical lunar variations;
3. Solar and interplanetary effects in lunar variations;

4. Procedures for analysis of lunar variations;
5. Hydromagnetic aspects of ionospheric lunar variations;
6. Global planning.

For future work, the following outstanding problems have been pointed out:

1. Lunar variations in the magnetosphere;
2. Explanation of regional anomalies existing in the global distribution of the lunar semi-diurnal air tide;
3. Detailed study of the influence of oceanic and solid earth tides on the atmospheric pressure tides;
4. Explanation of the anomalous rotation of atmospheric wind tides;
5. Detailed quantitative relationship between neutral atmospheric tides, dynamo region winds, and geomagnetic tides;
6. Explanation of the anomalous dependence of lunar geomagnetic tides on solar activity;
7. Assessment of the magnitude of piezoelectric potentials produced by earth tides.

The Committee does not suggest a special symposium on lunar questions until the next General IUGG Assembly.

## REPORT OF NOMINATIONS COMMITTEE AND ELECTION

The Nominations Committee reported the following list of candidates which were then elected to office:

| | |
|---|---|
| President: | V. A. Troitskaya |
| Vice-Presidents: | G. M. Weill |
| | J. G. Roederer |
| General Secretary: | L. R. Alldredge |
| Members: | T. Nagata (past president) |
| | A. J. Dessler |
| | J. W. Dungey |
| | M. Nicolet |
| | O. Schneider |
| | R. Turajlic |

# EXECUTIVE COMMITTEE MINUTES MEETING HELD IN MOSCOW, USSR

The first session was held on Saturday, 31 July 1971. Those present at this meeting were: President Nagata, Dr. V.A. Troitskaya, Dr. R. Turajlic, Dr. J.G. Roederer and Dr. Leroy R. Alldredge. Dr. E. Thellier and Rev. J.O. Cardus, S.I. arrived in time for the other sessions that were held throughout the following two weeks. All of the results of the various sessions are reported together. Dr. Nicolet, Dr. Johnson and Mr. Casaverde had sent word to the General Secretary that they would be unable to attend the meetings. The last session was held on Thursday, 12 August. On this occasion both the old and new Executive Committees met together.

The minutes for the Leningrad Executive Committee Meeting, held in May 1970, were approved.

## AGENDA ITEMS SUBMITTED BY NATIONAL DELEGATIONS

In response to a U.K. proposal to have IAGA publish a quadrennial international review of geomagnetism and aeronomy so as to make it unnecessary for each national committee to write their own, it was decided that useful and meaningful National Reports would not be discouraged but that IAGA would encourage each Working Group Reporter and Commission Chairman to publish in the Transactions of each Scientific Assembly reviews of their various areas.

In response to a proposal from the USA regarding the use of a standard format for Assembly papers and the necessity of National Committee screening papers for submission, the Executive Committee agreed that although many problems are recognized in the enforcement of a standard format, nevertheless one would be tried. Regarding screening of papers, it was decided that the IAGA Conveners and Commission Chairmen would be relied upon as the official reviewers of papers but that the National Committees may screen papers before submission if they choose to do so.

## APPOINTMENT OF AD HOC COMMITTEES

The following Ad Hoc Committees were appointed to serve during the Moscow Assembly:

| | |
|---|---|
| Resolutions Committee: | A. J. Dessler, chairman |
| | R. Schlich |
| | Y. D. Kalinin |
| | J. O. Cardus |
| Nominating Committee: | T. Nagata, chairman |
| | A. J. Zmuda |
| | J. O. Cardus |
| | N. P. Benkova |
| | A. DeVuyst |
| Finance Committee: | O. Schneider, chairman |
| | R. B. Leaton |
| | N. Fukushima |

Near the end of the Assembly these committees reported as given below.

## REPORT OF NOMINATIONS COMMITTEE

The Nominations Committee report as quoted below was accepted by the Executive Committee.

"The Nominations Committee endorsed the following list for IAGA Officers

| | |
|---|---|
| President: | V. A. Troitskaya |
| Vice Presidents: | G. M. Weill |
| | J. G. Roederer |
| General Secretary: | L. R. Alldredge |
| Members: | T. Nagata (past President) |
| | A. J. Dessler |
| | J. W. Dungey |
| | M. Nicolet |
| | O. Schneider |
| | R. Turajlic |

"The Committee also recognizes the growing importance of solid earth geomagnetism for every discipline. It recommends that future Nominating Committees take note of this growing importance and possibly increase the representation of the solid earth geomagneticians in the IAGA Executive Committee.

"The Committee also recognizes the need for an Adjoint Secretary and recommends the IAGA Excutive Committee consider this office and an appointment to this office."

President Nagata's suggestion that Dr. N. Fukushima be appointed to the position of Adjoint Secretary was accepted. It is expected that the Adjoint Secretary will attend all meetings of the Executive Committee and will generally learn all he can about the operations of the Central Bureau.

## REPORT OF THE RESOLUTIONS COMMITTEE

The Resolutions Committee reported that 38 resolutions had been submitted. Dr. A.J. Dessler, Chairman of the Committee, pointed out that the business meeting of Commission VII was scheduled after the final plenary session so that resolutions passed there could not possibly be properly approved. It was noted that in the future all business meetings should be scheduled early in the assembly period to avoid this problem. It was also recommended that a firm deadline for receiving resolutions be maintained and that only resolutions written in both English and French be accepted from Commissions.

Copies of all resolutions which were passed by the Executive Committee and finally also by the final plenary session will be published separately in *IAGA News* No. 10 and in the *Transactions* (*IAGA Bulletin* No. 31).

## FINANCES

The Finance Committee submitted the following report which was accepted by the Executive Committee:

"The Finance Committee appointed by IAGA has carefully checked every item of the statement submitted by the General Secretary for the period January 1, 1967 to December 31, 1970, showing receipts amounting to $70,856.36 and expenditures of $43,886.03 with $26,970.33 available as cash in hand and in the Banks, at the closing date of the period under report.

"On the basis of this statement and the detailed additional information supplied by the General Secretary, which we deem satisfactory, we endorse the report and recommend that it be accepted.

"We also propose to express the acknowledgement of IAGA to Dr. Alldredge and his Institution for keeping the expenditures for personnel, supplies and equipment at a very low level; (actually, there were no expenditures at all for rent of quarters). It is also worth mentioning that expenditures for Symposia and Assemblies could be kept at a reasonable level thanks to the effort made by the National Committees in providing funds to this end."

A copy of the financial report from January 1, 1967 to December 31, 1970 discussed above will appear in the Report of the General Secretary in the Transactions of the Moscow Assembly (*IAGA Bulletin* No. 31). The budget for the years 1971-1975, calling for an allocation of $14,000/yr from IUGG, which will also appear in the report of the General Secretary, was approved by the Executive Committee.

It was agreed that the General Secretary should provide reasonable amounts of money to Commissions for postage, etc., without referring the matter back to the Executive Committee.

## PUBLICATIONS

It was agreed that IAGA should provide free of charge copies of *IAGA Bulletins* to the World Data Centers if they request them.

It was decided that each Symposium Convener should be encouraged to try to publish their symposium through regular Journal channels. The General Secretary was authorized to pay a few hundred dollars to help such publications if needed.

Note was made that the WMS final report was finished. A sample was available to view.

## SPONSORSHIP OF MEETINGS

It was agreed that IAGA would cosponsor the Equatorial Aeronomy Symposium being planned for Ibadan, Nigeria, in September 1972. This sponsorship will be at no cost to the Association except IAGA will send a representative who will be the Chairman of Commission IV or his representative.

It was agreed that the symposium on "Geomagnetic Anomalies; Rock Magnetism and Petrography" which had earlier been requested by Commission III would be a part of the Kyoto Assembly in 1973.

Commission III requested help in arranging for a Specialists, Workshop–type meeting of about one week duration. The Executive Committee agreed to approach the Japanese authorities for facilities in Kyoto during the week before the IAGA General Scientific Assembly in 1973. Dr. T. Nagata will see that this is done.

A proposal made by Drs. S. Matsushita and W. H. Campbell to hold a Special Symposium on "Worldwide Magnetic Variations" was referred to Commission IV for their suggestions.

## SECOND IAGA GENERAL SCIENTIFIC ASSEMBLY

President Nagata introduced Prof. N. Fukushima who indicated that the Japanese National Committee for Geodesy and Geomagnetism has asked their Government through the Science Academy for official approval to invite IAGA to hold its Second Scientific General Assembly in Kyoto from 10 September to 21 September 1973. He indicated that adequate facilities had already been reserved in Kyoto. The formal approval from the Government should be received soon.

Dr. Roederer indicated that the proposal to hold a STP Symposium in connection with the Second Scientific General Assembly has been withdrawn.

Commission Chairmen submitted a list of topics from their Commissions for presentation at this Assembly. This list as modified by the Executive Committee is shown under Plans for the IAGA Second General Scientific Assembly in *IAGA News* No. 19.

## INTERNAL REORGANIZATION OF IAGA

The Executive Committee invited Commission Chairmen to meet with it to discuss changes in Commissions and in Working Groups. Commissions were represented as follows:

Commission I – A. DeVuyst
II – R. B. Leaton
III – F. J. Lowes acting for T. Rikitake

IV – A. J. Zmuda acting for J. A. Jacobs
V – J. G. Roederer
VI – A. Egeland acting for A. Omholt
VII – G. M. Weill
VIII – A. J. Dessler
IX – N. V. Pushkov
X – Jt. Committee, Atmos. Elec., J. L. Koenigsfeld
XI – Jt. Committee, Lunar Var., O. Schneider

This meeting was very productive resulting in the internal organization and appointed officers shown in the front of *IAGA News* No. 10 This organization is tentative since some of the appointed officers shown were not contacted at the Assembly. Commission Chairmen were encouraged to complete their working group memberships as soon as possible.

## RELATIONS WITH OTHER ORGANIZATIONS

The Executive Committee took note of an item from IUGG Council Meeting to the effect that an International Magnetospheric Study (IMS) report had been published by a joint working group of IUCSTP and COSPAR without reference to participation by IAGA. IAGA was requested to discuss the project and make its own recommendations. The Executive Committee appointed a committee consisting of V.A. Troitskaya, A.J. Zmuda, G.M. Weill and T. Nagata to consider this problem. The committee consideration resulted in Resolution 1 which was subsequently passed by IUGG in a slightly modified form. The above committee was subsequently retained to further consider the IMS problem.

It was agreed to drop the IAGA/IAMAP Joint Committees on Atmospheric Electricity and Lunar Variations. Subsequent to this action IAMAP agreed to it and incorporated the Atmospheric Electricity organization into the IAMAP International Commission structure, and the Lunar Variation organization was made a Committee of IAGA.

Drs. J. C. Cain (USA) and H. Kautzleben (Germany) were nominated as members of the Inter-union Committee on Mathematical Geophysics, which is replacing the old Upper Mantle Committee, on Use of Theory and Computers. (Both were confirmed by the IUGG Council.)

Dr. J. Veldkamp was nominated to be one of the IUGG representatives in FAGS. (Subsequently Dr. E. Anderson was given this appointment.)

Dr. T. Nagata was nominated to be the IUGG representative to SCAR. (The IUGG Council later confirmed this appointment.)

Dr. G. M. Weill was nominated to serve on an Ad Hoc Committee of IUGG to determine the proper place of Geochemistry in IUGG.

## NEXT MEETING OF EXECUTIVE COMMITTEE

It was agreed that the next meeting of the Executive Committee should be held just before the COSPAR meeting in Madrid, in May of 1972. Dr. J.O. Cardus agreed to inquire of local authorities regarding facilities for such a meeting.

# REPORTS OF IAGA ORGANIZATIONAL UNITS

## COMMISSION I
## OBSERVATORIES AND INSTRUMENTS
## A.P. DeVuyst - Chairman

During the XV General Assembly the Business, Review and Scientific Session of the Commission I was held on Wednesday, August 4, 1971 at 3 p.m. as described below:

### ADMINISTRATIVE NOTICES

Because of retirement from service Mr. J.H. Nelson, reporter of Working Group I-1 and Dr. V. Laursen, reporter of Working Group I-3, had submitted their resignations. During the remaining period, Mr. K. Svendsen and Dr. K. Lauridsen acted as reporters respectively for these two Working Groups. Those present asked the Chairman to express greetings and gratitude to Dr. Laursen and Mr. Nelson.

The Chairman pointed out that on request of the Executive Committee a report on the evaluation of the effectiveness of Commission I was made by the Chairman in deliberation with the reporters. This report was read by the Chairman and discussed by the attendees. It was fully approved with the remark that more emphases should be laid on the work accomplished by the observatories.

### REVIEW BY COMMISSION CHAIRMAN

In general a certain number of observatories have acquired considerable experience in the routine operation of digitally recording magnetometers for normal or rapid variations. On the other hand, absolute measurements at many stations are made by proton magnetometers.

Most members of IAGA are interested in the record of performance of the various systems, their reliability and the problems of integrating them into the observatory routine. The Chairman suggested a scientific session in 1973 on this subject followed by a panel discussion and also the creation of a new working group. (See report on business meeting.)

### REVIEWS BY REPORTERS OF WORKING GROUPS I-1, I-2, AND I-3

Mr. Svendsen reported on two resolutions in relation with homogenity of the geomagnetic network.

Dr. P. Serson reported on the value of the gyromagnetic ratio and on the reference list and bibliography of magnetic instruments.

Dr. K. Lauridsen reported on the results of the intercomparison between stations. (See report of permanent service.)

### SCIENTIFIC SESSION

The following papers were added to the seven papers that were originally scheduled. (See IAGA Program and Abstract Book.)

I-8 Butigam, Z. and R. Turajlic, "Automation of basic ground procedures for collecting information for geomagnetic phenomena studies".

I-9 Auster, V., E. Bernitz, K. Leugning, D. Lenners, and H. Schmidt, "Data acquisition system with buffer storage and magnetic tape recorder".

I-10 Loomer, E. and E. R. Nibblet, "An automatic magnetic observatory system" (AMOS).

## BUSINESS MEETING

The Commission agreed to recommend the establishment of a new working group on "Processing Techniques of Observatory Data" (hardware and software).

After discussion, it was evident that within Commission I, a new working group for guidance on the operation of digital recording systems and data storage should be established.

At the business meeting Commission I passed four resolutions. Two of these were later adopted as IAGA Resolutions numbers 9 and 10 (see resolutions elsewhere in this publication). The other two resolutions are given below:

*I. S.I. Units for Geomagnetic Data*

It is recommended that:

1 (a) Observations of the geomagnetic field be expressed in terms of the magnetic induction B; unit tesla = weber $m^{-2}$

(b) If, during the transitional period, it is desired to express observations in gammas, a footnote should be added stating that one gamma is equivalent to one nano tesla.

2 (a) Values of intensity of magnetization "be expressed in terms of magnetization"; unit ampere $m^{-1}$.

(b) If, during the transitional period, it is desired to express observations in e.m.n. $cm^{-3}$, a footnote should be added stating that one e.m.n. $cm^{-3}$ is equivalent to $10^3$ $Am^{-1}$.

*II. Gyromagnetic Ratio*

IAGA recommends the continued use of the provisional gyromagnetic ratio for protons in water ($2.67513 \times 10^4$ rad $S^{-1}$ $T^{-1}$) until the Conference Internationale des Poids et Mesures adopts a value.

It was agreed that at the second IAGA General Scientific Assembly, to be held in Kyoto, Japan, in 1973, a two day scientific session on "Modern Magnetic Observatory Techniques" should be held in three parts with a tentative program as described below:

Part I: Review Papers

- I-1 Absolute instruments (K. Wienert, GFR)
- I-2 Proton and proton vector magnetometers (A. P. DeVuyst, Belgium)
- I-3 Coil systems for bias field (P. Serson, Canada)
- I-4 High precision instruments for secular variation ground stations (R. Turajlic, Yugoslavia)
- I-5 Recording
  - 5-1 General problems involving recording of rapid and normal variations (C. Sucksdorff, Finland)
  - 5-2 Torgue sensors (V. Bobrov, USSR)
  - 5-3 Fluxgate sensors (Primdahl , Denmark)
  - 5-4 Atomic sensors (B. Stuart, U.K.)
  - 5-5 Induction (L. Baransky and B. Kazak, USSR)
  - 5-6 Super conducting
- I-6 Data Handling
  - 6-1 Semi-automatic (B. Caner, Canada)
  - 6-2 Automatic (Schmidt, GDR)
  - 6-3 WDC (Svendsen, USA)

Part II: Contributed papers

Part III: Panel discussion; modern and most reliable equipment for magnetic observatory data handling.

It was also agreed that a symposium on "Magnetic Observations and Anomalies at Sea" should be held during the same assembly. Topics to be covered would be: "Shipborne and Airborne Measurements and Anomalies and their Interpretation".

## WORKING GROUP I-3, COMPARISON OF MAGNETIC STANDARDS

**E. K. Lauridsen – Reporter (for V. Laursen)**

The attendees at the working group meeting were: E. Kataja, Finland; M. Kivinen, Finland; P. Peltonen, Finland; K. Borg, Sweden; A. P. DeVuyst, Belgium; F. Primdahl, Denmark; O. R. Meyer, GRF; H. Schmidt, GDR; K. L. Svendsen, USA; R. W. Kuberry, USA; K. Wienert, GFR; Ju. Burtsev, USSR; H. Meyers, USA; W. Paulishak, USA; E. Iufer, USA; R. Turajlic, Yugoslavia; V. Bobrov, USSR; C. Sucksdorff, Finland; D. Voppel, GFR; and H. Kautzleben, GDR.

The report for the period 1969-71 reproduced below was distributed to all attendees. Kring Lauridsen made the following additional comments:

> Many years experience has shown that the logarithmic constant of QHM's generally decrease by about 3-5 log. units per year. It is therefore strongly recommended that QHM's used for determination of observatory base line values should be compared to a primary standard from time to time.
>
> For some years the Rud Skov Observatory has been disturbed by a DC-electrified railway. This however, does not affect the standard values of the observatory in a systematic way, and it may still serve as a center for comparisons. A displacement of the observatory is under preparation.

The Working Group decided that:

> The observatories should be requested not to rely on secondary standards without regular calibration.
>
> The possibility of comparing H-standards by means of the QHM's at disposal of the Association's permanent service on comparisons at Rude Skov should be advertized in *IAGA News*. Mr. Svendsen kindly promised to inform scientists about this facility when contacting observatories which could be potential users.
>
> Sincere thanks should be sent to the retiring Reporter Dr. V. Laursen and to the retired member Mr. J. H. Nelson. Dr. DeVuyst kindly promised to write and express the greetings and the gratitude of the Working Group towards these colleagues.

## A REPORT ON PERMANENT SERVICE ON COMPARISONS OF MAGNETIC STANDARDS FOR THE PERIOD 1969-1971

**V. Laursen – Reporter**

The operation of the IAGA Permanent Service on Comparisons of Magnetic Standards is entrusted to a Working Group of Commission I. Since the 1967 General Assembly this Working Group has been constituted as follows:

V. Laursen (Denmark), reporter
G. Fanselau (German Dem. Rep.)
B.R. Leaton (Great Britain)
E. Le Borgne (France)
O. Meyer (German Fed. Rep.)
J.H. Nelson (USA)
L. Prior (Australia)
K. Yanagihara (Japan)

In July 1970, Mr. J. H. Nelson, because of his reitrement from service in the U.S. Coast and Geodetic Survey, requested to be relieved of his membership, and in consultation with the Reporter, Dr. DeVuyst, Chairman of Commission I, suggested to IAGA that Mr. Nelson be replaced by Mr. R.W. Kuberry, Chief of the Fredericksburg Observatory. Mr. Kuberry has kindly accepted to serve as a member of the group.

As in previous report periods the comparison observations have been carried out by means of calibrated QHM-magnetometers sent by air freight from the Rude Skov observatory to the participating observatories and back. The comparisons have not been so very numerous, and it is felt that the service offered by the IAGA could be much more widely used, and that many more observatories might benefit by joining the comparison program. This applied for instance to observatories at which the standard value of H is based on relative instruments of the QHM type. It is generally recognized that the QHM offers a convenient means for the day-to-day determinations of H at a magnetic observatory, but from the long series of observations that are now available it is also obvious that the main constant of a QHM is likely to change slowly in the course of time (see f. inst. C.A. van der Waal: "Corrections for absolute and semi-absolute magnetic instruments", Australian Bureau of Mineral Resources, Geology and Geophysics, Record No. 1966/207), so that after some years the values obtained should be checked against a standard value based on really absolute instruments. The change of constant is usually of a regular, quasi-linear nature, so that the constant-values to be adopted during the interval between two comparisons can be obtained with sufficient accuracy through interpolation.

All the comparisons so far carried out have been arranged at the request of the participating observatory, and it is felt that if the requests have been relatively few in number this may be due in part to a certain lack of information concerning the Service. It was part of the program of the four World Magnetic Survey Missions to carry out comparison observations at the visited observatories by means of IAGA instruments, and to draw the attention of the local observers to the facilities offered by the IAGA Service. A further reference to these facilities is given in Dr. Wienert's "Notes on geomagnetic observatory and survey practice", prepared on the basis of experience gained during the WMS missions (UNESC) 1970).

The following comparisons have been carried out during the report period:

1. A comparison by means of QHM 228, 229, 230 between Rude Skov and the observatory at Vienna (Austria),
2. A comparison by means of QHM 50, 51, 91 between Rude Skov and the observatory at Lourenço Marques (Mocambique).

The results of the comparisons are given below in the form of differences between observatory standards of H. Also quoted is the result of a comparison carried out in 1968 between Rude Skov and the observatory at Coimbra (Portugal).

| | |
|---|---|
| 1968, April | Rude Skov – Coimbra = 18.3$\gamma$ |
| | (The Coimbra standard based on QHM 307) |
| 1970, December | Rude Skov – Vienna = -11.1$\gamma$ |
| | (The Vienna standard based on HTM 523932, 551636, 570710) |
| 1971, January | Rude Skov – Lourenco Marques = -37.2$\gamma$ |
| | (The Lourenco Marques standard based on QHM 299) |

During the period under review no comparisons have been carried out between Rude Skov and Fredericksburg. A summary list of all previous comparisons between the two observatories is given in the 1969 report (see *IAGA Bulletin* No. 27, p. 60).

The Rude Skov standard to which the station differences refer has been based partly on the classical magnetometer measurements and partly on routine measurements of H by means of the proton magnetometer. The latter measurements are made in the two-meter Helmholtz coil of the observatory, in which a vertical zero-field can be produced, and in which a liquid filled variometer, designed by E. Kring Lauridsen, is used to detect and measure any spurious H-field produced by the coil current.

For reasons of age the present Reporter has requested to be relieved of his responsibility in connection with the Service on Comparisons. I take this opportunity to express my sincere thanks to the members of the Working Group for the interest they have taken in the work, to the many Directors of the Observatories who have cooperated so willingly in the comparison program, and to the Observatory staffs who have carried out the Observations with all the care necessary for a successful accomplishment of this program.

# COMMISSION II
# REPRESENTATION OF MAIN MAGNETIC FIELDS
## B.R. Leaton – Chairman

The following general review of the work of the Commission was given by the Chairman.

A general review of the activities of Commission II from 1967 to 1969 was given at Madrid and reported in *IAGA Bulletin* No. 27. I do not propose to cover that ground again. I shall leave it to Reporters of Working Groups and Chairmen of small committees to report more fully on their activities but I would like to emphasize a few of those.

### WORLD MAGNETIC SURVEY

A separate part of the Report of the World Magnetic Survey (Grid Values for the IGRF 1965.0) has already been published. The larger and main part of the report *"The World Magnetic Survey 1959-69"* has just recently been published although distribution is only just beginning. At this point I particularly would like to thank Dr. A.J. Zmuda for the excellent and hard work that he has put into editing this book, persuading all the contributors to write their parts and organizing the very considerable technical effort of preparing manuscripts for typesetting and the actual printing.

### INTERNATIONAL GEOMAGNETIC REFERENCE FIELD (IGRF)

This has been quite extensively used now and considerable effort has been put to assessing its merits. We have reconsidered the IGRF at this Assembly and decided if changes are to be made to it and what they shall be.

### WORLD MAGNETIC ARCHIVE

This project was sponsored jointly by Commissions I and II but the main burden of acting on the resolutions made at Madrid has fallen on Professor Ota as reporter of Commission II, Working Group 6. He has produced two issues of the *WMA Inventory* and circulated them widely. Professor Ota has asked that opportunity be found for discussing the progress and continuation of the WMA project.

### SURVEYS

I would like to thank Dr. Serson for again producing an excellent report of the activities of his Working Group. I am very appreciative of the conscientious way in which he undertakes the task of Reporter and the continuing excellence of the results. He will be reporting himself about land and airborne surveys. I am particularly interested in his comments for the retrieval of the large amount of total field data which is primarily intended for mineral exploration purposes. I am concerned that we should try to get as much success with the oceanographic data. There are signs that the oceanographers are making real progress in the rationalization of the media and methods of data exchange. This will lead the way to a rather easier extraction for main field purposes from these data files. I would like to see some effort made by Commission II in approach to the custodians of oceanographic data to see the best way in which we can make useful selections from their data banks.

### SYSTEM OF INTERNATIONAL UNITS (SI UNITS)

The joint committee of Commissions I and II, set up to consider the implications within IAGA of adoption of the international system of units, has been active and has come up with a set of proposals which will be the subject of discussion at this Assembly. It looks as though we shall be able to carry on the same members as before even though we may have to give them a different name from the one we are used to.

### ORGANIZATIONAL CHANGES

I sent out a circular to Working Group Reporters in September 1970 asking for comments on two proposals for reorganizing Working Groups of the Commission. These proposals are a consequence of a proposal from Dr. Cain that Commission II should be responsible for solving the problems of modeling the external field. Since then Commission V has shown an increasing interest in this subject as it stems naturally from the Commission's work. The interest shown there is at the moment greater than that in Commission II so that these two structural changes are probably not now appropriate.

The Reporter of Working Group II-5 (Planetary Magnetic Fields) has represented that it is inappropriate at the present time to have such a Working Group.

Much of the work of Working Group II-4 is concerned with recent secular change of the main field. However, Commission III has a Working Group with this same name. Although some of its work reflects on that of Commission III, much of its work appears to be more directly concerned with the terms of reference of Commission II. I have discussed this matter informally with the Chairman of Commission III and he has made a suggestion to the Working Group Reporter which I shall read later.

## OUTLOOK

We have developed a number of long term commitments. The World Magnetic Archive has a finite aim and presumably once the bulk of the archive has been set up the ad hoc Commission I and Commission II Joint Committee can be wound up. These commissions can then make sure that the archive is kept up to date. Regarding the IGRF, however, if it is judged that this venture is a success then clearly there will be a continuing commitment to improve it and update it. We should consider whether the Analysis Working Group is the appropriate body to perform this function or whether we should attempt to set up an organization of a rather more permanent nature. Even though the WMS has now been successfully brought to a close, it is part of the terms of reference of the Commission to foster and encourage the magnetic survey of the earth in all its forms and in particular where there is a shortage of data. I would appreciate very much any suggestions that people may have to further this aim.

## WORKING GROUP II-1, LAND AND AIRBORNE SURVEYS

**P.H. Serson – Reporter**

A meeting of the Working Group was held Monday evening, 2 August 1971; 13 delegates attended.

P.H. Serson gave a progress report for the Working Group as indicated below:

### Land Surveys

The 1967 report of Working Group II-1 (*IAGA Bull.* No. 25, 33-37, 1967) presented a tabulation by country of the number of magnetic survey stations occupied in the preceding 5 years. The total number of stations was 20,000. About 1500 of these could be classed as active repeat stations, in the sense that they had been occupied, or were likely to be occupied, at least twice in a 10-year interval.

The 1967 tabulation contained several errors and was far from complete, listing only 40 countries. Attempts have been made to revise the table, but little information is available concerning measurements since the conclusion of the World Magnetic Servey interval, and a complete listing of countries is impractical – there are more than 50 countries in Africa alone. We will therefore simply indicate some of the more serious omissions of the earlier report, and add the information received on activity since the beginning of 1967.

A most important omission from the 1967 report is the work in Africa of l'Office de la Récherche Scientifique et Technique Outre-Mer (ORSTOM). During the years 1953-1966, 800 (DHZ) stations were occupied in 9 countries of west Africa, giving a density of about 4 points per square degree. Eighty principal stations have been reoccupied several times in the last 10 years. In addition, Z has been measured at over 50,000 points in connection with gravity surveys. ORSTOM has also established 270 (DHZ) stations in 4 countries of equatorial Africa.

Other information omitted, or incorrectly reported in the 1967 table is as follows:

Belgium: 20 repeat stations and 700(DHZ)
German Federal Rep.: 130 repeat stations and 2000(F)
South Africa and South West Africa: 53 repeat and 200(D)
United Arab Rep.: 148(DHZ) and 862(HZ)

Magnetic surveys completed since the beginning of 1967, with numbers of stations occupied, include:

Angola, 1966-67: 93(DHZ)
Bulgaria, 1940-67:(DHZ) every 25 km
Hungary, 1955-67:(DHZ) every 25 km
Italy, 1959-67: 30 (DHZ)
Luxembourg, 1968: 7(DHF) and 44(HF)
Morocco, 1967: 17(DHF) and 400(HF)
Mozambique: 240(DHZ)
Poland, 1960-70: (DHZ) every 25 km
Spain, 1963-67: 32(DHZ)

Few statistics are available on the reoccupation of repeat stations since the beginning of 1967:

Canada: 97
Democratic Republics of Eastern Europe: 40
Ireland: 18
Latin America: 200 (Inter-American Geodetic Survey)
U.S.A.: 47

Many other countries maintain a continuous program of reoccupying selected magnetic stations to determine secular change. Such a program is strongly recommended to maintain the quality of magnetic charts achieved during the World Magnetic Survey.

We conclude that there are probably more than 2000 active repeat stations (occupied at least twice in 10 years). Unfortunately, there are long delays in publishing, or otherwise making available, the observations obtained at perhaps half of these stations. Magnetic survey organizations are urged to report their repeat station results annually to one of the agencies responsible for compiling world magnetic charts, in the United Kingdom, U.S.A. or U.S.S.R., rather than holding them until a new map is published.

**Airborne Surveys**

Project Magnet of the U.S. Naval Oceanographic Office continued its airborne magnetic surveys of the world's oceans. Since the beginning of 1967, observations of D, I, & F were obtained at 35,000 points on more than 1,000,000 km of flight-lines. In addition, the U.S. Naval Oceanographic Office made a more detailed survey extending from the east coast of the United States to some 320 km beyond the continental shelf into the Atlantic Ocean.

The Canadian three-component airborne magnetometer was flown 200,000 km during the 4-year period, in surveys of western Canada, the northeast Pacific Ocean, the Canadian Arctic Islands, and a large part of the Arctic Ocean.

Concerning airborne surveys of total intensity intended primarily for petroleum and mineral exploration, statistics covering 50 countries have been compiled by the Society of Exploration Geophysicists. The total distance flown during the last 4 years is estimated as 10 million km, and the area covered would be of the order of 10 million $km^2$. Nearly half of the total was flown in Canada, 20 percent in Africa, and 20 percent in the U.S.A. Most of the surveys were sponsored by governments, and the data are accordingly available to scientists.

**Other Items**

H. Kautzleben gave additional information about recent surveys in eastern Europe. A long discussion was held on how to encourage continuance of old surveys and the starting of new surveys. This discussion terminated in passing three resolutions which were finally passed as IAGA Resolutions numbered 21, 22 and 23 (see resolutions elsewhere in this report).

It was pointed out that K.A. Wienert's manual *"Notes on Geomagnetic Observatory* *and Survey Practice"* was short of instructions for chart making. The reporter indicated he has made a start on a bibliography of chart making, but what is really needed is a very simple chart making manual. No one volunteered to write such a manual.

## WORKING GROUP II-2, OCEAN SHIPBORNE SURVEYS
### B.R. Leaton, Acting Reporter (for M.M. Ivanov, Reporter)

Eight members attended the Working Group meeting as follows: B.R. Leaton (U.K.), R. Turajlic (Yugoslavia), J. Dooley (Australia), H. Meyers (USA), V.N. Lugovenko (USSR), P. Hood (Canada), O. Meyer (FRG) and D. Voppel (FRG).

Following an unfortunate misprint in the program, neither F. Eleman, who was printed there as Reporter, nor M.M. Ivanov, who should have been listed as the Reporter, was present. B.R. Leaton took the chair. The attendees agreed that M.M. Ivanov should remain as Reporter. The following report which had been prepared by M.M. Ivanov, was later summarized at the Business Meeting of Commission II by Chairman B.R. Leaton.

### Progress Report on Ocean Shipborne Surveys

Magnetic surveys of the oceans and seas by ships may be of two types: the first, measurements of the three components of the magnetic field, which give complete information on the distribution of the vector of the magnetic field; the second type, measurements of the modulus of the field vector only.

The surveys of the first type are carried out on a small scale, for example: the well-known surveys of the non-magnetic ship "Zarya" which cannot be used on the high seas any longer because she is very old, the work of Yugoslavia in the Adriatic and some others.

The main difficulties encountered in carrying out this work are those connected with the development of a three-component magnetometer. The surveys of the second type are carried out by many countries including the USA, Great Britain, Japan, the USSR and many others.

The main purpose of these surveys is a geological interpretation of their results. It is well known, for example, that their results form one of the bases for the hypothesis of the ocean floor spreading. We know very many works devoted to the interpretation of the magnetic fields of separate regions of the world ocean which allows us to speak about the complexity and inhomogeniety of the structure of the upper layers of the ocean floor. Recently a number of works were published to summarize the surveys of separate regions of the oceans, for example, the USA papers on the Pacific, some work on the Atlantic, and the data on the Indian Ocean. Many papers dealing with this problem are presented to the appropriate symposia of the present Assembly.

The Reporter recommended that the interested countries pay more attention to the desirability of increasing the scale of three-component surveys, as well as that a special symposium on ship-borne surveys be held at the next Assembly.

### Other Business

There was a long discussion on how to improve exchange for marine data. O. Meyer reported that the IOC hoped to prepare a report by September on how best to achieve uniform coverage and to plant data in the International Data Center system. The difficulties were recognized by extracting from this over-saturated data set where a selection only would be adequate for Commission II purposes.

Following a suggestion from Commission I a suitable symposium topic for Kyoto 1973 was suggested as follows:

"Magnetic and Gravity measurements and anomalies at sea"

1. Instruments (sea, air, space)
2. Anomalies (results and interpretation)
3. Determination of position

It was suggested that this could be joint IAGA-IAG. When it was later learned that only IAGA would be at Kyoto the suggestion was modified by omitting gravity and it now becomes an inter-commission symposium embracing IAGA Commissions I, II and III.

## WORKING GROUP II-3, ROCKETS AND SATELLITES

**J.C. Cain – Reporter**

A meeting of working group II-3 was held and attended by the Reporter and 14 consultants.

It was agreed to continue the working group with the following tentative membership: J.C. Cain (US) reporter, Sh.Sh. Dolginov (USSR), E.J. Iufer(USA),A.N. Pushkov (USSR), and B. Theile (FRG).

It was noted that the proposed membership does not have a wide international representation and that an attempt will be made to broaden the membership to workers in other countries. However, the policy established would be that only those actively engaged in research and who would be active as committee members would be listed.

The title of the working group would be modified to "New Earth Satellites". This change recognizes that the use of sounding rockets in contributing to the representation of the earth's field has been minimal.

A survey was made of satellite experiments that have or will contribute to representation of the field. It was noted that although the experiments of the Cosmos and Ogo series have each been and are being successfully used, no country appears to have definite plans for future experiments. Both NASA and the Intercosmos groups have new experiments under consideration, but neither are definite. Noting this gap the following resolution was drafted: "In order to continue to provide information to improve the geomagnetic main field and particularly to follow the secular variation which cannot be accurately extrapolated more than a few years in time, it is strongly recommended that a resurvey by low earth satellite be made no later than 1976. Since there are yet uncertainties about the results of using only scalar observations to produce an accurate vector model, every effort should be made to make not only scalar observations accurate to 1 gamma, but also vector measurements with accuracies better than $0.1^\circ$ (ca. 100 gamma)".

This proposed resolution was later simplified and passed by IAGA as Resolution No. 24 (see IAGA Resolutions elsewhere in this publication).

A proposal was made that a scientific session entitled "Magnetic Surveys by Low Earth Satellite" be organized for the next IAGA Scientific symposium in Kyoto, Japan. This symposium should include not only the evaluations of past data, but also a discussion of instrumental techniques for scalar and vector measurement.

## WORKING GROUP II-4, ANALYSIS OF GEOMAGNETIC FIELDS

**A. J. Zmuda – Reporter**

Working Group II-4 held two business meetings and had one scientific session. The Working Group recommended the following in a Resolution submitted to the Resolutions Committee: "That the International Geomagnetic Reference Field 1965.0 be continued in use at least until the 1973 IAGA Assembly. At that time additional evaluations will be undertaken and recommendations made for future use of the IGRF." This Resolution slightly modified finally became IAGA Resolution No. 25.

Current evaluations of the IGRF show that it is fitting surface and near-surface observations to ±150 gamma or less and is fitting near-earth satellite observations to ±30 gammas or less. The trend on the IGRF is that it is satisfying the needs of those workers interested in surface and near-surface data. However, many of those using satellite data feel that they have a need for a better description.

It was suggested that those involved in improving the fit of harmonic descriptions always include an evaluation of the IGRF along with the evaluation of the proposed model, so that meaningful comparisons can be made.

A summary of a paper presented by the Reporter is given below:

### Review of Evaluations of IGRF

In the evaluations that led to the determination of the *International Geomagnetic Reference Field 1965.0,* the ranges of values for the spherical harmonic coefficients submitted were moderately broad. As examples in the main field coefficients, differences of 50 to 100 gammas were common in the ranges of the coefficients of the lower order harmonics; the coefficients of the higher order harmonics had lower means and spreads though there were sometimes differences in sign. For a specific secular variation coefficient, the range of values lies within 2 to 21 gammas. There were some coefficients in specific harmonic sets considerably outside the range of values for the comparable coefficients in the remaining sets. For example, the coefficient in the POGO harmonic set, derived from satellite observations has the value 26 gammas/year while the values for the other sets lie within the range 12 to 17 gammas per year.

The various sets of harmonic coefficients were evaluated by a number of authors and some of the sets were weighted to form what became in October 1968, *The International Geomagnetic Reference Field 1965.0*. The reference field was a series of solid spherical harmonics and their derivatives in geocentric spherical coordinates. There were 80 coefficients for the main field and 80 coefficients for the secular change field. The field represented was that of internal origin; no provision was made for external contributions. Thus, the fields due to ionospheric, magnetopause, tail-sheet, and ring currents are not included. Rms deviations of various types of observations from those computed by the IGRF 1965.0 were determined by J.C. and S.J. Cain. The rms differences in scalar intensity are between 160 and 227 gammas for points at the earth's surface or at Project Magnet altitudes, generally less than 10,000 feet. At the altitudes of near-earth satellites, $\lesssim$1500 km, the rms difference is between 32 and 57 $\gamma$. These are residuals, 160-227$\gamma$ for surface and near-surface points and 32-57$\gamma$ for near-earth satellite altitude, which probably should be used as standards to determine if a new harmonic series should replace the existing IGRF, or if new evaluations show an improving or deteriorating status for the existing IGRF.

The IGRF 1965.0 was subsequently applied to new Project MAGNET data by personnel of the U.S. Naval Oceanographic Office who prepared a series of maps showing the residuals, or observed minus computed values, of the scalar magnetic intensity. These data were supplied to the speaker through the courtesy of H. Stockard and G.A. Young of the Naval Oceanographic Office. The residual maps included the following characteristics: (1) Absolute residuals as large as 100 to 400 gammas are common with cyclical periodicities with wavelengths often a fraction of a degree. These variations are presumably of geologic origin and not easily representable analytically by spherical harmonics; (2) Considering the residual data in the South Atlantic and the west coast of U.S. and Mexico, one could probably make a case for a harmonic with a half wave of 20° in $\theta$ and amplitude of $\sim$150$\gamma$ (or 300 $\gamma$ peak-to-peak). The order of the harmonic would be $n = 360°/40° = 9$ which is just outside that presently covered in IGRF.

Analysis by M. Sugiura of the magnetospheric field distortions observed by OGO's 3 and 5 shows a distribution of residuals markedly different from that expected from the superposition of the field of external sources on that of internal origin.

In general, recent evaluations of the IGRF yields residuals compatible with those determined in earlier studies. There is no compelling reason to modify presently the existing reference field although trouble spots are emerging in the contributions from the secular change and from the external current systems.

## WORKING GROUP II-5, PLANETARY MAGNETIC FIELDS

**R. Hide - Reporter**

The meeting of Working Group II-5 was only attended by four people who acted as mourners at its funeral. The meeting lasted only a few minutes and after reading a letter from Reporter R. Hide recommending the group be discontinued, it was decided to abolish this group.

## WORKING GROUP II-6, DATA INTERCHANGE

**M. Ota - Reporter**

Approximately 20 people attended the meeting of this group. The *World Magnetic Archive (WMA) Inventories* which had been compiled by M. Ota were distributed. These Inventories (first and second issues) contain the materials which were sent to M. Ota by IAGA representatives or their agents in accordance with the announcement noted in *IAGA News* No. 8.

A Resolution was passed by the group regarding the World Magnetic Archive. This Resolution later was passed by IAGA as Resolution No. 26 (see Resolutions elsewhere in this publication).

It was agreed that the Reporter should send a general circular letter to the usual observatory and organizational addresses to encourage their efforts towards the WMA.

# COMMISSION III
# MAGNETISM OF THE EARTH'S INTERIOR
## F.J. Lowes, Acting Chairman for T. Rikitake, Chairman

The Review and Business Meeting of Commission III was held at 10:00 a.m., Saturday, 7 August 1971. Professor Rikitake was unable to be present, and asked Dr. Lowes to take his place for the Assembly. The meeting opened with brief reviews by the Working Group Reporters, all but Dr. Orlov being present.

After some discussion the meeting recommended to IAGA that the present work (compilation of observatory data) of Working Group III-2, Secular Variation, be transferred to Commission II, and that the Working Group, with new membership, should in future concern itself with wider aspects of secular variation, e.g. its determination from archeo- and paleo-magnetism , and its interpretation. (The acting chairman later proposed A. Cox as the Reporter of this Working Group.)

The previous proposal for a Symposium "Geomagnetic Anomalies, Rock Magnetism and Petrography" to be held in 1973 was approved, as were the proposals from Working Group III-6. (The Acting Chairman later approved two proposals from Working Group III-3.)

Five resolutions, from Working Groups III-3, III-5 and III-6 were approved. Four of these later were adopted by IAGA as Resolutions numbers14, 15, 16 and 17.

The meeting approved the recommendations of the Commission I ad hoc Working Group on S. I. Units.

The meeting recommended that Professor Rikitake should continue as Chairman of the Commission.

The meeting also recommended to IAGA the special advantages to Commission III of holding meetings jointly with IASPEI.

### WORKING GROUP III-1, ELECTRODYNAMICS

**F.J. Lowes – Reporter**

One session of the 1969 IAGA meeting in Madrid was devoted to discussions of the dynamo problem.

**Dynamo Theory**

There is now general agreement that the magnetic field of the earth (and sun etc.) is maintained by some sort of self-exciting dynamo mechanism, and the last two years has seen a big increase in the work being done on this problem, but there is no agreement on the particular mechanism likely to be evolved.

Gibson has extended the investigation of Herzenberg type dynamos to other geometrics and to higher order approximations. Gibson and P. H. Roberts have extended the calculations on the original Bullard-Gellman dynamo, and it now seems that this system, which marked the beginning of real interest in the problem, almost certainly does *not* work! However, by making the corrective motions less symmetrical Lilley produced a system which appeared to be stably self-exciting, though Gubbins (unpublished) doubts this.

Work on such dynamos, in which both the magnetic field and the fluid motion are of "large" scale continues, but most recent work is on "periodic" or "turbulent" dynamos, in which "small" scale motions maintain large scale magnetic fields.

Small scale motions which are periodic in space have been investigated by G. O.

Roberts and by Childress, and have been shown rigorously to be capable of maintaining or increasing large scale magnetic fields (and for a very wide range of situations).

Turbulent motions with specified average properties with or without large scale differential rotation have been discussed by Steenbeck & Krause, Rädler, Moffatt, Parker, and Lerche. A great many approximations are necessary, but these works suggest that such systems are capable of producing not only the earth's comparatively stable field, but also the oscillating field of the sun. At first it was thought that mirror asymmetry of the turbulence (such as could be produced by rotation) was necessary, but Rädler and Lerche now suggest that even isotropic turbulence could maintain large scale magnetic fields.

Of course we do not know at present if the motions of the earth's core are of small or large scale! Nor do we know whether the energy comes from thermal convection, sedimentation, or, as Malkus argues, from precession.

Also, all this work has been on the "kinematic" dynamo problems in which the effect of the electromagnetic forces on the fluid motion is ignored. The much more difficult "hydromagnetic" problem is practically untouched though Braginski, Kropachev and Soward are now working on the problem.

Similarly there has been hardly any work on the instability and time variation of the earth's dynamo, though Cook & P. H. Roberts, and Suffolk, have investigated further the Rikitake couple-dynamo model.

**Electromagnetic Interaction of Core and Mantle**

For reasonable values for the electrical conductivities of the core and mantle, Rochester suggests that the observed geomagnetic field variations are probably insufficient to produce the more rapid changes in the length of the day. (However shorter period variations, not visible at the surface, cannot be ruled out.) Hide has suggested that the coupling is inertial, produced by Taylor columns associated with "bumps" on the core-mantle boundary. Malkus has suggested that a precession driven turbulent hydromagnetic boundary layer could give the coupling.

**Membership**

The addition of F. Krause (G.D.R.), E. Lilley (Australia), W.V.R. Malkus (U.S.A.) and E.P. Kropachev (USSR) is recommended.

## WORKING GROUP III-2, SECULAR VARIATION

**V.P. Orlov – Retiring Reporter**

A meeting was held on Tuesday, 3 August 1971 at 18.30. Dr. Orlov, Reporter, was unable to be present because of illness. Dr. Pushkov presented Dr. Orlov's report as follows:

The working group has suffered a great loss with the deaths of Dr. Vestine and Dr. Lucke. This is a great blow to us all.

Because of the distance involved the members of the Working Group have not carried out any joint scientific investigations and have not had special meetings. Cooperation has been by correspondence and exchange of papers and data.

The most accurate information on the Secular Variation (SV) at discrete points is presented by the annual mean values at the worldwide magnetic observatories. But the global SV distribution is known less accurately because of shortage and uneveness of the magnetic observatory distribution on the earth's surface. Also, information from some observatories has been delayed or not given at all.

The collection of SV-data has been considered the most important SV problem. As previously, the Reporter has continued cooperation with worldwide magnetic observatories, collected the annual mean values, published them and delivered them to the magnetic observatories, the Working Group members and any organization or scientist concerned.

On the whole, during the interval of 1967-1971 were compiled and delivered the following summaries:

No. 3, issue of the year 1968

No. 4, issue of the year 1969

No. 5, issue of the year 1970

No. 6, issue of the year 1971 (being compiled).

These Summaries contain information, obtained at 168 magnetic observatories from 49 countries.

The detailed descriptions of the magnetic observatories were published in 1957 ("Description des Observatories Géomagnetiques," Uccle-Bruxelles, 1957). Since then at a number of the observatories there have been changes in equipment or site, changes that could affect the annual mean values and consequently, SV values. For that reason all magnetic observatories were asked to supply the following information:

1. Precise geographical co-ordinates ($\Psi$ and $\lambda$) and altitude above sea-level
2. Type of instrument for determination of the absolute values of magnetic elements
3. Variations of what elements are recorded
4. Were there any changes in the absolute values due to a change of the observational site, installation of some new equipment, comparison with the standards.

This additional information has been published in the Summaries No. 4 and No. 5.

The Reporter, emphasized that this work – collection of the annual means – was possible only due to the active participation of the Directors and the staff of the magnetic observatories. Many thanks are due to them all.

The Reporter expressed a certain regret at the delay of data by some observatories, especially by the observatories of New Zealand, Argentina, and French Antarctica.

The Reporter took an active part in compilation of SV analytical description that was necessary as part of the IGRF. The report on this investigation was submitted to the IAGA Conference in September of 1969 in Madrid. The Reporter indicated that tabulations had been made and that copies could be obtained from him.

The meeting then asked Dr. Pushkov to express appreciation to Dr. Orlov for the work he has done.

It is proposed that the Working Group should consist of A.N. Pushkov, Reporter, (USSR); L.R. Alldredge (USA); G. Barta (Hungary); E. Fabiano (USA); H. Kautzleben (GDR); S.R.C. Malin (U.K.); and T. Yukutake (Japan).

After some discussion the meeting agreed that with its present main purpose being the compilation of observatory data, it would be more logical if the Working Group, with A.N. Pushkov, as Reporter, was transferred to Commission II. (Editors note – In the new organization this transferred Working Group became Working Group II-5– "Recent Secular Variations.")

## WORKING GROUP III-3, ELECTROMAGNETIC INDUCTION
**I. Gough – Reporter**

A meeting of the Working Group was held on Wednesday, 4 August 1971 at 18:30. The Reporter and six members of the W.G. were present, with eleven interested colleagues.

The reporter welcomed Mme. Rotanova as a New Member of the W.G., and all participants at the meeting.

Worldwide activity in electromagnetic induction studies was briefly reviewed. Of special significance in recent years were numerous magnetotelluric studies in many countries; the development of two-dimensional arrays of magnetometers in geomagnetic deep sounding; the extension of magnetometer measurements to the sea floor; and theoretical advances in the inversion of magnetic variation anomalies to conductive structures. Special note was taken of the valuable meeting held in Reading, England from March 30 to April 2 1971. It was noted that electromagnetic induction was becoming a powerful method for study of tectonically active regions of the Earth, and of the interior of the Moon.

Three Resolutions were proposed. Two of these became IAGA Resolutions, (see Resolutions Nos. 15 and 16 reported elsewhere in this publication).

The IAGA/IASPEI/IAVCEI Symposium on Electrical Conductivity in the Earth and Moon, to be held on August 6 was noted.

Two Scientific Sessions of Commission III, scheduled for August 9 were noted. The

Reporter thanked his colleagues for their strong response to his action which led to these Sessions. The W.G. thanked the Reporter for his work for the Sessions.

The W.G. discussed a proposal that an attempt be made to organize a specialist meeting of workshop type, for scientists engaged in electromagnetic induction studies. Such a meeting might be held in the summer of 1972 and last for about one week. The Reporter will undertake to investigate the possibility of holding such a meeting.

The meeting was adjourned at 20.00. At 20.05 it was reconvened, after some participants had left, to consider a proposal by Dr. N. Rotanova, seconded by Professor Ashour, that Professor M.N. Berdichevski be elected to the Working Group. The W.G. requests the addition of Professor Berdichevski of the USSR to its membership.

After later discussion three Symposia were suggested for the 1973 meeting:

(a) Electromagnetic induction studies of tectonic regions: deep conductivity structures and physical processes in the Earth.

(b) Laboratory measurements of electrical conductivity of rocks and electromagnetic field studies.

(c) Electrical conductivity of the earth and moon.

(The first two were approved by the Commission Chairman and forwarded to the Executive Committee.)

## WORKING GROUP III-4, ROCK MAGNETISM

**C.M. Carmichael – Reporter**

The working group held a business meeting Thursday, 5 August 1971 at which there were 7 members of the working group and 27 interested scientists in attendance. Since the meeting took place prior to the scientific sessions there was no formal discussion of progress, but the meeting offered an opportunity for many workers in the field who had not previously met, to get to know each other.

The meeting discussed and approved the proposed symposium on Geomagnetic Anomalies, Rock Magnetism and Petrography for the 1973 IAGA meeting. This symposium will be jointly sponsored by the Rock Magnetism and Geomagnetic Anomalies working groups and Dr. Hahn the reporter for the Geomagnetic Anomalies working groups attended and took part in the discussion. It was intended to have one or more invited papers in each of three sessions, followed by contributed papers.

In the scientific sessions of Commission III there were 27 papers presented, 5 by title only, of interest to the Working Group. The sessions gave everyone an excellent opportunity to hear about the extensive rock magnetic research being conducted in the USSR.

The past two years have seen greater use of the electron probe microscope for the analysis of small grains; electron microscopy for the photography, identification and measurement of sub-micron particles; Mossbauer spectroscopy to distinguish between the different iron oxides produced from hydroxides; and direct observation of domain walls in specially polished sections.

Single domain particles of spinels seem to be larger than previously thought, while single domain rhombohedral particles are smaller. The piezomagnetic investigations seem to indicate that magnetic detection of seismic stress build-up could only be possible if a body with particularly favourable magnetic minerals were present at a seismic site.

## WORKING GROUP III-5, ARCHEOMAGNETISM

**R.L. du Bois – Reporter**

A meeting was held at 18.30 on Wednesday, 4 August 1971, and one Scientific Session of the Commission was devoted to papers in Archeomagnetism.

One resolution was proposed, which became IAGA Resolution No. 14.

The Assembly provided an opportunity for many scientists working in Archeomagnetism to meet for the first time. The large number of papers presented indicates the growth of the subject, particularly in its application to the study of secular variation. Accuracy of data is of course most important.

Both the geographical and time extent of data coverage is increasing.

Considerable new archeomagnetic intensity data, back as far as 9000 years, are available for many parts of the world. It seems that by using the Thellier double heating method accuracies of better than ± 5% can be obtained for archeointensity data, but several workers commented on the need for careful preselection of materials for study (using only well oxidized once fired pieces), and on the use of multiple specimens (5 or 6 specimens were suggested) to increase the accuracy and reliability of the results. Results are reported generally as a ratio of ancient to modern field intensities but it has been suggested desirable to report also absolute values for the ancient field intensity. The detailed characteristics of the heating curves were studied by one group of investigators to obtain much information on the magnetic history of the material.

Spectral analysis of some of the inclination data has suggested the presence of some specific frequencies of variation, but more data and work are needed to complete these studies.

New directional data for some areas has meant that preliminary comparisons can be made between the data for different regions, but data from the southern hemisphere is needed for these and other studies.

Workers seems to suggest that the $\alpha_{95}$ precision values of $1°$ to $3°$ can be obtained from archeomagnetic results. With data of this character it will be possible in the future to compare in detail regional ancient time variations and to define accurately secular variation and interpret its origin.

The size of the samples used varies with laboratories but all workers seem to agree on the use of 8 to 20 individually oriented specimens to determine direction. The smaller number (8) seems to be satisfactory when collecting materials *in situ*, whereas the larger number (20) has been suggested where bricks or tiles are used to measure inclination.

The subject of dating is of universal concern, and some of the discrepancies among archeomagnetic data may be due to errors in age assignment. It seems to be desirable for each investigator to give particular attention to this problem, and collecting one's own specimens seems to be most desirable.

## WORKING GROUP III-6, PALEOMAGNETISM

### K.M. Creer – Reporter

A meeting of the Working Group was held at 18.30 on Friday 6 August 1971. Several Symposia were proposed for the 1973 meeting:

(a) Magnetic Polarity Transitions

(b) Paleomagnetic intensity variations and the Carbon-14 balances

(c) The Lunar Magnetic Field: present steady field, ancient field, and theoretical models.

One Resolution was proposed, which became IAGA Resolution No. 17.

Scientific sessions (2½) on Paleomagnetism were held on 12 and 13 August. A total of 33 papers were offered, of which 27 were actually read (11 by USSR scientists).

The main topics discussed fall under 4 headings: (A) paleosecular variations, (B) reversals, (C) reversal stratigraphy and (D) applications to geological problems.

(A) Paleosecular variations are now being widely investigated by (a) studying sequences of lava flows, and (b) the changes in remanence directions recorded within intrusive igneous bodies, the idea being that the secular variation was recorded as the Curie point isotherm migrated from the surface to the interior.

Global analyses of studies made on Tertiary rocks have been made to inquire whether the field can better be represented, on average, by a dipole slightly offset from the geocentre, or slightly tilted to the geographic axis, rather than by an axial geocentric dipole as usually assumed.

(B) Features of the geomagnetic field during transitions between settled periods of one polarity to the other were discussed, in particular, (a) the suggestion of some experimental data that it might retain dipole characteristics during the transition, and (b) the time taken to reverse. Reports of studies on sequences of lava flows, within igneous intrusions, and in sediments, were presented. Theories proposed to account for the statistics of geomagnetic reversals were also described.

(C) Use is being made of the time distribution of reversals as an aid to stratigraphy. USSR research has been strongly applied to this object. Reports were presented describing how zones of normal or reversed magnetization had been traced over hundreds of kilometers, and their relationship with paleontological zones. Measurements of the remanence of ocean sediment cores were described as well as from continental rocks.

(D) Paleomagnetic evidence for the anti-clockwise rotation of the Danakil Alps in Ethiopia were presented. Studies of paleozoic rocks from western Ireland were described and compared with those from eastern N. America. Paleomagnetic data for Siberia were compared with similar data for Czechoslovakia and Europe for the Ordovician.

Perhaps the most important single aspect of these sessions was the contribution from USSR workers who, until now, except for a few group leaders, have not been allowed to participate in the international discussion of scientific problems in geomagnetism.

### WORKING GROUP III-7, GEOMAGNETIC ANOMALIES
**A. Hahn – Reporter**

A meeting of the Working Group was held at 18.30 on Friday, 6 August 1971.

**Progress Report**

According to a decision taken at the Madrid meeting 1969 the National Committees were asked whether they were willing to take part in the evaluation of "Project Magnet" profiles with respect to local anomalies. As a result of a circular letter there were 15 responses, 8 of them expressing a real interest in cooperation. To these latter addresses a comprehensive description of the method of H.A. Roeser was submitted about 1 year ago.

The execution of a plan to compile the magnetic surveys existing in Europe is still held back by the fact that the survey of the Federal Republic of Germany, being a link between the western and eastern surveys, is not yet available. As it is expected to be available next year the compilation can probably start in the near future.

Starting from satellite data attempts were made to produce anomaly charts of large areas of the world. The anomalies obtained were interpreted by correlating them to the distribution of the heat flow via depth of the Curie-interface. Work of this type has been done by J. C. Cain, I. Zietz, N. P. Benkova and T. N. Simonenko.

Analyses of long range profiles across the USA and the USSR led to similar power spectra in both continents showing maxima at 167, 72, 48 km wave lengths, which were related to the distribution of crystalline rocks within the crust. V.N. Lugovenko and S.A. Serkerov have treated this topic.

Statistical methods were developed for the treatment of magnetic fields, yielding criteria for the splitting of measured absolute fields into anomalous and regional field, for preferred directions, horizontal and vertical discontinuities, and the depth to interfaces between layers of different magnetization, especially the Curie-interface. (See papers by V.I. Kolesova, E.N. Poze and J.G. Zolotov, and W. Mundt.)

A method was developed for the quantitative interpretation of magnetic anomalies measured above single veins of magnetic rocks by taking into consideration the parts of the anomaly produced by the induced and the remanent magnetization of the body respectively. The result leads to some conclusions on paleomagnetism .

**Membership**

The replacement of L.M. Morley (Canada) by P.T. Hood (Canada) was recommended.

## COMMISSION IV
## MAGNETIC VARIATIONS AND DISTURBANCES
### A. Zmuda, Acting Chairman (for J.A. Jacobs, Chairman)

The Commission held twelve scientific sessions in which a total of 133 papers were given. The Business Meeting of the Commission and of the Working Groups yielded among other actions a total of eight resolutions for submission to the IAGA Resolutions Committee. Through the zealous efforts of the Working Group Reporters and others a substantial amount of material was consolidated on the progress made during the last four years and on the progress and problem areas discussed at this meeting.

## SUGGESTED CHANGES IN REPORTERS

Working Group IV-5, Dr. R. Gendrin for Dr. V.A. Troitskaya
Working Group IV-7, Dr. O. Raspopov for Dr. V. Schlich
Both changes were proposed by the retiring Reporters and are acceptable to their potential successors.

## SCIENTIFIC SESSIONS

### Morphology and Classification of Micropulsations
**V.A. Troitskaya–Reporter**

In the papers presented in this session mainly pulsations of Pc2-5, Pi2, Pc2 and IPDP type were discussed. New experimental results obtained for the family of Pc2,3,4, and 5 pulsations lead to the suggestion of a new classification, dividing the range of Pc2-5 pulsations into six-period intervals instead of the existing four intervals. It was stressed that the distribution of the amplitudes and spectra of Pc4 pulsations on the earth's surface depends on the geomagnetic activity and first of all on the position of the plasmapause and DR- currents. It was suggested that the properties of Pc4 reflect the changes of the geometrical structure of the magnetosphere and can be used for the tracing of its changes. The results of detailed analysis of diurnal variations of the periods of continuous pulsations were presented.

The difference of the Pc3 and Pc4 amplitude distribution on the earth's surface was stressed. Confirmation of the different dependence of the properties of Pc pulsations with periods less than 40 sec. and greater than 40 sec. from the parameters of the solar wind was presented. New ideas about the mechanism of Pc5 generation were developed showing the possibility of the location of their source inside the magnetosphere.

A new type of long-period irregular pulsations (periods of 150 to 300 sec.) generated in the polar regions and connected with the development of aurora was described. The comparison of Pi2 spectra on stations located far from each other in longitude showed the existence of fundamental maxima observed at all stations.

Different morphological properties of pulsations were analyzed on several profiles and it was stressed that the character of polarization must be taken into account in elaborating the new classification. It was also noted that it would be useful to take into consideration the existing classification of VLF emissions in elaborating the new classification of pulsations. The conception of the westward drift of protons deduced from the properties of IPDP was outlined in two papers. The possibility of estimating the energy of the drifting protons from the properties of IPDP was described. The comparison of Pil pulsations with aurora pulsations, and the behaviour of these pulsations and aurora in conjugate points suggests that their source is located near the equatorial plane.

### Interpretations of Geophysical Indices
**M. Sugiura–Reporter**

This session was held on Tuesday at 10:00 a.m. on 10 August, 1971 and a few changes were made in the original program as follows:
Paper IV-50 was transferred to a Commission V session (V-25) and Paper IV-52 was withdrawn.

Dr. Sugiura discussed Dst in terms of the ring current as observed by OGO's 3 and 5. In particular, the distribution of the quiet-time ring current was shown to be substantially different from the widely accepted models. Dr. V.A. Troitskaya described new indices derived from micropulsations to represent parameters for magnetospheric and solar wind conditions. Dr. Intriligator reviewed recent studies of correlations between solar wind and magnetospheric activity. Good correlation between the southward component of the interplanetary magnetic field and substorm activity was emphasized.

**Interpretation of Geophysical Indices and Other Magnetic Index Studies**
**M. Sugiura – Reporter**

This session was held on Wednesday at 10:00 a.m., on 11 August, 1971.

The paper presented in the Second Part of the session on indices was: IV-67, Carpenter, D.L.: "Plasmapause Monitoring using VLF Technique" (invited paper).

The speaker reviewed the behavior of the plasmapause during magnetospheric disturbances as revealed by the whistler technique. Not being pressed in time, thorough presentation was possible, and the paper was a valuable contribution to the sessions on indices.

After Carpenter's paper a panel discussion was held to evaluate the present status of the art in deriving and interpreting indices and to plan for the future. Panel members were: Drs. Troitskaya, Intriligator, Nishida and Carpenter. Dr. Troitskaya proposed cooperation with other workers to test the validity of the micropulsation indices that she and her colleagues have developed. Dr. Intriligator emphasized the importance of "streams" in the solar wind, and promised to publish outstanding events of streams, Alfven waves, discontinuities, etc., and starting times of sectors. Dr. Nishida reviewed various possibilities for an electric field index or indices, and concluded that the electric field over the polar cap might offer a good possibility, but more studies are needed to evaluate the technique. Dr. Carpenter suggested parameters expressing motions of the plasmapause during substorms and storms. He also suggested a possibility of monitoring field lines in the ring current region using a VLF technique. The panel discussions were stimulating, and valuable in assessing the present status. The participants agreed that there should be a similar session on indices in the next IAGA General Assembly in 1973. It is noted that small scientific sessions not pressed in time are more suitable for this type of discussion, and this probably applies to other areas.

## DISCUSSION AND RESOLUTIONS

### Project "Geomagnetic Meridian"

*Introduction*

Details of project "Geomagnetic Meridian" which was discussed at length in Commission IV and which resulted in IAGA Resolution No. 2 are given below:

There are some indications to insufficient information, restricting the possibilities of an investigator in the works, devoted to distribution in space and time of the earth's magnetic field variations. It is evident that a network of observatories, existing in the world, is unsatisfactory for both: quantitative aspect and technical equipment.

It is also obvious that there is no possibility to place magnetic observatories every 200-300 km all over the Globe for solving the totality of geophysical problems on the base of data obtained at such a net of stations. Therefore it is necessary to create several streamlined nets of temporary and stable observatories for solution of specific scientific problems. The given project contains one of suggestions concerning the development of such a net of magnetic stations.

*Formulation of a problem (Problem wording)*

It is known that the magnetospheric substorm manifests most vividly in the earth's magnetic field variations. However, it is not clear up to now what relation is between sources, responsible for field variations. The sources may be following: currents on the magnetosphere surface, ring and asymmetric currents, polar electrojets, equatorial electrojet, currents in the magnetospheric tail and currents along field lines. The problem is how to distinguish the influence of those sources according to measurement data obtained satellites and earth's surface. Evidently, some valuable information may be obtained from measurements along the geomagnetic meridians from the Auroral zone to the Equator. Using this information it may become possible to develop such problems as:

1) connection between the symmetrical and asymmetrical ring currents in the magnetosphere and polar magnetic disturbances;

2) study of asymmetric ring current on storm phases and its relation with

ionospheric processes;

3) introduction of new magnetic activity indices based on physical division of observed variation into the field of currents in the ionosphere and that in the magnetosphere;

4) prediction of the magnetic activity and "weather" in the magnetosphere.

Besides the magnetic observatory data along a meridian may be used with great effect while studying long periodic geomagnetic variations and the earth's electroconductivity.

The indicated problems are undoubtedly of great scientific value and in the next decade the efforts of investigators of many countries will be to a considerable extent directed to their solution.

*Proposals on Observation Meridians Choice*

Meridional profiles of magnetic observatories may be easier created in the places where there is a number of magnetic observatories and consequently for complete profile, it is necessary only to add to their number some temporary or stationary stations. In this connection we must pay attention to a geomagnetic meridian of 105-115° (see Fig. 1): from Spitsbergen on Trömse via Eastern Europe and Near East to Addis Ababa. There are a number of geophysical observatories on this meridian and only 4-5 stations should be added to create a net of stations with intervals not more that 5° in latitude. A remarkable peculiarity of the indicated meridian is that observations on this meridian may be extended in the Southern Hemisphere to the Antarctic Continent where there are observatories Mawson, Devis and Mirny close to 110° meridian. Besides some well-known pairs of conjugated stations Sogra-Kerguelen, Pskov-Kroze and Dolgoschelje-Heard Island are situated close to meridian 105-115°. The significant observations on this meridian will be even greater by the beginning of 1973, when communication satellite ATS-F with a magnetic observatory on board will be launched. The satellite is expected to be on geographic longitude of 35°E that approximately corresponds to geomagnetic longitude of 105°. Thus conditions for obtaining significant scientific results will be created.

The second perspective geomagnetic meridian is that of 140-150°; from Franz Josef Land to Novaja Zemlja and Jamal, through Omsk-Alma-Ata and further to Delhi-Hajdarabad. Not less than 10 magnetic observatories are under operation on this meridian now and the "Blank places" are mainly on USSR territory. So 6-7 magnetic stations in addition will be enough for fruitful work on that meridian.

The offered meridians are not the only suitable ones; in future the required data could be obtained from the stations along other meridians as well.

*Expected Forms of Cooperation and Data Exchange*

A net of observatories with standard magnetograms of 20mm/hour is expected, with the future possibility of collecting magnetograms of some individual periods with resolution of 90mm/hr. The WDC-B2 on Geomagnetism in Moscow is responsible for collection, keeping and propagation of data. Every participant of the project may receive data according to the rules of international exchange from WDC-B2 on Geomagnetism in Moscow. In the near future after the IAGA Assembly it is planned to organize a research group, consisting of scientists from countries participating in observations, for the analysis of obtained data and preparation of joint publications.

*Resolution*

The following Resolution is suggested concerning this project: IAGA again confirms Resolutions 6, 7, 12, adopted at Madrid sessions, 1969, and stress a great scientific significance of the projects of simultaneous observations along the geomagnetic meridians of 105-115° and 140-150° from Auroral Zone to Equator. IAGA recommends to the national geophysical institutes to participate most actively in this project.

**List of Stations on the 105° Meridian**

| | | | | | |
|---|---|---|---|---|---|
| 1. | ALERT | (CANADA) | 26. | SURLARI | (RUMANIA) |
| 2. | MURCHISON | (SWEDEN) | 27. | SIMFEROPOL | (USSR) |
| 3. | BARENTSBURG | (USSR) | 28. | KANDILLI | (TURKEY) |
| 4. | BEAR ISLAND | (NORWAY) | 29. | TBILISI | (USSR) |
| 5. | TROMSO | (NORWAY) | 30. | PENDELI | (GREECE) |
| 6. | ABISKO | (SWEDEN) | 31. | KSARA | (LEBANON) |
| 7. | UTSJOKI | (FINLAND) | 32. | TEHRAN | (IRAN) |
| 8. | KIRUNA | (SWEDEN) | 33. | NITSANIM | (ISRAEL) |
| 9. | IVALO | (FINLAND) | 34. | MISALLAT | (UAR) |
| 10. | SODANEYLA | (FINLAND) | 35. | ADDIS ABABA | (ETHIOPIA) |
| 11. | MURMANSK | (USSR) | 36. | BUNIA | (CONGO) |
| 12. | LOVOZERO | (USSR) | 37. | LWIRO | (CONGO) |
| 13. | DOMBAS | (NORWAY) | 38. | NAIROBI | (KENYA) |
| 14. | LOVO | (SWEDEN) | 39. | TANANARIVE | (MADAGASCAR) |
| 15. | NURMIJARVI | (FINLAND) | 40. | PLAISANCE | (MAURITIUS) |
| 16. | LENINGRAD | (USSR) | 41. | KERGUELEN | (FRANCE) |
| 17. | BOROK | (USSR) | 42. | MAWSON | (AUSTRALIA) |
| 18. | MINSK | (USSR) | 43. | DAR-ES-SALAM | (TANZANIA) |
| 19. | MOSCOW | (USSR) | 44. | KROZET IS. | (FRANCE) |
| 20. | KAZAN | (USSR) | 45. | HEARD IS. | (FRANCE) |
| 21. | SVERDLOVSK | (USSR) | 46. | PSKOV | (USSR) |
| 22. | LVOV | (USSR) | 47. | DOLGOSHELIE | (USSR) |
| 23. | KIEV | (USSR) | 48. | SOGRA | (USSR) |
| 24. | JASSY | (RUMANIA) | 49. | ARKHANGELSK | (USSR) |
| 25. | ODESSA | (USSR) | | | |

**Project Geophysical Test Ground in the Antarctic**

Commission IV discussed the need for better Antarctic geomagnetic measurements. This discussion led to IAGA Resolution No. 8. Details of this project are given below.

*The Main Objects of the Project*

1. Detailed exploration of the structure and the main regularities of the temporal and spatial distribution of geomagnetic variations at high latitudes and their dynamics with the object of finding out the minimal number of base stations and their location so that their data could allow one to reestablish a complete picture of disturbances in the whole polar cap.

2. Investigation of the relationship of the state of the lower atmosphere with different types of geomagnetic disturbances and their intensity with the object of developing an effective way of preparation of synoptical maps of the state of the ionosphere using the data of several base magnetic stations.

3. In a number of papers it is shown that the geomagnetic variations in the polar caps are most closely connected with the variations of the parameters of the solar wind. Thus continuous observation of the state of the geomagnetic field at points chosen in a proper way allows the state of the solar wind to be followed, which in its turn permits a short-time forecasting of the state of the magnetosphere and and ionosphere to be carried out.

4. As it is shown by the analysis of the experimental data the sector structure of the interplanetary magnetic field obviously influences the development of geophysical phenomena in the lower atmosphere and in particular it affects the state of weather. One may suppose that if the data on the changes in the state of the solar wind obtained by ground stations is timely taken into account it will allow substantial corrections to be introduced into weather forecasting.

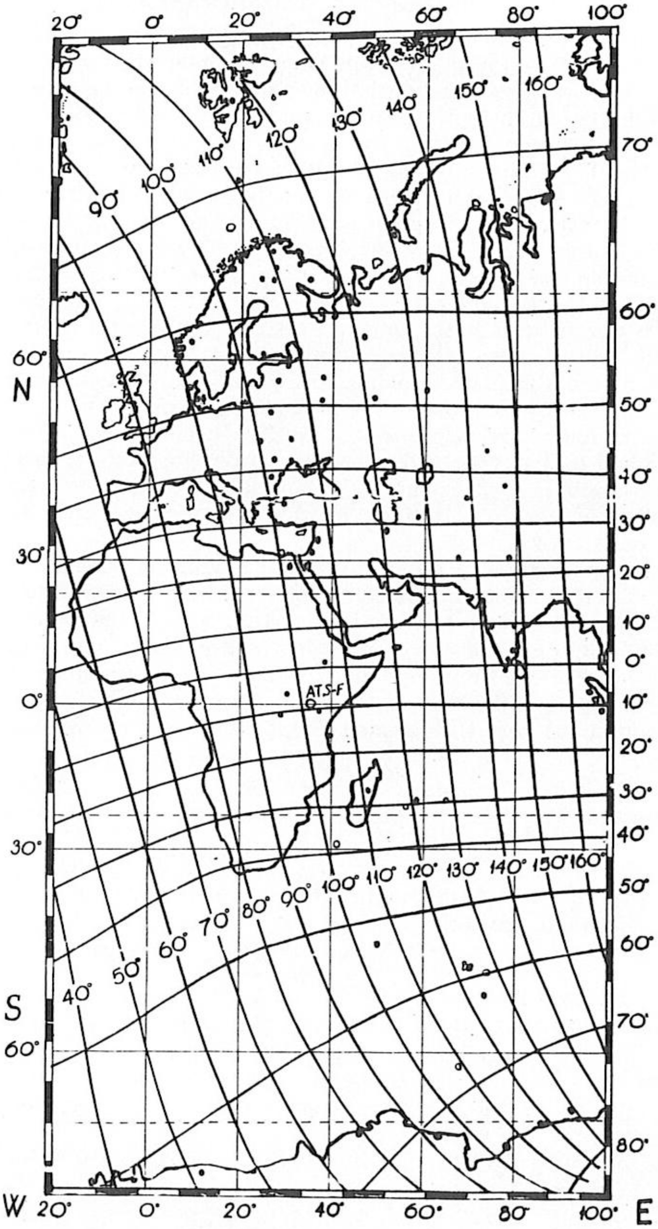
5. When investigating the structure of the magnetosphere and the physical processes taking place there it is of great importance to carry out simultaneous observations at the opposite ends of a line of force of the geomagnetic field (at conjugated points).

СХЕМА РАСПРЕДЕЛЕНИЯ ГЕОМАГНИТНЫХ ОБСЕРВАТОРИЙ ПО ПРОЕКТУ

„ГЕОМАГНИТНЫЙ МЕРИДИАН"

THE SCHEME OF DISTRIBUTION OF THE GEOMAGNETIC OBSERVATORIES ACCORDING PROJECT

"GEOMAGNETIC MERIDIAN"



*The Program of Primary Tasks*

Detailed exploration of the regularities of the distribution and the structure of high-latitude magnetic variations can be carried out only if the stations are located all over the polar cap in a definite way. The stations have to be distributed in such a manner that at a certain (arbitrary) moment of the universal time magnetic variations could be observed at the most interesting areas which are:

1. The auroral zone (the circle of the corrected geomagnetic latitude of $\varphi = 67^\circ$)
2. The high-latitude zone ($\varphi = 78^\circ$)
3. The midday-midnight meridian
4. The morning-evening meridian
5. The morning and the evening sectors at the latitudes of from $\varphi = 65^\circ$ to $\varphi = 80^\circ$

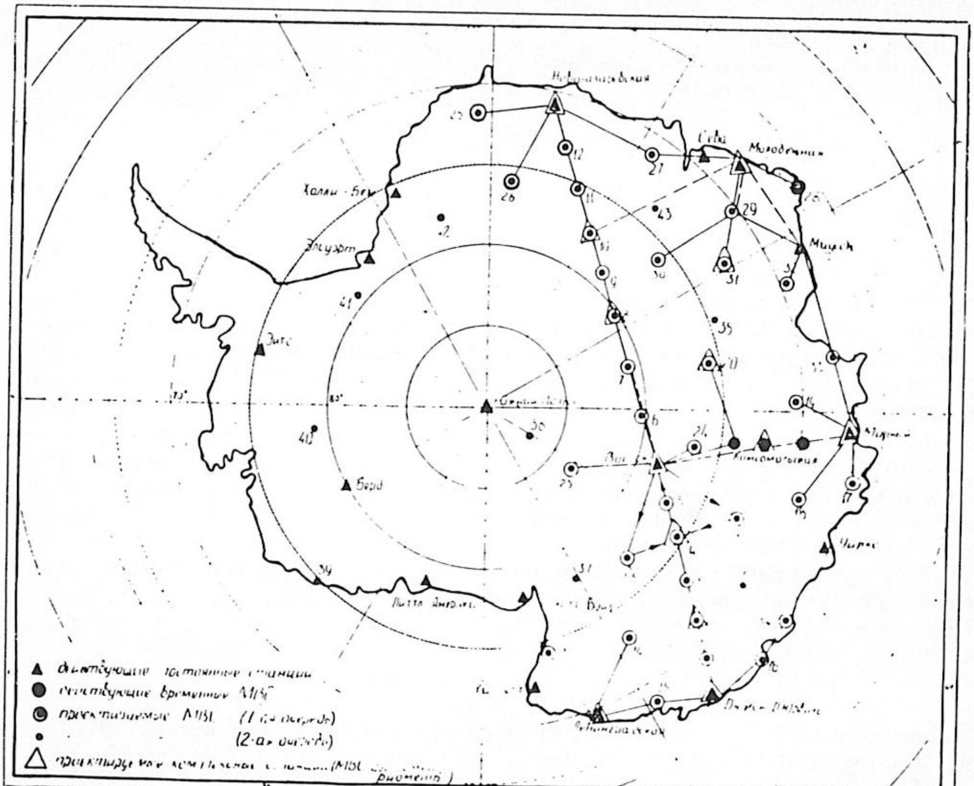
Under the Arctic conditions these requirements can be simultaneously met approximately at 01′ of the Universal time when the midnight meridian passes through the Vostok and Novo-Lazarevskaya stations and the midday meridian passes through the Dumond-d'Urville station; the pole is situated approximately at $G = 76^\circ$, $\lambda = 123^\circ$ E Long (corrected geomagnetic coordinates). The morning meridian will pass through the Oasis station (Point No. 17), and the evening meridian will pass near the Scott Base and Little America stations. At this moment magnetic variations can be observed along the whole length of the polar oval, from any point lying within the oval and from the evening and the night sector of the auroral zone. The data on the daytime sector of the auroral zone can be obtained from the MacQuarry Island station ($\varphi$=65) which is almost at the same meridian where the Dumond-d'Urville station is at that time. It is necessary to note that in this case it is not difficult to set up a network of stations in the morning sector of the polar cap. The fact is that 01′ the morning sector embraces the eastern coast of Antarctica where there are several permanent geophysical observatories (including the Mirny and Molodyezhnaya stations of the USSR) and where it is relatively easy to set up a great number of temporary magnetic stations. The Leningradskaya, Hallet, Scott Base, Little America and Bird stations will be within the evening sector at this time. A number of temporary stations can be set up by the personnel of the Leningradskaya station. Further development of observations in this region is possible on the basis of international cooperation

With the same location of the stations the dynamics of variations in the polar cap can be followed in the course of the next 6 - 8 hours of observations (during this time the midnight meridian will shift to the Bird station). During these hours data will be obtained in the high-latitude zone along two mutually perpendicular meridians (the midnight meridian will become the morning one and the evening meridian will become the midnight one) as well as in the night sector of the auroral zone.

Good conditions are also created for observations at conjugated point. The Dumond-d'Urville - Novo-Lazarevskaya magnetic meridian corresponds to that passing across the central part of Greenland and the Cape Tobin station. Thus it is possible to carry out observations at conjugated points at a wide interval of latitudes from $\Phi = 68^\circ$ to the pole.

On the basis of the above-mentioned principle of locating the stations, the following suggestions on their distribution in the Antarctic can be recommended (their accessibility is taken into account):

along the Dumond-d'Urville – Novo-Lazarevskaya geomagnetic meridian – twelve stations (average spacing of 2.5-3° of latitude),
along the Scott Base – Oasis meridian – four stations (Nos. 17, 18, 21, 22),
along the high-latitude zone – eight stations (Nos. 13, 15, 16, 17, 34, 19, 20, 7),
at the latitude of $\Phi = 80^\circ$ – three additional stations (Nos. 14, 23, 14),
along the auroral zone – six stations (Nos. 11, 12, 25, 26, 27, 28),
in the transitional zone at the latitudes of from $\Phi = 65^\circ$ to $\Phi = 78^\circ$ – five more stations (Nos. 29, 30, 31, 32, 33).



It is suggested that 34 temporary stations should be set up altogether in addition to the three stations which are now in operation (see the map). It is desirable to set up stations at other points (they are marked on the map), but the delivery of equipment there will entail great difficulties.

The work of the whole network of stations in Antarctic is planned for 3 – 4 years. After detailed explorations of the structure of the high-latitude magnetic variations and their relationship with other geophysical phenomena further observations will be carried out only at several base stations (about 10). For operative reception of information, which is necessary for diagnostics and forecasting magnetospheric processes, it is contemplated to equip the base stations with magnetovariation units transmitting the data to a satellite.

## SUGGESTED TOPICS FOR SPECIAL SYMPOSIA OR SESSIONS AT IAGA SCIENTIFIC ASSEMBLY IN 1973

1. Micropulsation theory and experimental results including comparison with satellite data, proposed by Working Group IV-5 which set up the following program committee:

Dr. Pellat with Dr. Gendrin also participating as Working Group Reporter.

2. "Prediction of all aspects of substorm phenomena utilizing mainly ground observations", proposed by Working Group IV-5.

3. "Worldwide distribution of geomagnetic disturbance phenomena", suggested by S. Matsushita and W. H. Campbell (also submitted as a resolution to the Resolutions Committee).

4. A small, limited set of review papers on "Conjugate phenomena", proposed by Working Group IV-7.

## WORKING GROUP IV-I, MORPHOLOGY AND INDICES

**D. Van Sabben–Reporter**

Between assemblies the Reporter has distributed several papers to the Working Group members. Some of these are included here to help understand the Moscow report.

### Review of Work as Described by Reporter in June 1971

At the IAGA-IASPEI Scientific Assembly in Madrid, 1969, the *contents of the monthly, quarterly and yearly IAGA Bulletins*, as prepared and issued by the International Service of Geomagnetic Indices (ISGI), were discussed, following a questionnaire on the publication of magnetic disturbance data in 1969. As a result, the publication of C-figures of individual stations has been discontinued (Resolution 3, Madrid) and some measures have been taken to reduce the published amount of less important data on rapid variations. A preliminary list of sudden commencements and solar flare effects was added to the monthly report of selected days and Ci-figures.

In accordance with the same resolution, the reporter studied the possibilities to put the *K-indices of individual stations in machine readable form,* in order to make them available on request. It appeared that for practical and economical reasons it is most appropriate to do the work at the ISGI-center in De Bilt, at least for the time being. The tables of K-indices will be prepared mechanically starting with *IAGA Bulletin* **12x1**, 1969 and the data will remain available on magnetic tape.

From the 1969 questionnaire it appeared that many people are in favor of publishing a yearly *survey of magnetic storms* including magnetograms. This idea has been further elaborated and the opinions have been asked from a number of interested persons. The result is a tentative scheme for such a survey in the *IAGA Bulletin,* **12**, which will be discussed at the Moscow Assembly.

Studies on the *indices $K_n$ and $K_s$* (for the northern and southern hemispheres) and their mean value $K_m$ have been made by Mayaud (1969). From 9 years of data, the differences between $K_n$ and $K_s$ and their daily and annual variations were investigated. The UT-effect in these variations was compared with the UT-variations of the indices Dst and AE (Mayaud, 1971).

From a comparison between the index $a_m$ (related to $K_m$) and a corresponding index derived from the K-data of only 2 antipodal stations (Hartland and Toolangi), Mayaud concluded that it is possible to determine a good *series of disturbance indices, going back to 1868*, from the records of the stations Greenwich-Abinger-Hartland and Melbourne-Toolangi. He undertook this work, which is nearly completed now, at the same time composing a *historical list of sudden commencements* of magnetic storms, which is mainly based on the material of the same stations.

The *relation between sunspot-activity and magnetic indices* has been studied by E. J. Chernosky (1971). He found a good correspondence between the occurrence of new spot groups and the values of $A_p$ a few days later.

The *variation of the AE-index with the direction of the earth's dipole axis* relative to the earth-sun line has been investigated by Cowley, Ecklund and Reid (preprint). Their result indicates an average northward component in the solar wind direction for the period 1957-1964.

In order to study the *asymmetry of the magnetospheric ring current* and its variation in time, Kamide and Fukushima (1971) introduced 4 parameters to characterize the asymmetric ring current and compare them with the Dst- and AE-indices for 5 magnetic storms.

The method of the *selection of international quiet and disturbed days* has been the subject of discussion at the Madrid Assembly and at a meeting in Potsdam during the symposium on "Solar Regular Daily Variations", April 1970. In his paper, Mayaud (1969) suggested basing the selection of quiet days on the occurrence of quiet 48-hour periods, centered at 1200 UT, instead of 24-hour periods and on the $a_p$-index, instead of $K_p$. He also suggested abandoning the selection of disturbed days and the publication of $S_d^{\cdot}$, and to introduce instead the daily variations of local quiet days in the yearbooks.

A study on the latitude dependence of the *index* $\chi$ has been made by Fanselau (1968), who had introduced this index as a measure for the time-variability of disturbance. He suggested using $\chi$ as a classification tool. The question of the method of classification will be further discussed at the Moscow Assembly.

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**Business Meetings held in Moscow**

The Working Group met twice during this Assembly.

It considered that, according to Resolution No. 3 of the Madrid Assembly in 1969, the publication of K-indices of individual stations can be discontinued, because these indices will be available on magnetic tape from the year 1969 onwards. Instead of these K-indices, the W.G. recommends publishing Dst and other planetary indices in the *IAGA Bulletin* 12, in addition to the Kp-index. It discussed the possibility of also including a survey of magnetic storms, containing for each storm the planetary indices, data on its ssc, K figures and magnetograms of the H-component from a number of selected stations. This survey would appear in the yearly *IAGA Bulletin* within 9 months after the end of a year. The choice of the stations which would contribute to the survey is a subject for further discussion. A sample case will be made available shortly.

Considering the work of Dr. Mayaud on the selection of the international Q- and D-days, the W. G. could not reach a consensus regarding the proposed change of the classification method. It agreed that some information should be added to the selected days, indicating their real level of disturbance.

Dr. Mayaud presented a scheme for the publication of the 100 years-series of magnetic indices which he has recently determined, and of the scc-data for the same period. The W. G. recommends the publication of this work by IAGA.

Since the introduction of new forms of the reporting of rapid variations after the Madrid Assembly, stations with quick-run records report the exact times of certain ssc's in tenths of a minute. In case of an ssc (main impulse preceded by an inverse impulse) the meaning of this time can be dubious. In order to improve the instructions for future reporting a study will be made of the data which have been collected up to now.

According to Dr. Romana stations frequently report si (sudden impulses) during magnetic storms. It was decided that such si's will no longer be published, unless they have the character of an ssc.

The number of pc's reported is extremely different for different stations. This could be improved by putting a minimum amplitutde in $\gamma$'s for the reporting of pc's. A study will be made of this question, using the data on 5-10 clear pc-cases, which will be put on the check lists for 1971, to be sent to all observatories.

Finally the W. G. considered the proposal made by Dr. Mansurov for a resolution concerning a new magnetic index which is closely related to the radial component of the interplanetary magnetic field. Suggestions were made for a revision of this resolution.

**Report on the Provision of Daily International Magnetic Character Figures Before 1890**
**Van Sabben–Reporter**

A proposal to study the possibility of extending the existing series of *Ci-indices* as far as possible backwards, was referred to IAGA by the Royal Society, London, in 1969, following discussions between Professors Chapman and Mustel, who concluded that such indices would be valuable in the study of correlations between meteorological and geomagnetic data.

The proposal was forwarded to the Working Group on Morphology and Indices of IAGA Commission IV. The reporter of this Working Group checked the existence of Ci-indices for the early years and found that for the period 1884-1889 such daily indices were already determined and published by J. Bartels in: *Terr. Mag.*, **52**, 33-38, 1947 (*see* also: *Trans Washington Meeting,* 1939, *IUGG Assoc. Terr. Magn. Electr.*, Bull. no. 11, 183-195, 1940).

The proposal was discussed by the Working Group at the IAGA-IASPEI Assembly in Madrid, Sept. 1969. It was considered that Ci, in order to have any significance as an index of magnetic activity, has to be based on the data of a sufficient number of observatories, because it is the average of C-values, which are determined on the very rough scale 0, 1, 2. The figures of 1884-1889 are based on six or seven stations only. Still less stations were in operation before that time. Therefore, it was concluded that it would be of little value and it could even be misleading to publish Ci-values for these early years. However, it was considered worth while trying to determine series of *K-indices* from the records of some of the oldest stations. A small study-group for this purpose was formed. The K-indices are on the scale 0-9. Moreover they are given for 3-hour intervals and therefore the daily index A, based on the 8 K-values, is a much better index for the disturbance level at a station than the C-figure for that day.

The study-group discussed the availability and usefulness of the old records. The work of determining the K-indices was undertaken by Dr. P. N. Mayaud, who is most experienced in this field. In order to obtain a homogeneous series of data and to reduce the local time variation of magnetic activity, he used the records of two nearly antipodal stations, which had been simultaneously in operation since 1868, namely Greenwich (since 1848) and Melbourne (since 1868). From a comparison of the mean A-index from these two stations with the existing planetary indices for the trial period 1959-1967, Dr. Mayaud showed that the correlation for the daily values is very good. He visited observatories and determined the three-hourly K-indices from their records, back to 1868, at the same time collecting the material for a catalogue of "sudden commencement – times" of magnetic storms.

The result of his work will be published as *IAGA Bulletin*, No. 33, which will contain the daily A-index for the Northern and Southern stations separately, the mean A-index for 12 hour-periods and a running graph of these mean values, together with the catalogue of ssc-times, for the period 1868-1967.

For the period 1848-1868 only the Greenwich records can be used. As it appeared that the A-index is sometimes very different for the Northern and Southern stations, it must be concluded that for these early years a reliable planetary index cannot be determined.

## WORKING GROUP IV-2, DAILY VARIATIONS
**D.J. Stone–Reporter**

### General

The working group met at 18.30 hours on 3 August, 1971 and D.J. Stone reported on the activities of the Working Group since the 1969 General Scientific Assembly in Madrid and on scientific progress in Daily Variations in the last two years.

Following agreement among the members of the Working Group to hold a symposium specially devoted to Daily Variation problems, the International Symposium on Solar Regular Daily Geomagnetic Variations was sponsored by the International Association of Geomagnetism and Aeronomy of the IUGG and the National Committee of Geodesy and Geophysics of the GDR in Potsdam during 23-29 April, 1970 at the Central Institute for Physics of the Earth of The German Academy of Sciences at Berlin *(IAGA News*, No. 9). The symposium was attended by some 30 delegates whose special interests lie in this field. As such it was a small symposium, but it was nevertheless very successful in providing a detailed presentation of the present state of knowledge in the subject, and was notable for the valuable discussion sessions concerning future developments which helped to focus attention on the important unsolved problems.

Research in daily variations has continued in the last two years in four main areas and important new results have been obtained. These four main areas have been (1) new morphological results, (2) development of improved three dimensional models for the dynamo theory, (3) calculation of daily current systems, (4) examination of the role played by the magnetosphere in daily variation effects. Review papers by Maeda (1968) and Price (1969*a*) together with summaries of major studies of Sq and L by Matsushita (1967) and an account of recent work on Sq (Price, 1969*b*) together provide a good summary and references of the subject until 1969.

**Morphology of Daily Variations**

Many new morphological results have been obtained, some describing purely local features, while others are global in nature. This continuing advance in the detailed description of daily variation fields should assist in the definition and understanding of the true nature of the physical phenomena involved.

Mayaud (1969) suggested some modification to the classification of international magnetic days which would affect the quiet days selected for computation of Sq. Chapman, Gupta and Malin (1970) discussed the computation of solar and lunar geomagnetic variations, and values of solar and lunar harmonics at 54 stations were obtained by Gupta and Chapman (1969) using spectral analysis, Malin (1969*a*) presented values for Irkutsk for the IGY period, and Green and Malin (1970) gave values for Watheroo based on data from 1919 – 1958 and discussed variation with season and magnetic activity. Riddihough (1969) discussed the geographic pattern of daily variations over North West Europe, while Dodon (1968) considered the effect of global anomalies on Sq using 1964 data, and Kane (1970) discussed the nature of the daily variation field. Day to day variability of Sq(H) was investigated by Brown and Williams (1969) and of the equatorial electrojet in Peru by Burrows (1970). Mizzi and Schlapp (1971) discussed the cause of a type of quiet day variation. The relationship between H ranges was examined for equatorial and mid latitudes by Kane (1971). The problems associated with the interpretation of low latitude daily variations were carefully explained by Hutton (1970). The variation of the monthly means of the geomagnetic field on quiet days was examined by McDonald (1970), and Chikovani (1970) examined the variability of Sq at magnetically conjugate and subfocal observatories and concluded that the day to day position of the foci of the northern and southern current system vary independently. Thomas (1969) reported on a search for superposed effects in Sq. Semi-annual variations of Sq(H) were examined by Pogrebnoy (1969) to determine the dependence upon R, the relative sunspot number, for Huancayo, Apia and Moscow data.

Vertlieb and Wagner (1970) considered the possibility of analysing Sq variation by using natural orthogonal functions. Malin and Chapman (1970) attempted an explanation of the Chapman-Miller method and included a Fortran program of the method. Malin (1970) also attempted to separate the oceanic and ionospheric contributions of L, and Malin (1969*b*) considered the ocean effect on the vertical component of L.

Chapman and Kendall (1970) examined tidally induced variation of magnetic fields at five stations in the British Isles. Sharma and Rastogi (1970) considered lunar tidal effects in the horizontal magnetic field at San Juan.

Knowledge of the wind systems is necessary for dynamo theory models and calculations of current systems. Lindzen and Chapman (1969) reviewed atmospheric tides, Kato and Matsushita (1969) considered tidal wave transmission through the ionized atmosphere, and Geller (1970) investigated the lunar semi-diurnal tide. Taffe (1970) developed the theory of hydromagnetic effects on atmospheric tides and compared the results with observations of the atmospheric tides in the ionosphere. The lunar barometric tide and the lunar semi-diurnal wind variations at Hong Kong and Uppsala were investigated by Haurwitz and Cowley (1969*a, b*) and Chapman (1969) analyzed the lunar and solar semi-diurnal variations of barometric pressure at Copenhagen. Papers by Richmond (1971), Murphy (1969) and Woodrum, Justus and Roper (1969) described various features of ionospheric winds.

## Dynamo Theory

Three separate phenomena are connected by dynamo theory. These are (1) atmospheric motions (2) varying ionospheric conductivity (3) daily variations, and the interrelations of these were discussed by Matsushita (1969). If the atmospheric motions and the conductivity are known then dynamo theory enables the resulting ionospheric currents and associated daily variation fields to be mathematically determined. Tarpley (1970*a,b*) considered in some detail theoretical models of the atmospheric dynamo for solar and lunar tides, while Cocks and Price (1969) considered the theory of Sq currents in a simple three dimensional model ionosphere. However the atmospheric winds are the least well determined of the variables involved in dynamo theory, and the problem of determining the winds from a knowledge of the conductivity and the daily variations was discussed by Mohlman and Wagner (1970) and Price and Cocks (1969), who pointed out that for this problem some assumption of the nature of the wind velocity has to be made in order to get a unique solution. Cho and Yeh (1970) examined the effect of the dynamo electric field on the thermospheric wind and Giles and Martelli (1971) determined electric fields and neutral winds in the ionospheric E and F regions from observations of artificial ion clouds, but further and better wind measurements are still required for definitive Sq dynamo theory calculations. Vardanyan (1970) analyzed the role of the dynamo mechanism in producing magnetic disturbance and ionospheric inhomogeneities. The ionization effects of the wind in the nighttime ionosphere was calculated by Fujitaka, Ogawa and Tohmatsu (1971), while a diurnal model of the E region was given by Keneshea, Narcisi and Swider (1970).

## Daily Variation Current Systems

Some progress has been made with the models and calculations of the daily variation current systems. The major part of these it is generally agreed, flow within the E region and this has been supported by some recent rocket measurements. Cloutier and Haymes (1968) made vector measurements of the mid latitude Sq current and Pogrebnoy and Fatkullin (1969*a*) reported on rocket investigations of mid and low latitude ionospheric currents by scalar measurement of the main geomagnetic field along rocket paths and also on electric fields in the low ionosphere over the magnetic equator (Pogrebnoy and Fatkullin, 1969*b*). Fukushima(1968) discussed three dimensional electric currents in the ionosphere, and Cole (1969) described the theory of electric currents in the E layer. Stening (1969, 1970 and 1971) assessed the contributions of various tidal winds to the Sq current system and also the longitudinal and seasonal variations of the Sq current system. Mishin, Bazarzhapov, Mishina and Popov (1970) derived by spherical harmonic analysis average Sq current systems and the UT changes of the current values at the northern and southern focii during different seasons. The effects of the earth's daily rotation on Sq and $Sq^p$ currents were summarized by Mishin and Popov (1971).

Some problems in evaluating current systems using a computer were discussed by Stone (1969). Ashour (1971 *a, b*), and in several related papers, obtained theoretical solutions to the electromagnetic induction problem for a variety of models and considered the application of the results to island and coastline effects on geomagnetic variations. Several authors (Czechowsky, 1971; Fukushima 1971; and Mansurov and Mansurova 1970) considered the effects and calculations of current systems in the polar E region. Richmond and Venkateswaren (1971) discussed the ionospheric current systems association with geomagnetic crochets and Kawasaki and Akasofa (1971) computed the disturbance vectors for model three dimensional current systems.

## Magnetospheric Effects

Much attention has been concentrated in the last few years on the possible contributions to the daily variations from the magnetosphere. Olsen (1970*a*) has examined the contributions to the variations in the surface magnetic field from the magnetopause current system, and in (1970*b*) has more generally considered contributions to the daily variations from non-ionospheric currents, namely neutral sheet, ring and magnetopause currents and has suggested that magnetospheric currents may make a significant contribution to the day to day variability of Sq. There are also possible interactions between the ionosphere and the magnetosphere affecting daily variations and this has been examined by Matsushita (1971). Matsushita and Tarpley (1970) have discussed the communication of the dynamo region electric fields to the magnetosphere along the earth's magnetic lines of force, and have deduced the communicated electrostatic field distributions in the magnetosphere and the drift motions of magnetospheric plasma particles produced by these electric fields and the earth's magnetic field. Block and Falthammar (1968) and Shunk and Walker (1969) discussed theoretically the effects of field aligned currents on the structure of the ionosphere, although generally the effects of field aligned currents have not been well understood. Van Sabben (1970) evaluated the contribution to solstitial Sq currents from the magnetosphere and computed magnetospheric currents arising from an ionospheric dynamo (1969). Electric currents and polarization fields at the base of the magnetosphere have been discussed by Wagner (1971). Some progress has thus been made in recent years in clarifying the role played by the magnetosphere in determing daily variations.

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## WORKING GROUP IV-3, EQUATORIAL ELECTROJET

**D.J. Stone – Reporter (for D.G. Osborne)**

The working group meeting was held at 18:30, Wednesday, 4 August, with 13 persons in attendance. In the absence of D.G. Osborne, D.J. Stone acted as reporter. The value of the group to members was discussed and in reply to a question by Dr. R. Hutton, the reporter summarized the activities of the last four years. A comprehensive circulation list of persons interested in the equatorial electrojet and related topics has been compiled, and the activity of the group has centered around the dissemination of information to these people and the organization of collaborative studies. As requested at the Madrid meeting, Dr. Osborne circulated a request for details of planned equatorial experiments and studies in order that duplication of effort would be avoided and better colloboration achieved. It was agreed that this was a useful exercise and should be repeated on a regular basis. The question of the desirability of continuing the group on a separate basis was discussed and the view was expressed strongly by Dr. Onwumechilli that the group was continuing to fulfill a necessary function by providing a central organizational focus and stimulus for equatorial studies and the view was generally well supported.

The main business of the meeting centered around the proposed International Equatorial Aeronomy Symposium to be held in September 1972, in Nigeria. Dr. Awe, Nigerian national representative, who is on the symposium committee, was present at the meeting and explained the present planning. It was unanimously agreed that IAGA be asked to support and cosponsor this symposium as they had previously done with similar symposiums on this subject.

Dr. J. Cain suggested that it would be desirable for the symposium to have a special session devoted to electrojet data. The session could be organized around the POGO data and should also feature invited speakers with ground data. The possibility exists of a combined analysis of ground and satellite data. Those wishing to work on such a project should contact Dr. Cain with proposals for studies and requests for the POGO data which would shortly be available. The working group agreed with the suggestion and welcomed Dr. Cain's offer, and it was agreed that the reporters should circulate this information.

## WORKING GROUP IV-4, SPECIAL DISTURBANCE EVENTS

**S.I. Akasofu – Reporter**

Prior to the Moscow assembly the Reporter had notified the Commission Chairman of the following progress during the past period.

### Analysis of Intense Magnetic Storms

The following storms have been analyzed, and the results are published in *Solar-Geophysical Data.*

January 7-8, 1967
January 13-14, 1967
February 2-3, 1969
March 23-25, 1969
April 27-28, 1969
May 14-16, 1969
June 11-14, 1969
July 26-27, 1969
August 26-27, 1969
September 27-30, 1969
November 8-10, 1969
December 5-6, 1969

| | |
|---|---|
| January 1-3, 1970 | August 16-19, 1970 |
| March 7-9, 1970 | October 16-18, 1970 |
| April 20-22, 1970 | November 7-8, 1970 |
| May 27-29, 1970 | December 14-15, 1970 |
| June 27-28, 1970 | January 27-29, 1970 |
| July 8-10, 1970 | |

**DP2**

Dr. A. Nishita has selected many DP2 events to be studied together by a number of workers who are interested in polar magnetic disturbances. We have scaled and digitized all the available magnetic polar reports. The scaled data will be distributed among the workers in a few weeks.

**Standardization of the Nomenclatures and Motion for Polar Magnetic Disturbances**

During the last several years, various types of polar magnetic disturbances have been distinguished and studied. However, there seems to be some confusion and misunderstanding as to the precise definition of each type of disturbances among the workers in this particular field. Professor Nagata has asked us to take up this problem and to standardize the nomenclatures.

The Working Group has completed a preliminary glossary of all the nomenclatures. The final glossary will be produced after meetings in Moscow.

**Special Meeting of Ad Hoc Group on "DP2"**

A special meeting of an ad hoc group on "DP2" met on the morning of August 1, and each member reported results on his studies of DP2. The scientists who attended were: M.S. Bobrov, A. Grafe, G. Rostoker, Y.I. Feldstein, R.Y. Afonina, E. Kaneda and A. Mishida.

The Reporter indicated that the scalings for the periods (which were agreed upon to study during the Leningrad symposium in 1970) have been completed and that the numerical tables for the scalings will be sent to each member for his study.

**Official Meeting of Working Group**

The Working Group met in the evening of August 5th and discussed the preparation of the standardized nomenclatures for varying components of the geomagnetic field.

The Working Group proposed publication of the Special Scaled Magnetic Records for the DP2 study in the *IAGA Bulletin*

The Working Group suggested the following changes in the membership of the Working Group:

Dr. C.U. Wagner to be replaced by Dr. A. Grafe (they are both from the same institute),

Drs. L.L. Vanyan, Institute for Space Research, Moscow USSR, P.M. McGregor, Bureau of Mineral Resources, Australia, and V. Mishin, SibIZMIRAN, Irkutsuk, to be added as new members.

## WORKING GROUP IV-5, MICROPULSATIONS

**V.A. Troitskaya – Reporter**

The activity of the working group is discussed in the following sentences.

Four scientific sessions concerning different aspects of micropulsations research were prepared and fixed for the Second IAGA General Scientific Assembly to be held in Kyoto, Japan.

A catalogue giving the list of stations and descriptions of the equipment for quick run sensitive installations for the micropulsation recording was prepared and distributed by Dr. H.B. Liehmon.

A technical report on the requirements for a standard installation for micropulsation registrations was presented at the session on micropulsations by Dr. W. H. Campbell. After the presentation, it was agreed that the report should be distributed among the members of the Working Group IV-4 for further consideration.

Special attention was given to new indices of activity based on pulsations due to their potential value in the general problem of the physics of the magnetosphere and especially in the diagnostics of its parameters from surface observations. A scientific session will be dedicated to this subject.

Preliminary decision was taken to conduct quick run registrations at all observatories during four weeks in a year, which coincide with the weeks of the extensive observations of aurora and airglow in the geophysical calendar for 1971 and 1972. V. Lincoln agreed to distribute to existing stations additional circulars showing the International Geophysical Calendar if necessary.

It was established by writing that most of the members of the Working Group IV-5 are in favor of reconsidering the existing classification of micropulsations. This is a very serious problem which has to be treated very carefully. Therefore, it is thought that a small group must be chosen for preparing the proposal for such changes, which must be discussed in writing during the next two years and accepted if suitable at the IAGA Scientific Assembly in 1973.

It was recommended that the small ad hoc group to prepare the proposals consist of: Dr. Saito, Japan, Chairman; Dr. Heacock, USA; Dr. Romana, Spain; Dr. Selzer, France; Dr. Volker, West Germany; Dr. Rostoker, Canada; Dr. Aubert, East Germany, and Dr. Bolshakova, USSR.

The possible topics for the scientific sessions and symposia were discussed during the meeting and after it. Finally the following general topic was selected: "Micropulsations: Theories and new experimental results".

A small program committee was established consisting of: Dr. A. Hasegawa – Reporter (Japan), Dr. D.I. Southwood, U.K. and Dr. Pellat, France.

The Committee agreed to work in close contact with the new reporter of Working Group IV-5, Dr. Gendrin.

Another suggestion of the Working Group IV-5 was to organize a broad symposium on "Prediction of Substorms" in which different IAGA commissions should participate.

## WORKING GROUP IV-6, MAGNETOSPHERIC FIELD VARIATIONS

**M. Sugiura – Reporter**

As a contribution from this Working Group, Dst indices, which represent activity in the magnetosphere, have been recalculated for the years 1957 to 1970. In so doing the gap in the previous series, namely 1959 and 1960, has been filled. The previously published Dst series was calculated on a yearly basis, and the evaluation of the secular changes for the observatories used was not necessarily made in a uniform manner. This caused Dst values to tend to be a little more positive in some years than in others, making direct comparison of Dst for different years, for instance, to study long term variations, somewhat questionable. Therefore in the new Dst series, the reference level for each observatory was determined in such a way that Dst for different years can be meaningfully compared. Thus all the Dst values published in the past are now superseded by the new series.

The Dst index can still be improved by increasing the number of observatories whose data are used in the calculation. However, unavailability of hourly values has always been, and still is, the main hindrance in the efforts of improving the Dst index and of speeding up its publication.

The primary purpose of deriving the Dst index is to use this index for diagnosis of magnetospheric activity. Hence the interpretation of Dst in terms of magnetospheric field variations is an important step. This subject will be discussed in the Scientific Session on Interpretations of Geophysical Indices and at the Working Group meeting during this General Assembly. As to magnetospheric field variations we still do not have a complete understanding of the quiet-time magnetospheric field which should be the basis for the study of disturbance variations in it. Progress has been made, however, with a recent analysis of OGO 3 and 5 magnetometer observations regarding the quiet-time magnetospheric field. Results of this analysis will be discussed in the Scientific Session on Quantitative Magnetospheric Models. According to this study, the distribution of the quiet-time ring current is quite different from what it has been usually thought, and the ring current is found to be active even under average quiet conditions.

Working Group IV-6 on Magnetospheric Field Variations met in the evening of August 9, 1971 and discussed the interpretation of Dst in terms of OGO 3 and 5 observations of the magnetospheric field. It was pointed out that these observations have identified the region of the quiet-time ring current for the first time and that the earlier identifications by particle measurements were erroneous. This is a great step forward in understanding of Dst activity.

Studies of (a) the quiet-time magnetospheric field and (b) ring current activity will be the main objectives of this Working Group in the immediate future.

## WORKING GROUP IV-7, CONJUGATE POINTS

**R. Schlich – Reporter**

Since the last General Assembly of 1967 at St. Gall the Working Group on Conjugate Points met at Madrid, 10 September 1969, during the Joint IAGA-IASPEI Scientific Assembly. Very few members of the Working Group could attend this meeting. However several recommendations concerning conjugate point experiments were issued and published in *IAGA News* No. 8 (September 1969).

There has been no other official meeting of the Working Group, but discussions about conjugate point studies and planning of conjugate point experiments have been organized during several international meetings or by individual arrangements. According to the information which was received, conjugate point experiments have been conducted during the period 1967 to 1971 at the following sites: Great Whale River, Byrd; Thule, Vostok; Reykjavik, Syowa; Dolgoschelié, Heard; Sogra, Kerguelen; Pskov, Crozet Island; and Hurouqué, Hermanus.

In London, 27 to 31 January 1969, during the First conference on Solar Terrestrial Physics Program for the International Years of the Active Sun, the Working Group on "Conjugate Point Experiments" made several recommendations for specific programs of research, for the continuation and addition of conjugate station pairs and for techniques for conducting conjugate point experiments. These recommendations are published in *S.T.P. Notes* No. 4 and have been endorsed by this Working Group.

A Symposium on Conjugate Point Studies (French-Soviet experiments) was held at Borok (USSR) from 2 to 14 July 1969. French and Soviet scientists had the opportunity to discuss the latest results obtained during their experiments – 45 communications were presented – to consider unsolved questions which can be answered by conjugate point studies, and also to fix the scientific program for the coming years. In 1972, a second Symposium on Conjugate Point Studies (French-Soviet experiments) will be held in France.

The Working Group plus a few additional colleagues met at Moscow, on 10 August 1971. The participants were as follows: R. Gendrin, France; F. Glangeaud, France; B.V. Kiseliov, USSR; N. Kleimenova, USSR; J.A. Kopytenko, USSR; V.K. Koshelevshii, USSR; V.M. Mishin, USSR; O.M. Raspopov, USSR; V.K. Roldugin, USSR; R. Schlich, France; N.A. Smirnowa, USSR; P.P. Solomedenko, USSR; E.F. Vershini, USSR and W.H. Campbell, USA.

The report of the activities of the Working Group since the last General Assembly of 1967 at St. Gall was submitted and adopted by the Working Group. (See first part of this report.)

After discussion, the members of the Working Group proposed two resolutions. The first of these was later adopted as IAGA Resolution No. 6. (See Resolutions elsewhere in these Transactions.) The second resolution given below is considered as an interim resolution of the group.

"Considering the importance of conjugate point studies, the Working Group asked the Reporter of Working Group IV-7 on Conjugate Points to select some people to prepare review papers (one or two for each conjugate point program) about the results which have come out of the operation of conjugate pairs of stations. These papers are to be presented as invited reviews at the next IAGA meeting at Kyoto. If short papers on conjugate phenomena are submitted to the General Sessions of IAGA, it is requested that these be scheduled for presentation immediately following the review paper session."

R. Schlich, Reporter of the Working Group IV-7 since 1963, asked to be replaced in his functions. O.M. Raspopov was proposed and subsequently accepted as Reporter of the Working Group.

# COMMISSION V
# SOLAR-MAGNETOSPHERE RELATIONS
## J.G. Roederer - Chairman

Detailed reports from each of the Working Group Reporters are not available. Chairman Roederer has given a very good but brief summary of the work of Commission V under the "Highlights" of the Final Plenary Session elsewhere in these Transactions.

# COMMISSION VI
# AURORA
## G.G. Shepherd, Acting Chairman
## (for A.Omholt, not present in Moscow)

### BUSINESS MEETING

The business meeting of Commission VI took place on Thursday afternoon, August 12, 1971. The following matters were discussed.

#### Working Groups

*(a) Function*

Of our four working groups, only two have been active in terms of projects. Morphology and Radio Aurora, and the latter has virtually completed its study on nomenclature. The others, on Spectroscopy and Excitation, and Particles and Fields, have only reporters and very small memberships, whose duty is to review progress in their fields. In addition to the working groups there has been an independently instituted joint program committee with Commission VII.

It was decided that the value of the working groups would be enhanced if the working group chairmen had responsibilities in arranging symposia. For example, a working group meeting could be arranged to follow a scientific session on the same topic. This would ensure that an appropriate membership was in attendance, and that the scientific background pertinent to the discussion had been fully presented. Accordingly it was agreed that the working group reporters would constitute the Commission VI membership to the joint program committee, and that working group reporters would accept the responsibility for arranging particular sessions corresponding to their working groups.

*(b) Structure*

In order to maintain a proper balance in the Commission, it was agreed that two additional areas should be represented. One is to be on electric fields in the ionosphere and the existing one on particles is to be divided into two areas; auroral particles in the ionosphere and auroral particles in the magnetosphere. Their prime function is to participate in the planning and arranging of the symposium, and in this regard to maintain a liaison with the corresponding working groups of Commission V. They will be represented by persons named coordinators, and they shall be members of the program committee.

**Nominations**

The IAGA Executive Committee announced the results of nominations for Commission Chairmen. Names for working group reporters and coordinators were discussed and agreed upon as follows:

Chairman: G.G. Shepherd (Canada)
Co-chairman: S.I. Isaev (USSR)

Working Groups:

VI-1, Morphology – A. Egeland (Norway)
VI-2, Spectroscopy and Excitation – A. Vallance-Jones (Canada)
VI-3, Radio Aurora – R.S. Unwin (New Zealand)
VI-4, Particles and Fields – D.S. Evans (USA)

Program Coordinators:

1. Electric Fields in the Ionosphere – R. Bostrom (Sweden)
2. Auroral Particles in the Ionosphere – Yu.I. Galperin (USSR)

**Plans for Kyoto Symposium**

The means of organizing the Kyoto Symposium are to be along the lines already discussed. Certain principles were agreed upon. The working group reporter or the coordinator, who is responsible for arranging a session, should have considerable autonomy in controlling the selection of speakers and the number of papers. Only in this way could he organize his session so as to achieve the objectives already outlined and to ensure full presentation, full discussion, and adequate reporting of the results of the session. There would also be a need for sufficient "open" sessions that all the accepted contributed papers could be fitted into the program.

**Reorganization of IAGA**

Attention was drawn to the statements made at the Plenary Session, regarding the reorganization of Commissions V, VI, VII and VIII. A number of different points of view were expressed. Some felt that to maintain the phenomenological basis of auroral and airglow, Commissions VI and VII should be maintained as separate Commissions. Others felt that the division should be along the lines of fundamental physical processes. There are clearly many implications and many aspects to be discussed, and we urge that time be given for these aspects to be considered.

## COMMISSION VII
## AIRGLOW
## G. Weill - Chairman

**GENERAL COMMENTS**

The membership of Commission VII has been quite active in preparing, attending and contributing to the Aurora and Airglow Symposium that was held jointly with Commission VI from August 9 through 13, 1971.

The Symposium was comprised of seven sessions which were chaired by Drs. Schiff, Shepherd, Feldstein, Pudovkin, Vallance-Jones, Weill and Walker, in that order.

A total of 60 invited papers and 64 contributed papers were given at this joint Symposium and it is expected that about 45 of these papers will appear in a group publication early in 1972.

During the preceding years, some of the Working Groups had been fairly active by correspondence, but the planning of Working Group meetings for the Moscow Assembly was insufficient and the Working Groups had no efficient meeting. The Business Meeting of Commission VII was held on the afternoon of August 13, 1971 after the final plenary assembly of IAGA. The resolutions adopted by the Commission could therefore not be officially passed by IAGA and are given in this report for the record.

## BUSINESS MEETING

The Commission was informed of the establishment of an Airglow station in the Sierra Nevada, at altitude of 3500m, near Granada, Spain. This station has been equipped with a scanning photometer since 1969 and is operated by the Max-Planck-Institute for Aeronomy, Post Box 20, 3411 Lindau/Harz, West Germany, attention Dr. G. Lange-Hesse and H. Lauche, in cooperation with the University of Granada, Physics Department, Granada, Spain. The station is close to a vertical ionospheric sounder operated by the same Institute at Almeria, Spain.

The Commission was also informed of the establishment of an Airglow station at Stara Zagora, Bulgaria.

Commission VII proposed that its internal organization be revised to include four Working Groups:

VII-1 – Instruments and Calibrations
VII-2 – Excitation Processes
VII-3 – Photometry and Spectroscopy
VII-4 – Laboratory Data

The Commission also proposed to nominate five reporters on the following subjects:

– Mesospheric emissions.
– Exospheric emissions.
– Tropical airglow.
– Airglow effects of photoelectrons.
– Planetary airglow.

It is expected that Working Group Reporters and Reporters at large would undertake to review the progress in their respective fields at a symposium in 1973, in Kyoto, Japan, and participate as required in the organization of this symposium.

A new Chairman and Co-chairman were nominated by IAGA, forthcoming quadriannum, namely Dr. M. Gadsden, Chairman, and Dr. B. Tinsley, Co-chairman. The new Chairman agreed to contact scientists who have been proposed as Working Group Reporters.

The following resolutions were proposed by Commission VII.

### Resolution 1 (with Commission VI)

IAGA Commissions VI and VII, recognizing the need for a small executive body to actively coordinate special projects of joint interest, *recommend* that an Aurora and Airglow Program Committee (AAPC) be reappointed for the period between the XV and XVI IUGG General Assemblies. The AAPC will comprise the Chairmen of both Commissions and an Acting Secretary.

### Resolution 2

Commission VII, noting progress made during the previous quadriennum, *recommends* that AAPC should sponsor the following international efforts during the forthcoming period of low solar activity:

Photoelectron effects on airglow (existing project to be redirected)
Airglow effects connected with Appleton ionospheric anomalies
Special supporting programs of ground observation during the lifetime of Atmospheric Explorer aeronomic satellites
Participation in planning of scientific meetings of their field of interest.

**Resolution 3**

Commission VII, noting with satisfaction that airglow stations are being established in Stara Zagora, Bulgaria and Volgograd, USSR, that these stations, together with existing stations of Abastumani, Alma-Ata, USSR, Granada, Spain and Haute-Provence, France, constitute a unique longitudinal chain *recommends* that their operation be *coordinated.*

**Resolution 4**

Commission VII, *noting* with regret that it has been difficult to keep track of the changing airglow stations and observational programs, *recommends* that the existing recommendations for circulation of information and data to WDC's be more closely followed (cf *IUCSTP Notes,* No. 6).

**Resolution 5**

Commission VII, recognizing the benefits which have already been derived from the current program of intercomparison of photometric standards, noting the necessity of further improvements, *recommends* that the current program should proceed with due speed, that it be extended to national standards laboratories wherever possible and that workers in aeronomy continue to strive towards better accuracies in absolute photometric scales.

**Resolution 6**

Commission VII, noting that in the field of Airglow, Resolutions 17, 18, 20 and 21 passed at St. Gall, in 1967, are still valid, *recommends* that they be enforced (Ref. *IAGA News*, No. 6).

**Circulation of Data**

a. Stations making synoptic or quasi-synoptic measurements of airglow are invited to notify the Secretary of the Aurora and Airglow Program Committee (AAPC) annually (preferably in March) of the general nature of the program of observation and analysis, including appropriate details of their experimental arrangement, observing schedule and types of reduction made or planned. IAGA Commission VII requests that the following information be included:

Schedules and types of observations initiated or planned.
Modifications in station networks or schedules (past or planned)
Station coordinates and name
Availability of data to interested scientists, with full address where they can be obtained.

The Program Committee will compile this information and forward it to the WDC's concerned for cataloging and circulation purposes.

b. It is recommended that every three or six months the following data be distributed by responsible organizations to WDC's when available:

5577 OI zenith intensities
6300 OI zenith intensities
NA D lines zenith intensities
OH bands zenith intensities
airglow continuum zenith intensities
North/South ratios, 5577, zenith distance 75°

These data should be in conformity with those published for the IGY period (YAO, 1962).

c. Data of particular interest to the international programs coordinated by the Aurora and Airglow Program Committee (AAPC) should in due time be made available to or through the WDC's; these will forward the corresponding requests to the groups involved.

# COMMISSION VIII
# UPPER ATMOSPHERES
## A.J. Dessler - Chairman

Two changes should be noted in the Commission VIII program of invited reviews. In place of the papers as listed in the program papers 1 and 3 should be changed to read:

VIII-1 – Tinsley, B., The Interplanetary Atmosphere
VIII-3 – Bloch, L., Electric Field Phenomena in the Ionosphere.

## WORKING GROUP VIII-3, EXOSPHERIC PROBLEMS
**B. A. Tinsley – Reporter**

Work on exospheric problems that has taken place since the last IAGA Assembly in St. Gall include the launching of a French satellite which carried into space for the first time a Balmer $\alpha$ photometer. Lyman $\alpha$ photometers were also on board. Ground Based Balmer $\alpha$ observations are continuing in the USA, USSR, and France and some coordinated observations with the satellite and ground based equipment are planned.

A Lyman $\alpha$ detector with a hydrogen absorption cell on board has been operated on the OGO 6 satellite and the results have been interpreted in terms of the diurnal variation of exospheric hydrogen temperature. A temperature maximum near 1800 hr. local time and a dawn to dusk difference of 200°K have been found. Ion mass spectrometer measurements have been used to obtain the diurnal variation of neutral hydrogen abundance, assuming charge-exchange equilibrium. A factor of two diurnal variation has been seen in addition to solar activity related changes in abundance.

Further measurements of the helium 10830 Å emission have been made. There is some conflict with theoretical calculations of the diurnal variation, especially for observations near the Appleton Anomaly, where the ambient electron density is high. Seasonal variations of low latitude helium are also being studied.

Satellite neutral mass spectrometer measurements have yielded data on the enhanced helium density in the winter hemisphere. The maxima and minima are found not at the poles but at about 60° north and south latitude. This clearly has an important bearing on the nature of the mechanism producing the seasonal variation.

## WORKING GROUP VIII-6, METEORS
**T. R. Kaiser – Reporter**

This report is largely a collation of information, generously supplied by many colleagues throughout the world, on the progress of meteor science since the last General Assembly of IAGA in Madrid, 1969. It is inevitable that some may find their work inadequately represented; I can say only that the somewhat arbitrary line drawn between astronomical aspects of the subject and those areas relevant to aeronomy (and hence to IAGA) is entirely my own. The substance of the report thus deals with upper atmospheric data derived from meteor observations, the physical effects accompanying the entry of meteoroids into the atmosphere and the constituents of the atmosphere of meteoric origin.

### Upper Atmospheric Parameters from Meteor Observations

There has been continuing progress, and developing international collaboration, in the measurement of wind parameters using the radio-echo technique. The Table I following updates that given in the Madrid report (1969) in listing the stations which either are making regular observations or which have been operated for specific intervals and from which data are available. Some of the stations were listed as "projected" in 1969 and it is gratifying to learn that they are now functioning.

**Table I**
**METEOR WIND STATIONS**

| | Geographical Location | | Freq. MHz | Mode | Status |
|---|---|---|---|---|---|
| Hayes Is. | 80 N | 55 E | 33 | pulse | O |
| Tomsk | 57 N | 85 E | 30 | pulse | R |
| Obninsk | 56 N | 38 E | 24 | pulse | R |
| Kazan | 56 N | 49 E | 30 | pulse | R |
| Sheffield | 53 N | 1 W | 24.8 | pulse | R |
| | | | 36.3 | pulse | |
| Bracknell | 51 N | 1 W | 36.3 | pulse | R |
| Kiev | 50 N | 31 E | 34 | pulse | R |
| Kharkov | 50 N | 36 E | 37 | pulse | R |
| Garchy | 47 N | 3 E | 30 | CW | R |
| Durham | 43 N | 71 W | 36.8 | pulse | R |
| | | | 73.6 | pulse | |
| Frunze | 43 N | 75 E | 36 | pulse | R |
| Havana | 40 N | 90 W | 41 | pulse | O |
| Dushanbe | 38 N | 69 E | 36 | pulse | R |
| Stanford | 37 N | 122 W | 30.1 | pulse | O |
| Kingston | 18 N | 77 W | 36 | pulse | R |
| Mogadishu | 2 N | 45 E | 37 | pulse | O |
| Adelaide | 35 S | 130 E | 26.8 | CW | R |
| | | | 27.5 | pulse | |
| Christchurch | 44 S | 173 E | 27 | pulse | R |
| Molodeshnaya | 67 S | | | | |

**R: Making regular observations. O: Other**

The most comprehensive studies of circulation in the meter zone are probably those made by the Soviet scientists at a complex of stations covering a wide range of latitudes (Lysenko *et al.*, 1971; 1969). The most sophisticated single system is that at Havana; although few data have yet been published, the feasibility of continuous measurements with good height resolution has been established (Deegan *et al.*, 1970). In Adelaide (Elford & McAvaney, 1971), seasonal averages of zonal and meridional winds between 75 and 105 km have been obtained and comparisons made with results of rocket measurements at Woomera. In both Garchy and Sheffield, wind fluctuations over a wide range of periods have been interpreted in terms of tidal phenomena, planetary waves and gravity waves (Muller, 1970; Revah, 1969, 1970; Spizzichino, 1969 *a, b, c,* 1970 *a, b;* Spizzichino 1971; Spizzichino *et al*, 1971; Muller, 1971). Wind structure has also been obtained from single station observations of fading of persistent meteor radio-echoes (Phillips, 1969).

Comparisons between meteor wind data and ionospheric drifts are reported from Christchurch, New Zealand (W.J. Baggaley) and from Sheffield (Muller, 1970).

Vernaini and Cevolani (1971), using Schmidt camera data, have obtained mean atmospheric temperatures at the 90 km level for each month of the year.

### Meteor Physics

Lebedinets and Shushkova (1970*a, b*) have extended their work on ablation theory and derived rates of collisional meteoric ionization as a function of altitude. They also conclude that sputtering from micrometeoroids contributes a significant influx of meteoric atoms in the height range 130 – 140 km. Theoretical and laboratory studies of ablation of simulated meteoroids, leading to data on excitation and ionization, have been made at the Ames Research Centre of NASA (Baldwin and Schaeffer, 1970; Givens and Page, 1971; Boitnott and Savage, 1970) and at TRW Systems, California (Tagliaferri and

Slattery, 1969; Friichtenicht, 1969; Becker and Friichtenicht, 1971; Friichtenicht and Becker, 1971). Rajchl (1969, 1970) has investigated the properties of the interaction layer in front of a meteoroid entering the atmosphere.

Verniani (1969) has written a comprehensive and critical review on meteoroid structure; he has also (unpublished) analysed 5759 radio-meteors from the Havana system giving simultaneous values of electron line density and velocity from up to six stations. In spite of fragmentation, he finds that the dependence of line density on the basic parameters is close to that predicted by the single body theory.

The U.A. Research Section of the NRC (Canada) and their collaborators continue combined visual-photographic-radio observations and spectroscopic studies (Halliday, 1969; Gault, 1970; Hemenway, 1971; Millman, 1971*a, b*). They operate a network of 12 photographic stations for the study of bright events (McIntosh, 1970).

Harvey (1970) has considered the theory of collision cascade of ablated meteor atoms and concludes that most optical radiation does not come from the direct cascade, but from relaxation of the resulting 'meteor gas'. Astavin-Razumin (1968) has associated optical meteor flares with atmospheric eddies.

Diffusive processes in meteor trains, as deduced from the decay of radio echoes, have been studied by Aminov and Kostylev (1970) and Jones (1970). Kaiser *et al* (1969) predicted that diffusion may be inhibited for trains aligned within $1^\circ$ of the geomagnetic field. This has been investigated experimentally by Watkins *et al* (1971) who, while failing to confirm the effect, discovered that bright meteors apparently can grow field aligned 'whiskers' of ionization. Several workers (Brown and Elford, 1971; Jones, 1969; McIntosh, 1969) have investigated the effects of irregularities in ionization and of wind shear on meteor radio-echoes, particularly on their decay rates. Liu (1970) has generalized the diffusion equation to include the initial expansion phase of atoms evaporated from a hot meteoroid.

The effects of D-region chemical processes on the duration of echoes from overdense trains has been studied in some detail at Sheffield by Nicholson (in preparation). He finds that observed duration distributions for various showers, over a range of wavelengths, can be fitted, for the shorter durations, by three-body attachment with a coefficient of 0.002 $sec^{-1}$ at 90 km altitude. A rapid decrease in number of echoes at longer durations cannot be explained by a straightforward three-body process and it is suggested that this may be associated with a rapid increase in ozone concentration below 80 km (especially at night). A dramatic increase near sunrise in the duration of echoes at low altitudes, observed during the Quadrantid shower, may be due to photo-detachment. This occurs for a solar zenith angle of $95^\circ$ (at the meteor layer) and it is therefore deduced that an electron affinity of 4 – 6 eV would be necessary. An alternative explanation could be a sunrise change in the profile of $0_3$ and 0. Baggaley (1971) reaches a similar conclusion and suggests that observations of enduring trains may yield the diurnal variation of oxygen content in the upper mesophere and lower thermosphere. He has also used multi-frequency meteor observations to deduce the initial radio of the ionized trains as a function of altitude (Baggaley, 1970).

### Meteoric Constituents in the Atmosphere

Further rocket mass-spectrometer studies of metallic constituents of the atmosphere (Keneshea *et al*, 1970; Goldberg and Blumle, 1970) largely confirm the picture reported at Madrid, namely a layer of $Mg^+$ and $Fe^+$ of 55 - 10 km half width at 93 km with density of the order of 3 x $10^3$ $cm^{-3}$ and narrow layers above 100 km with $Si^+$ and/or $Mg^+$ and/or $Fe^+$ with density ~ 2 x $10^3$ $cm^{-3}$. Swider (1970) discusses the ionization and loss processes for metallic ions and concludes that their depletion may occur through the formation of hydrates. He emphasizes that the evidence strongly supports a meteoric origin for most, if not all, of the metallic species observed. In $E_s$ layers the meteoric species can predominate over atmospheric ions due to their providing a reservoir of long lived ions (Whitehead, 1970). Following previous, relatively unsuccessful attempts, to correlate $E_s$ with meteoric activity this is being reinvestigated by C.D. Ellyett (1971). Gadsden (1970) has derived a model of metallic ion and atom concentration from a simplified diffusion equation. He assumes a sink as a lower boundary condition (possibly identifiable with water vapour) and concludes that diffusion rather than ionization or horizontal global transport best fits the data.

The ion composition at altitudes 130 – 155 km has been studied by Danilov *et al* (1970) by rocket measurements during the Orionid meteor shower, October 1968. Peaks for mass $24^+$ and $26^+$ were observed above 143 km which the authors identify with $C_2^+$ and $CN^+$.

Brownlee and Hodge (University of Washington) have developed balloon borne dust sampling systems capable of stratospheric collection of particles of 10 micron and larger with a flux of 1 $m^{-2}$ $day^{-1}$. Of two flights in April 1969, one was negative except in so far as one very fragile and fluffy particle was found; the other gave a positive result corresponding to a cumulative flux of $10^{-4}$ $m^{-2}$ $s^{-1}$ for particles larger than $10^{-8}$g. This is two to three orders of magnitude less than reported from previous balloon measurements.

**Instrumentation**

The following are some recent developments in observing techniques which have been reported.

The Eindhoven University of Technology have developed (Lorencin, 1970) an automatic recorder for a meteor radar which presents real time, duration, range and amplitude on punched tape. The University of Sheffield has brought into operation an on-line digitizer for radio-meteors which records the basic echo parameters on an incremental magnetic tape recorder. The CNET at Garchy (A. Spizzichino) has also introduced on-line computer analysis for radio-meteor wind data and has constructed a mobile wind radar.

The Instituto di Fisica dell'Atmosphera del CNR, Bologna, Italy, is developing a multi-station phase-coherent radar system capable of achieving an accuracy of 0.1 km in locating the reflection point on a meteor train (Carreri, *et al,* 1969; Bortolotti, 1970).

The University of Adelaide (W.G. Elford) has a 2 MHz array for L.F. observations of meteors and have obtained echoes from altitudes up to 130 km.

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# COMMISSION IX
# HISTORY
## N. Pushkov - Chairman

Commission IX conducted a scientific session and a business meeting. The scientific session was devoted to the memory of the late Professor S. Chapman. It was attended by 32 persons. Prof. S.-I Akasofu gave a memorial talk about Professor Chapman and his work on the theory of magnetic storms and aurora. Mr. B. R. Leaton talked about Professor Chapman's work on the main magnetic field and secular variation and Dr. O. Schneider reported on Professor Chapman's work on tides in the lower and upper atmosphere and their geomagnetic manifestations.

All lectures were well prepared and listened to by the audience with great interest.

Father A. Romana, Mr. D. Knapp, Mr. E. Chernosky and Dr. N. Pushkov told about their meetings with Professor Chapman.

At the business meeting Dr. N. Pushkov, Chairman of the Commission, enumerated seven articles related to the history of geomagnetism and aeronomy that were prepared and partly published by members of the Commission and other persons since the Madrid Assembly.

Dr. N. Pushkov stated that some members of the Commission had informed him that they wanted to leave the Commission and four scientists, Drs. S.R. Malin, D. Winch, Dr. Benzle and Father A. Romana, requested admission into the Commission. It was agreed that they should be listed as members of the Commission.

The Commission decided to prepare a scientific session devoted to the history of geomagnetism, aeronomy and related sciences in the Pacific area and especially in Japan, in 1973.

With the approval of the Executive Committee the following organization was decided upon for the next period.

E.J. Chernosky – Chairman N.V. Pushkov – Co-chairman
D.G. Knapp – Reporter for Working Group on American Area
N. Fukushima – Reporter for Working Group on Pacific Area
G. Fanselau – Reporter for Working Group on European Area

## COMMENTS GIVEN BY DR. O. SCHNEIDER ON DR. S. CHAPMAN'S WORK ON TIDES IN THE LOWER AND UPPER ATMOSPHERE AND THEIR GEOMAGNETIC MANIFESTATIONS

The 72 titles of papers, reports and books on lunar variations in Geomagnetism and in the lower atmosphere bear witness to Chapman's great interest in this domain of the geophysical sciences, and to the important contributions he made to further our knowledge of tidal phenomena. This impressive work straddles over nearly the whole span of his scientifically active life. His very first studies on a geomagnetic subject, finished in 1913 and published early in the following year, in an extensive paper in the Philosophical Transactions of the Royal Society, London, were devoted to the lunar variations (along with the solar ones), and so were his last papers. It is noteworthy that the genius of this outstanding man, later admired by two successive younger generations during the second half of his life, led him to make fundamental statements right from the outset of his career. In fact, his paper of 1913 "On the diurnal variation of the earth's magnetism produced by the moon and the sun" already contains his phase-law of lunar geomagnetic variations. This summarizes and roughly explains the luni-solar character of the bulk of geomagnetic lunar variations, a feature which had been recognized earlier mainly through the work of Chambers and Moos, but had not been understood so specifically. It states that the main harmonic components of the lunar tide present in any geomagnetic element undergo a progressive phase shift during a lunation in such a way that the oscillation averaged over the full lunation is semi-diurnal. This behavior he understood as the result of a solar diurnal modulation of the lunar oscillations, the former being responsible for the ionization, and hence conductivity, of the atmospheric dynamo, and the latter for the tidal movement. The purely gravitational excitation of the lunar periodic air motion, as distinct from the analogous solar phenomenon, justifies, as Chapman readily recognized, the great theoretical interest of the minute lunar geomagnetic oscillations.

It was quite natural that, starting from these first geomagnetic studies, Chapman was soon led to consider the underlying oscillations of the neutral atmosphere. It took him, however, five years until his first paper on air tides appeared, an analysis of more than half a century's record of pressure at Greenwich. From that time onwards, both lunar geomagnetic variations and air tides were subjects of his interest for the rest of his life. It is impossible to go into the details of the amazing work done by Chapman in these fields, often in collaboration with his pupils or other colleagues, the more so as he always was equally active in theoretical studies, empirical determinations, and the mathematical and statistical questions involved.

Let me, however, try to summarize the main topics. In the field of geomagnetic lunar variations, Chapman made several attempts to confirm their tidal origin by grouping the data according to the moon's distance and declination, an attempt that was partly successful in so far as the general trend of the amplitudes is concerned, whereas the phase relationships are still a little obscure. Another question considered again and again in Chapman's empirical determinations is the dependence of L on *solar* activity, smaller and less significant than the corresponding effect in Sq. *Geomagnetic* activity was also considered by Chapman as an important factor to be taken into account in lunar geomagnetic studies, not only on behalf of its strong incidence on the noise level, but also as a possible physical agent. In fact, an apparent dependence of L on geomagnetic activity led Chapman for some time to the hypothesis that the lunar geomagnetic variation might be mainly generated in the auroral regions, a concept which he later abandoned.

In recent years he paid much attention to the secondary but clearly recognizable effects of ocean tides in geomagnetic lunar variations.

In the domain of the tides of the neutral atmosphere, Chapman's first active participation fell into an epoch when the question of the resonance magnification of air tides was still unsettled. He devoted much attention to the theory of the vertical propagation of the atmospheric oscillations, and to the generation of a pressure-induced tidal variation of the air temperature, which he was able to demonstrate by analyzing a 62 year's record from Batavia (now Djakarta), thus proving the adiabatical character of the lunar air tide. A great effort was made by Chapman towards increasing our knowledge of the world-wide distribution of the atmospheric tidal parameters, and a very considerable part of what we know about this is due to his own painstaking determinations carried out for many places all over the world, the last example being the analysis made of a 66 year's record from Copenhagen, published in 1969. He also reverted lately to one of his favorite subjects, the demonstration of partial tides.

In the study of atmospheric, aeronomical, and geomagnetic tides, the problems of analytical procedures, computation, and assessment of statistical significance are of great importance, due to the unfavorable signal-to-noise ratio, as distinct from earth or ocean tides. Chapman devoted a considerable part of his effort to developing suitable procedures, the most outstanding result being the well-known Chapman-Miller method of analysis, first published in 1940. It consists essentially of the successive application of harmonic analysis in two stages, the first one diurnal, and the second one monthly or half-monthly, the raw data being hourly or bi-hourly values suitably grouped and summed. Corrections are provided to allow for flattening effects and for the non-coincidence of the fundamental lunar diurnal period with the length of the working interval, which is usually an integer multiple of solar hours. Several other papers deal with additional numerical methods and with the determination of probable errors.

As we all know, Chapman was fully aware of the importance of an adequate nomenclature for geophysical concepts, and this is particularly true in the field of magnetic and atmospheric oscillations of tidal character. The term "geomagnetic tides" itself, previously used by Humboldt in a tentative fashion, became generalized thanks to Chapman's suggestion, and he is also responsible for terms such as vectogram, daygraph, harmonic dial, and dialgram.

The complex nature of geomagnetic and meteorological tidal phenomena, as well as the need of a proper geographic coverage, call for an efficient international coordination of the work on lunar effects. Chapman attached great importance to the efforts for ensuring an efficient coordination to this end. To mention only a few examples, it was thanks to his initiative, that lunar age was one of the criteria taken into account for establishing the dates of World Days during the International Geophysical Year. As President of the International Association of Meteorology, he devoted the Presidential Address of the Washington Meeting to the subject of air tides. The recent establishment of the World Magnetic Archives, mainly due to his initiative, largely obeys to the desire of compiling the greatest possible quantity of data suitable for the study of solar and lunar geomagnetic variations.

Finally, his is the merit for the existence of the Joint IAGA-IAMAP Lunar Committee, set up after two decades of preparatory work at the Oslo Assembly of the IUGG in 1948. Chapman was its Chairman until 1960, and Honorary President until his death, always participating most efficiently in the Committee's work, and keeping an active interest in the first preparatory steps for the organization of the Symposium on Lunar Effects in Geophysical Phenomena that will be held during this Assembly.

**Papers, Books, and Reports by S. Chapman Dealing with, or Related to, Lunar Variations and Atmospheric Oscillations**

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2* 1914 On the lunar variation of the earth's magnetism at Pavlovsk and Pola, *Phil. Trans. R. Soc. London,* **A 214**, 295-317.

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4* 1915 Lunar diurnal magnetic variation and its change with lunar distance, *Phil. Trans. R. Soc. London,* **A 215**, 161-176.

5* 1917 On the influence of lunar declination on the lunar-diurnal variation of magnetic declination at Zikawei, *Terr. Mag.,* **22**, 121-124.

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10* 1918 An example of the determination of a minute periodic variation as illustrative of the law of errors, *Month. Not. R. Astr. Soc.,* **78**(8), 635-638.

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32* 1936 Lunar atmospheric tide at Melbourne, 1869-1892, 1900-1914, *Quart. J. R. Met. Soc.*, **62** (267), 540-551 (with M. Hardman and J.C.P. Miller).

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38 1940 The lunar tide in the atmosphere, *Nature*, **145** (3668), 257.

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43* 1947 Location of current causing the solar and lunar diurnal variations, *Nature*, **160** (4068), 535-537 (with D.F. Martyn).

44* 1948 The lunar atmospheric tide at twenty-seven stations widely distributed over the globe, *Proc. R. Soc. London*, **A 195**, 310-328 (with K.K. Tschu).

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47* 1951 Note on a supposed determination of the lunar diurnal tide in the ionosphere, *J. Met.*, **8** (2), 133-134.

48* 1952 Lunare Schwankungen im Luftdruck, L(p): Lunare Schwankungen in anderen meteorologischen Elementen. Sections 32874 and 32875 of: *Landolt-Bornstein, Zahlenwerte und Funktionen*, **3**, 680-685. Also: Eigenschwingungen der Atmosphäre (with J. Bartels and W. Kertz), *ibid.* Section 32876.

49 1952 The calculation of the probable error of determination of the lunar daily harmonic component variations in geophysical data: a correction, *Australian J. Sci. Res.*, **A 5**, 218-222.

50* 1954 Tides in the atmosphere, *Scientific American*, **190** (5), 39.

51* 1956 A comparison of the annual mean solar and lunar atmospheric tides in barometric pressure, as regards their worldwide distribution of amplitude and phase, *J. Atm. Terr. Phys.*, **8** (1-2), 1-32 (with K.C. Westfold).

52* 1957 Lunar and solar daily variations of the horizontal geomagnetic vector at Greenwich, 1848-1913, *Abh. Ak. Wiss. Göttingen*, Math.–Phys. Kl., Sonderheft N 3, 48 p. With an appendix on the lunar daily variation of magnetic declination at Pavlovsk and Sitka.

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57 1963? The lunar daily magnetic variation L. IAGA Committee on the History of Geomagnetism and Aeronomy (Typescript).

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59 1968 Lunar and solar daily geomagnetic variations at San Fernando and Greenwich in relation to the associated electric current system, *Abh. Ak. Wiss. Gottingen*, Math.–Phys. Kl., Sonderheft No. 6, 67 p. (with B. Fogle).

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61 1968 Range and daily movement of the solar and lunar daily geomagnetic variations S and L in X, Y and Z at 100 stations, High Altitude Observatory, National Center for Atmospheric Research, Boulder, Colo., *NCAR MS 68-132* (with J. Ch. Gupta). Revised edition, 1970.

62 1969 The lunar and solar semidiurnal variations of barometric pressure at Copenhagen, 1884-1949 (66 years), *Quart. J. R. Met. Soc.,* **95** (404), 381-394.

63 1969 Atmospheric tides, *Space Sci. Rev.,* **10**, 3-188 (with R.S. Lindzen).

64 1969 Note on the computation of the solar and lunar daily magnetic variations of X and Y from hourly or bihourly values of H and D, *Gerl. Beitr. Geoph.,* **78** (2), 103-114 (with J. C. Gupta).

65 1970 Atmospheric Tides, Thermal and Gravitational, ix + 200 pp., Reidel, Dordecht (with R.S. Lindzen).

66 1970 Lunar tidal components $O_1$ and $N_2$ in atmospheric pressure, *Pure Appl. Geoph.*, **80** (III), 309-318 (with S.R.C. Malin).

67 1970 The determination of lunar daily geophysical variations by the Chapman-Miller method, *Geoph. J. R. Astr. Soc.*, **19**, 15-35 (with S.R.C.Malin).

68 1970 Atmospheric tides, thermal and gravitational: Nomenclature, notation and new results, *J. Atm. Sciences*, **27** (5), 707-710 (with S.R.C. Malin).

69 1970 Note (2) on the computation of the solar and lunar geomagnetic variations, *Gerl. Beitr. Geoph.*, **79** (1), 5-10 (with J.C. Gupta and S.R.C. Malin).

70 1970 Sea tidal generation of electric currents and magnetic fields. Applications to five stations within the British Isles, *Planet. Space Sci.,* **18**, 1597-1605 (with P.C. Kendall).

71 1970 Model calculations on sea tidal generation of electric currents and magnetic fields, *Quart. J. Mech. and Appl. Math.,* **XXIII** (4), 535-547 (with P.C. Kendall).

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* Summaries of the papers marked by an asterisk* are contained in: Annotated Bibliography on Lunar Influences on Atmospheric and Geophysical Phenomena; by Wilhelm Nupen and Geza Thuronyi, *Meteorological and Geoastrophysical Abstracts* (Am. Met. Soc.), **14** (12), 3958-4019 (December 1963).

List compiled by O. Schneider, Universidad Nacional de La Plata, Argentina.

## JOINT IAGA - IAMAP COMMITTEE ON LUNAR EFFECTS

**O. Schneider, Chairman**

**S. Malin - Reporter**

A description of the origin, purpose and history of the Joint IAGA-IAMAP Committee on Lunar Variations is given in the Transactions of the XIV General Assembly of IUGG, St. Gall, Switzerland, 1967 (*IAGA Bulletin* No. 25, page 135). Bibliographies of papers relevant to the work of the Committee have been published previously in *Meteorological and Geoastrophysical Abstracts,* **14**, No. 12, 3958-4019 (1963), *IAGA*

*Bulletin*, No. 25, p. 135 and *IAGA Bulletin*, No. 27, p. 111. The bibliography presented here lists further papers that do not appear in the above publications.

## PROGRESS REPORT AND BUSINESS MEETING

The meeting was held on August 6 and was continued on August 9, 1971. Twenty-two delegates attended, including the following committee members: M. Bossolasco, J.C. Cain, J.O. Cardus, E. Chernosky, G. Fanselau, J.C. Gupta, W. Kertz, S.R.C. Malin, S. Matsushita, O. Schneider and D.E. Winch.

A report on progress since the Madrid meeting was presented by the Chairman. He announced that 86 papers had been brought to his attention in the two-year period – many more than during the previous four-year period, indicating the current vigorous state of the subject. These papers were reviewed under various headings, covering the whole range of lunar variation studies, both theoretical and observational, from the magnetosphere to the solid earth. Considerable progress had been made in relating results from different disciplines. The full version of this review is given at the end of this report.

In addition to the Scientific Session and Business Meeting, a Symposium was being held on "Lunar Variations in Geophysical Phenomena". This inter-Association symposium was convened by O. Schneider under the auspices of IAGA, with the following Association representatives: N. P. Benkova (IAGA), B. Haurwitz (IAMAP), P. Melchior (IAG) and C. Wunsch (IAPSO).

Among the items considered in the business meeting were the following:

## STUDY GROUPS WITHIN THE LUNAR COMMITTEE

Following a suggestion made at the Madrid meeting, a number of study groups were tentatively established there. These had been very active during the two-year interval; the Committee considered that they performed a valuable task in furthering lunar studies and recommended that they be formally established as part of the structure of the Lunar Committee:

I. Theoretical problems of atmospheric oscillations (W. Kertz)
II. Internal (lithospheric and hydrospheric) aspects of geomagnetic and aeronomical lunar variations (J. Larsen)
III. Solar and interplanetary effects in lunar variations (H. Maeda)
IV. Procedures for analysis of lunar variations (B. Haurwitz)
V. Hydromagnetic aspects of ionospheric lunar variations (S. Matsushita)
VI. Global planning (S.R.C. Malin)

The Committee recommended that new empirical determinations should be undertaken in close consultation with Study Groups IV and VI, and proposed the submission of a resolution to this effect.

## PROBLEMS REQUIRING SPECIAL ATTENTION

After some discussion, the Committee considered that, of the many outstanding problems connected with lunar variations, the following were worthy of particular attention:

a. Lunar variations in the magnetosphere
b. Explanation of regional anomalies existing in the global distribution of the lunar semidiurnal air tide
c. Detailed study of the influence of oceanic and solid earth tides on the atmospheric pressure tides.
d. Explanation of the anomalous rotation of the atmospheric wind tides
e. Detailed quantitative relationships between neutral atmospheric tides, dynamo region winds and geomagnetic tides
f. Explanation of the anomalous dependence of lunar geomagnetic tides on solar activity.
g. Assessment of the magnitude of piezoelectric potentials produced by earth tides.

## CONTINUATION OF LUNAR COMMITTEE

Considering the present high level of activity in lunar studies, and the many problems still requiring solution, it was unanimously agreed that the Lunar Committee should continue its work.

## MEETINGS

Because of the essentially interdisciplinary nature of its work, the Committee decided that no meeting (either business or symposium) should be held until the next General Assembly of IUGG, unless there was a joint IAGA-IAMAP Scientific Assembly in the meantime.

## MEMBERSHIP

The Committee was aware of the parent Associations' desire that full membership of the Committee should be restricted to twelve with members of study groups as consultants. The suggested membership is:

J.C. Cain (USA)
J.O. Cardus (Spain)
G. Fanselau (DDR)
M. Fatkullin (USSR)
J.C. Gupta (Canada)
B. Haurwitz (USA)
W. Kertz (W. Germany)
J. Larsen (USA)
H. Maeda (Japan)
S.R.C. Malin (U.K.)
S. Matsushita (USA)
O. Schneider (Argentina)
A.M. Van Wijk (South Africa)
D.E. Winch (Australia)

## SUGGESTED MEMBERSHIP OF STUDY GROUPS

I. Theoretical Problems of Atmospheric Oscillations
**W. Kertz**, O. Burkard, B. Haurwitz, R. Sawada, R. Lindzen, H. Teitelbaum, Ch.L. Pekeris, M.A. Geller, M. Siebert

II. Internal Aspects
**J. Larsen**, S.R.C. Malin, G.M. Brown, J. Meunier, D.J. Stone, M. Bossolasco, R. Hewson-Browne, A. Palumbo, A.T. Price

III. Solar and Interplanetary Effects
**M. Maeda**, A.T. Price, J.C. Gupta, J.C. Cain

IV. Procedures
**B. Haurwitz**, O. Schneider, S.R.C. Malin, G. Fanselau, J.C. Gupta, D. Winch

V. Hydromagnetic Aspects of Ionospheric Lunar Variations
**S. Matsushita**, N.P. Benkova, R.G. Rastogi, J.D. Tarpley, S. Kato, C.O. Hines, W.H. Campbell, G. Fanselau, K. Rawer, P.C. Kendall

VI. Global Planning
**S.R.C. Malin**, V.A. Zaguliaeva, D. Winch, S. Matsushita, M. Siebert

## CHAIRMAN'S REVIEW ON LUNAR STUDIES

This report covers mainly, but is not restricted to, work done since the General Scientific Assembly, Madrid, 1969. It is based on the six titles compiled in the attached reference list comprising papers by authors who are members, or not, of the Lunar Committee. Additional information was drawn from personal reports sent in by Committee members. The progress up till the Madrid meeting had been summarized previously in *IAGA Bulletin* No. 27 *(Transactions of the General Scientific Assembly, Madrid, Spain,* Pages 110-115).

To begin with, let me refer to the **neutral atmosphere.** We have here to mention the important book on *Atmospheric Tides, Thermal and Gravitational*, by Chapman and Lindzen (1970), the first comprehensive treaty on the subject after a decade. Its lecture will have a healthy effect on anyone not fully aware of the intrinsic connection between atmospheric oscillations at large, and the ionospheric and geomagnetic tides caused by them, both as regards our understanding of their mechanism and the analytic methods of treatment. The same authors have also produced an article of similar scope in *Space Science Reviews* (Lindzen and Chapman, 1969).

Five papers have come to our knowledge dealing with the **theory of atmospheric oscillations**; they are by Lindzen (1967, 1968), Taffe (1969), and by Geller (1969, 1970). One of them, a doctoral thesis by Geller, deals specifically with the lunar semi-diurnal tide in the atmosphere, deriving the equations of tidal theory with Newtonian cooling. The phase lag in the surface pressure oscillation is shown to be a consequence of the upward energy flux. Haurwitz and Cowley (1969*b*) have summarized and discussed the **planetary distribution** and annual variation of the lunar pressure tide.

For a full understanding of these global aspects of air tides, especially their amplitude and phase anomalies, still more detailed empirical determinations are needed. Several such **new determinations** were made during the period under report, most of them concerning the pressure temperature, and winds at ground level, but in some cases also tidal winds in the ionospheric E-layer level (Woodrum *et al*, 1969; Zagulyaeva and Fatkullin, 1969). Chapman (1969) in a noteworthy paper published about one year before his death, gives the results of the analysis of a 66 year's record of air pressure at Copenhagen, while King and vanWijk (1969) extended the still scanty information on pressure tides in the northern hemisphere by an analysis of a 12 year's record at Hermanus, finding a relatively high $1_2/s_2$ ratio. Palumbo and Vittozzi (1969*b*) made new determinations for Napoli. An important new feature is the demonstration, by Malin and Chapman (1970*b*) of the distance–dependent $O_1$ and $N_2$ partial tides in air pressure at Hongkong. These are the second most important tidal components after $M_2$, their amplitude ranging between some 10 and 20 microbars, with a marked seasonal variation in $O_1$. Tidally generated winds were analyzed for Hongkong and Uppsala by Haurwitz and Cowley (1969*a*) and by Rao and Reddy (1971); the latter authors are to report on their results, covering six Indian stations, at the present Assembly. Palumbo and Corrado (1971*a*) undertook the difficult task of searching for the pressure induced temperature tide at Naples; we hope to hear about their results during this Assembly. Also scheduled for this meeting is a report by Pava (1971) on his studies concerning monthly variations of pressure and air displacements caused by tidal displacements caused by tidal forces.

Coming now to the *upper atmosphere*, I have to mention the work by Batten (1970), Bedinger, *et al* (1968), Richmond (1970) and Tarpley (1970) on **tidal winds** in the lower and middle ionosphere, and their implications for the atmospheric dynamo. The theory of **tidal wave** transmission through the ionized atmosphere was treated by Kato and Matsushita (1969), while Taffe (1969*a*) worked on hydromagnetic effects in atmospheric tides. The same author also considered the effect on tidal wave lengths exerted by the variation of atmospheric scale height (Taffe, 1969*b*) Tarpley and Matsushita (1971) studied the effect of lunar time variations of the electrostatic field on the sporadic E-layer, and while here will report on their results.

The planetary distribution of lunar variations in the F-region and its relationship to the main geomagnetic field was analyzed by Benkova and collaborators (1971) who are expected to report on this work during our present Assembly, and another group of Soviet scientists have investigated the height distribution of lunar ionospheric tides in the neighborhood of the magnetic equator (Zagulyaeva and Fatkullin, 1969).

**New determinations of lunar variations in ionospheric parameters** were reported by a fairly great number of authors. Little work had been carried out earlier on lunar tidal effects in ionospheric absorption. Chakravarty and Rastogi (1970) have recently made such determinations based on the minimum frequency of the D region at Colombo, Ceylon. Rastogi (1969) reported separately on similar work. Also concerned with absorption, but covering a variety of frequencies, was a study by Kotadia and Patel (1969) who analyzed a nine years' record from Freiburg.

Coming now to the **normal E region**, we have a study by Isikara (1970) for Istanbul, and an investigation by Butcher and Weeks (1969) on measurements of the lunar tide in the phase height of E. Regarding **sporadic E**, its lunar response in the equatorial region has been investigated by Joshi and Kotadia (1970), while Tarpley and Matsushita (1970) have done similar work on the blanketing frequency of E.

As regards the F-region, a doctoral thesis by Sharma (1971) has come to our knowledge. He investigated especially the lunar variations of electron density at low and mid-latitude stations. This author and Rastogi (1970*b*) have reported again on similar studies over Huancayo. R. A. Brown (1968) used routine hourly readings at Ibadan to obtain the lunar variations of **hmF2** and **foF2**, finding for the latter a standing wave with a node of hm = 308 km. Also concerned with lunar effects on diverse parameters of the F-region are the determinations made by Rudina and co-authors (1971), who carried out an extensive work based on horizontal wind and ionization drift velocities, on which they will report here. The lunar perturbation of low latitude critical frequency of F2 was the subject of a study by Rush and Venkateswaran (1968).

Several previous attempts are on record at finding lunar tidal variations in parameters characterizing morphological features (such as height) of the visual aurora. A recent study by Forsyth (1970) failed to furnish evidence for the lunar origin of a 29.5 day period in radio aurora.

The interaction of the ionosphere with the magnetosphere, as far as L is concerned, was considered by Matsushita (1971*a*) and again by Matsushita and Tarpley (1970). Hydromagnetic tidal oscillations of the magnetosphere and their effects on the distribution of plasma density were the subject of theoretical considerations by H. Maeda (1971), who expects that a significant lunar variation induced from below can exist in the magnetospheric plasma density. He will report on the fundamentals of this theory at the present Assembly. There can be little doubt that attempts will be made in the next few years, at demonstrating directly lunar tidal effects in the magnetosphere by means of satellites.

The atmosphere dynamo winds, the link between the upper atmosphere and geomagnetic tides, were treated in two papers by Matsushita (1969, 1971*b*) and also by Tarpley (1970).

This brings us down to **lunar oscillations of the geomagnetic** field. Many of the theoretical studies done in this domain were devoted to oceanic effects, which have been found in recent years to be a significant source of contributions to the classical lunar geomagnetic tides. Larsen (1968) has given solid experimental and theoretical evidence of electric and magnetic field variations induced by deep sea tides, and he will report on these topics at the present Assembly (Larsen, 1971). Malin (1970*a*) was successful in demonstrating that under certain reasonable assumptions the parts of ionospheric and oceanic origin present in the geomagnetic lunar variations can be separated. Applying this to observations made at stations on the British Isles, he finds that the oceanic contribution is important. Meunier (1967) had already shown earlier that earth currents measured not too far inland have a periodic lunar component induced at the sea tides, and a similar influence on earth currents at a coastal station has recently been reported again by Brown and Woods (1971), who found an abnormally great $L_2$ at Aberystwyth (normal at inland stations: L/S = 1:10 to 1:5; here: 3:1 to 4:1). Osgood and co-authors (1971) have made magnetic field observations at Exeter and Sidmouth, and were able to show that lunar residuals found there are consistent with the theory that part of the associated electric currents flow in the English Channel. Leakage of current from the Atlantic is interpreted as being the cause of a significant part of lunar geomagnetic field variations in the British Isles, in a recent paper by Windle *et al* (1971). Chapman and Kendal had already reported at the Madrid Assembly on their model calculations and empirical tests of the sea tidal generation of electric currents and magnetic fields; detailed accounts on this work have been published in the meantime (Chapman and Kendall, 1970; Kendall and Chapman, 1970).

Diverse aspects of the **morphology of L in geomagnetism** were studied by a number of investigators. Fanselau (1971) completed earlier studies for the Potsdam-Seddin-Niemegk group of observatories, and he will report on his results to this Assembly. Malin (1970*b*, 1971) made a new analysis of the worldwide distribution of L, paying special attention to the already mentioned sea tide influences. A comprehensive treatment of L in geomagnetism is given in a chapter by Matsushita (1967) contained in the book on *Physics of Geomagnetic Phenomena,* by Matsushita and Campbell.

Little is known about the cause of the contradictory, but generally weak, response of geomagnetic lunar tides to solar activity. Chapman and Fogle (1968) have looked into this problem in their analysis of long series at San Fernando and Greenwich. Chapman, Gupta, and Malin (1971) have reconsidered the whole question, and Gupta and Malin will report on their results at this meeting.

New determinations of geomagnetic or electrotelluric tides were done for many places by the following authors, some of whom are going to report on their work here: Cardus (1971): Moca, Z component; Mrs. de Cuevas: Hermanus; Miss Green: 20 years of record at Toolangi; Green and Malin (1971): 40 years at Watheroo; Gupta (1971): 53 years at Sodankyla; Palumbo and co-authors (Palumbo and Corrado, 1971*b*; Palumbo and Pinna, 1970; Palumbo and V. Hozzi, 1969*b*): Diverse Italian Stations; Jeevananda Reddy (1971): Earth Currents at Barrow; Schneider, *et al*. (1971): Diverse Argentine Stations; Sharma and Rastogi (1970*a*): San Juan (Puerto Rico); Winch (1970*a, b, c*, 1971): Partial Tides; Worthy: 7 years of data from the Private Observatory of Stonyhurst.

To conclude, we have to consider some recent papers bearing on the mathematical and computational side of lunar analysis. Brown (1969) has suggested that the "luni-solar" character of geomagnetic and ionospheric tides might be the outcome of "sum and difference frequencies" being produced by the nonlinear response of the atmosphere to the applied forces. Gupta and Chapman (1969) have applied spectral analysis to the study of lunar daily geomagnetic variations, a procedure also applied by Black (1970), who used a specially developed method based on discrete Fourier transforms. A differential method for lunar analysis was developed by Malin and Green (1971), and they will report here on it. Malin and Chapman (1970*a*) have published a simplified guide to the Chapman-Miller method. Haurwitz and Cowley (1970) gave a direct demonstration of the lunar barometric tide with a minimum display of analytical work. Geomagnetic raw data stored with a high degree of time resolution were used by Matsushita and Campbell (1971) in determining lunar geomagnetic variations, a work on which they will report here. A healthy demonstration of a typical pitfall in the search for lunar influences was given by Knopoff (1970), who pointed out how an apparently long, but actually insufficient record, may invite spurious conclusions. Lindzen (1969) published some remarks on data necessary for the detection and description of tides and gravity waves in the upper atmosphere. Chapman and Malin (1969, 1970) devoted two articles to questions of tidal nomenclature and notation, and finally, your Chairman (Schneider *et al*, 1971) gave a lecture here at this Assembly on Professor S. Chapman's work on tides in the lower and upper atmosphere and their geomagnetic manifestation, covering 72 titles of papers and books written by the late Honorary President on this subject, partly in collaboration with others.

A reference list of papers dealing with Lunar Variations in Geomagnetism, Aeronomy and the Earth's Atmosphere at large, mainly covering the period July 1969 to March 1971, but also including some titles not listed in the Chairman's previous Progress Report (Joint IAGA-IAMAP Committee on Lunar Variation; *IAGA Bulletin No. 27, Transactions of the General Scientific Assembly, Madrid, Spain*, edited by L. R. Alldredge, pp. 110-114, 1969) is attached.

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# JOINT IAGA - IAMAP COMMITTEE
# SYMPOSIUM ON ATMOSPHERIC ELECTRICITY

**Dr. V.P. Kolokolov . USSR – Convener**

**Tuesday, 3 August 1971, Electrical fields, Global effect, Location effect**

Morning: Chairmen: Koenigsfeld, J.L. (Belgium), and Krasmogorskaya, N.V. (USSR)

1) Kolokolov, V.P., Distribution characteristics of thunder-storm activity over the globe (USSR).
2) Grigoriu, A., The planetary convection as the primary cause of the aeroelectric field in clear zones and of its universal diurnal variation (Roumania).

Discussion: 30 min.

3) Inkov, B.K.T.V. Lobodin, and L.G. Machotkin, Investigation of thunderstorm activity by radiotechnical methods (USSR).
4) Markson, R., and B. Vonnegut, Airborne potential gradient measurements to determine the temporal variation of ionospheric potential (USA).

Afternoon: Chairmen: Imyanitov, I.M. (USSR), and Mühleisen, R.P. (FRG)

1) Mühleisen, R.P., The air earth current density over the ocean and the global fine weather vertical current (FRG).
2) Ette, A.I.I., An effect of space charge advection on vertical air-earth current measurement (Nigeria).
3) Bhartendu, Power spectra and coherence coefficient spectra of atmospheric potential gradients at land stations (Canada).

Discussion: 30 min.

4) D.E.Olson, Micropulsations observed during the measurement of air-earth current density with radiosondes (USA).
5) Anderson, R., H. Dolzealek, *et al.*, Atmospheric electricity measurements during the solar eclipse of 7 March 1970 (USA).
6) Bragin, Yu.A., A.A. Kocheyev, Preliminary results of the direct research of the space electric charge distribution to 94 km altitude (USSR).

**Wednesday, 4 August 1971, Electricity of Clouds and Precipitation**

Morning: Chairmen: Dolezalek, H. (USA), and Kolokolov, V.P. (USSR)

1) Krasnogorskaya, N.V., A.I. Neizvestny, An Investigation of Charged Particle Coagulation (USSR).
2) Latham, J., A quantitative assessment of precipitation mechanisms of thunderstorm electrification (England).
3) Borzilov, V.A., and Yu.S. Sedunov, On the diffusive charging of a droplet collective in a low ionised atmosphere (USSR).

Discussion: 30 min.

4) Imyanitov, I.M., E.V. Chubarina, and Yu.M. Shvarts, On the effect of electric forces on cloud development (USSR).
5) Kasemir, H.W., Airborne measurement of the electric field and analysis of charge distribution of thunderclouds (USA).
6) Shishkin, N.S., On possible role of corona discharge in thunderstorm development (USSR).

Discussion: 30 min.

Afternoon: Chairmen: Latham, J. (England) and Shishkin, N. S. (USSR)

1) J. Doyne Sartor, A crucial role for the electrical relaxation of ice in charging of cloud particles (USA)
2) Kachurin, L.G., V.I. Bekryaev, and V.F. Psalomshchikov, Electrification of crystallizing clouds (USSR).
3) Aufdermaur, A.N., Charge separation due to riming in an electric field (Switzerland).
4) Magono, C., T. Iwabuchi, On the electrification of ice crystals (Japan).
5) Muchnik, V.M., On a thunderstorm theory (USSR).

6) Vohra, K.G., An ionic recombination model of nucleation in the atmosphere (India).

Discussion: 30 min.

**Thursday, 5 August 1971, Physics Lightning.**

Morning: Chairmen: Ishikawa, T. (Japan) and Lobodin, T.V. (USSR)

1) Polk, C., and J. Toomey, Location of major thunderstorm regions by the analysis of electric and magnetic field spectra at ELF (USA).
2) Hill, R.D., Optical characteristics of lightning channel (USA).
3) Newman, M.M., Studies on initiation and propagation of lightning and possible control (USA).
4) Llanwyn-Jones, D., The application of E.L.F. atmospheric observations to deduction of the characteristics of tropical lightning (England).
5) Tříska, P., and J. Laštòvička, Long-term observations of the sudden decrease of atmospherics at 5 kHz (Czechoslovakia).
6) Dawson, G.A., The instability of electrically stressed water drops and the initiation of lightning (USA).

Discussion: 30 min.

Afternoon: Chairmen: J. Bricard (France) and Kachwin, L.G. (USSR).

1) Storebo, P.B., Steady-state aerosols (Norway).
2) Schumann, G., Size distribution of aerosols after radioactivity measurements (Germany).
3) Jammet, H., and J. Salam, The resolving power of the air ion mobility spectrometer (USSR).
4) Wajsfelner, R., J. Bricard, Madelaine *et al.*, Mobility spectrum of small negative radioactive ions in air (France).
5) Cabane, M., J. Bricard, J. Madelaine *et al.*, Mobility spectra of small gaseous ions in air (France).
6) Prüller, P.K., Investigation of atmospheric ion spectra, hygienical and biometeorological significance of ionization (USSR).

Discussion: 15 min.

7) Kinoshita, K., T. Ishikawa, and N. Kitagawa, Discharge experiments using dummies and rabbits, simulating strokes on human bodies (Japan).
8) R. Siksna, The structure of the aggregates formed as atmospheric ions by means of hydrogen bonds between molecules of some organic substances and water. Some elements of organic chemistry for gaseous ionics (Sweden). Discussion: 30 min.

# SPECIAL SYMPOSIA

IAGA was given the responsibility of convening eight of the 31 special symposia which were a part of the General Assembly. All of these special symposia were on interdisciplinary topics of interest to more than one Association.

The programs for the eight special symposia convened by IAGA were included in the IAGA program booklet and are not therefore repeated here. Some comments, reported on a few of these symposia, are included here.

## AUTOMATIC ACQUISITION OF DATA AND TIME SERIES ANALYSIS
### A.P. DeVuyst - Convener

Changes in the published program were made as follows: Papers not presented. (See IAGA Program & Abstracts Book.)

S3-2 De Meyer, F., Generalities about the analysis of time series.
S3-3 Delhomme, J.P., Elimination of the noise in the time series during the

determination of the unit response of physical phenomena.

S3-6 Burke, M.D., G.L. Cumming, D.I. Gough, E.R. Kanasewich, E. Nyland and D. Rankin, A small computer based data management system for a geophysical research laboratory.

S3-7 Dyubkin, I.A., A.P. Koptev and L.N. Klyukvin, The results of the automation of the processing of the scientific information in the expeditions of the Arctic and Antarctic Research Institute.

S3-12 Kanasewich, E.R., Field digital recording with variable aperture seismic array.

S3-16 Olberg, M., A significance test for band-pass filtered time series.

S3-17 Kagan, R.L. and E.I. Fedorchenko, On calculation of statistical characteristics of time series excursions.

S3-21 Raghavendra, V.K., Time series analysis of the daily average rainfall along the mid west coast of India during the southwest monsoon season.

S3-22 Rao, K.N. and V.K. Raghavendra, Time series analysis of 158 years' rainfall of Madras (India) (Period 1813-1970).

S3-30 Milea, E., V. Iliescu, A. Doneaud and G. Stocia, Some contingencies between the thermic singularities in Romania during 1920 to 1960 and the types of atmospheric circulation.

Papers added:

Vanicek, P.L., Spectral analysis by least squares.

Bibl, K. and B. Reinink, Online digital data.

Wilmore, P.L., Data collection for modern seismographs.

Wright, J.W., Ionospheric measurements by digitally controlled radio sounding system.

The following opening remarks were made by the Convener.

This Symposium is an attempt to inform people from different disciplines how to obtain data in digital form (machine readable form) and how to submit these large quantities of collected data to specific methods of analysis. Some of these techniques or methods are used by research people in one particular field but may be applied to other fields. It was therefore specified that the content of the papers should have emphasis on methods rather than on the results themselves or interpretation of them. Each speaker should have this in mind when presenting his paper.

The field of statistical practice in which time series arise divdes itself roughly into two categories: a) the statistics of economical, sociological and short-time biological data, on the one hand, and b) the statistics of meteorological, geophysical and physical data. This second category of time series typified by meteorological data is the subject of this symposium. A problem familiar to all those who work with observational geophysics is the reduction and handling of large quantities of data collected by various types of continuous recording equipment. The advantages of an automatic system for recording and reducing observations are not only that the man-hours are less but that the observations and results are permanently available in an orderly and systematic form which contains all the relevant information.

Most research people would agree that the last decade is characterized by what has come to be known as the "digital revolution." This revolution has consisted of the wide spread conversion from analog to digital means for recording and processing of geophysical data. It was originally stimulated by the potential power and flexibility of computers and the application of quantitative analytical methods which are the subject of time-series analysis. However in many aspects this revolution is not always a success for many reasons, some financial, some purely subjective, but in general because of lack of information. It is the principal aim of this symposium to supply this information with examples from different disciplines, examples of instrumentation and quantitative techniques.

By coincidence we are gathering here in Moscow and it must be said that firm axiomatic basis in the founding of the theory of stochastic processes was led by the Russian mathematicians A. Kolmogorov and A. Khintchine (1933) and that the latter also did the basic work in stationary processes (1934).

In the field of the generalized analysis the work of Norbert Wiener stands in the foremost place. His classic paper "Generalized Harmonic Analysis" (1930) represents a true discontinuity in the normal development of ideas.

In the last decade processes such as: smoothing, fitting of a least square polynomial, auto- or cross-correlation, filtering power spectrum, Fourier transform and more specific as an example Fast Fourier Transform are powerful means of research in all fields.

Let me remind you that in the final analysis, the potential usefulness of statistical approach depends upon the coordination of statistical methods with knowledge of the practical and the theoretical aspects of the discipline which is involved.

## PHYSICS OF MAGNETOSPHERIC SUBSTORMS
## V.A. Troitskaya -- Convener

The symposium comprised five sessions and a panel discussion on actual problems of the morphology and theory of magnetospheric substorms. Among the most important results are the following:

1. Data confirming penetration into the magnetosphere of the solar wind plasma through the neutral points.
2. Similarity of energy spectra of the particles in the plasma sheet and in the magnetosheath, was considered as an indication of penetration of solar wind plasma into the magnetospheric tail.
3. Data on the diminishing of the plasma sheet thickness before the break up and its widening during the phase of expansion.
4. Data indicating the instability of the plasma sheet.
5. The formulation of conceptions on the development of the substorm, consisting of three phases: the growing phase, the phase of expansion and the recovery phase.
6. The important role of the vertical component of the interplanetary field in triggering substorms was stressed in many papers.
7. New information was presented on a variety of events observed on the earth's surface during all three phases of substorms.
8. The important role of three dimensional current systems developing during substorms in the magnetosphere and troposphere including currents on the dayside of the magnetopause was stressed. The dynamics of behavior of current systems along a meridian, showing their difference for different substorms, was shown in a special film.
9. New data on electric fields obtained on satellites were presented showing the surprising stability of the electric field in the region of the polar cap. During the substorms in the region of the plasmasphere there exists strong non-stationary electric fields.
10. Most important data on instabilities in the magnetosphere were presented and an indication of their role in the development of the substorms is the sharp intensification of the magnetic noise in the plasma sheet during the expansion phase. Experimental and theoretical results show also that scattering of energetic electrons in the morning hours is the result of the particle wave interactions. The importance of the ratio of hot plasma to cold plasma density for developing of instabilities leading to generation of substorms was shown. An artificial injection of cold plasma was suggested to test the existing conceptions.
11. New data on distribution of the regions of particle precipitation and the parameters of their fluxes were presented. Most interesting results on details of conjugation of aurora obtained during conjugate flights in both hemispheres were obtained.

## AURORA AND AIRGLOW - ALL ASPECTS
## G. Weill - Acting Convener (for A. Omholt - Convener )

The Symposium on Aurora and Airglow – All Aspects, was held in seven sessions from August 9 to 13, 1971. The sessions of prime interest to Commission VI were: Laboratory Data; Auroral Physics 1967-71 (2 sessions); A Case Study; the Period 6-9 March 1970; and Low Energy Electrons in Aurora and Airglow. A number of important papers was presented and the attendance at all sessions was good. The response in terms of contributed papers was better than expected and some sessions were very long on that account. Overall, the symposium was considered highly successful.

Two problems were evident that one would wish to solve in forthcoming symposia. Some invited speakers were unable to obtain travel funds and cancellations occurred at dates too late to obtain alternates. The sessions were not all well balanced in contributed papers and this situation was aggravated by the withdrawals of contributed papers that occurred. A tighter control over the number of papers per session seems to be indicated. The membership was all enthusiastic about an Aurora and Airglow symposium in 1973, but with a trend to emphasizing particular processes, and increasing the overlap between auroral and airglow topics.

# NEW IAGA ORGANIZATION

## NEWLY ELECTED OFFICERS

The newly elected Executive Committee of the IAGA for the period 1970-1975 are as follows:

| | |
|---|---|
| **President:** | Dr. V. A. Troitskaya<br>Soviet IGC Committee<br>Molodezhnaya 3<br>Moscow B-296, USSR |
| **Vice Presidents:** | Dr. G. M. Weill<br>Dr. J. G. Roederer |
| **General Secretary:** | Dr. Leroy R. Alldredge<br>NOAA Environmental Research Laboratories<br>Boulder, Colorado 80302, USA |
| **Members:** | Dr. T. Nagata (past President)<br>Dr. A. J. Dessler<br>Dr. J. W. Dungey<br>Dr. M. Nicolet<br>Dr. O. Schneider<br>Dr. R. Turajlic |

## NEW ORGANIZATIONAL STRUCTURE AND APPOINTED OFFICERS

Several changes were made in the IAGA Commissions and Working Group structure. Commission Chairmen and Working Group reporters were changed. In several cases there were some modifications made in names of Working Groups and transfer of Working Groups between Commissions.

It was decided that the two IAGA-IAMAP Joint Committees, Atmospheric Electricity and Lunar Variations, be abolished as Joint Committees. The atmospheric electricity work was assigned to IAMAP and the lunar variation work to IAGA.

Details of the Working Group membership are not yet available but the organization as far as it is now known and which should exist until the Scientific General Assembly in Kyoto, in 1973, is as follows:

### COMMISSION I

| | | | |
|---|---|---|---|
| **Title:** | **Observatories and Instruments** | | |
| **Chairman:** | A.P. DeVuyst<br>Centre de Physique<br>du Globe, Dourbes<br>Nismes-Provence de<br>Namur, Belgium | **Co-chairman:** | P.H. Serson<br>Dominion Observatory<br>Department of Mines and<br>Technical Surveys<br>Ottawa, Ontario<br>Canada |

Working Groups

| | |
|---|---|
| Magnetic Observatories I-I | **Reporter**: K.L. Svendsen (USA), |
| Geomagnetic and Telluric Instrumentation I-2 | **Reporter**: V.N. Bobrov (USSR) |
| Comparison of Magnetic Standards I-3 | **Reporter**: E.K. Lauridsen (Den.), |
| Processing Techniques for Observational Data I-4 | **Reporter**: E.I. Loomer (Canada) |

## COMMISSION II

Title: Representation of Main Magnetic Fields

Chairman: B.R. Leaton
Royal Greenwich Observatory
Herstmonceux Castle
Halisham, Sussex
England

Co-chairman: A.J. Zmuda
Applied Physics Laboratory
Johns Hopkins University
8621 Georgia Avenue
Silver Spring, Maryland 20910,
USA

Working Groups

| | |
|---|---|
| Land and Airborne Surveys II-1 | **Reporter**: P.H. Serson (Canada) |
| Ocean Shipborne Surveys II-2 | **Reporter**: M.M. Ivanov (USSR) |
| Near Earth Satellites II-3 | **Reporter**: J.C. Cain (USA) |
| Analysis of Geomagnetic Fields II-4 | **Reporter**: A.J. Zmuda (USA) |
| Recent Secular Variations II-5 | **Reporter**: A.N. Pushkov (USSR) |
| Data Interchange II-6 | **Reporter**: H. Maeda (Japan) |

## COMMISSION III

Title: Magnetism of the Earth's Interior

Chairman: T. Rikitake
Earthquake Research Institute.
The University of Tokyo
Tokyo, Japan

Co-chairman: G.N. Petrova
Geophysics Institute
of the Academy of Sciences
Physics of the Earth,
B. Gruzinskaya 10,
Moscow G-242, USSR

Working Groups

| | |
|---|---|
| Electro-Dynamics III-1 | **Reporter**: F.M. Lowes (U.K.) |
| Secular Variation III-2 | **Reporter**: A.V. Cox (USA) |
| Electromagnetic Induction III-3 | **Reporter**: D.I. Gough (Canada) |
| Rock Magnetism III-4 | **Reporter**: C.M. Carmichael (Canada) |
| Archeomagnetism III-5 | **Reporter**: R.L. DuBois (USA) |
| Paleomagnetism III-6 | **Reporter**: K.M. Creer (U.K.) |
| Geomagnetic Anomalies III-7 | **Reporter**: A. Hahn (W. Germany) |

## COMMISSION IV

Title: Magnetic Variations and Disturbances

Chairman: J.A. Jacobs
Killam Memorial
University of Alberta
Edmonton, Alberta
Canada

Co-Chairman: M. Sugiura
NASA, GSFC
Code 612
Greenbelt, Md. 20771
USA

Working Groups

| | |
|---|---|
| **Morphology and Indices IV-1** | **Reporter:** D. VanSabben (Neth.) |
| **Daily Variations IV-2** | **Reporter:** D.J. Stone (U.K.) |
| **Equatorial Electrojet IV-3** | **Reporter:** D.G. Osborne (U.K.) |
| **Special Disturbance Events IV-4** | **Reporter:** S.I. Akasofu (USA) |
| **Micropulsations IV-5** | **Reporter:** R. Gendrin (France) |
| **Magnetospheric Field Variations IV-6** | **Reporter:** M. Sugiura (USA) |
| **Conjugate Points IV-7** | **Reporter:** O.M. Raspopov (USSR) |

COMMISSION V

**Title:** **Solar-Magnetosphere Relations**

**Chairman:** J.G. Roederer
Physics Department
University of Denver
P.O. Box 10127
Denver, Colorado 80310 USA

**Co-Chairman:** C.G. Fälthammar
The Royal Institute of Technology
Division of Plasma Physics
Stockholm 70, Sweden

Working Groups

| | |
|---|---|
| **Solar Wind Interaction with Earth and Planets V-1** | **Reporter:** N.F. Ness (USA) |
| **Morphology of Radiation Belts V-2** | **Reporter:** D.J. Williams (USA) |
| **Particle – Field Interactions V-3** | **Reporter:** |
| **Cold Plasma and Low Energy Particles V-4** | **Reporter:** K.I. Gringauz (USSR) |
| **Solar Energetic Particles V-5** | **Reporter:** T. Obayashi (Japan) |

COMMISSION VI

**Title:** **Aurora**

**Chairman:** G.G. Shepherd
Department of Physics
York University
Downsview, Toronto
Canada

**Co-chairman:** S.I. Isaev
Polar Geophysical Institute
Apatity
Murman Region
USSR

Working Groups

| | |
|---|---|
| **Morphology VI-1** | **Reporter:** A. Egeland (Norway) |
| **Spectroscopy and Excitation VI-2** | **Reporter:** A. Vallance Jones (Canada) |
| **Radio Aurora VI-3** | **Reporter:** R.S. Unwin (N. Zealand) |
| **Particles and Fields Effects VI-4** | **Reporter:** D.S. Evans (USA) |

COMMISSION VII

**Title:** **Airglow**

**Chairman:** M. Gadsden
Department of Natural Philosophy
Aberdeen University
Aberdeen AB9, ZUE
Scotland

**Co-chairman:** B.A. Tinsley
University of Texas at Dallas
P.O. 30365
Dallas, Texas 75230
USA

Working Groups

Instruments and Calibration VII-1 — **Reporter**: R. Pastiels (Belgium)
Excitation Processes VII-2 — **Reporter**: J.C.G. Walker (USA)
Photometry and Spectroscopy VII-3 — **Reporter**: T. Tohmatsu (Japan)
Laboratory Data VII-4 — **Reporter**: H.I. Schiff (Canada)

Additional Reporters at Large

Mesospheric Emissions — **Reporter**: N.N. Shefov (USSR)
Exospheric Emissions — **Reporter**: L.M. Fishkova (USSR)
Tropical Airglow — **Reporter**: P.V. Kulkorni (India)
Airglow Effects of Photoelectrons — **Reporter**: P.V. Kulkornis (India)
Planetary Airglow — **Reporter**: C.A. Barth (USA)

## COMMISSION VIII

**Title: Upper Atmospheres**

**Chairman**: T.M. Donahue
Department of Physics
University of Pittsburgh
Pittsburgh, Pennsylvania 15213
USA

**Co-chairman**: Y.M. Marov
Institute for Applied Mathematics
Academy of Sciences
Minsskaya Square 4
Moscow, USSR

Working Groups

Composition, Temperature and Density Variations VIII-1 — **Reporter**: M.N. Izakov (USSR)
Ionospheric and Thermospheric Dynamics VIII-2 — **Reporter**: B.A. Tinsley (USA)
Ionization Processes VIII-3 — **Reporter**: R. Eather (USA)
Electromagnetic Interactions VIII-4 — **Reporter**: L. Block (Sweden)
Meteors VIII-5 — **Reporter**: T.R. Kaiser (U.K.)
Planetary Atmospheres VIII-6 — **Reporter**: W.B. Hanson (USA)

## COMMISSION IX

**Title: History**

**Chairman**: E.J. Chernosky
Air Force Cambridge
Research Laboratories
48 Berkeley Street
Waltham, Massachusetts 02154
USA

**Co-chairman**: N.V. Pushkov
IZMIRAN
Vatutenki
P/O Adademgorodok
Moscow, USSR

Working Groups

American Area IX-1 — **Reporter**: D.G. Knapp (USA)
Pacific Area IX-2 — **Reporter**: N. Fukushima (Japan)
European Area IX-3 — **Reporter**: G. Fanselau (Ger. DR)

## COMMITTEE ON LUNAR VARIATIONS
(Including the Neutral Atmosphere)

| | | | |
|---|---|---|---|
| Chairman: | O. Schneider<br>Observatorio Astronomico<br>Paseo del Basque<br>La Plata, Argentina | Co-chairman: | S.R. Malin<br>Royal Greenwich Observatory<br>Herstmonceaux Castle<br>Hailsham, Sussex<br>England |

Working Groups

| | |
|---|---|
| Theoretical Problems of Atmospheric Oscillations WG-1 | Reporter: W. Kertz (W. Ger.) |
| Internal Aspect of Geomagnetic and Aeronomical Lunar Variations WG-2 | Reporter: J. Larsen (USA) |
| Solar and Interplanetary Effects in Lunar Variations WG-3 | Reporter: H. Maeda (Japan) |
| Procedures for Analysis of Lunar Variations WG-4 | Reporter: B. Haurwitz (USA) |
| Hydromagnetic Aspects of Ionospheric Lunar Variations WG-5 | Reporter: S. Matsushita (USA) |
| Global Planning WG-6 | Reporter: R.S. Malin (U.K.) |

## COMMITTEE ON ANTARCTIC RESEARCH

Chairman: (and the IUGG Liaison Officer to SCAR) T. Nagata (Japan)

Members: V. A. Troitskaya (USSR)
D. L. Carpenter (USA)

(Total membership will be enlarged to 15 or 20)

Proposed Working Groups
Geomagnetic Variations and ULF
Radar and Optical Auroras
VLF and Whistler
Ionosphere and CNA
Rockets
Balloons

It should be noted that several of the above named people have not yet been contacted. It is hoped that all will agree to serve as indicated.

# RESOLUTIONS

## SCIENTIFIC RESOLUTIONS

### RESOLUTION 1

**Noting** the COSPAR and IUCSTP decision taken at their Seattle meetings in May 1971 to support and approve the First Report of the IMS Special Study Group and to recommend that subsequent to the completion of its task with the issue of the Second Report, the present IMS Special Study Group be dissolved and replaced by an appropriate body, the **IAGA recommends** that IUGG endorse the principle of the proposed IMS program and set up a working group in IUGG to consider particularly the ground-based, rocket-borne and balloon-borne research programs which are closely related to the proposed IMS program. (Note: This resolution was later passed by the IUGG as an official IUGG resolution in a slightly modified form.)

**Prenant note** de la décision prise par le COSPAR et l'IUCSTP à leur réunion de Seattle en mai 1971 d'encourager et d'approuver le premier rapport du Groupe Spécial d'Etude de l'IMS et de recommander qu'après l'achèvement de sa mission, lors de l'édition du second rapport, l'actuel Groupe Spécial d'Etude de l'IMS soit dissous et remplacé par un organisme approprié, **l'IAGA recommande** à l'UGGI d'admettre le principe du programme proposé pour l'IMS et de constituer un groupe de travail dans l'UGGI en vue d'étudier, en particulier, les programmes de recherche au sol, par ballons et par fusées, qui sont étroitement liés au programme proposé pour l'IMS.

### RESOLUTION 2

IAGA **confirms** resolutions 6, 7 and 12 adopted at its 1969 Assembly in Madrid and stresses the great scientific importance of the project Geomagnetic Meridian for simultaneous ground observations along the geomagnetic meridians of 105°-115° and 140°-150°E and covering latitude extending from the auroral zone to the equator. This project is planned for the 1973-75 period. IAGA also recognizes the need for related satellite observations and strongly **supports** the launching of the geostationary satellite ATS-F, which will be positioned near by geomagnetic meridian 100.5°E.

L'AIGA **confirme** les résolutions 6, 7 et 12 adoptées lors de son Assemblée de Madrid en 1969 et souligne le grand intérêt scientifique du projet Méridien Géomagnétique, dont le but est de faire des observations simultanées au sol le long des méridiens géomagnétiques 105°-115° et 140°-150° Est de la zone aurorale jusqu'à l'équateur. Le projet est prévu pour la période 1973-1975. L'AIGA reconnaît également le besoin d'observations complémentaires par satellite et elle **encourage** fortement le lancement d'un satellite géo-stationnaire ATS-F qui serait situé près du méridien géomagnétique 100.5°E.

### RESOLUTION 3

IAGA **strongly supports** the proposal of the IUCSTP to extend the multidisciplinary patrol observations of solar activity and related geophysical phenomena after the end of IASY in 1971 as a special extended multidisciplinary IUCSTP project for monitoring of Sun-Earth Environment (MONSEE) at least through the next solar cycle. IAGA **recommends** the appropriate commissions take an active part in working out MONSEE programs.

L'AIGA **encourage** fortement la proposition de l'IUCSTP d'étendre les observations programmées multidisciplinaires d'activité solaire et de phénomènes géophysiques après la fin de l'IASY en 1971 au moins jusqu'à la fin du prochain cycle solaire dans le cadre d'un projet multidisciplinaire spécial de l'IUCSTP pour la surveillance de l'environnement soleil-terre (projet MONSEE). L'AIGA **recommande** aux commissions concernées de prendre une part active à la réalisation des programmes MONSEE.

## RESOLUTION 4

The IAGA Assembly **accepts with gratitude** the proposal of IZMIRAN to organize and manage for IAGA an analytical center on secular variation with the following functions:

1) collection of data on secular variations from magnetic observatories and from repeat stations;

2) publication of secular variation charts and tables of annual values of magnetic elements from magnetic observatories;

3) spherical harmonic analysis of secular variation.

The Statute of this center must be drafted by IZMIRAN with the help of the Chairmen of Commissions I and II.

L'Assemblée de l'AIGA **accepte avec reconnaissance** la proposition de l'IZMIRAN d'assurer, pour l'AIGA, l'organisation et le fonctionnement d'un centre analytique de la variation séculaire qui aurait les fonctions suivantes:

1) réunir les données de variation séculaire provenant des observatoires magnétiques et des stations de répétition;

2) publier des cartes de variation séculaire et des tables des valeurs annuelles des éléments magnétiques des observatoires;

3) effectuer l'analyse sphérique harmonique de la variation séculaire.

Les statuts de ce Centre doivent être rédigés par l'IZMIRAN avec l'aide des présidents des Commissions I et II.

## RESOLUTION 5

**Considering** the great progress made in recent years in the determination of lunar tidal parameters in data for individual stations, IAGA **recommends** that in future work particular emphasis be placed on regional and global studies and on theoretical interpretation of the phenomena.

**Considérant** les grands progrès accomplis ces dernières années dans le domaine de la détermination de divers paramètres des marées lunaires, à partir de données de stations individuelles, l'AIGA **recommande** que les recherches futures soient orientées de préférence vers des études régionales et globales et vers l'interprétation théorique des phénomènes.

## RESOLUTION 6

The IAGA, on the basis of resolution 8 adopted at Madrid in 1969, and **considering** that the Soviet institutions are ready to start geophysical observations (magnetic variations, VLF, ionospheric absorption, and vertical sounding) at several locations near Petropavlovsk and Topolovka, which are conjugate to Canberra and Hobart, **recommends** that effective links be established between the Soviet Geophysical Committee and the appropriate Australian institutions to bring this program into operation.

L'AIGA, s'appuyant sur la résolution 8 adoptée à Madrid en 1969 et **considérant** que les institutions soviétiques sont prêtes à entreprendre des observations géophysiques (variations magnétiques, VLF, absorption ionosphérique et sondages verticaux) en plusieurs stations situées à proximité de Petropavlovsk et Topolovka, conjuguées de Canberra et Hobart, **recommande** que les liens effectifs soient établis entre le Comité Géophysique Soviétique et des Institutions Australiennes compétentes pour mettre en oeuvre ce programme.

## RESOLUTION 7

**Considering** the great value of the century-long series of magnetograms collected since 1872 at the geomagnetic observatories of Colaba and Alibag (Bombay) to the international scientific community, IAGA **recommends** that arrangements be made through appropriate authorities of India, 1) for the preservation of all the original magnetograms by preparing a few microfilm copies and depositing them in Indian and International World Data Centers, and 2) for appropriate scaling of the records of the period 1872-1924.

**Considérant** la grande valeur de la série centenaire des magnétogrammes obtenus depuis 1872 aux observatoires de COLABA et ALIBAG (Bombay) pour la communauté scientifique internationale, l'AIGA **recommande** au Gouvernement de l'Inde d'assurer, à l'aide des autorités compétentes, 1) la conservation des magnétogrammes originaux par leur duplication sur des microfilms qui seraient déposés dans les Centres Mondiaux de Données Indiens et Internationaux; 2) l'exécution de mesures appropriées sur les enregistrements de la période 1872-1924.

## RESOLUTION 8

IAGA **endorses** the project *Geophysical Test Ground in the Antarctic* scheduled for 1975 which is intended to:

1) determine the locations and minimal number of stations required for analysis of the temporal and spatial distributions of high-latitude geomagnetic variations;

2) investigate the effect of geomagnetic variations on the state of the lower atmosphere;

3) continue the work associating geomagnetic variations in the polar cap with various parameters of the solar wind and the structure of the interplanetary magnetic field.

L'AIGA **approuve** le projet *Geophysical Test Ground in the Antarctic* qui est prévu pour 1975 et dont les buts sont:

1) la détermination des lieux et du nombre minimum de stations requises pour l'analyse des distributions dans le temps et dans l'espace des variations magnétiques de haute latitude;

2) la recherche de l'effet des variations magnétiques sur l'état de la basse atmosphère;

3) la poursuite du travail par lequel les variations magnétiques de la calotte polaire sont comparées à divers paramètres du vent solaire et à la structure du champ magnétique interplanétaire.

## RESOLUTION 9

The IAGA, **recognizing** the importance of observations from the southern hemisphere, particularly in the vicinity of the equatorial electrojet, **notes with satisfaction** the observations made at Arequipa and supplied to the World Data Centers, and **recommends** the continuation of this good work.

L'AIGA **reconnaissant** l'importance des observations dans l'hémisphère Sud, et particulièrement dans le voisinage de l'électrojet équatorial, **note avec satisfaction** les observations faites à AREQUIPA et transmises aux Centres Mondiaux de Données, et **recommande** la poursuite de cet excellent travail.

## RESOLUTION 10

The IAGA, **considering** the need for recent data on a global scale, **recommends** the establishment of magnetic observatories in the regions where the present coverage is sparse especially in the southern hemisphere, and **strongly urges** that existing observatories make their results available through transmission to the World Data Centers and prompt publication of yearbooks.

L'AIGA **considérant** le besoin d'observations récentes à une échelle mondiale, **recommande** la création d'observatoires magnétiques dans les régions où leur densités est faible (spécialement dans l'hémisphère Sud) et **insiste** vivement pour que les observatoires existants rendent leurs résultats accessibles en les transmettant aux Centres Mondiaux de Données et en publiant immédiatement leurs Annuaires.

## RESOLUTION 11

IAGA **notes with satisfaction** the implementations of the recommendation, made at the XIV General Assembly, that meteor drift studies be extended to the equatorial regions. Such observations were made by the equatorial expeditions of the Academy of Sciences of the USSR (1968-1970). IAGA **supports** the extension of this technique for investigating the global circulation in the upper atmosphere.

L'AIGA **note avec satisfaction** la mise en oeuvre de la recommandation, prise à la XIV-ème Assemblée Générale, d'étendre aux régions équatoriales les études relatives aux vents météoriques. De telles études ont été effectuées au cours des expéditions équatoriales de l'Académie des Sciences de l'URSS (1968-1970). L'AIGA **encourage** l'extension de cette technique pour l'étude de la circulation globale dans la haute atmosphère.

## RESOLUTION 12

IAGA welcomes the developing regional cooperation in meteor wind and ionospheric drift studies, based on the work in the USSR, France and U.K. IAGA **recommends** that this coordination be extended to other areas (USA, Australia, New Zealand, etc.)

L'AIGA accueille favorablement la coopération régionale qui se développe dans les études sur les vents météoriques et les vents ionosphériques à l'initiative de l'URSS, de la France et de la Grande-Bretagne. L'AIGA **recommande** que cette coopération soit étendue à d'autres régions (U.S.A., Australie, Nouvelle Zélande, etc.)

## RESOLUTION 13

Reflecting the current needs of the scientific community, IAGA **recommends** that the following changes be made as soon as practicable in the contents of the Bulletin No. 12 series:

1) to include, in addition to the planetary indices $K_p$ and its derivatives, the indices Dst, AE, $K_m$, $K_n$, and $K_s$;

2) to include data on magnetic storms, including reproductions of magnetograms for the H-component, reduced to the same time scale and comparable intensity scales, from 12 to 16 observatories for approximately ten storms each year;

3) to discontinue the publication of K-indices from individual observatories in the Bulletin; instead these K-indices be stored in magnetic tape wherever practicable in the World Data Centers.

Selon les besoins actuels de la Communauté scientifique, l'AIGA **recommande** que les changements suivants soient faits, aussitôt que possible, dans le contenu des Bulletins de la série No. 12:

1) introduire, en supplément aux indices planétaires $K_p$ et à leurs dérivés, les indices Dst, AE, $K_m$, $K_n$, et $K_s$;

2) publier, pour environ 10 orages magnétiques par an, des données comprenant en particulier la reproduction de magnétogrammes de la composante horizontale provenant de 12 à 16 observatoires, ces magnétogrammes étant réduits à la même échelle de temps et à des valeurs d'échelle comparables;

3) cesser la publication des indices K provenant des observatoires, ceux-ci étant par contre stockés sur bande magnétique dans les Centres Mondizux de Données là où c'est possible.

## RESOLUTION 14

IAGA **recommends** that every possible effort be made to obtain archeomagnetic samples from the areas of Australia, Middle East, and Africa by well qualified workers.

L'AIGA **recommande** que tous les efforts soient faits pour que des chercheurs qualifiés prélèvent des échantillons archéomagnétiques en provenance d'Australie, du Moyen Orient et d'Afrique.

## RESOLUTION 15

IAGA **stresses** the importance of the study of conductive layers in the intermediate depth range 20 to 100 km, especially in view of the relevance of such studies to partial melting in the upper mantle.

L'AIGA **souligne** l'importance de l'étude des couches conductrices dans le domaine de profonduers 20-100 km, surtout à cause de l'intérêt qu'elle présente pour le problème des fusions partielles dans le manteau supérieur.

## RESOLUTION 16

IAGA **supports** the collaboration of scientists making magnetotelluric and geomagnetic deep soundings along an extended east-west profile in Eurasia, the stations of which should be located with due regard to tectonic features.

L'AIGA **encourage** la collaboration de scientifiques faisant des sondages magnétotelluriques et géomagnétiques profonds le long d'un grand profil Est-Ouest en Eurasie, la localisation devant être choisie en fonction des lignes structurales.

## RESOLUTION 17

IAGA **recommends** urgently that member countries support collaborative paleomagnetic and radiometric dating research for the purposes of:

1) determining the reversal time scale more accurately using rocks from all countries;

2) obtaining more information about the fine structure of polarity events and polarity transitions.

L'AIGA **recommande** instamment que les pays membres encouragent des recherches coopératives de paléomagnétisme et de datation radiométrique en vue de:

1) déterminer avec plus de précision, en utilisant des roches de tous pays, l'échelle de temps des inversions;

2) obtenir des informations plus nombreuses sur la structure fine des évènements et des changements de polarité.

## RESOLUTION 18

IAGA **asks** the stations: Resolute Bay, Thule and Vostok, to provide the data on diurnal Z variations to IZMIRAN (USSR Academy of Sciences) for experimentally determining an index characterizing the interplanetary field sector structure.

L'AIGA **demande** aux stations de Resolute Bay, Thulé et Vostok de fournir les données de variation journalière de la composante Z à l'IZMIRAN (Académie des Sciences de l'URSS) dans le but de déterminer, à titre expérimental, un indice caractérisant la structure sectorielle du champ interplanétaire.

## RESOLUTION 19

IAGA **supports** the resolution of XIV Plenary Meeting of COSPAR in which it was recommended to agencies supporting atmospheric research that the planning of coordinated rocket, satellite, and incoherent radar backscatter programs include simultaneous composition measurements with all available techniques for the purpose of cross-calibration and the obtaining of systematic data.

L'AIGA **appuie** la résolution de la XIV-ème réunion plénière du COSPAR qui recommandait aux organisme assurant des recherches atmosphériques d'inclure, dans les programmes coordonnés de fusées, satellites et sondeurs à diffusion incohérente, des mesures simultanées de composition de l'atmosphère, en employant toutes les techniques disponibles, en vue de comparer les étalonnages pour obtenir des données homogènes.

**RESOLUTION 20**

IAGA **recommends** coordinated measurements of the temperature, composition, and density of the thermosphere with different methods for improvement of the knowledge of the diurnal variations of structural parameters and of their dependencies on latitude.

L'AIGA **recommande** que soient faites, par des méthodes différentes, des mesures coordonnées de la température, de la composition et de la densité de la thermosphère afin d'améliorer la connaissance des variations journalières et de la distribution en latitude des paramètres structuraux.

**RESOLUTION 21**

The IAGA **recognizing** the shortage and poor distribution of present ground level data for evaluating geomagnetic secular change, **urges** all countries to measure the vector field at their repeat stations at least once in 10 years, more frequently in regions with special features (e.g. secular variation foci, tectonically anomalous areas, etc.) and, where appropriate, to set up repeat stations on the islands of the South Pacific and Atlantic Oceans and to report results promptly to World Data Centers or organizations that prepare world charts.

L'AIGA, **considérant** l'insuffisance des données au sol dont on dispose actuellement pour estimer la variation séculaire du champ magnétique terrestre, **recommande** instamment à tous les pays de mesurer le vecteur du champ dans leurs stations de répétition au moins une fois tous les 10 ans et plus fréquemment dans les régions présentant des caractères particuliers (par ex., foyers de variation séculaire, aires d'anomalies tectoniques, etc.), d'établir, quand c'est possible, des stations de répétition dans les îles du Pacifique et de l'Atlantique Sud et d'envoyer rapidement les résultats aux Centres Mondiaux ou aux autres organismes qui préparent les cartes mondiales.

**RESOLUTION 22**

The IAGA **recognizes** that, even though the World Magnetic Survey is concluded, surface survey data are still needed in some areas and **urges** all countries to make suitable observations.

L'AIGA **considère** que, bien que le Réseau Magnétique Mondial soit achevé, des déterminations de données de surface sont encore indispensables dans certaines régions et **demande** instamment à tous les pays de procéder aux mesures nécéssaires.

**RESOLUTION 23**

The IAGA **recognizes** the vital contribution of vector surveys over marine areas to our knowledge of the geomagnetic field and **urges** their continuation.

L'AIGA **reconnaît** la contribution capitale des campagnes de mesures vectorielles en mer à la connaissance du champ magnétique terrestre et **recommande** instamment de les continuer.

**RESOLUTION 24**

The IAGA **recognizes** the valuable contribution made by near-earth satellites to the determination of the geomagnetic secular change and **recommends** a resurvey by low-level satellites not later than 1976.

L'AIGA **prend** acte de l'importante contribution des satellites de basse altitude pour la détermination de la variation séculaire et **recommande** le renouvellement d'un tel levé pour 1976 au plus tard.

**RESOLUTION 25**

The IAGA **recommends** 1) that the present International Geomagnetic Reference Field (IGRF) be retained until at least 1973.5; 2) that future evaluations should emphasize improving secular change coefficients; 3) that comparisons between observed and computed values should always include an assessment of the IGRF; and 4) that results using other reference fields should also be compared with IGRF.

L'AIGA **recommande** 1) que le présent "Champ Géomagnétique International de Référence" (IGRF) soit retenu au moins jusqu'à 1973.5; 2) que, dans les prochaines déterminations, l'accent soit mis sur l'amélioration des coefficients de variation séculaire; 3) que les publications concernant des valeurs observées et calculées contiennent une comparaison avec l'IGRF; 4) que de telles comparaisons soient faites même lorsque d'autres champs de référence sont utilisés.

**RESOLUTION 26**

The IAGA **recommends** that as a contribution to the World Magnetic Archive, numerical magnetic-observatory data, past and current, be put into machine-readable form whenever practicable for transmittal to a WDDC and that pre-IGY magnetograms and hourly-value tables be microfilmed for transmittal to a WDC.

L'AIGA **recommande** que, dans le cadre des Archives Magnétiques Mondiales, les données numériques passées et présentes des observatoires magnétiques soient mises dans toute la mesure de possible sous une forme lisible par un ordinateur et transmises à un Centre Mondial de Données Numériques et que les magnétogrammes antérieurs à l'A.G.I. ainsi que les tableaux de valeurs horaires soient microfilmés et transmis à un Centre Mondial de Données.

## RESOLUTION OF THANKS

The International Association of Geomagnetism and Aeronomy expresses its warmest thanks to the Organizing Committee of the Soviet Academy of Sciences for the XV IUGG General Assembly. In particular it expresses thanks to Academician A. P. Vinogradov, President of the Organizing Committee; Professor V. V. Beloussov, Vice President of the Organizing Committee; Dr. B. S. Volvovsky, General Secretary of the Organizing Committee; Dr. A. D. Powsner, General Secretary of the Geophysical Committees; Dr. K. Yu. Zybin, who was responsible for Geomagnetism and Aeronomy arrangements, and to Mrs. N. A. Beloussova for most interesting arrangements for the Ladies.

L'AIGA exprime ses remerciements les plus chaleureux au Comité d'Organisation de l'Academie des Sciences de l'URSS pour la XVème Assemblée Générale de l'UGGI. En particulier, elle remercie l'Académicien A. P. Vinogradov, Président du Comité d'Organisation; le Professeur V. V. Beloussov, Vice-Président du Comité d'Organisation; le Dr. B. S. Volvovsky, Secrétaire Général du Comité d'Organisation et le Dr. A. D. Powsner, Secrétaire Général du Comité Géophysique. Elle remercie aussi le Dr. K. Yu. Zybin qui a assuré le déroulement des réunions de l'AIGA et Mme N. A. Beloussova pour le très intéréssant programme pour les Dames.

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