

A — REPORT ON THE WORK OF THE DEPARTMENT
OF GEOMAGNETISM OF THE INSTITUTE OF GEOPHYSICS,
N.A.U.M.

August 1963 — December 1966

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Measurements of the Earth's magnetic field have been continued at the Magnetic Observatory of Teoloyucan, Mex.; results read in the magnetograms are sent monthly to centres at De Bilt, Netherland, the Magnetic Observatory at Tortosa, Spain, Geophysikalisches Institut at Göttingen, Germany, Geomagnetic Data Center, U. S. Coast & Geodetic Survey, Washington, D. C., and WDC C2 for Geomagnetism at Kyoto University, Japan.

Some contributions appeared with data obtained through the years 1963 and 1964 and another one is in press for 1965, while those corresponding to 1966 are being processed. These publications are sent to 119 magnetic observatories and national geophysical institutions (but only with some of them in exchange of their own publications) as well as to other cultural institutions that have requested our productions.

63 base stations were observed and processed for a base magnetic chart of the Mexican Republic using their values to construct the "Chart of Magnetic Declination for the Epoch 1965.0". A description of the operations and a discussion of the handling of the data have been presented in an article published in the *Anales del Instituto de Geofísica, U.N.A.M.*, in 1966. 8 sites have been observed annually to prepare the curve of secular variation in one region to control in a more precise way field observations.

POSITION OF THE MAGNETIC OBSERVATORY OF TEOLÓYUCAN, MEXICO

Geographic Coordinates

$$\varphi = 19^{\circ} 44' 43'' \text{ N}$$

$$\lambda = 99^{\circ} 10' 40'' \text{ W.G.}$$

Magnetic Coordinates

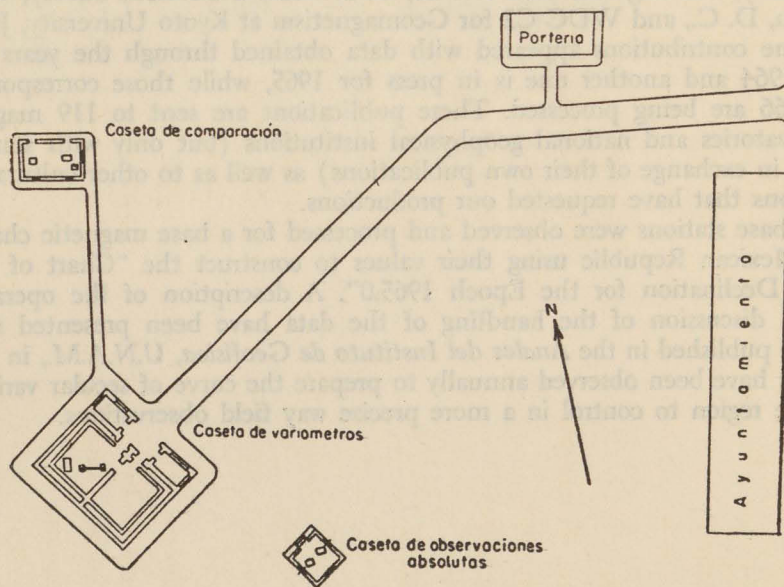
$$\Phi = 60^{\circ} 25' 50'' \text{ N}$$

$$\lambda = 327^{\circ} 02' 25''$$

$$\Psi = + 6^{\circ} 06'$$

MEAN VALUES OF THE MAGNETIC OBSERVATORY OF TEOLÓYUCAN, MEXICO

Year	Declination	H	Z
1963	8° 45'.8	30032	32400
1964	8° 47'.5	30007	32341
1965	8° 43'.6	29971	32309



PLANO DEL OBSERVATORIO
MAGNETICO DE TEOLÓYUCAN
EDO. MEXICO.

OBSERVED BASE MAGNETIC STATIONS
OF THE ISOSONIC CHART FOR 1965.0

Station	Site	Coordinates		Declination
		N	W	
Puebla, Puebla	Airfield	19 91 26	98 09 42	8 31.2
Ciudad Victoria, Tamaulipas	Old "González-Garza" airfield	23 44 17	99 08 52	8 53.3
Tampico, Tamaulipas	Airport	22 16 44	97 52 14	8 36.8
Tampico, Tamaulipas	Country Club	22 15 21	97 52 29	8 36.5
Nautla, Veracruz	Nautla Lighthouse	20 13 03	96 47 11	8 21.5
Veracruz, Veracruz	b) Airport	19 09 08	96 11 17	8 01.5
Tehuacán, Puebla	"Peñaflor" Golf Club	18 29 00	97 23 55	8 19.8
Acapulco, Guerrero	"Pie de la Cuesta" airfield	16 53 51	99 59 08	8 39.8
Acapulco, Guerrero	Golf Club	16 50 49	99 52 11	8 39.8
Petatán, Guerrero	a) Old airfield	17 32 47	101 18 00	8 31.9
Mérida, Yucatán	b) Airport	20 55 58	89 39 08	5 48.6
Chetumal, Quintana Roo	Airport	18 30 22	88 18 51	5 24.8
Chetumal, Quintana Roo	Sport-field	18 30 22	88 17 04	5 23.7
Ciudad del Carmen, Campeche	New airport	18 39 34	91 49 46	6 35.7
Uruapan, Michoacán	a) Airfield	19 24 36	102 03 12	9 43.6
Manzanillo, Colima	b) Airfield	19 07 02	104 21 19	9 23.6

OBSERVED BASE MAGNETIC STATIONS
OF THE ISOGONIC CHART FOR 1965.0

Station	Site	Coordinates			Declination
		N	W		
Guadalajara, Jalisco	a) Airport	20 31 46	103 17 45	9 43.6	
Tepic, Nayarit	Airport	21 28 21	104 53 00	9 28.5	
Tepic, Nayarit	Central Park	21 30 29	104 53 39	9 27.6	
Durango, Durango	a) Airport	24 00 30	104 39 30	9 49.3	
Torreón, Coahuila	Airport	25 34 53	103 23 24	10 08.3	
Hgo. del Parral, Chihuahua	Airfield	26 54 43	105 46 18	10 36.2	
Chihuahua, Chihuahua	b) Airport	28 39 40	106 04 43	11 16.2	
Ciudad Juárez, Chihuahua	Airport	31 38 30	106 26 30	11 48.8	
Tejocachic, Chihuahua	Main square	28 46 01	107 59 54	11 13.2	
Zitácuaro, Michoacán	Landing field	19 27 00	100 18 57	8 47.8	
Teoloyucan, Edo. de México	Observatory	19 44 47	99 10 53	8 43.0	
San Juan Sabinas, Coahuila	Airport	27 51 26	101 07 11	9 54.3	
Montemorelos, Nuevo León	"Gil de Leyva" Park	25 10 29	99 50 32	9 16.4	
San Luis, Potosí, San Luis Potosí	Airport	22 11 28	100 01 00	9 08.9	
Zacatecas, Zacatecas	Cemetery	22 45 28	102 33 16	9 28.8	
Minatitlán, Veracruz	Airport	18 08 52	94 25 24	7 37.7	

OBSERVED BASE MAGNETIC STATIONS
OF THE ISOGONIC CHART FOR 1965.0

Station	Site	Coordinates		Declination
		N	W	
Tuxtla Gutiérrez, Chiapas	Airport	16 45 08	93 05 50	7 16.6
Comitán, Chiapas	Hospital	16 15 11	92 07 21	7 08.8
Comitán, Chiapas	Highway	16 12 58	92 08 55	7 08.6
Tapachula, Chiapas	Airport	14 52 55	92 18 50	6 50.0
Salina Cruz, Oaxaca	"Obrero Mundial" School	16 10 41	95 11 48	7 46.1
Mazatlán, Sinaloa	b) Airport	23 11 36	106 26 04	10 19.6
Culiacán, Sinaloa	Airport	24 47 00	107 26 20	10 29.4
Los Mochis, Sinaloa	Airport	25 48 45	108 58 54	11 03.6
San José de Guaymas, Sonora	"Abelardo Rodríguez" School	27 59 11	110 53 28	12 14.4
Punta Peñasco, Sonora	Airfield	31 19 07	113 33 02	13 17.8
Ensenada, Baja California (N)	a) "El Ciprés" Airfield	31 47 57	116 36 44	13 06.5
El Rosario, Baja California (N)	"Riveroll" School	30 03 52	115 44 22	14 02.2
Bahía de los Angeles, B. C. (N)	N E of Hotel "Díaz"	28 56 52	113 33 30	12 40.5
Bahía de Tortugas, B. C. (S)	Road to airfield	27 41 20	114 53 18	12 52.2
La Paz, Baja California (S)	b) Airport	24 07 03	110 19 24	11 05.4
Punta Palmillas, Baja California (S)	Airfield	23 01 48	109 43 34	10 42.6

OBSERVED BASE MAGNETIC STATIONS
OF THE ISOSONIC CHART FOR 1965.0

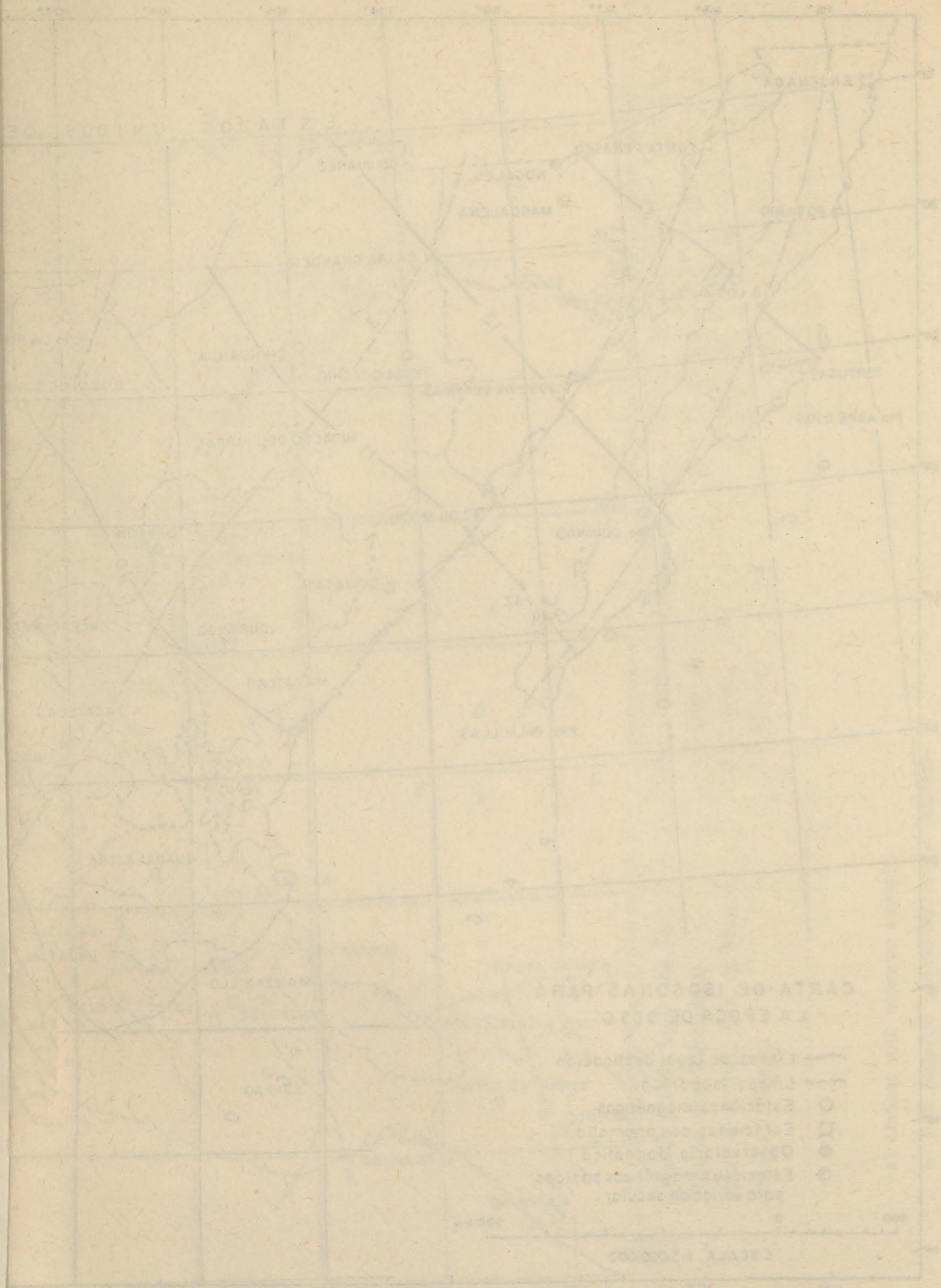
Station	Site	Coordinates		Declination
		N	W	
Y Santo Domingo, B. C. (S)	Deviation to Santo Domingo	25 31 01	111 54 32	11 50.0
Punta Abreojos, B. C. (S)	Landing field	26 42 39	113 34 31	12 14.1
Concepción del Oro, Zacatecas	Y Saltillo-Zacatecas highway	24 37 34	101 23 15	9 04.4
Rancho "La Peña", Coahuila	a) Field N E of village	28 44 12	102 13 12	10 17.0
Nuevo Casas Grandes, Chihuahua	Airfield	30 24 18	107 52 53	11 50.9
Laguna de Jaco, Coahuila	Plain S of park	27 57 28	103 56 50	10 38.5
Oaxaca, Oaxaca	University Stadium	17 04 00	96 42 36	8 14.2
F. Carrillo Puerto, Quintana Roo	Landing field	19 33 56	88 02 44	5 21.4
Puerto Juárez, Quintana Roo	Navy barracks area	21 10 52	86 48 24	4 12.9
Matamoros, Tamaulipas	b) Airport	25 43 02	97 31 49	8 27.8
Paso de Cortés, Edo. de México	Monument	19 05 10	98 40 21	8 21.5
Nogales, Sonora	b) Airport	31 13 10	110 59 14	12 51.8

a) Stations with magnetic anomaly.

b) Base magnetic stations for secular variation.

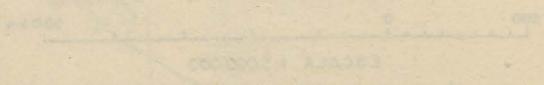


Fig. 1. Isogonic chart of Mexico for the Epoch 1965.0



CARTA DE ISOCORAS PARA
LA ESCALA DE 1:500,000

- Línea de nivel de altitud
- Línea de nivel de altitud
- Estación de ferrocarril
- Estación de ferrocarril
- Observatorio astronómico
- Estación meteorológica
- Estación meteorológica



THEORETICAL WORK IN GEOMAGNETISM

Professors Anselmo Chagoy and Manuela G. de Alvarez, both of the Institute of Geophysics of the National Autonomous University of Mexico, and mathematicians interested in the analysis of geophysical models, have been working on various problems of theoretical nature but leading to a better understanding of the significance of observational and experimental magnetic data. Previous work done by Prof. Chagoy on the definition of the theory of dipoles, quadripoles and octipoles as well as on their implications for the gravimetric and terrestrial magnetic potential have appeared in the *Anales del Instituto de Geofísica, U.N.A.M. Revista de la Sociedad Mexicana de Física* and other scientific journals in Mexico. Another contribution (in preparation) discusses the introduction of a mathematical procedure to define an operation through a substitution by Taylor's series in such a way as to have them form semigroups.

In the case of gravity data, advantage is taken of this property with respect to the defined operation to treat the first terms of a series of the orders 0, 1 and 2 analogously to a common quadratic form where translations and rotations reduce the canonic form to principal axes and planes (of symmetry), with results coinciding with the experiment. In the case of magnetic data, the same treatment leads to definitions of William Thomson and Adolphus Schmidt and to deeper consequences of these definitions as in the canonic form. "Substitutions" S have been used to analyse the magnetic field up to 1960 with a centre in the Earth's geographic centre. S_C with centre at C as defined by Thomson and Schmidt.

Mrs. Alvarez has concentrated in the study of models describing the Earth's magnetic field by introducing terms indicating field anomalies at a planetary scale, viz. multipoles of at least 3rd. order in such a way as to make the model very simple, with a good approximation to the real phenomenon. For this reason, advantage is taken of the terms of the octipole which are the most significant when anomalies are introduced. Of course, the system of references should be one in which the dipole and the quadripole give a symmetric field with respect to an axis (dipole) and to a perpendicular plane (quadripole), with the geomagnetic centre C as centre of coordinates. In this analysis of the octipole in C , it was found that 4 out of 7 corresponding coefficients increased while the other 3 decreased; this is not a noticeable simplification although it explains the model in terms of 4 simple octipoles.

B — REPORT ON THE WORK OF MAGNETIC DEPARTMENTS OF OTHER INSTITUTIONS IN MEXICO

(August 1963 — December 1966)

Terrestrial magnetic and aeromagnetic surveys are also conducted in Mexico for locating and estimating the extent, composition and possibilities of exploitation of oil and mineral resources by two major agencies of the Federal Government of Mexico. In the first case, terrestrial magnetic measurements have been part of the geophysical exploration programs of Petróleos Mexicanos, through its Exploration Division headed by Ing. Santos Figueroa, and in the second case, aeromagnetic surveys have been used by the Consejo Superior de Recursos Naturales no-Renovables whose General Manager is Ing. Guillermo P. Salas (also Director of the Institute of Geology of the N.A.U.M.).

A summarized description of the principal aspects of both programs is given below:

MAGNETIC SURVEYING FOR OIL

Petróleos Mexicanos, the Mexican Government oil and gas producing company, has conducted a detailed magnetic survey of the Peninsula of Yucatan, in the southeastern part of the country, in search of deposits of commercial value. The same area had previously been surveyed by a gravity party until 1962 to determine basement rock relief and structural conditions of the subsurface. Magnetic work began in the latter part of the same year, and is still continuing under the supervision of the Exploration Department of Petróleos Mexicanos at Coatzacoalcos, Ver.

A relative large amount of geologic work had also preceded the magnetic survey of the Peninsula of Yucatan, including reconnaissance studies along the axis of Sierra de Ticul and the southern and central parts of the Peninsula as well as a general stratigraphic study of other isolated areas. Drilling was performed in the Merida-Progreso zone by the former petroleum companies that operated in Mexico prior to 1938, and whose reports are in the files of Petróleos Mexicanos. At the time of initiation of the magnetic survey, Petróleos Mexicanos had bored three wells on basis of gravimetric results in the northern part of the State of Yucatan, where regional "highs" had been identified, two wells ending in igneous rocks and one in evaporites.

Magnetic work was carried out in new areas to have a good coverage of the Peninsula of Yucatan in a period of almost three years of work to locate areas of magnetic anomalies for more geophysical work. A total of 16,385 stations were observed in 666 days, with an average of 26 stations per day

along 16,263 kilometers of routes. Topographic work was simultaneously done and other information gathered during the execution of the program.

Petróleos Mexicanos has also carried out magnetic work in a wide area comprised between the southeastern part of the Mexican Plateau and the Gulf of Mexico coast, from the central part of the State of Veracruz, to the Soto la Marina river, in the State of Tamaulipas. The period of work extended from June 5 to November 21, 1966, utilizing national highways and doing more detailed work in special areas: Actopan-Ixmiquilpan, in the State of Hidalgo, and Rio Verde-Cardenas, in the State of San Luis Potosi as well as to the northwest and west of Tampico, in the State of Tamaulipas. Magnetic anomalies and profiles were prepared from field data, calculated and revised for final drawing of maps at the central offices of Petróleos Mexicanos, in Mexico City.

It is interesting to notice that the national highways utilized for magnetic work east of the Mexican Plateau cross the north-south elongated Sierra Madre Oriental, and that of the three special areas of study, that of Actopan-Ixmiquilpan is located to the west of Sierra de Pachuca, a highly mineralized range in central Mexico while that of Rio Verde-Cardenas lies in the heart of the Jurassic-Cretaceous limestone folds of the Sierra Madre Oriental, and that of Tampico borders the Gulf of Mexico, forming a triangle of great significance for the study of structural and dynamic traits of the coastal plain and its mountainous backbone. Thousands of stations were observed along national highways and in special study areas, including topographic surveying for the preparation of reliable maps.

AEROMAGNETISM

Aeromagnetic surveying work for the evaluation of mineral resources was begun in Mexico since 1962 by the Higher Council of Non-Renewable Natural Resources. Instruments included a continuous recording Flux-gate "Gulf-Airborne Magnetometer Mark III", a RT/APN-1 radioaltimeter with sensitivity scale from 0 to 2,000 feet, an "Interprises Mark IX" model camera, and occasionally other electronic magnetometers of various types. The instruments were installed on a "Twin Pioneer" aircraft with flight speed of 100 knots (185.6 Km/Hr), a great support capacity for taking off and landing in short strips, a maximum height of operation (ceiling) of 7,000 feet, and 4 flying hours of autonomy.

All recorded magnetic anomalies of the 800 rank were compared with geologic data, specially intrusive rock outcrops to detect contacts with other adjacent rocks for the evaluation of economic possibilities of each area from the viewpoint of mining. Other terrestrial geophysical studies came afterwards, particularly magnetometric lines with adequate separation, sampling of rocks and minerals, and in some areas gravimetric and seismologic surveys.

Electrical resistivity, induced polarization and natural potential methods for certain minerals as well as tests of applicability of aerial radiometric methods were also used simultaneously with the aeromagnetic methods.

In general, the aeromagnetometer aircraft operated from a nearby base to fly parallel lines oriented along the geologic structure in study, whose separation depended on requested specifications. Compilation and drawing of isomagnetic patterns were made in a preliminary way in the central offices (Mexico City) for analysis and study by geologists, and later on the final drawing was done in the Department of Cartography and Drafting of the Council. In total, it is estimated that more than 150,000 Km² have been explored by aeromagnetic and supplementary methods in the Mexican territory, with results of great significance for the location and evaluation of mineral deposits, and for the knowledge of the structure and dynamic of the Earth's crust.

The following aeromagnetometric studies were made between 1962 and 1966:

State of Baja California — a) Area to the east of the Alamo region, covering 4,386 Km² with 90 flight lines and 5 control lines with a total of 4,435 Km of aeromagnetic lines, including 5 additional lines of 8 Km of average length; b) Area to the south of San Quintín, with parallel flight lines oriented NE 35° SW and separated 1 Km each at a constant height of 300 m over the surface, supplemented by a terrestrial magnetometric survey and other geological observations.

State of Sonora — A large disturbed zone in the northern part of Cabullona, with an extension of 1,556 Km², covered by 6 flight lines of 2,240 m each, indicating magnetic anomalies of the 800 rank which coincide with dioritic outcrops, although a very small "high" was located away from that rock with an anomaly of the 350 rank, supplemented with an induced polarization and natural potential survey to define the possibilities of existence of sulphides.

State of Durango — A number of areas in its central and eastern parts (Municipalities of Durango, Mapimí, Rodeo and San Juan de Guadalupe) and covering almost 6,000 Km² were flown by 200 flight lines separated by variable distances (500 to 1,000 m) at an average height of 300 m over the surface with a total of 13,687 Km of aeromagnetometric lines.

States of Jalisco and Colima — From a base at the port of Manzanillo, a large area was covered by 157 flight lines with a separation of 1 Km and 5 transverse control lines similarly separated, and supplemented by a geologic-magnetometric survey over anomalous areas with terrestrial lines oriented in

various directions and separated by distances of 200 to 300 m with reading stations every 50 m as well as a gravimetric study.

States of Michoacán and Guerrero — Area with a total extension of 17,328 Km² flown by 156 aeromagnetic lines and 5 transverse control lines separated 1 Km from each other, with a total of 16,990 Km of aeromagnetometry from a base in the port of Zihuatanejo, supplemented by a detailed geological and geophysical terrestrial survey.

State of Oaxaca — Area with an extension of 8,470 Km² flown by 105 aeromagnetometric lines and 5 transverse control lines separated 1 Km from each other, with a total of 8,623 Km at a height of 300 m over the surface, whose results were compared with geological and geophysical data of various sources.

C — AERONOMY

The inception of aeronomic studies in Mexico really took place during the International Geophysical Year 1957-1958, although some governmental agencies had sporadically carried out experiments and measurements in the higher atmosphere, for example, ozonometric determinations. At present, the Institute of Geophysics of the N.A.U.M. is practically leading that work, and its programs are closely linked with various institutions and organizations.

The program of current studies at the Department of the Outer Space has also included various topics of aeronomic nature. There may be cited among them measurements of ozone carried out with an instrument acquired by the Mexican Federal Government and installed at El Cerillo, west of Mexico City as well as magnetic investigations of the higher atmosphere and the ionosphere. New projects of experimental and theoretical work are being developed within the program of the National Commission for the Outer Space of the Ministry of Communications and Transports, with the participation of the Institute of Geophysics.

Another responsibility incumbent to the Department of the Outer Space of the Institute of Geophysics is that of training advanced students and graduates in specialized research and scientific writing. In the lapse 1964-1966, 6 (six) candidates to professional degrees or graduates in Physics of the School of Sciences of the N.A.U.M. prepared their thesis or did postgraduate work under the direction of Prof. Ruth Gall, and the titles of their productions are included in the bibliography. It must be mentioned that Mrs. Gall has been responsible in many respects for progress in aeronomic studies in Mexico, not only in the Department of the Outer Space but also in various institutions and agencies in this country.

Other programs of aeronomic interest are carried out at the Institute of Geophysics, viz. Solar Radiation, in charge of the Section of Atmospheric Radiation by Dr. Ignacio G. Galindo Estrada, and Cosmic Radiation, at the Department of the Outer Space by Prof. Oscar Troncoso. Solar-terrestrial relationships constitute also a subject that is being stimulated in the same departments within the IYQS Program under the guidance of Mrs. Gall. A preliminary approach was made during the International Geophysical Year 1957-1958 in connection with Boreal Aurorae, but the presence of Prof. Sidney Charman, as a Distinguished Lecturer during four months (Oct. 1965 — Feb. 1966), contributed in a large measure to initiate a program on air glow at the Institute of Geophysics.

OZONE AND AIR GLOW. This part of the program in Outer Space studies at the Institute of Geophysics of the N.A.U.M. includes both problems, and is in charge of the Laboratory of Atmospheric Physical Chemistry under the direction of Ing. Armando P. Báez, in collaboration with Mr. Luis Lemoyne, a physicist.

A) *Ozone*: The National Commission for the Outer Space has donated a Dobson spectrophotometer for ozonometric determinations in the higher atmosphere. This made possible the integration of Mexico in the International Ozone Network, a fact that has a far reaching importance because such observations had never been made in these latitudes, and will help to better understand the dynamical mechanism of the atmosphere on account of the close relationships of ozone and meteorological phenomena. An example is the influence of ozone content and the radiation balance in the stratosphere, since it is one of the three major components for the absorption of long wave and short wave radiation of the solar spectrum. It is also convenient to mention the correlation between the mechanism of deviation of the total content of ozone and the atmospheric circulation.

Ozone observations are to be carried out at El Cerrillo, a radio station of the Ministry of Communications and Transports some 20 Km to the north of the city of Toluca, State of Mexico.

B) *Air Glow*. For the moment only measurements of night glow, a radiation of the higher atmosphere during nights, are being made in this important branch of the photochemical processes of the higher atmosphere. This radiation is a result of the excitation and dissociation of atoms and molecules constituting the higher atmosphere, namely, oxygen, nitrogen, sodium, oxyhydrile groups, etc., resulting from various processes among which the most important is the recombination of ions.

The systematic study of spectrum emission lines 5577 Å and 6300 Å that are better known and studied, are carried out by means of an automatic photometer designed by Ing. A. P. Báez in collaboration with experts of the

National Bureau of Standards, at Boulder, Colorado, and built in the shops of the Institute of Geophysics.

Diurnal, seasonal and annual variations of night glow in these latitudes, where no previous measurements of that kind have ever been made, will allow a better understanding of the mechanism responsible for the radiation emitted.

SOLAR RADIATION. Theoretical and practical problems are studied by Dr. Ignacio G. Galindo Estrada at the Laboratory of Solar Radiation of the Institute of Geophysics, as follows:

Atmospheric Turbidity: Its study has been continued from the moment of extinction of solar radiation.

Utilization of Solar Energy. The possibility of converting solar energy into electric power through the use of paraboloid collectors is being studied in collaboration with the Federal Commission of Electricity, specially for far away rural areas where electric lines would be costly and anti-economical.

Conversion of Salt Water into Drinking Water. This study is being carried out in collaboration with the Mexican Ministry of the Navy as a project for the utilization of salt water in warships and outer island posts.

At the present moment only 4 (four) Solar Radiation Stations are installed, but there is a project of raising them to 16 (sixteen) in the whole country, for which purpose applications for funds and assistance have been made to the above mentioned agencies and the World Meteorological Organization.

COSMIC RADIATION. Experimental research work on Cosmic Ray phenomena as well as the maintenance of the Cosmic Ray detectors is in charge of a group under Prof. Oscar Troncoso's direction. Observations of the cosmic radiation intensity are made with a Simpson neutron monitor (with two sets of 3 proportional counters each) installed in the campus of the National Autonomous University of Mexico. As a result of an agreement between the Cosmic Ray Group of the University of Chicago and the Institute of Geophysics of the N.A.U.M., Professor Troncoso's group has been operating the neutron counter for continuous recording of the neutronic component of the cosmic radiation.

For the last ten years observational data have appeared in monthly sheets and are available for those interested at the University of Chicago. At present, a study is being made of the intensity diurnal variation, anisotropies, solar effects, etc., of the cosmic radiation. Training of some young physicists is also carried out in order to enlarge the experimental research group.

In the near future the station at Ciudad Universitaria will be improved with new detectors, a Carmichael neutron supermonitor (6NM-64), and

a directional meson telescope (MM-64) with five observing directions. Lastly, in a subterranean vault, situated at only 20 m of distance from the other two instruments, at 40 m water depth equivalent, another directional meson telescope will be installed.

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