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L'OBSERVATOIRE GÉOPHYSIQUE DE SURLARI: PASSÉ, PRÉSENT, FUTUR

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Key words: Permanent observatories and magnetical stations. Reference international magnetic field. Recording level.

Abstract: *Surlari Geophysical Observatory: Past, Present, Future.* Necessary information is provided in order to define the place of the Surlari Geophysical Observatory in the network of international magnetical observatories. The main tasks of these being mentioned, the paper analyses how the Surlari Geophysical Observatory worked as the fundamental magnetical station of Romania and how it fulfilled the international tasks. The very brief presentation of the 50 years of observatory activity is concluded with several desires for the future works.

À l'occasion de cet événement anniversaire nous devons d'abord brièvement illustrer dans quelle mesure l'Observatoire Géophysique de Surlari a toujours été, est encore et, nous l'espérons, restera un membre de la communauté mondiale des observatoires.

Il serait utile de rappeler les principales conditions qu'un observatoire géomagnétique doit remplir pour satisfaire aux exigences des standards internationaux:

– fournir les enregistrements permanents et continus des variations temporelles du champ magnétique terrestre et, en même temps,

– fournir les valeurs précises de sa direction et de son intensité dans un point donné sur la surface de la Terre.

La permanence ne veut pas dire qu'un observatoire qui a été installé à l'époque de Gauss assure sa fonction dans un futur illimité. Il suffit de considérer une période assez longue pour que la série des valeurs moyennes annuelles puisse permetre le calcul de la variation séculaire au moins pour une durée de quelques cycles d'activité solaire.

Quant à la précision, on considère comme satisfaisantes les valeurs d'un dixième de minute pour les éléments angulaires (D,I) et d'une nT pour celles d'intensité.

Pour les magnétogrammes classiques, la vitesse de déroulement est de 200 mm/heure, ce qui permet la résolution des variations géomagnétiques dépassant une centaine des secondes.

Beaucoup des recherches plus modernes n'imposent pas la connaissance du niveau absolu des enregistrements, mais elles demandent en échange une analyse pertinente de l'amplitude, de la phase et de la fréquence du champ géomagnétique transitoire, ainsi que l'image de sa distribution spatiale.

On peut affirmer résolument que l'Observatoire Géophysique de Surlari a répondu à toutes ces éxigences tout au long des cinquantes années de son activité permanente, qui couvrent une période dépassant quatre cycles complets d'activité solaire.

Si dans la première moitié de cette période les éléments d'intensité étaient détérminés avec une précision d'environ 5 nT, dans la seconde moitié, grâce aux instruments protoniques, la precision a été améliorée jusqu'à environ 1 nT. Quant aux éléments angulaires, la précision a toujours été d'environ un dixième de minute.

Quelques mots sur la position occupée par l'O.G.S dans le temps, ainsi que dans l'espace, dans cette immense orchestre qui, dirigée par les centres mondiaux, cherche l'interprétation la plus fidèle et la plus sensible des harmonies offertes par la suite des phénomènes du champ magnétique planétaire. Car, si dans le temps, la cinquantaine est infinitessimale à l'échelle géologique, elle devient très représentative par rapport à la vie humaine.

On doit remarquer que, si au début de ce siècle l'actuel grand orchestre comptait seulement 12 instruments, jusqu'en 1925 ce nombre est quadruplé, et arrive, en 1950, à une centaine (Fig. 1). À présent le réseau mondial d'observatoires magnétiques dispose de plus de 210 stations, dont la répartition n'est pas très uniforme (51 en Europe; 32 en Asie, 59 en Amérique du Nord; 14 en Amérique du Sud; 20 en Afrique, 5 en Australie et 57 en Antarctique) (Figs. 2, 3).

Cette distribution assez peu homogène est due à des

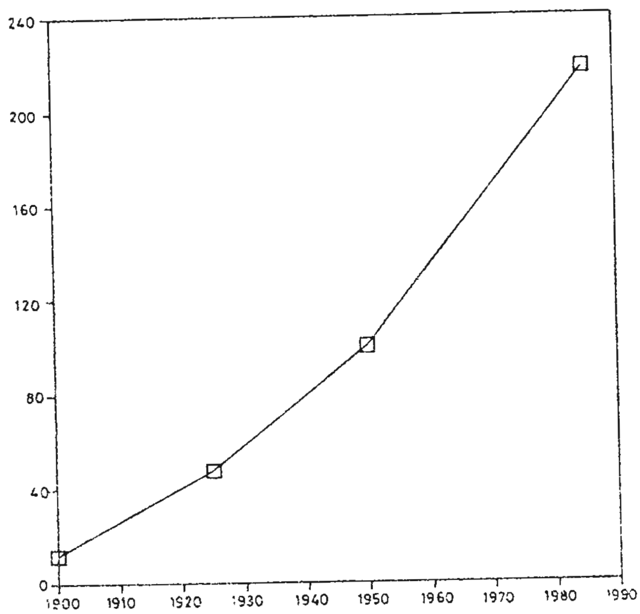

Fig. 1 – Evolution du nombre des observatoires géomagnétiques du réseau mondial

motifs soit politiques, soit financiaires, soit logistiques. On remarque l'impulsion donnée par l'organisation de la première Année Géophysique Internationale en 1957, suivie par la croissance de leur densité dans les zones polaires, qui a été stimulée par les missions spatiales munies de senseurs magnétiques, qui ont fait une magistrale démonstration sur l'importance de la connaissance des particularitées des variations géomagnétiques boréales et australes pour les modèles de la structure et de la dynamique du système ionosphère-magnétosphère.

L'O.G.S a eu le privilège d'anticiper avec 15 ans cette période d'impulsion, ce qui lui confère une certaine importance supplémentaire.

Il faut aussi mentionner que, sur les 97 observatoires qui se sont engagés dans la transmission de leur données dès le début de 1957, seulement 48, parmis lesquels se trouve l'O.G.S, ont réalisé cette tache d'une manière continue.

Dans l'espace, quoique notre observatoire soit situé dans une zone de densité maximale, comme on peut remarquer en regardant la distribution des autres en fonction de la latitude et de la longitude géographique

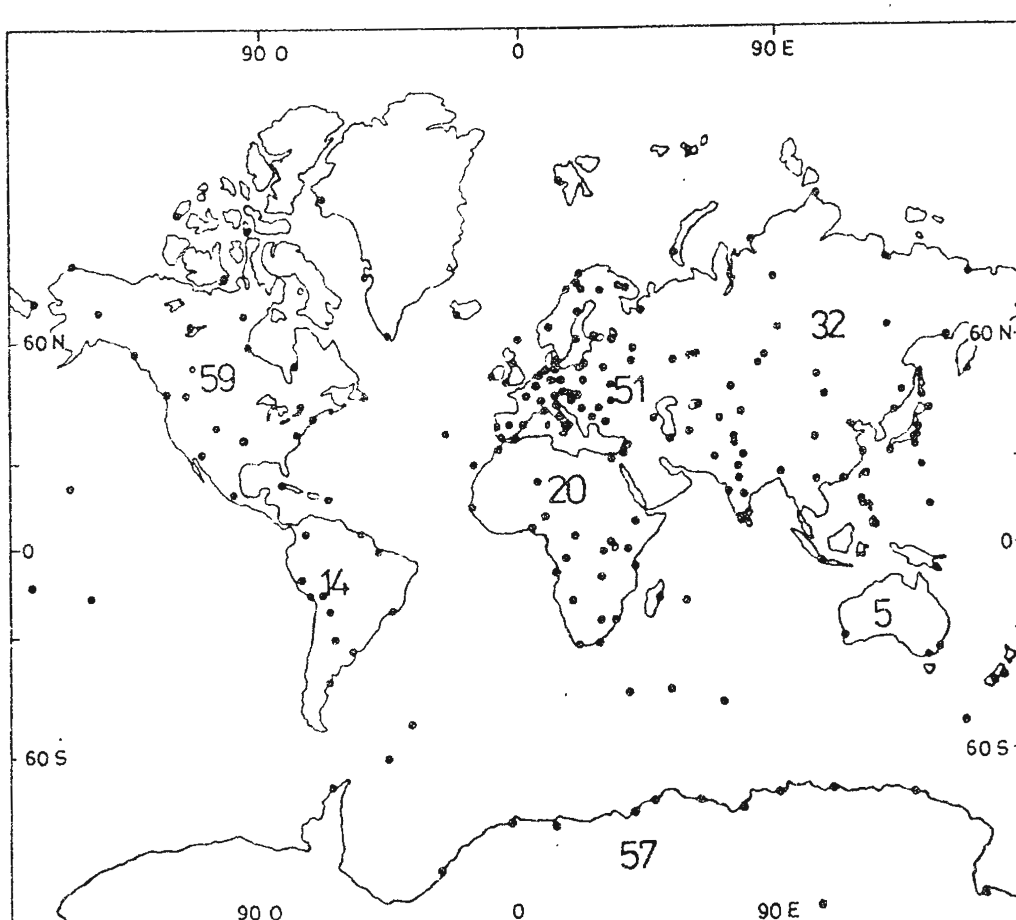

Fig. 2 – Répartition des observatoires géomagnétiques en 1933

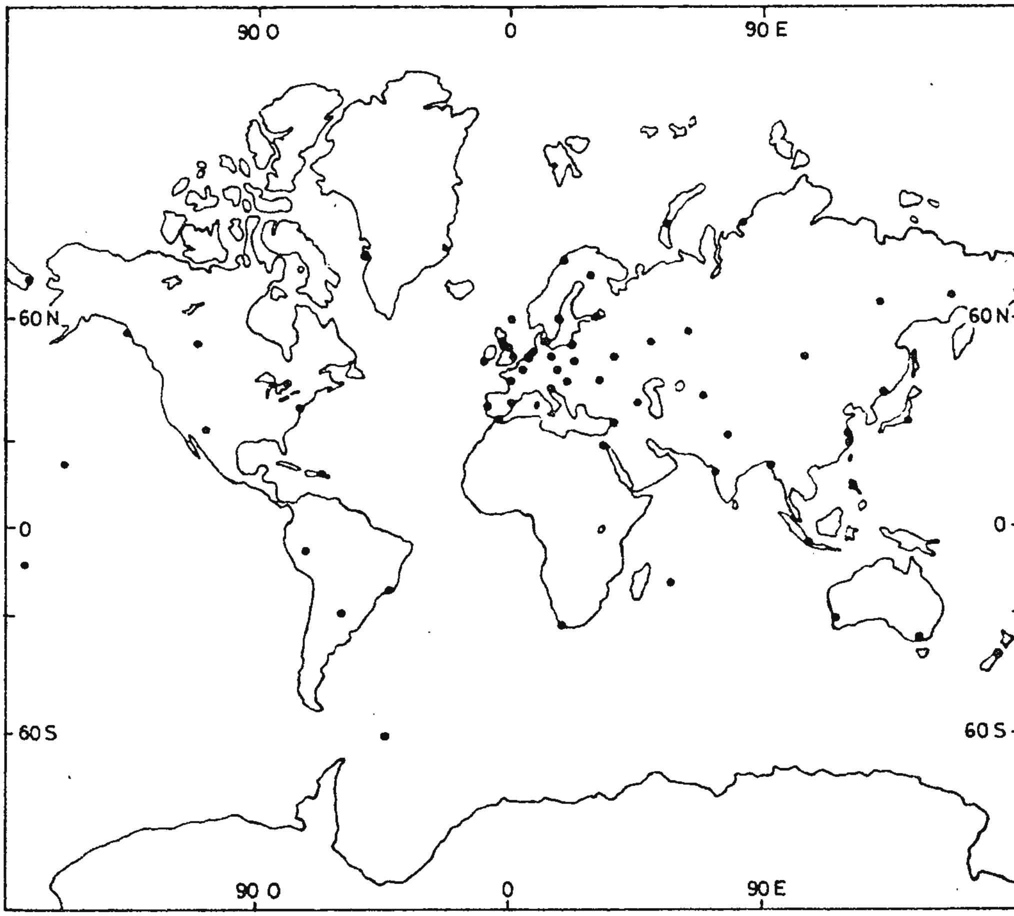

Fig. 3 – Répartition des observatoires géomagnétiques en 1978

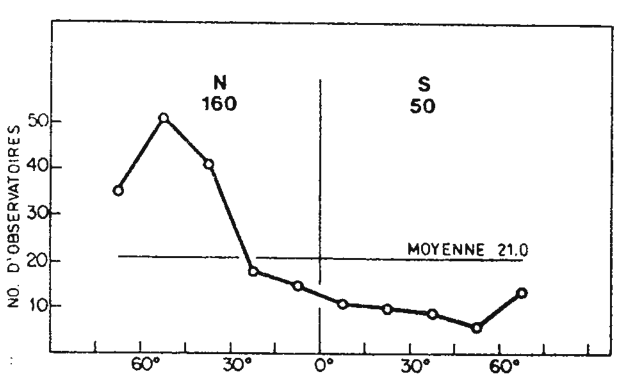

Fig. 4 – Distribution des observatoires géomagnétiques en fonction de la latitude

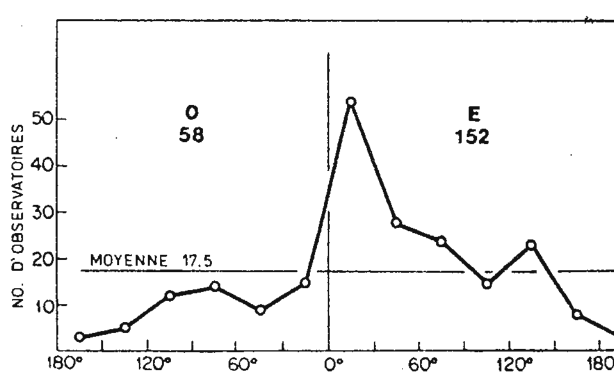

Fig. 5 – Distribution des observatoires géomagnétiques en fonction de la longitude

(Figs. 4, 5), l'intérêt de son emplacement est favorisé, d'une part, par ses coordonnées géomagnétiques, liées au déplacement des centres de systèmes de courants ionosphériques qui coulent dans l'hemisphère du Nord et, d'autre part, par les effets inductifs dépendants des conditions tectonophysiques dans lesquelles il se trouve.

Les objectifs de l'O.G.S. comprennent les deux catégories d'activités dont nous avons déjà parlé.

Dans la première catégorie, imposant des enregistrements avec une bonne connaissance du niveau des bases, se trouvent:

– La détermination des valeurs moyennes annuelles de minimum trois éléments géomagnétiques indépendents, utilisés pour la dérivation de la variation séculaire;

– La détermination du niveau absolu, dégagé par des phénomènes de perturbations irrégulières (phénomènes auroraux, sous-orages etc.), ou des effets à long terme sur Sq, L, Dst;

– La réduction à la même époque des réseaux de répétition;

– La corrélation des divers travaux de prospection et des cartes magnétiques;

– La représentation globale du champ géomagnétique international de référence (IGRF);

– L'analyse harmonique sphérique pour la détérmination du champ géomagnétique principal, le champ dipôle et la position des pôles géomagnétiques, la séparation du champ nondipôle et son drift.

Toutes cettes connaissances sont essentielles pour: l'étude de l'intérieur profond de la Terre, les propriétés physiques internes, les mouvements du fluide du noyau, l'origine et le mécanisme du champ géomagnétique.

Les activités de cette catégorie sont prolongées dans les: mesures pour calibrer et standardiser les divers types d'instruments utilisés dans les prospections terrestres, aériennes ou marines, dans les problèmes de navigation ou militaires.

L'O.G.S. est impliqué dans la plupart de ces objectifs. À l'echelle de notre pays il a développé au fur et à mesure son activité par la mise en service des deux nouvelles stations permanentes à Dreptu (1981) et à Deva (1991), fermant sur le territoire roumain un triangle équilatéral (Fig. 6).

La deuxième catégorie d'activités, celles qui n'imposent pas le contrôle rigoureux du niveau absolu d'enrégistrement sont:

– L'étude de la distribution de la morphologie des: pulsations, bayes, orages magnétiques et autres phénomènes individuels du champ transitoire irrégulier;

– L'étude des relations entre le Soleil et la Terre;

– La surveillance de l'activité géomagnétique par diverses méthôdes de caractérisation numérique (indices K, Kp, Sp etc.), avec la prognose de cette activité;

– L'étude de l'induction électromagnétique dans le sous-sol avec des informations sur la conductivité de la croûte et du manteau supérieur;

– L'étude de la dissipation énérgétique dans le système ionosphère-magnetosphère, la structure et la dynamique de ce système;

– Les effets des perturbations géomagnétiques sur les radio-communications, sur la navigation, sur les lignes de transport énergétique;

– La possibilité de prédiction des tremblements de terre par des arguments séismomagnétiques.

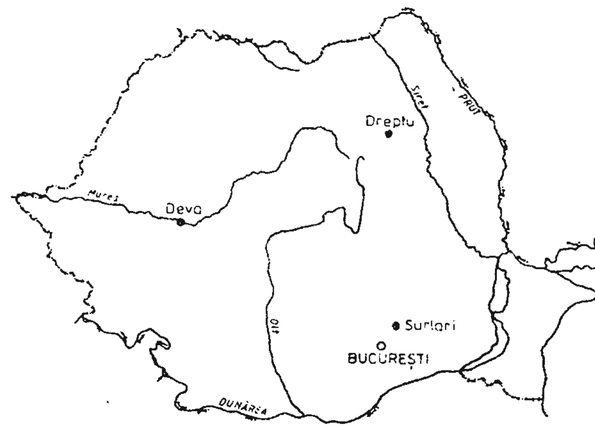

Fig. 6 – Station d'enegistrement permanent sur le territoire roumain

C'est le moment de mentionner que, en commencant par 1968, l'O.G.S. a ouvert un ample chapitre de recherches, par des travaux d'enregistrements géomagnétiques dans plus de 200 stations temporelles, distribuées à peu près uniformement sur le territoire de la Roumaine. Les données obtenues ont fondementé des études d'induction par les méthodes des sondages géomagnétiques et magnétotelluriques sur des géotraverses, avec des contributions remarquables sur une meilleure connaissance de la structure géologique profonde du pays.

C'est toujours à l'O.G.S. qu'on doit l'initiative et la réalisation de la première carte magnétique sur le plateau continental de la Mer Noire.

Rappelons aussi le développement des recherches pétromagnétiques grâce aux conditions offertes par les laboratoires amagnétiques de l'observatoire.

Beaucoup des études effectuées de l'Observatoire sont faites en collaboration avec des institutions diverses comme: l'Institut de Géodynamique de l'Académie Roumaine, la Direction Topographique Militaire, l'Institut National de Métrologie, l'Observatoire Astronomique etc.

Les perspéctives pour le proche avenir ont le but d'aligner la base métrologique de l'Observatoire sur les observatoires modernes. Nous n'allons pas insister sur les grandes difficultés rencontrées dans ce domaine qui nous empêchent à présent de participer au programme INTERMAGNET.

Laissant ouverte la voie à de meilleurs espérances, nous ne pouvons pas achever sans apporter un éloge à ceux qui ont mis la pierre fondementale de l'observatoire, les académiciens Sabba Ştefănescu, Liviu Constantinescu et, malheureusement le très récemment disparu, Mircea Socolescu.

Nous ne manquerons pas de souligner également la passion scientifique et le dévouement que nombre des chercheurs et collaborateurs de l'observatoire ont toujours apporté à leur tâche.

Nous devons remercier chaleureusement à tous ceux qui par la présence, par le soutien scientifique ou matériel ont apporté une contribution à cet événement de la science roumaine.

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RELATIONSHIPS BETWEEN THE OBSERVATORY RESEARCH AND THE ACADEMIC EDUCATION

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Key words: Observatory. Education.

Abstract: Close co-operation relationships have always existed between the Surlari Geophysical Observatory and the Department of Geophysics at the University of Bucharest. The four generations of scientists who were responsible for the foundation, functioning and development of the Observatory were also involved in the initiation and evolution of the Romanian geophysical university education. This short paper is an attempt to provide a brief image on the complexity of these co-operation relationships which perfectly combine the teaching activity with the scientific research.

Interconnections at different levels carried out between persons and activities at the Surlari Geophysical Observatory and Geophysical education can be presented, in a formal shape, on four main directions:

– persons leading and acting in both institutions;

– equipment available at Geophysical Department, Bucharest University used for specific research at the Surlari Geophysical Observatory and controlling, accuracying and adjusting magnetic instruments of the department;

– direct implication of the Surlari Geophysical Observatory as institution and its staff within the running of academic activity and

– continual implication of several specialists from the observatory and especially its both leaders for elaboration and supervision of MSc thesis.

The beginning was realised by early frontier generation of specialists represented by Mircea Socolescu, Sabba Ştefănescu and Liviu Constantinescu. Both laying the foundation and running at international level for that time of the geophysical observatory and also the foundation and development of geophysical education in our country are due to the above mentioned persons. Special acknowledgements are for Academician Professor Liviu Constantinescu who succeeded in dividing in a successful way his activity between research and academic education within the framework of the beginning of both activities. The fact that the young physicist, assistant of Academician Eugen Bădărău at Bucharest University, to whom it was offered, accepting to isolate himself for a while at the observatory, contributed in a fundamental way at its beginning and running into operation, representing a chance not only for the Surlari Geophysical Observatory but also for the Romanian geophysical academic activity. At the same time he had the leisure to concentrate on the up-to-date problems, preparing the first two academic courses in Romania concerning Geomagnetism and Gravity. Even today both of them represent the fundamental references for the respective fields.

For the same period and in both directions the contribution of his closest collaborator, Nicolae Milea, unfortunately tragically and too early interrupted has to be mentioned.

From the third generation of geophysicists chosen with a happy intuition since university studies the present chief of the Surlari Geophysical Observatory, Andrei Soare, should be pointed out, who assumed the leadership, collaborating with Academician Liviu Constantinescu since 1954. Andrei Soare kept the continuity of initial research activity at the highest possible level imposed by forerunners and developing the initial research facilities, simultaneously with the development of new metrology principles represented by arranging and equipping new laboratories and corresponding research facilities within the framework of more and more limited financial resources for research.

For a long time it has to be mentioned the teaching activity of the observatory's chief who, as associated professor, ensured the running of several typical education activities, such as: courses, laboratory activities and supervision of MSc thesis.

A geophysicist of large contribution in geomagnetism and petrophysics, the regretted Titus Neştianu contributed for a very long time with professionalism and abnegation at academic and training activity, many graduates being grateful for his directions. He was responsible for the organisation of the integrated laboratory research - education for studies of magnetic properties of the rocks.

For a short period, one of the graduates of the Faculty of Geology and Geophysics, Michael Enăchescu carried out his basic research activity at Surlari Geophysical Observatory where he got a very useful experience for his evolution on other geomagnetic meridians, honouring the Romanian geophysical school and research. This activity supplied passion for research, even if it is being carried on today in a field far from geomagnetism but basically closer to a geomagnetic pole - in Canada. Keeping his interest and talent for knowledge transmission by many conferences presented all over the world, he remains a representative person from this field.

The last example of this research - education connection is illustrated by Victor Mocanu, with a long term oscillation of equal interest between the two poles. He activated with equal passion and interest for a period within the framework of the Surlari Geophysical Observatory and then chose teaching geophysics. Victor Mocanu keeps strong connections with his initial activity, so balancing the options for the benefit of both of them.

On the other hand, the Faculty of Geology and Geophysics contributed by installing at the observatory of several equipments for determining either some geomagnetic components or physical properties. It is to be pointed out the utilisation of Askania variograph from the equipment of Geophysical Department of Bucharest University by specialists who succeeded in carrying on the first national map of distribution of electromagnetic vector. Now, this instrument runs as a permanent station at Deva observatory.

The second instrument belonging to the Geophysical Department which was installed at the observatory, due to the specific amagnetic conditions, is the astatic magnetometer LAM - 3. It was used for elaborating the first Romanian petromagnetic maps serving for improving the geological interpretation of magnetic data and so far has discovered several new economic areas of interest.

The research facilities and the special abovementioned conditions were also useful for the Geophysical Department from Bucharest University which could calibrate and check the work of geophysical instruments used not only for the academic activity but also for research agreements of the department.

The Surlari Geophysical Observatory was directly and continuously involved also in the teaching activity not only by the few above-mentioned examples but also working timetable for students of geophysics. All the staff of the observatory, and first of all its leadership, took those opportunities for carrying on multiple operations such as: presenting the equipment and the main duties of a fundamental station participating in the world-wide cooperation of observing the planetary magnetic field, types of typical activities and significances of final results, experiments on reduced models, carrying on micromagnetic prospections, control of the uniformity of the magnetic field inside the observatory.

Sometimes, students of the Geophysical Department participated in field activity helping for absolute measurements on the normal field and secular variation net.

Finally, it is to be pointed out the continuous preoccupation of the observatory's chief for elaborating many MSc theses, some of them of original character connected with the specific problems of fundamental research of geomagnetism. Only during the last decade, 18 MSc theses were supervised by the research staff of the observatory. Several results from these theses were so interesting that could also be included into the research reports of some teams of the Institute of Geology and Geophysics. We briefly mention the elaboration of new images of the normal field and secular variation on our national territory, improvement of processing software for primary observation data or re-interpretation of older prospection data by new information. It is also possible to point out a MSc thesis which presents a systematic and nearly exhaustive study of geomagnetic instruments, from the beginning to the modern epoch.

This brief presentation of the main aspects of academic education - research connection, typical to the observatory, also variable in time, remains a constant of tendency for looking for new forms and improved content, all superposed on professionalism and fellowship relation of implied persons. At this anniversary moment, we mention the hope not only for keeping but also improving, as shape and content of this connection which cannot be anything but beneficial for both sides. And because we are in this academic hall, it is not possible to finish in another way but with the traditional wish: VIVAT, CRESCAT, FLOREAT - Surlari Geophysical Observatory.

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THE MODERN ROLE OF THE NATIONAL GEOMAGNETIC OBSERVATORIES IN DEFINING THE MAGNETIC ANOMALY FIELDS: THE CASE OF THE ITALIAN AREA

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Key words: Geomagnetic Observatory. Magnetic Anomaly Field. Italian Area.

Abstract: During the last thirty years total field anomaly maps of the Italian area have been published. They were differently based on ground, aeromagnetic or marine data taken at different times with different magnetic equipments. Some disagreements appear among these charts especially in terms of long spatial wavelengths and gradients mainly because of the different normal fields used in the reduction procedure. The Italian Geomagnetic Group of Geodynamics Project has produced the most reliable representation of the Italian magnetic anomalies. More recently an original way to use both a global spherical harmonic model, like the IGRF (International Geomagnetic Reference Field) and the yearly mean values of a national magnetic observatory for Italy, has been applied in order to select the best normal field. The importance and significance of L'Aquila Observatory in central Italy is shown in the field measurements reduction procedures.

Introduction

The geomagnetic field is mainly due to complex magnetohydrodynamic phenomena that take place inside the planet, precisely where an alloy of iron, nickel and lighter elements are supposed to be forming the Earth's core. This part of the geomagnetic field as observed at the Earth's surface is commonly called main field.

A magnetic anomaly is defined, similarly to what happens in the case of a gravimetric anomaly, as the deviation of an observed magnetic field at certain location, from the expected value due solely to the main field.

Consequently a central role in the definition of a magnetic anomaly is then played by the analytical expression used for defining the main geomagnetic field whose global analytical expression worldwide used is called International Geomagnetic Reference Field (IGRF). This formulation is given by the solution of the Laplace equation applied to the Earth's magnetic field and is represented by a set of coefficients called Gauss coefficients, that is generally up to degree (n) and order (m)=10 if computed on the basis of ground measurements (see for example Langel, 1992). Only in the case of satellite measurements, as it was done, with the MAGSAT mission (Langel, 1985) it was possible to obtain a more detailed formulation for the global model with coefficients up to n=m=23.

As is well known the geomagnetic field is varying not only in space but also with time and then its long term variation (called secular variation) must be monitored and analysed at the same time and expressed as a set of Gauss coefficients up to the order n=m=8 (Langel, Estes, 1985). In order to deduce a map of magnetic anomalies, generally several measurements are taken with high spatial density in the area of study and this means that a certain time elapses between the first and last measurements are accomplished.

It is worthwhile to recall that certain assumptions are made for a best utilisation of IGRF in areas that include a Geomagnetic Observatory and a few repeat station, in order to take into account the non simultaneous measurement operations. In Molina and De Santis (1987), it is shown that while the IGRF field holds its validity for its spatial gradients, the time vari-

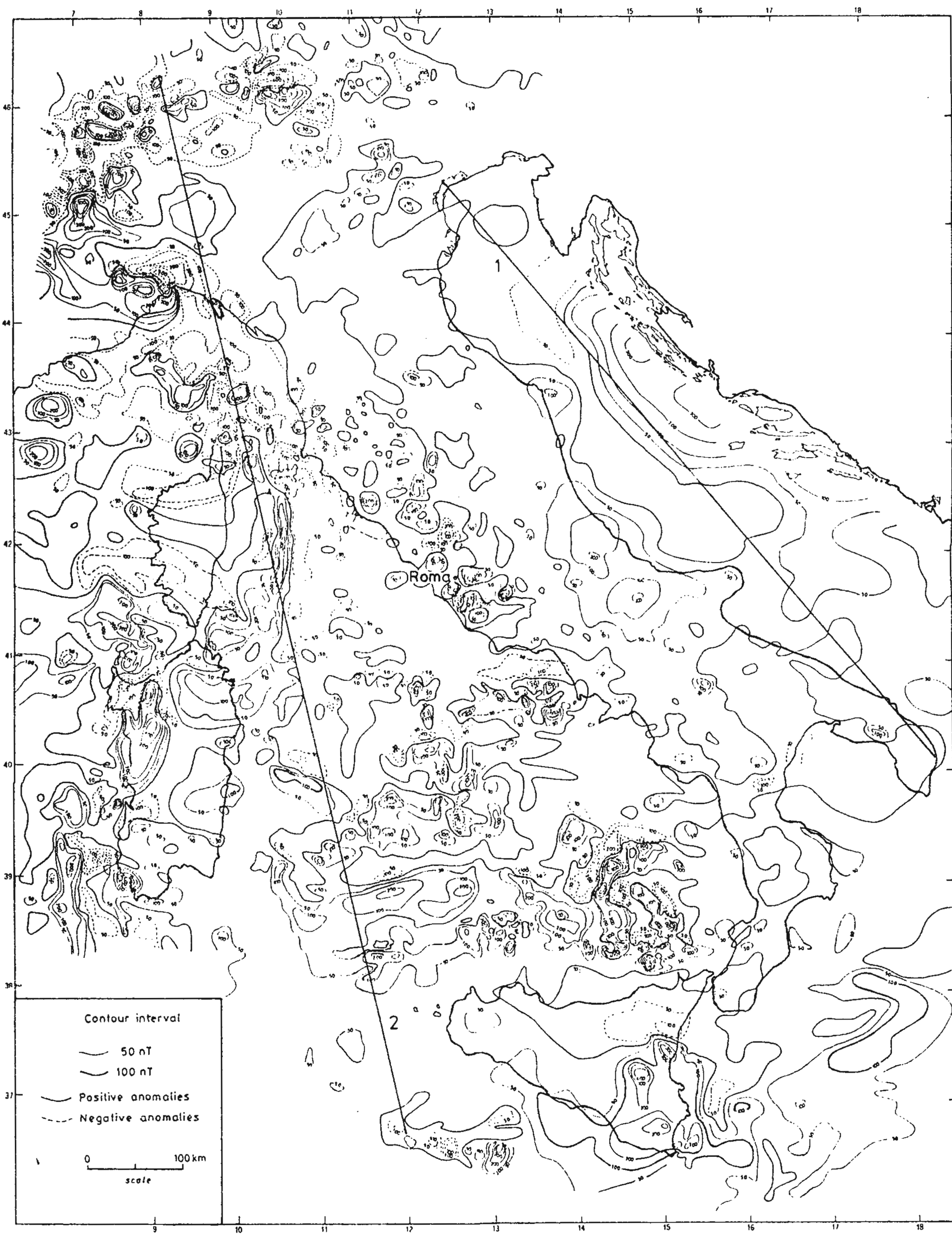

Fig. 1 – Magnetic anomaly map of the italian area and surrounding seas

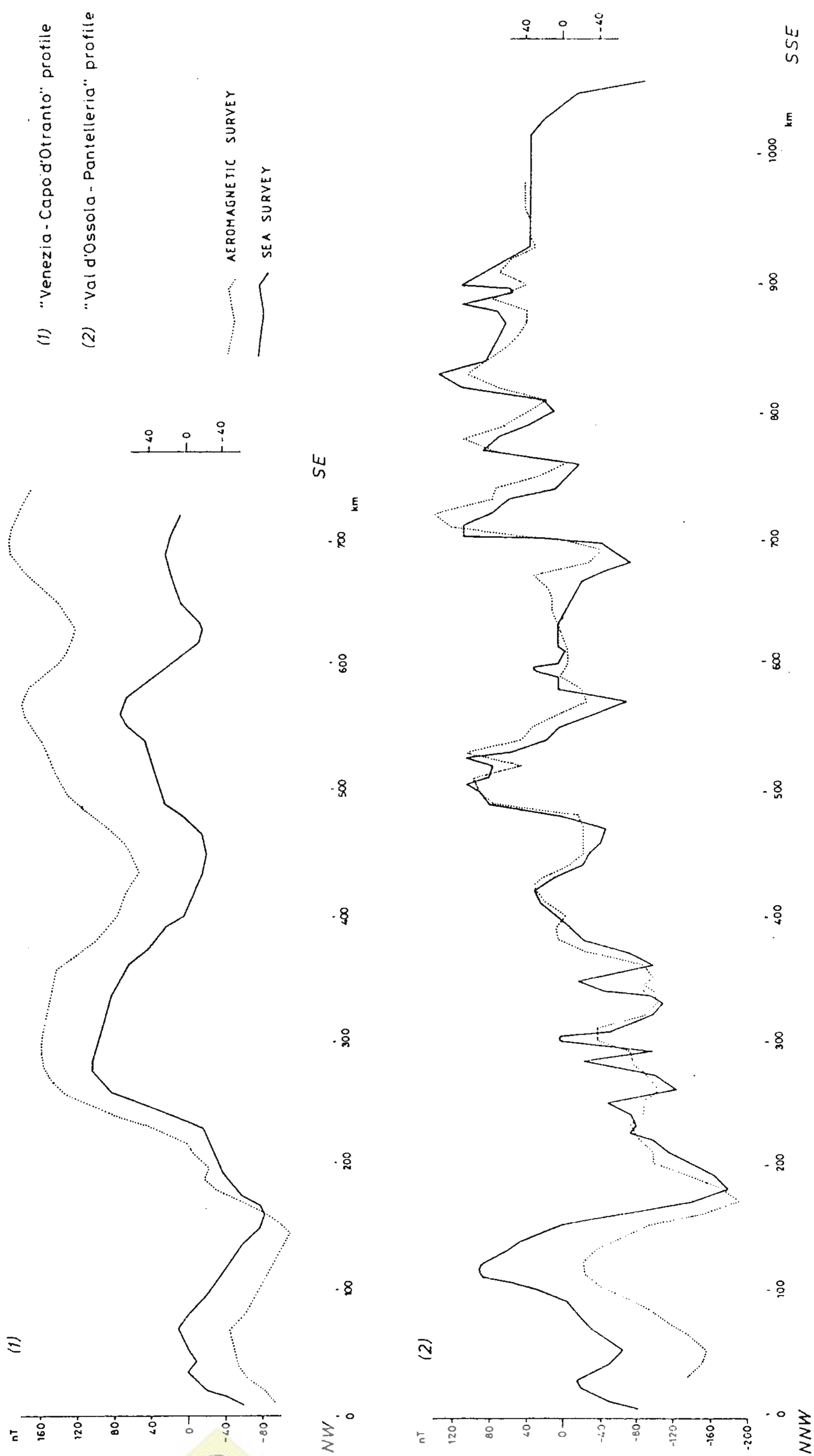

Fig. 2 – Comparison between anomaly profiles extracted from AGIP aeromagnetic map and from magnetic anomaly field of Italy. The traces of the profiles are shown on Fig. 1.

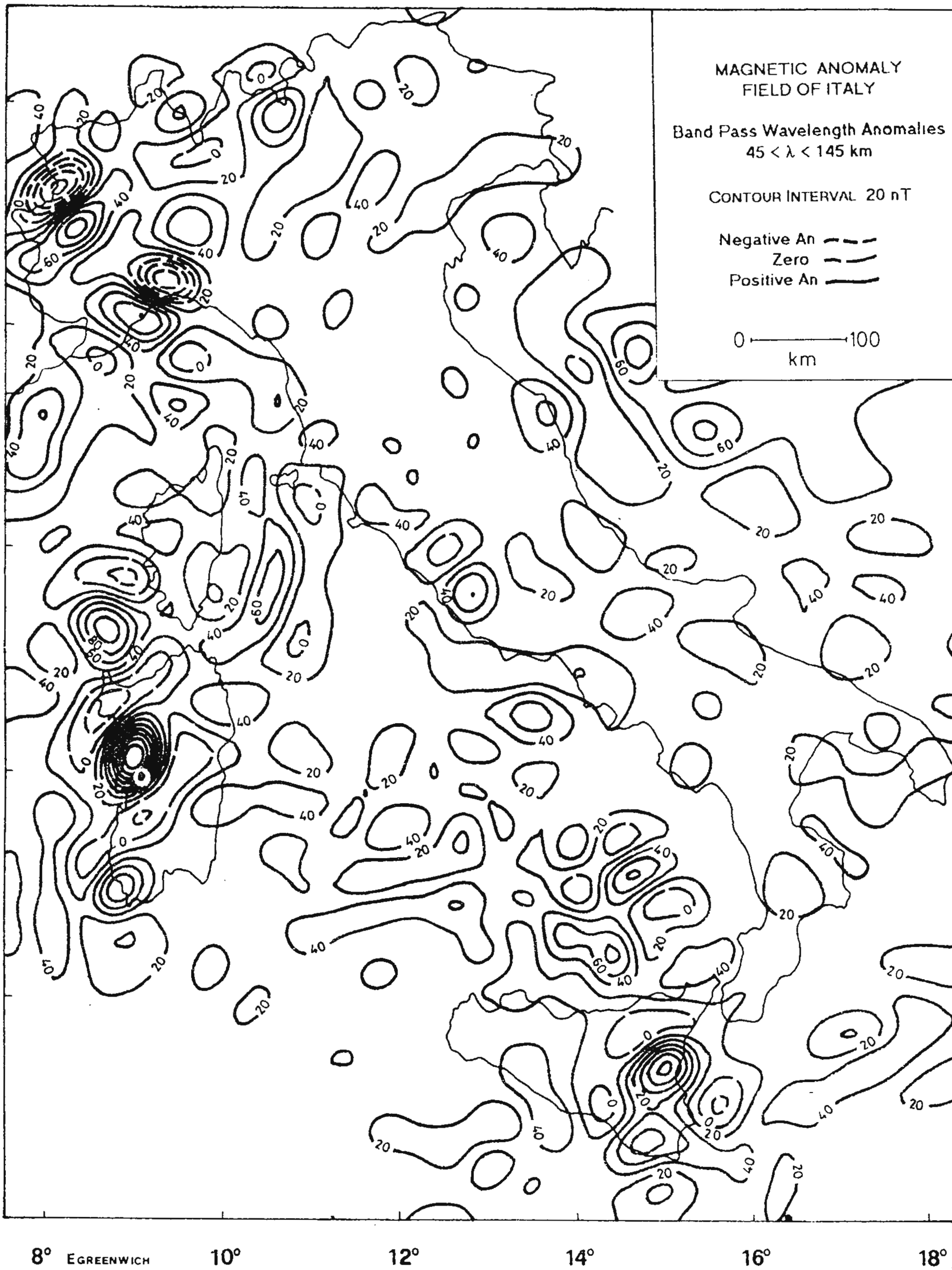

Fig. 3 - Band-pass filtered map of magnetic anomaly field of Italy (45 < λ < 145 km)

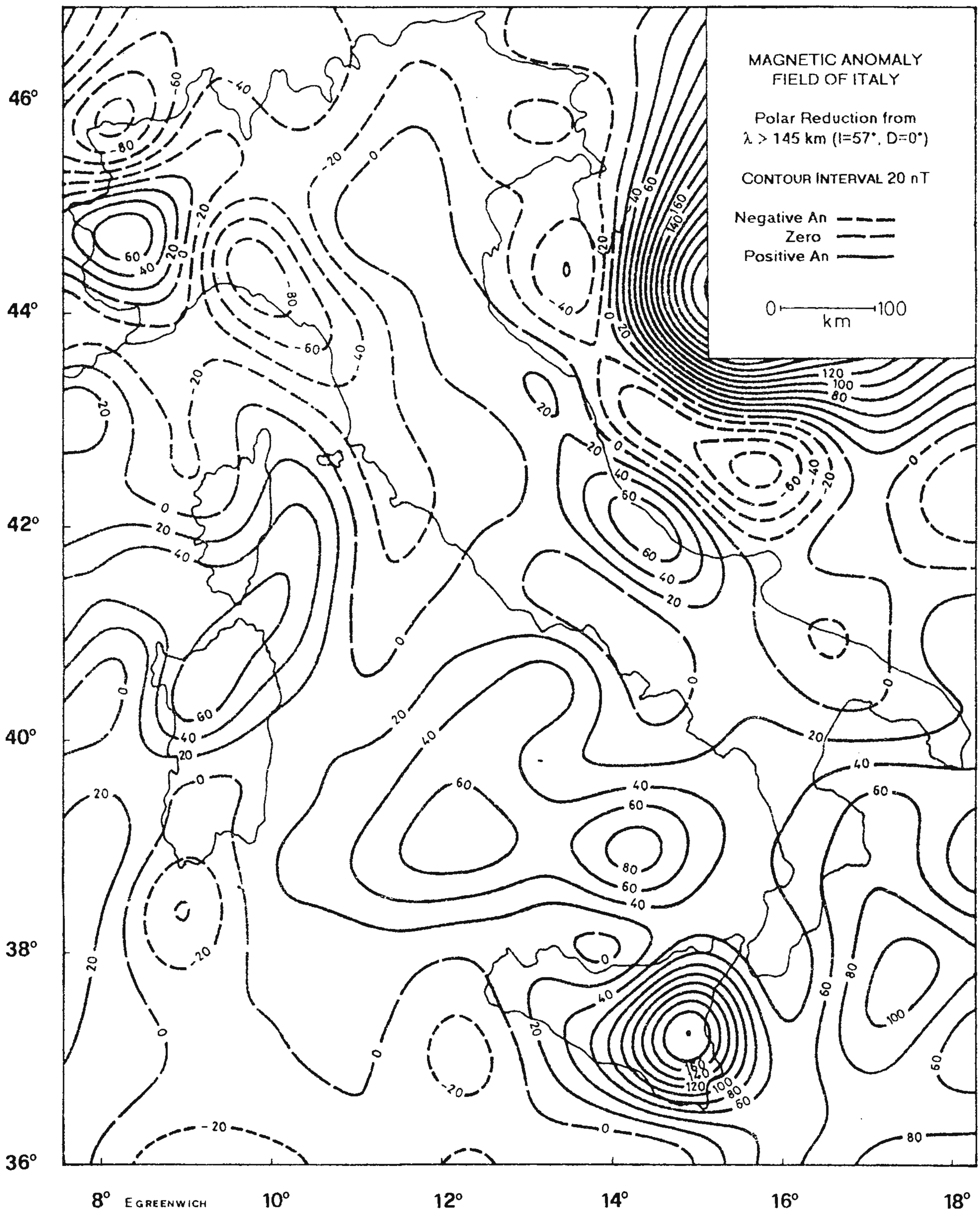

Fig. 4 - Polar reduction from low-pass filtered map ($\lambda > 145$ km) of magnetic anomaly field of Italy.

ation monitoring is optimally ensured if data from a nearly Magnetic Observatory are available; in fact its data can be input into a mathematical procedure. For Italy this newly computed reference field was called It. GRF and takes full advantage of existence of IGRF coefficients plus the data coming from a close Geomagnetic Observatory. In this paper an anomaly map of the total field in Italy obtained after the execution of several measurements taken in the interval 1965-1983 on land and at sea, is shown with the definition of some problems related to the data reduction.

The Data Set Reduction and Maps

Data used for the determination of a new magnetic anomaly map of Italy come from several field surveys conducted at various epochs. For what concerns sea measurements, some marine cruises undertaken during the 1965-1972 time span in seas surrounding the Italian peninsula, and including a total of 75000 nautical miles were used (Morelli et al., 1969, Morelli, 1970, 1973-1975). For what concerns land measurements data refer mainly to the measurements taken on the occasion of the National Geodynamic Project by the so called "Geomagnetism Group" (Molina et al., 1985, 1994). Several authors had already defined magnetic anomalies of total field for restricted areas of Italy and the computation of normal regional field used to determine the anomalous field was performed in a different way for different areas investigated in these previous studies.

Following the above quoted procedure, the use of It. GRF (Molina, De Santis, 1987) has permitted an optimal reduction of all data (sea and land) by the utilisation of the national geomagnetic Observatory of L'Aquila (AQU, $42^0 23$'N, $13^0 19$'E) and the use of the IGRF gradients for all the Italian area. For what concerns this presentation, only the regional scale anomaly contribution was considered. In Figure 1 the total field anomaly map of the Italian area is shown for land and sea areas in the Mediterranean area roughly from 36^0 to 47^0 latitude N and from 8^0 to 18^0 longitude E. Two almost N-S profiles (shown as (1) and (2) on Figure 1, at east and west side, respectively, of the peninsula), have been investigated comparing aeromagnetic AGIP data (Cassano, 1984) and corresponding ground data given by the anomaly map of Figure 1. Comparison is shown in Figure 2. Sensitive deviations appear, probably due to an unsuitable normal field used for the aeromagnetic data reduction. Particular intense deviations are present in Puglia (120-170 nT) and Piedmont (around - 80 nT). After a filtering and Polar Reduction procedure was applied to all magnetic anomalies data of medium and large wavelengths for this scale, anomaly maps were also obtained respectively for 45 $< \lambda <$ 145 km and $\lambda >$ 145 km (Figs. 3 and 4). The latter anomaly map was also reduced to the Pole.

These maps show the existence of a few magnetic signatures that allow the identification of corresponding magnetic domains: the Ragusana-Maltese platform, the Central Ionian sea, the Sardian-Corsican block, the abyssal Tyrrhenian plain, the Molisan basin and the Dalmatian body (all are characterised by maxima in the Pole reduced magnetic anomaly map).

Conclusions

The presence of a geomagnetic observatory in the middle of an area of interest is important because its secular variation can be used to constrain the variation in time of a normal field. Here a particular model called It. GRF is applied. It is based on a second-order polynomial in latitude and longitude, approximating the gradient fields of IGRF and fixing its absolute values to a difference in agreement with that one given by L'Aquila Observatory. The constant difference in time would represent the anomaly attributed to the observatory. The total intensity anomaly map is more reasonable and looks more consistent with the geological information. Moreover the normal field used for reduction of both sea and ground data permits to combine data taken at different epochs, improving the quality of the anomaly map so deduced.

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SECULAR VARIATION FROM THE HISTORICAL REPEAT STATIONS OF THE ITALIAN MAGNETIC NETWORK

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Key words: Geomagnetics. Secular variation. Italy.

Abstract: The study of geomagnetism on the basis of large data series is a very important tool: it helps to extend our knowledge of the geomagnetic secular variation to a longer time interval and can bring information on geophysical phenomena linked not only to geomagnetism. Following these considerations, we have tried to extend the Italian repeat stations data backwards with the inclusion of the historical Italian geomagnetic data catalogue (Cafarella et al., 1992a). We obtained several data sets from about 1800 till nowadays for different localities and the analysis of secular variation both in space and time over the last two centuries revealed interesting features.
In this framework it is shown that the contribution of the observatories is very important for the accurate definition of the secular variation pattern; the study of the repeat station data together with the observatory series, can bring fundamental information to improve the knowledge of the upper core fluid flow structure that is responsible of the secular variation.

Introduction

Only after the earliest measurements of the Earth's magnetic field, that took place in the 16th century, man's picture of geomagnetism started to clear up. Since then, more and more geomagnetic field measurements have been taken, and accurate magnetic charts and mathematical models have been derived from them.

Secular variation, the long time scale fluctuation of the Earth's magnetic field, was discovered at the beginning of the 17th century. Gellibrand noticed that the value of declination in London, that was well known in the late 16th century, had been steadly changing since then. At that time (1528–1634) it had decreased from 11.3^0E to 4.1^0E (e.g. Multhauf and Good, 1987). Now, we know that secular variation operates on a time scale of centuries and then it can be studied accurately only considering very long periods of observation. The history of the Earth's magnetic field adds greatly to our knowledge of the nature of the field itself and to the knowledge of the process that generates the field. In fact despite several studies the mechanisms of the dynamo process in the Earth's fluid core are not yet completely known (see for example Langel, 1991).

In Italy geomagnetic field measurements were taken in several places during the years for more than four centuries (Cafarella et al., 1992a, 1992b); moreover, at the end of the last century, magnetic networks and field measurements were also undertaken specifically with the intent to draw national magnetic maps. Several measurements, collected during the latest Italian magnetic networks, were then used in this work to set up some historical repeat station series. Starting from these historical sequences, detailed models of the secular variation over Italy in the last 100 years, were computed and discussed.

Historical Italian Geomagnetic Data Catalogue

With the publication of the "Historical Italian geomagnetic data catalogue" (Cafarella et al., 1992a, 1992b) is now possible to have direct access to a well organised set of ancient Italian data. In the Catalogue, Italian data from the 15th century to 1935 are collec-

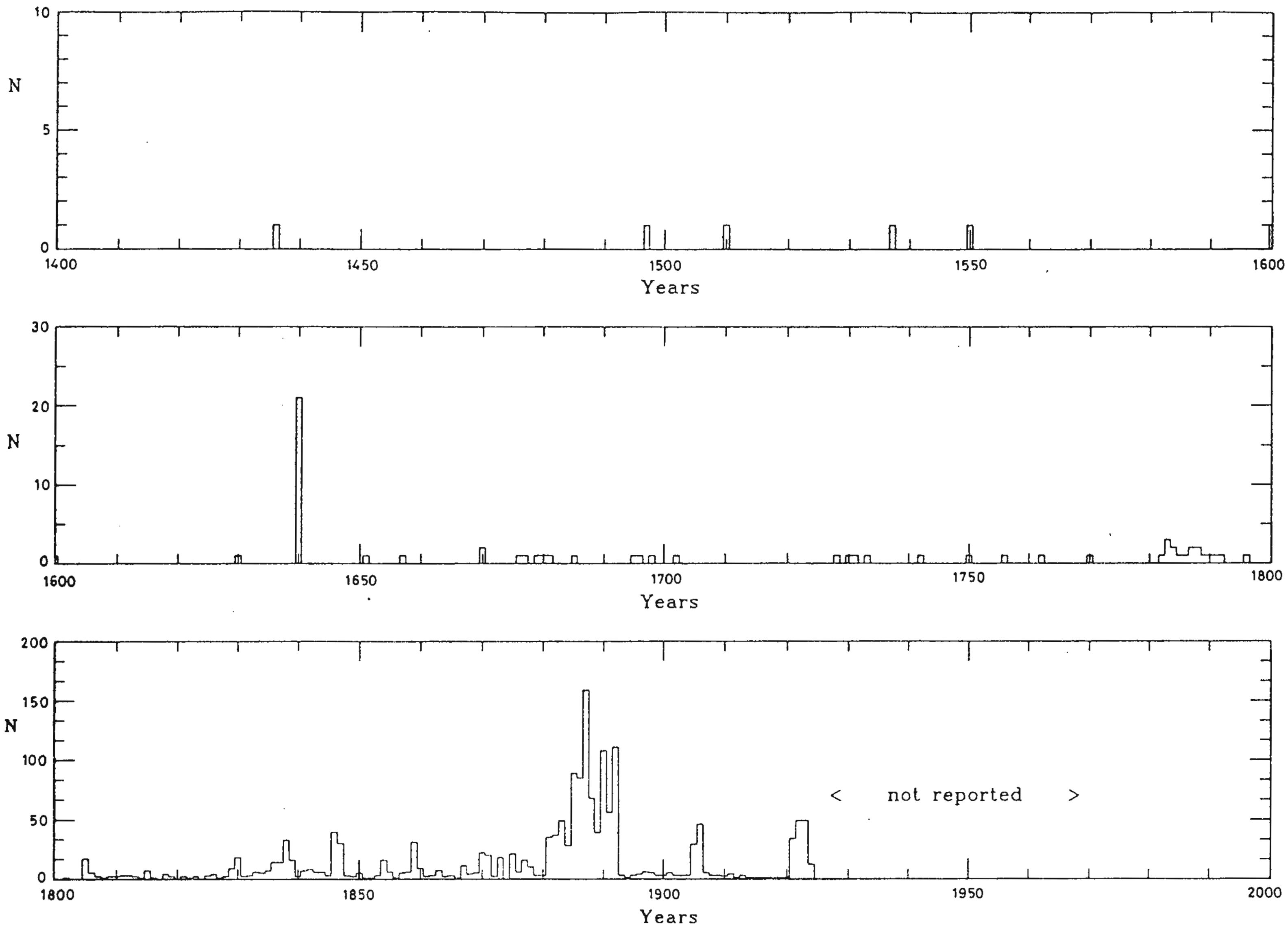

Fig. 1 – Histograms of the number of available D and I measurements made in Italy from 1400 till 1935 portrayed in three sets. Observatories data are not included here.

ted. The time distribution of the declination (D) and inclination (I) measurements is shown in Figure 1. Observatories data are not included in the histograms and the most recent measurements reported were made in 1935 or thereabouts. After this period, the number of data gets higher and higher and they are easily available in the more recent literature (Morelli, 1946; Talamo, 1975; Molina et al., 1980; Meloni et al., 1994).

The values reported between 1400 and 1600 all refer to declination data; the inclination measurements in Italy, in fact, started only in 1640. The concentration of data that can be noticed in the 1640's is given by the first geomagnetic survey made by Borri through Italy (about 20 measurements reported by Kircher in "Magnes Sive de Arte Magnetica", 1643. From this survey the author has compiled a magnetic map; unfortunately the precious map is lost). In the third histogram, another concentration of measurements, in coincidence with the very first Italian 3-component complete survey can also be noted; the survey was organised by the *Ufficio Centrale di Meteorologia e Geodinamica* and it was performed by Chistoni and Palazzo, from 1881 to 1892, with more than one hundred vector observations, all over Italy. Tacchini, the U.C.M.G. director, presented in 1892 the contour maps reduced to 1892.0 at the First Italian Geographic Congress, in Genoa (Tacchini, 1892). In the years between 1921 and 1929, Palazzo repeated again the measurements, but the new mapping was not brought to an end.

In order to study the secular variation in Italy from the historical repeat stations, here only measurements from 1800 to 1935 were used. The measurements extracted from the catalogue between 1800 and 1880 were made by different authors, such as Kreil, Gautier, Kesslits, Tadini, Alvarez (Cafarella et al., 1992a). In order to extend the time analysis, also measurements more recently have been taken were considered. The most important steps of this Italian more recent geomagnetic network history are summarised in the following.

In the 20th century the first complete D, I and horizontal intensity (H) survey was organised around 1935 by the Italian Geographic Military Institute (I.G.M.I.), using 1496 stations (46 repeat stations) and 1 Observatory (Castellacio). The cartographies were reduced to 1940.0 and new partial surveys allowed new maps publication at 1948.0 and 1959.0.

Following the International Geophysical Year, that took place in 1957, the idea of a World Magnetic Network was born and Italy took part in the project. The National Council of Research (C.N.R.) organised a new magnetic survey for this occasion. Measurements were made by the "National Institute of Geophysics" (I.N.G.) I.G.M.I., Bari University and Vesuvian observatory; 28 repeat stations and 2 observatories (L'Aquila and Castello Tesino belonging to I.N.G.) were used and the cartography for declination and horizontal intensity was reduced to 1965.0.

The following survey was organised by I.G.M.I. again, around 1973 and the D and H maps were published, reduced to 1973.0. The network was constituted by 1530 stations, 50 of which repeat stations and one was the observatory (L'Aquila of I.N.G.).

In 1979, a new magnetic Italian survey was carried out and it comprehended the old I.G.M.I. network plus some new stations with the special intent to draw maps for all elements in all details. It was composed of 106 repeat stations, two geomagnetic observatories (L'Aquila, Castello Tesino (TR)) and four temporary new observatories (Gibilmanna (PA), Locorotondo (BA), Corongiu (CA), Roburent CN)). The measurements were made between 1977 and 1981. I.N.G. and I.G.M.I. decided afterwards to publish new magnetic cartography every 5 years.

In 1985 I.N.G. and I.G.M.I. published the magnetic Italian D, H and F cartography, and in the years between 1985 and 1988 a partial survey was made by I.N.G., using only 46 repeat stations and one observatory (L'Aquila). On the occasion of the Italian Magnetic network repetition at 1990.0, the F, D and I measurements were taken between 1989 and 1992 on 115 repeat stations and one magnetic observatory (L'Aquila). The 1990 network was the same of the previous work, plus Egadi, Pontine and Lampedusa islands (Meloni et al.,1994).

Historical Repeat Stations

Some of the repeat stations used to draw and update national magnetic maps have a long history. Using both the data catalogue and the measurements of the more recent geomagnetic network surveys, some D repeat station series were created. Each set is associated with the locality where the longest series of measurements were taken. The spatial distribution of these localities is shown in Figure 2. Three different observatories were necessary to cover the whole period of about 120 years. In Figure 2 Pola, Castellacio and L'Aquila observatories are indicated with stars, while the historical repeat stations used in this study are indicated with a black circle.

Pola observatory is situated in the Istria Peninsula that belonged to the Austro-Hungarian Empire before the First World War. After 1918, Istria became part of Italy. The observatory worked from 1881 and 1922, when the geomagnetic field recording became affected by the city tramways. In 1932 the I.G.M.I. started regular absolute geomagnetic observation at Castellaccio together with variational recording, using Pola's in-

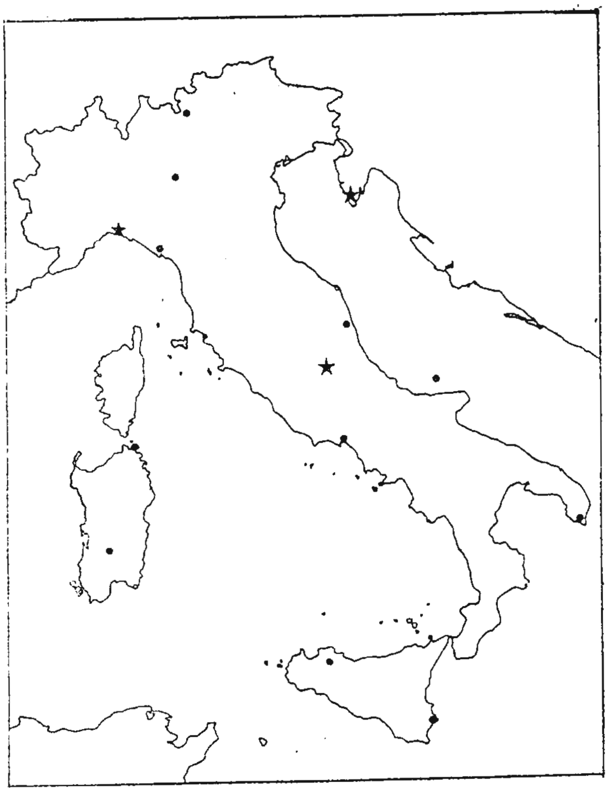

Fig. 2 – Historical repeat stations with several declination measurements. Stars refer to an absolute observatory series combination (Pola, Castellacio and L'Aquila).

struments (Palazzo, 1911; Tenani, 1933). Castellaccio observatory operated regularly until 1962. Starting in 1958 with testing and recording, and in 1960 with the first yearbook publication, I.N.G. founded the L'Aquila observatory which still runs regularly. As it can be seen in Figure 3, it was possible to create 12 repeat station series for declination.

At the top of Figure 3 all historical data sets used in this study are shown for declination; the plot of the time variation of D as recorded at the observatories of Pola, Castellaccio and L'Aquila is also reported. In order to have a continuous Italian absolute data set for secular variation studies, the geomagnetic absolute yearly means for these three observatories were combined together (see for example Parkinson, 1983) by shifting their absolute level, properly in order to make it coincide with the L'Aquila beginning value. This procedure was possible since the same secular variation was assumed for the three different data set (Cafarella et al., 1992b). The comparison between the two different kinds of data confirms the goodness of the historical repeat stations data sets.

Since measurements of the geomagnetic field at the astronomical observatory of Capodimonte (Naples) were made between 1885 and 1910, a second set of data instead of Pola's series, could also be used. In Figure 4 the two sets of data Pola and Capodimonte are shown: secular variation is quite the same for a very long period. It is possible to explain this similitude observing that the two observatories have quite the same longitude and in Italian area therefore the same secular variation. We have chosen Pola's series because it covers a longer period than Capodimonte.

The time dependence of historical data set is shown in Figure 3 following a decreasing latitude order from the top of the panel. The oldest measurements, extracted from the Historical Data Catalogue, were taken at the beginning of the last century. Data between 1881 and 1892 were all taken from the Chistoni-Palazzo survey and the measurements around 1920 were made by Palazzo. The more recent values reported in the figure were extracted from the different surveys organised in Italy by the I.G.M.I. and I.N.G. from 1935 to present.

A clear pattern of secular variation can be seen across Italy showing a monotonous westward increase of declination. Here the longest sequences among the historical sets are reported, but also several magnetic network data are available and it is also possible to compare secular variation by means of different epoch surveys.

Secular Variation from the Italian Magnetic Surveys

The Chistoni-Palazzo survey offers several precious measurements reduced at 1892. The spatial distribution of the stations is reported in Figure 5. The stations were quite uniformly distributed all over Italy. They took about 230 localities (Tacchini, 1892). Starting from this data set a normal field for this epoch was computed, using the Chistoni-Palazzo survey. The normal field in the form of a simple latitude (λ) longitude (ϕ) polynomials, if f is one component of the field, can be defined as:

$$f = a_{00} + a_{10}\Delta\phi + a_{01}\Delta\lambda + a_{20}\Delta\phi^2 + a_{02}\Delta\lambda^2 + a_{11}\Delta\phi\Delta\lambda$$

where a_{00}, a_{10}... are calculated by means of a mean squares method. The contour map of the normal field is shown in Figure 6 reduced at 1890.0 for declination and expressed in tenth of minutes.

A glance at the secular variation over the last century reveals interesting features. In Figure 7 the declination normal field map made using the 1990 repeat station survey data set is shown (Meloni et al., 1994).

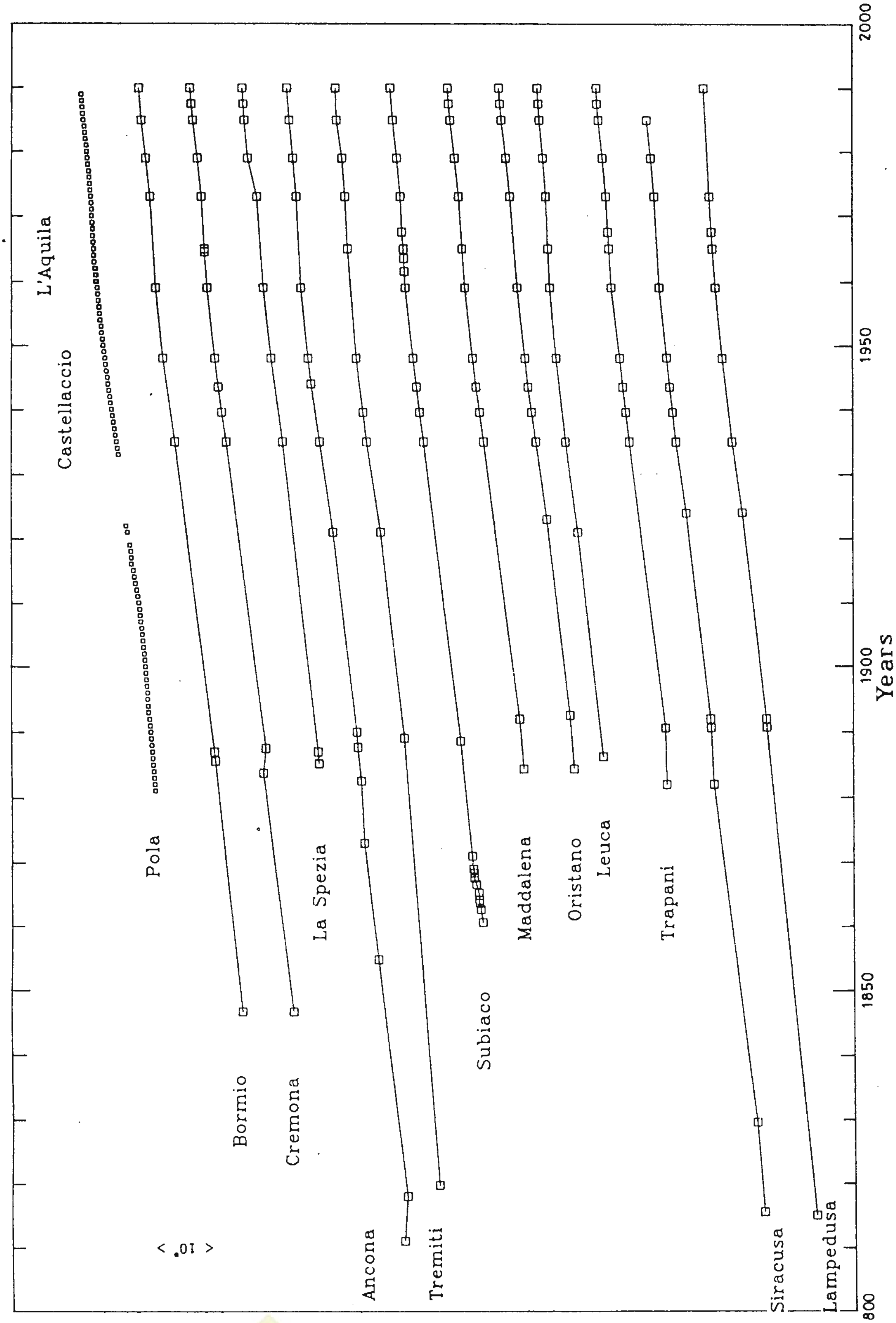

Fig. 3 – Time dependence of historical data sets; the y-units are arbitrary

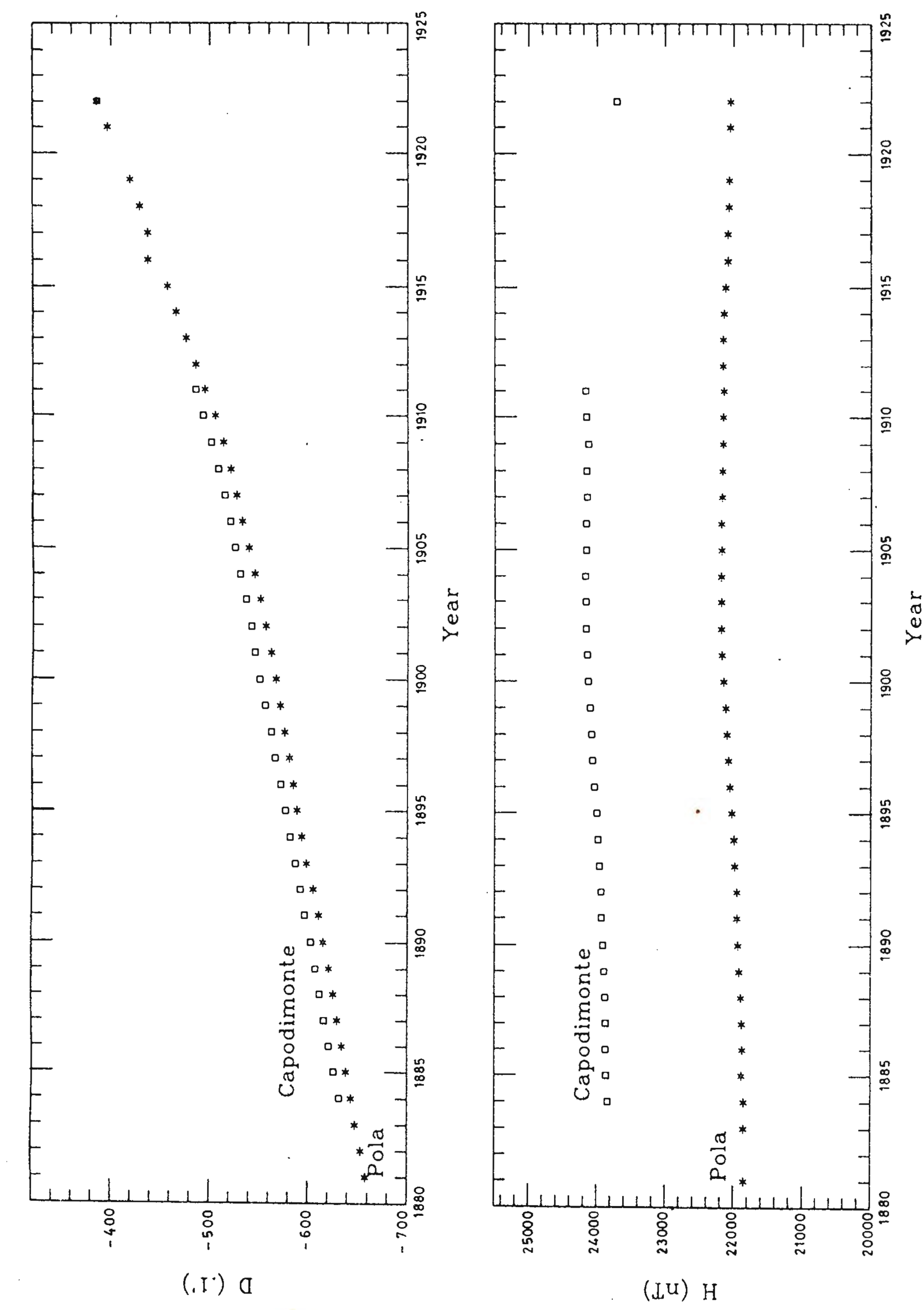

Fig. 4 – Measurements of declination and horizontal intensity at Pola observatory and Capodimonte astronomical observatory

Fig. 5 – Localities used during the first Italian geomagnetic survey made by Chistoni and Palazzo (1881–1892)

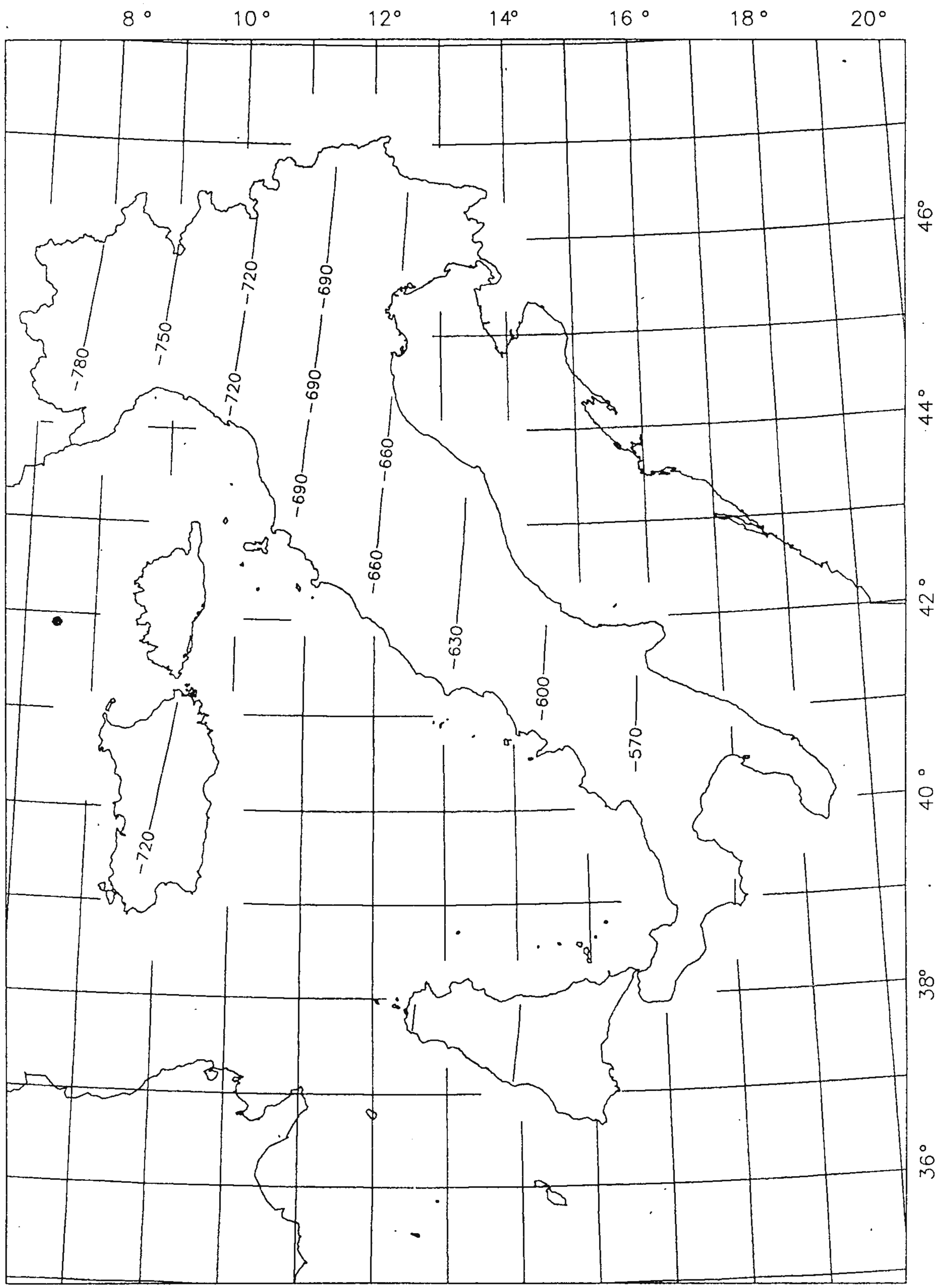

Fig. 6 – Contour map of declination reduced at 1890.0 using normal field approximation

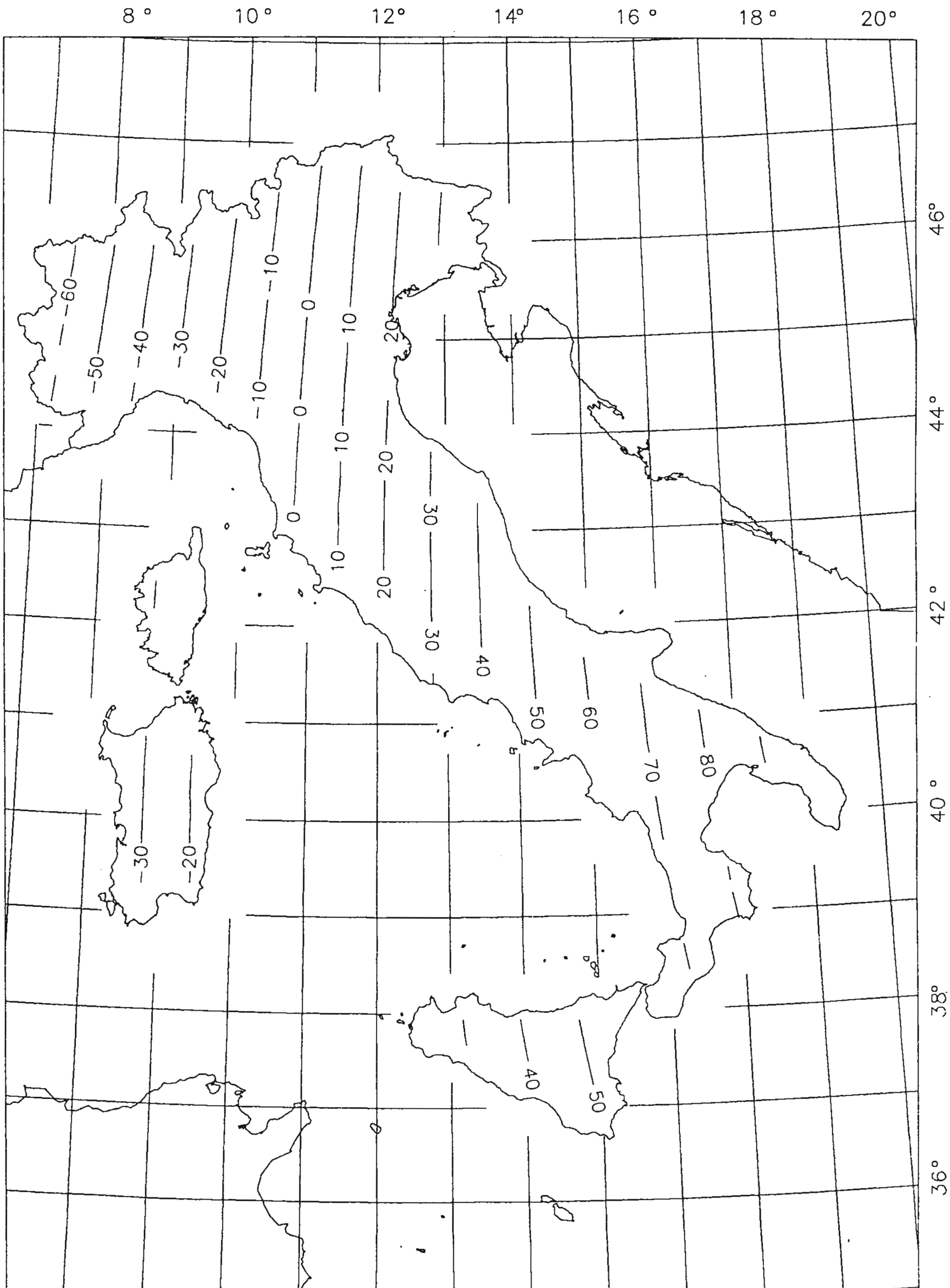

Fig. 7 – Contour map of declination reduced at 1990.0 using normal field approximation

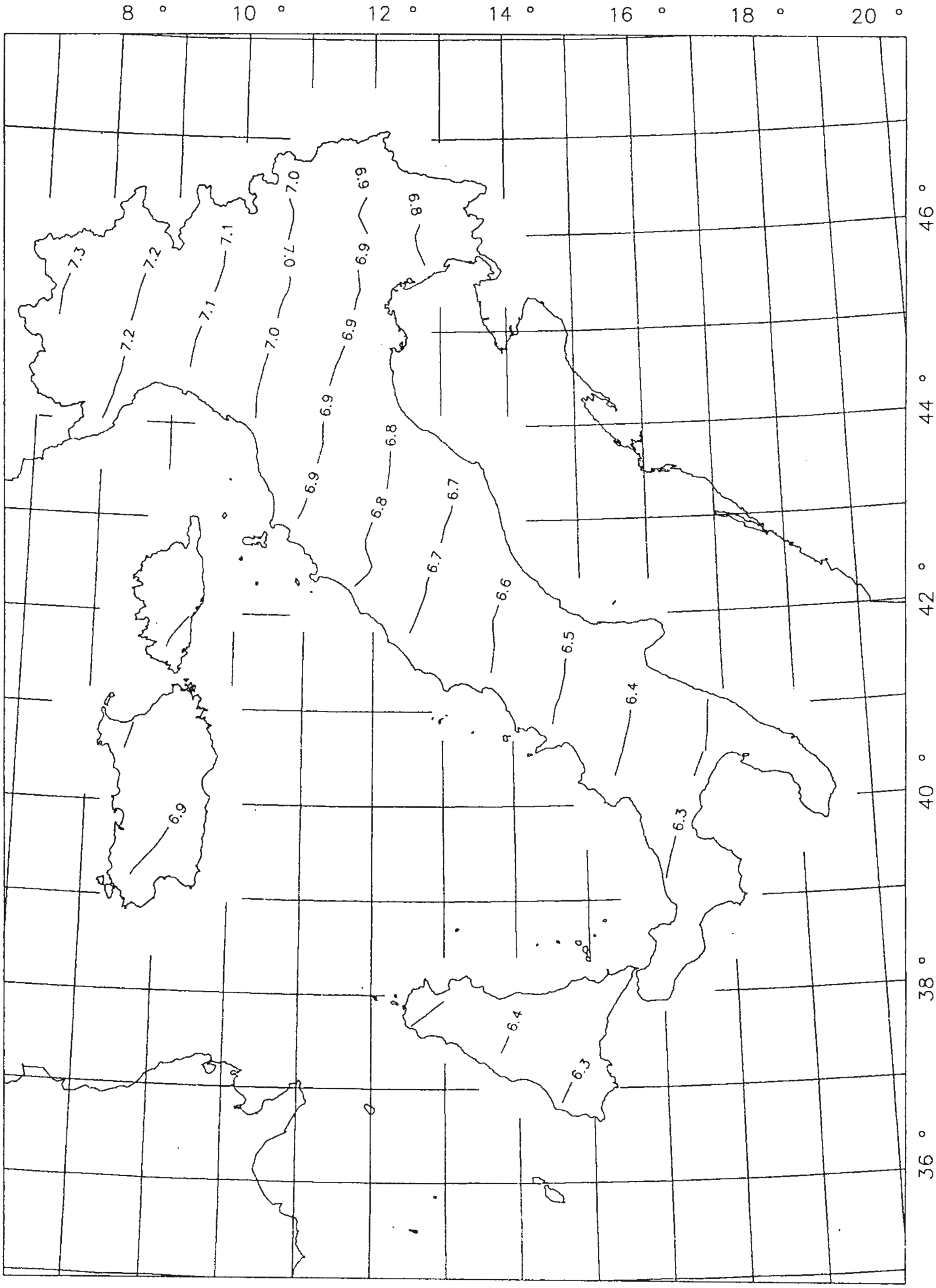

Fig. 8 – Yearly secular variation over the last century (1890–1990)

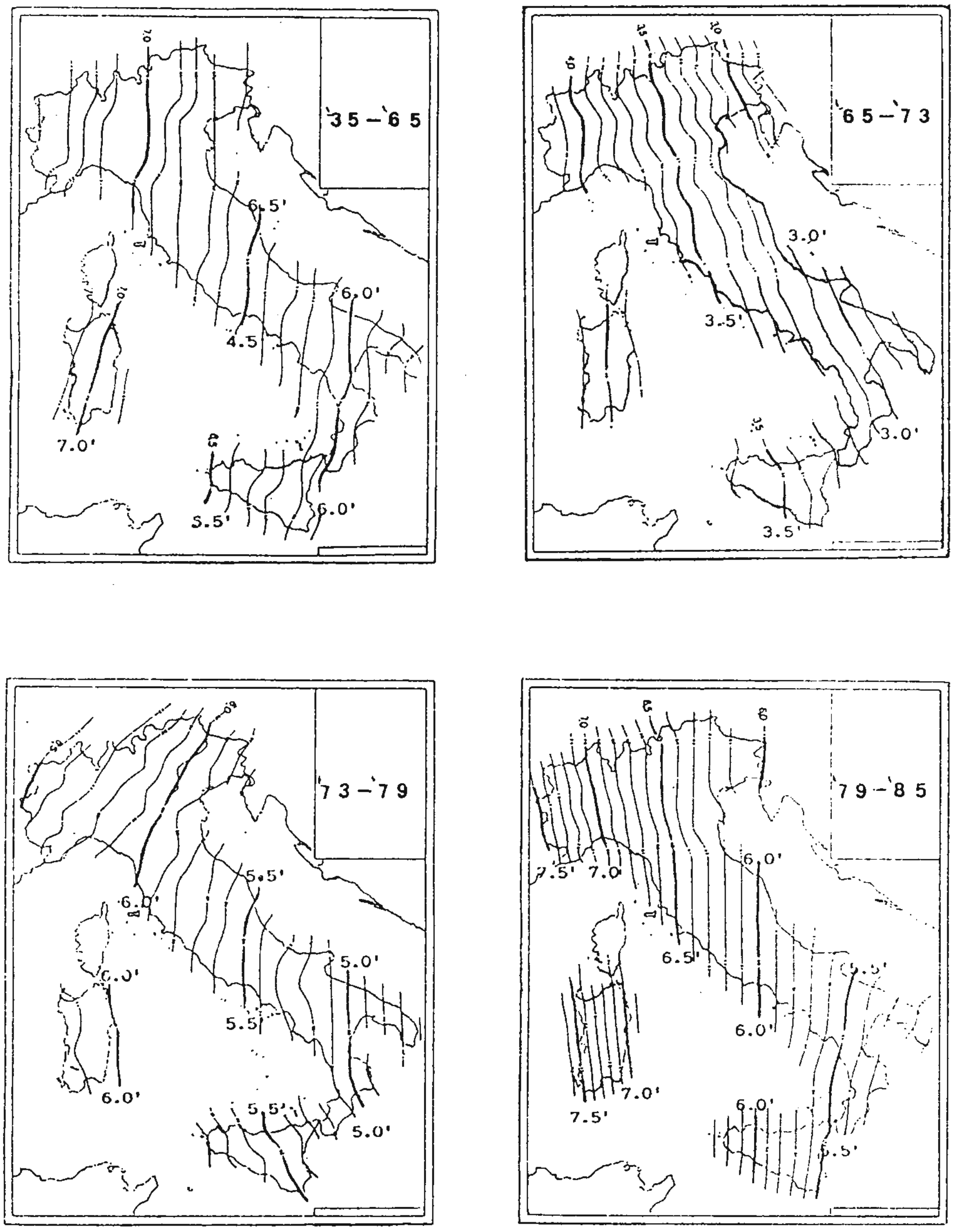

Fig. 9 – Yearly secular variation over the periods reported in the squares

One feature of interest is the agonic line position that passed through Italy in this time span.

In Figure 8 the yearly secular variation over the last century (1890–1990) is shown by means of a normal secular variation average field. For this map steady secular variation during the century was considered and the yearly variation was computed as $(E_n - E_0)/n$ where E_n and E_0 are the values of our component at the beginning and at the end of the interval of n years.

The mean value of secular variation during the last century over our peninsula is about 7 minutes per year.

The behaviour of the secular variation over shorter time intervals can be deduced using different surveys. In Figure 9, the D secular variations between the epochs (1935–65, 1965–73, 1973–79, 1979–85), reported in the squares, are plotted (Battelli, Dominici, 1991).

Conclusions

The study of secular variation of the geomagnetic field from observatory and repeat stations data yields fundamental information to the understanding of the geomagnetic field spatial and time variation and consequently to the knowledge of the upper core fluid flow structure that is responsible of the secular variation itself. The data reduction made on measurements taken at different epochs at different localities can be done accurately only if a geomagnetic standard reference, i.e. a geomagnetic observatory, is available. In Italy a favourable situation for the investigation of the detailed spatial temporal structure of the secular variation during the last two century was available.

A relatively dense network of magnetic repeat stations that can be considered historical, since they were reoccupied several times, with reliable series of observations, was existing in Italy; at the same time a few magnetic observatories were simultaneously operating across the Italian peninsula (starting from 1882) allowing the single epoch reduction and the calibration of all repeat station surveys. The secular variation was then estimated not only at the Observatory location but also at several repeat stations for different latitude and longitudes allowing a check of the secular variation trend across all Italian area.

A steady secular variation trend was computed also for different epochs using the available surveys showing the time gradient of the field variation at different epoch.

Starting from historical repeat stations, that covered in certain cases a little less than two centuries, it was possible to show almost uniform monotonous trend of the secular variation of declination across the Italian peninsula. In order to compute accurately the secular variation spatial time distribution the Chistoni-Palazzo survey data were used to compute normal fields for declination in the form of a single latitude-longitude polynomials. This normal field compared to the 1990's ones allowed the computation of a normal field for secular variation. The mean value of secular variation of declination during the last century over the Italian peninsula is about 7 minutes per year.

Historical data are very important to improve our knowledge of the geomagnetic field and its variations. The study about the Italian geomagnetic network at different epoch we proposed, can also turn out to be useful to understand the regional field and its properties.

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A COMPARISON OF THE GEOMAGNETIC STANDARDS AT SURLARI, NIEMEGK AND WINGST (Short Note)

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Key words: Geomagnetism. Observatories.

Abstract: Differences between the elements declination D, inclination I and total intensity F at Surlari, Niemegk and Wingst geomagnetic observatories are reported. While Wingst seems to deviate in I and F by + 0.14' and - 2.5 nT respectively, Surlari shows a misalignment of - 0.58' for D.

Measurements

In October 1993 Surlari celebrated its 50 years anniversary. Niemegk and Wingst took the opportunity of measuring the declination D, inclination I and total intensity F at Surlary main pillars. The base-line values are given in Table.

Lower case letters (ngk, wng) denote comparisons with intermediate standards from Niemegk (DIfluxgate: Zeiss 010B, Bartington and proton magnetometer: built at the observatory) and Wingst (DIfluxgate: Zeiss 010B, Bartington and proton magnetometer: Geometrics 856) respectively; upper case letters (SUA, WNG) indicate observatory standards. Base-line val-

Table

Base-line values measured at Surlari Observatory on October 10, 1993, and differences between the standards of Surlari, Niemegk and Wingst

Element	D	I		F		
Pillar	P7	P6	P7	P2	P6	P7
Base-line values						
SUA	2°50.83'	61°33.32'		47597.1 nT		
ngk	51.49	33.30	61°33.20'	47597.5nT	(596.5)	
wng	51.33	(33.35)	33.25	594.9	(593.9)	47595.4 nT
WNG	51.33	(33.45)	33.35	595.3	(594.3)	595.8
Differences						
SUA - ngk	- 0.66'	+ 0.02'			+ 0.6 nT	
SUA - WNG	- 0.50	- 0.13			+ 2.8	
ngk - wng	+ 0.16	- 0.05			+ 2.6	
ngk - WNG	+ 0.16	- 0.15			+ 2.2	

Note: SUA and WNG: observatory standards of Surlari and Wingst respectively.
ngk and wng: intermediate standards (DIfluxgates and protonmagnetometers) Niemegk and Wingst respectively.

ues in parentheses are calculated from pillar differences.

Discussion

– Wingst total intensity, which refers to the Varian 4931 observatory standard, seems to be too low (WNG minus SUA/ngk: - 2.5 nT). The same is true for the Geometrics 856 intermediate standard. Note: the Wingst values are related to the old NBS gyromagnetic ratio of 1963. If they had been referred to the recommended new constant (Rasmussen, 1991), the difference would have been even higher.

– Wingst inclination standard seems to be too high (WNG minus SUA/ngk: + 0.14'). It is represented by a proton vector magnetometer absolute results of the measurements of the horizontal intensity and the vertical component. Similar deviations have been observed since 1990, when the Zeiss 010B theodolite was first used for comparison measurements between Wingst and numerous observatories across Europe.

– Surlari declination shows a slight westward misalignment (SUA minus ngk/WNG: - 0.58').

Conclusion

Special investigations are recommended so as to solve the discrepancies at Wingst and Surlari. The international intercomparison at the forthcoming Dourbes meeting in September 1994 presents a good opportunity to do so.

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NEW RECORDING SYSTEMS AND MEASUREMENTS AT NIEMEGK OBSERVATORY

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Key words: Managing of the observatory. Analogue variation recording. Digital variation recording. Data acquisition. Data base management. Proton vector magnetometer. Flux gate magnetometer. Absolute measurements. Comparison of different measurement methods.

Abstract: The situation of recording systems and data processing at Niemegk observatory at the beginning of 1992 is presented. The availability of modern geomagnetic sensors and the changed situation of Niemegk observatory as a department of the Geo Research Centre Potsdam required a new conception for the management of the observatory. On the basis of experiences of other observatories and own developments a conception has been elaborated and is now in execution. It encloses the acquisition, transmission, preparation and storaging in a data base of several magnetic field data. The conception and first results of comparisons to classical measurements are presented.

Niemegk observatory has been founded as a part of the royal Prussian meteorological observatory at the Telegrafenberg in Potsdam in 1890. Because of disturbances from the Potsdam tram and electric railway it had to change its place twice. At least it was built near the forest approximately 1 km westward from the little town of Niemegk. At the 70th birthday of Adolf Schmidt, on the 30th of July in 1930 it was inaugurated and was named Adolf-Schmidt Observatory for Geomagnetism Potsdam-Niemegk. The position is about 55 km south-west of Potsdam. The astronomical coordinates are: $52^0 4.3'$ north and $12^0 40.5'$ east. In the past the observatory belonged to several institutions. The last change was at the beginning of 1992. Niemegk observatory became a part of the Geo Research Centre Potsdam, which was founded on the first of January in 1992.

The classical recordings are still the base of the observations at Niemegk observatory. Table shows an overview of recordings and measurements. In the variation house four variometer systems are installed. In the south room the X, Y and Z components are recorded, in the west room H, D and Z, while in the east room the H, D and F recording and a storm system for H, D and Z are situated. The normal sensitivity is approximately 2 nT/mm. The storm variometer has a sensitivity of about 10 nT/mm. The recording speed is 20 mm/h, in the east and in the west room additionally 60 mm/h recording equipments exist. The absolute measurements are carried out in the absolute house by means of two different classical theodolites, named Wanschaff and Schmidt, and two proton magnetometers. Short periodic geomagnetic variations are recorded in analogue format. A three component induction coil variometer is used as sensor. The mean value of the sensitivity of the recordings is about 0.02 nT/sec/mm, the recording velocity is 360 mm/h. Two earth current lines of 1000 m length are recorded with a sensitivity of approximately 0.5 mV/km/mm in north-south direction and of 0.2 mV/km/mm in east-west direction. The results of the observations are published in monthly reports and yearbooks.

In the last twenty years some developments were carried out in the observatory to install digital recording systems and computers. Since 1976 momentary values of the components F, Z and Y are recorded each minute by means of proton vector magnetometers. In 1969 a digital recording system for short periodic variations on computer magnetic tape was installed. Three components of the magnetic field (X, Y and Z) and two electric components (E_x and E_y) were recorded each second usually on the three world days of each month. In 1974 a process control computer was installed. It was used for digital recording of short periodic variations, for preparing the monthly reports and the yearbooks and for several scientific calculations. In the eighties a microcomputer based system for digital recording of spectral parameters of short periodic va-

Table

Overview of recordings and measurements of Niemegk observatory

Variation house					
variometer systems:					
south:	X	Y	Z	2 nT/mm	20 mm/h
west :	H	D	Z	2 nT/mm	20 mm/h
					60 mm/h
east :	H	D	F	2 nT/mm	20 mm/h
					60 mm/h
	H	D	Z	10 nT/mm	20 mm/h

Short periodic variation recording				
$\frac{dX}{dt}$	$\frac{dY}{dt}$	$\frac{dZ}{dt}$	0.02 nT/sec/mm	360 mm/h

Earth current recording			
E_x	north-south 1000 m	0.5 mV/km/mm	20 mm/h
E_y	east-west 1000 m	0.2 mV/km/mm	20 mm/h

Proton vector magnetometer			
F	Z	Y	momentary values each minute 1 nT (1976-1991) 0.1 nT (since 1992)

Absolute house		
Theodolite Wanschaff	D	H
Theodolite Schmidt	D	H
Proton magnetometer	F	

riations was installed. Since 1970 lots of digital recordings of several geomagnetic variations were produced. In addition the results of earlier observations were recorded in computer readable form. For example all hourly mean values of the observations since 1890 were brought on computer. Now there is a large data collection on magnetic tapes (9 tracks, 800 bit per inch).

The new political and economic situation in the united Germany and the new institute brought fully new conditions for the observatory. The staff was reduced to seven persons, but the possibilities to get modern devices became better. That means that the manual labour has to be decreased by using modern equipments. The management of the observatory has to become more automatically, but the standard has to remain at the same level or has to become better.

Considering this situation a conception for using new recording systems was elaborated. Figure 1 shows this conception. Because of the not very satisfactory statement of the digital recording of momentary values by means of proton vector magnetometers it was planned to purchase fluxgate variometers. In addition it was intended to take part in the INTERMAGNET system. For this purpose so-called automatic geomagnetic observatory, produced by GEOMAG in France, was ordered. This device consists of a three-component

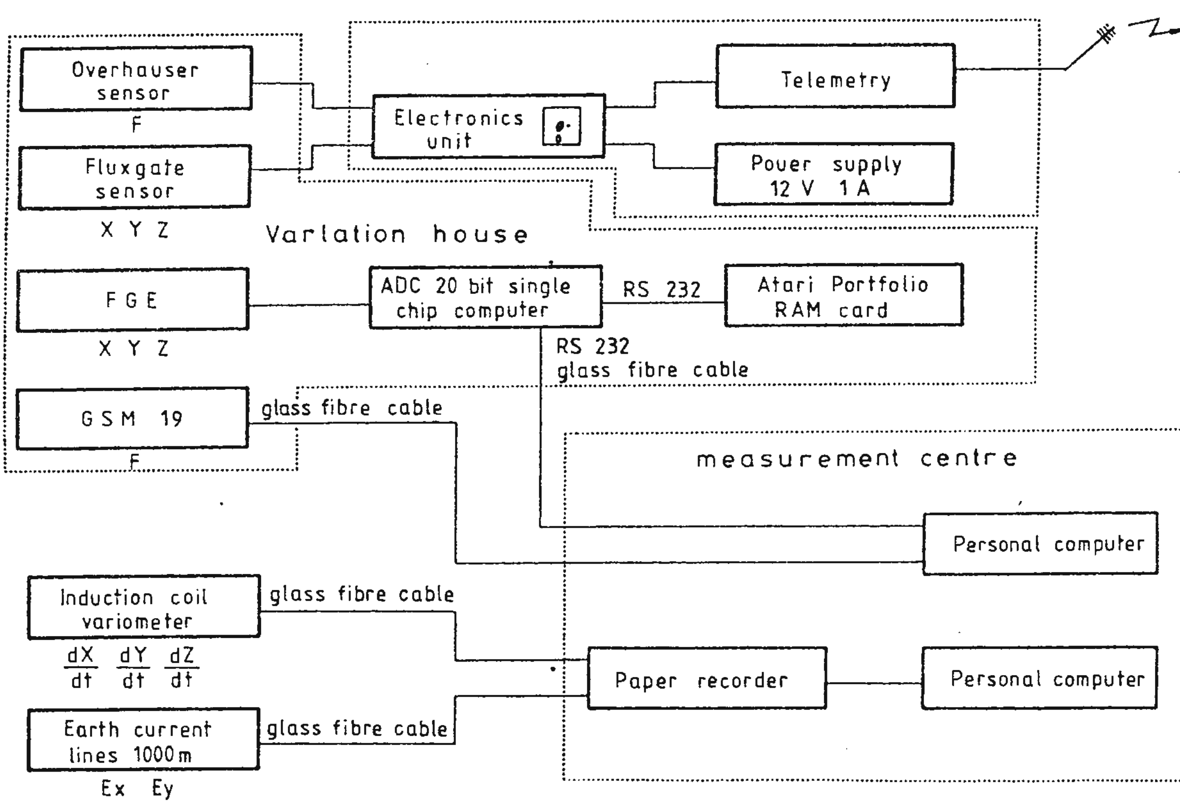

Fig. 1 – Conception of new recording systems at Niemegk Observatory

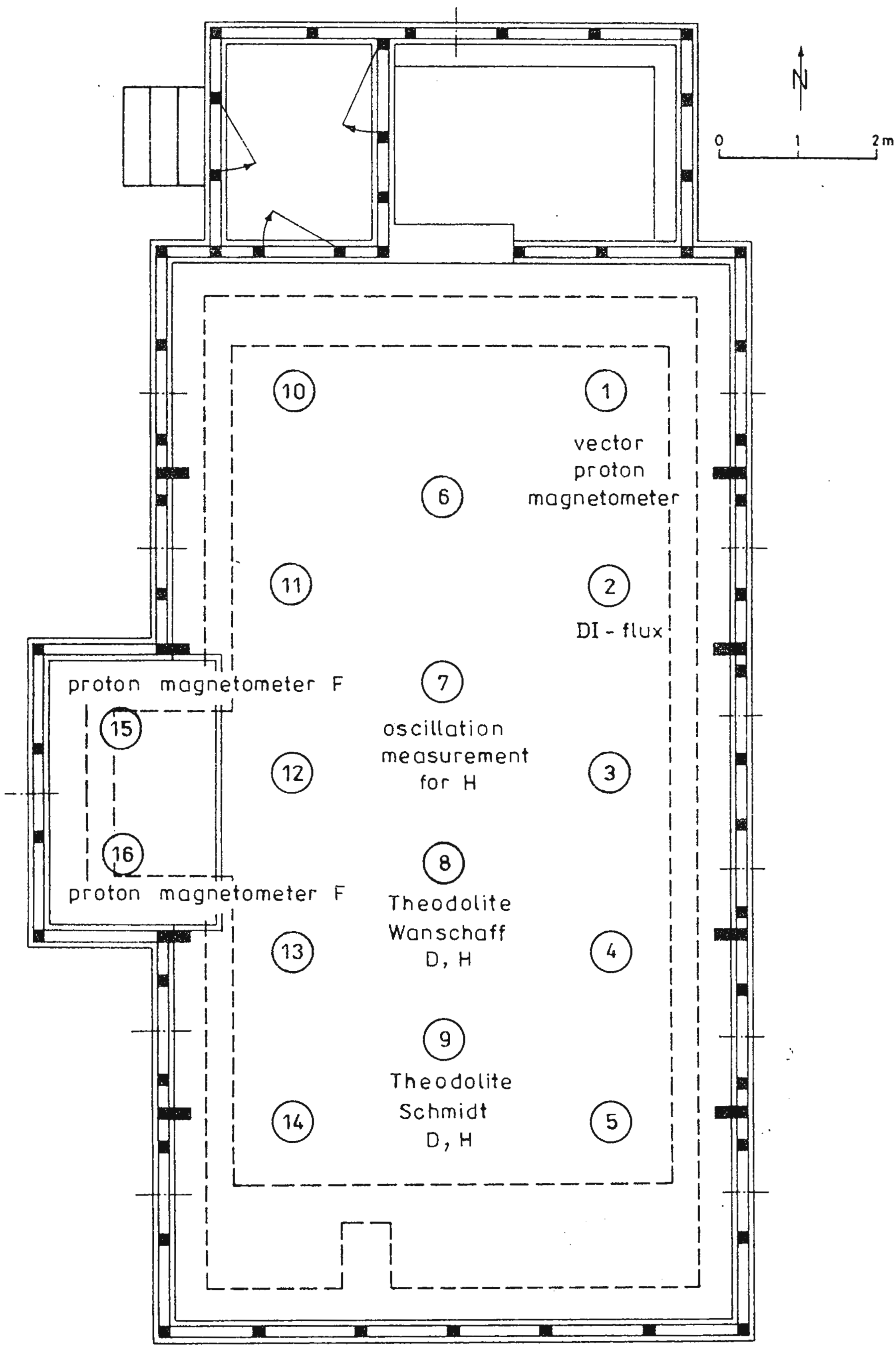

Fig. 2 – Lay-out of the instruments in the absolute house

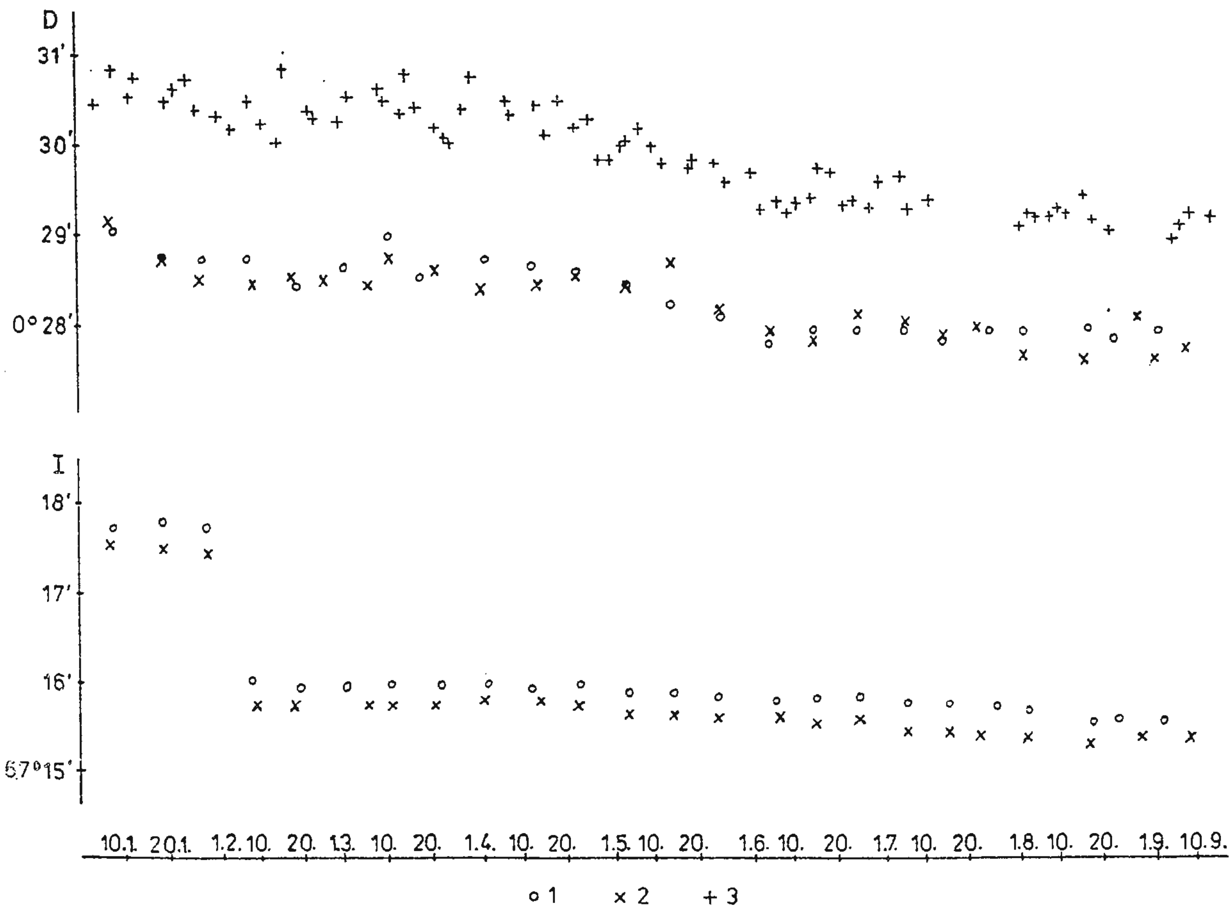

Fig. 3 – First results of the comparison of absolute measurements of D and I at Niemegk observatory in 1992. o, classical method; x, DI-flux; +, proton vector magnetometer.

fluxgate sensor, an Overhauser proton magnetometer and an electronic unit. A telemetry transmits the recorded variations via Meteosat to international computer networks. This device was installed in Niemegk in September 1993. Now the system runs at a preliminary place in test operation. The variations are recorded on a diskette in ASCII format. They are manually brought on a PC and compared with the recordings of the proton vector magnetometer. For the second a further fluxgate variometer is planned. A three-component variometer FGE is ordered at the Danish Meteorological Institute. This device consists of a suspended three-component sensor and the analogue electronics. It is intended to digitise the output voltages by means of a 20 bit CMOS analogue to digital converter. The digital recordings shall be read in by a small PC in pocked format, an Atary Portfolio with RAM card and sent to a PC in the measurement centre via glass fibre cable.

Digital recording of short periodic variations is carried out by a paper recorder, which is connected with a PC. The analogue to digital conversation is made near the induction coil sensors. The digitised signal in form of a frequency is transmitted via glass fibre cable to the measurement centre, where the paper recorder and the PC are located. The recorder velocity is 360 mm/h and the PC gets each second a set of three-component measurement values. In addition two earth current components (E_x and E_y) are recorded by the same way.

The conversion of absolute measurements by using modern methods was started about ten years ago. At the Niemegk observatory a Zeiss theodolite was completed with a proton vector magnetometer. It was used parallel to the classical absolute measurements and at measurement surveys. On the basis of several experiences, this device was improved more and more up to a half automatic stage. In addition to this method in 1992 two DI-flux theodolites were bought from Bartington and it is planned to buy a further Overhauser magnetometer for absolute recording of the total variation. Now absolute measurements are carried out parallel by means of three methods: the classical one, the DI-flux one and the proton vector magnetometer. All three methods shall be carried out parallel for several years and shall be compared. In the ground-plan of the absolute house (Fig. 2) it is shown, on which pillars the measurements are carried out. The first results of the comparison of 1992 are presented in Figure 3. At D component a good correspondence between DI-flux and the classical method is to be seen. Unfortunately a relative high difference of about two minutes exists between proton vector magnetometer and the classical method. Up to now the reason of this difference is not known. Further investigations have to be carried out to find the reason. At I component the results of the comparison between proton vector magnetometer and the classical method do not exist up to now. The constant difference of about 0.3 minutes between DI-flux and the classical method is probably the pillar difference. The jump of about 2.7 minutes in February is based on an adjustment of the H variometer on February the 2nd. The task of further investigations is the determination of pillar differences between the most important pillars of the Niemegk absolute house in the elements F, D and I.

At the beginning of 1993 all old computers, which were fifteen years old and older, had to be scrapped. Partly they were out of work and a repair was impossible or would take too much time. In the period since 1990 several personal computers were bought. All programs were transferred to PC. But the handling of all observatory data is not enough effectively at a PC. Because of that and because of the data centre conception of the Geo Research Centre Potsdam a Sparc workstation was bought. It has a main memory of 16 MB and a hard disk with a capacity of 1266 MB. The data handling shall be done by means of a data base, which is compatible with the data centre of the Geo Research Centre. All personal computers and the workstation of the observatory are connected by means of a local area network. It is intended to connect this LAN with the LAN of the Geo Research Centre in Potsdam. It gives in future the possibility for interested users to get the Niemegk observatory data direct via world wide computer networks. It is planned to make available all recordings of the observatory, which exist on computer magnetic tapes and all new recordings.

Niemegk observatory exists for more than sixty years at its today place. Up to now it is a relative quiet place. But the industrialisation of the eastern part of Germany increases. There is to pay attention, that this does not influence the accuracy of the recordings. In 1991 a railway line on a distance of about 11 km from Niemegk became electrificated. The result was a stronger influence of 16 2/3 Hz disturbances. Fortunately this does not disturb the recordings. But in 1992 the heating system of the variation house and the absolute house was reconstructed. The automatic heating boiler made periodic disturbances of some nanoteslas at several recordings. The boiler had to be switched off and a new one with a special constructed control was built in.

Niemegk observatory has a long tradition of development and manufacturing of geomagnetic devices. Unfortunately this tradition was stopped. In the Geo Research Centre only a little department for development of devices exists. At a rather low level there are activities on further development of geomagnetic devices. In particular a colleague works together with Russian institutes at the improvement of optical pumped magnetometers. It is expected that this development results in a very accurate magnetometer for the total variation for the observatory.

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A NEW DIGITAL MAGNETIC OBSERVATORY IN TRELEW, PATAGONIA

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Key words: Magnetic observatory. Argentina.

Abstract: A joint Belgian and Argentinian team improved the apparatus of the Trelew Observatory in Argentina. Reasons for the choice of this observatory, management and budgetary aspects are dealt with. The new instrumental array is described in detail and preliminary functioning results are provided.

Introduction

The second International Association of Geomagnetism and Aeronomy (IAGA) resolution adopted at the Vienna general assembly of the International Union of Geodesy and Geophysics in 1991 recommends "that those organisations in the developed countries that run magnetic observatory programs should each adopt one or more observatories facing problems and provide the necessary assistance and training to ensure continuing operation at a satisfactory standard, and that government funding agencies should consider this as a routine part of their international obligation to developing countries" (***, 1991). In 1992, IAGA announced Program Outreach which provides a central point through which contacts between potential donor observatories and those in need can be made (Williams, 1992).

Given the good connections existing between Argentinian and Belgian geophysicists, contacts were already established in late 1991 for studying the possibility for Belgium to help in improving the geomagnetic observatories of Argentina.

Choice of Trelew

We finally opted for a modernisation of the Trelew Observatory situated in the Chubut province, Argentinian Patagonia. The coordinates are:

Latitude: - 43.27^0, Longitude: 294.62^0.

The main reason for which we chose this observatory is that it is situated in a region where Observatories are very scarce. We see on Figure 1 that it is one of the few to lie between – 40 and – 60 degrees of latitude. The second reason is that the morphology of the geomagnetic field is extremely peculiar over this part of South-America. There is presently a record low in the modulus of the geomagnetic vector over eastern Brazil and Argentina. For instance, the mean value of the modulus is about 27000 nT in the Observatory of Trelew. This large scale feature of the geomagnetic field is of importance in a number of recent studies on the mechanism for geomagnetic polarity reversals (Gubbins, 1987), effect of the Earth's inner core on geomagnetic fluctuation and reversals (Gubbins, 1993; Hollerbach, Jones, 1993) and dynamo models (Gubbins, Sarson, 1994). A third reason is that the Trelew observatory is a reference station for computing the K index and that it is chronically late for providing this data to the data center.

Therefore it was felt that the needed help would better be materialised in the form of a complete digital observatory consisting of fluxgate sensors and a recording proton precession magnetometer. For good baseline control a DIflux would also be needed.

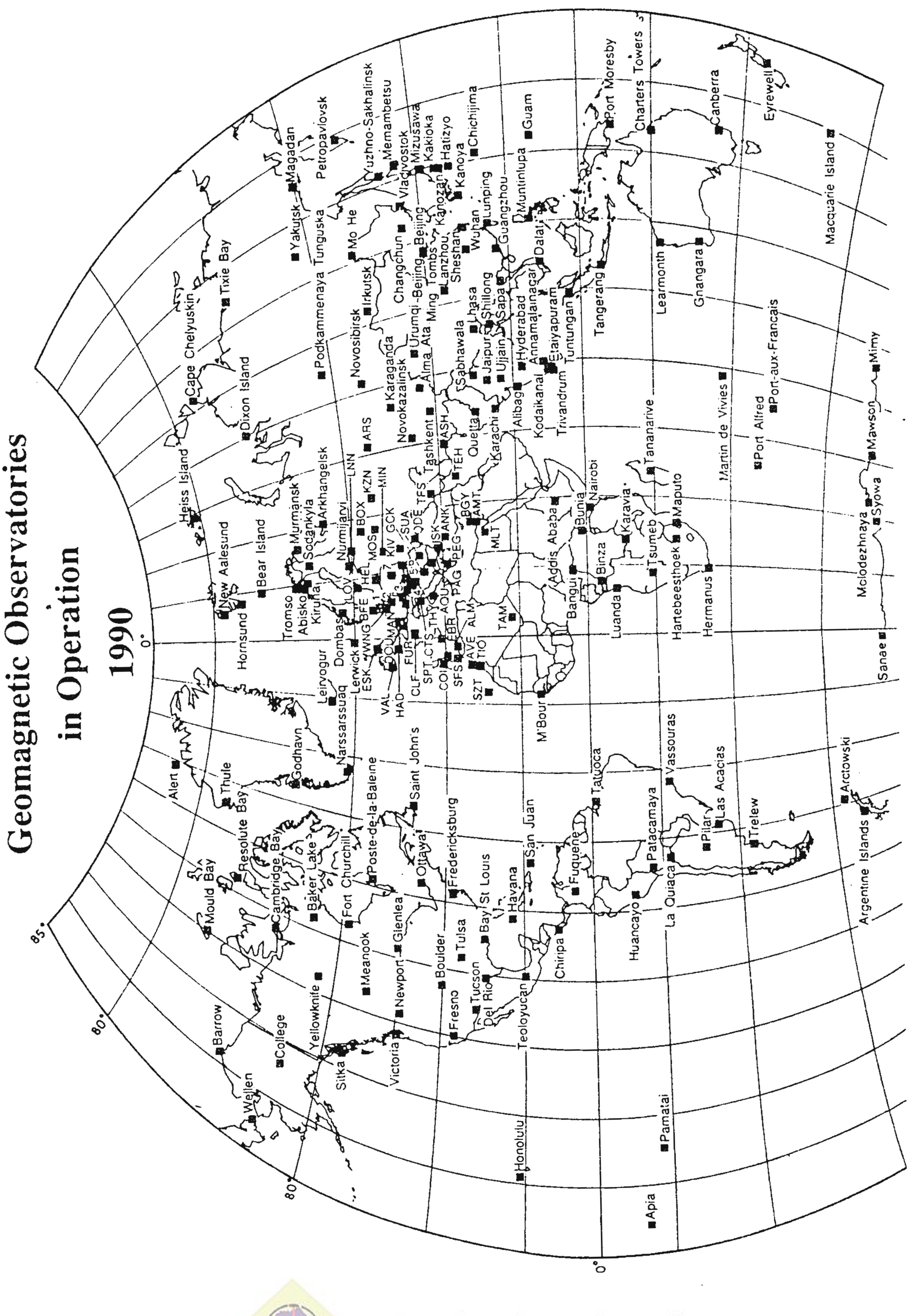

Fig. 1 – Map showing the global repartition of the magnetic observatories

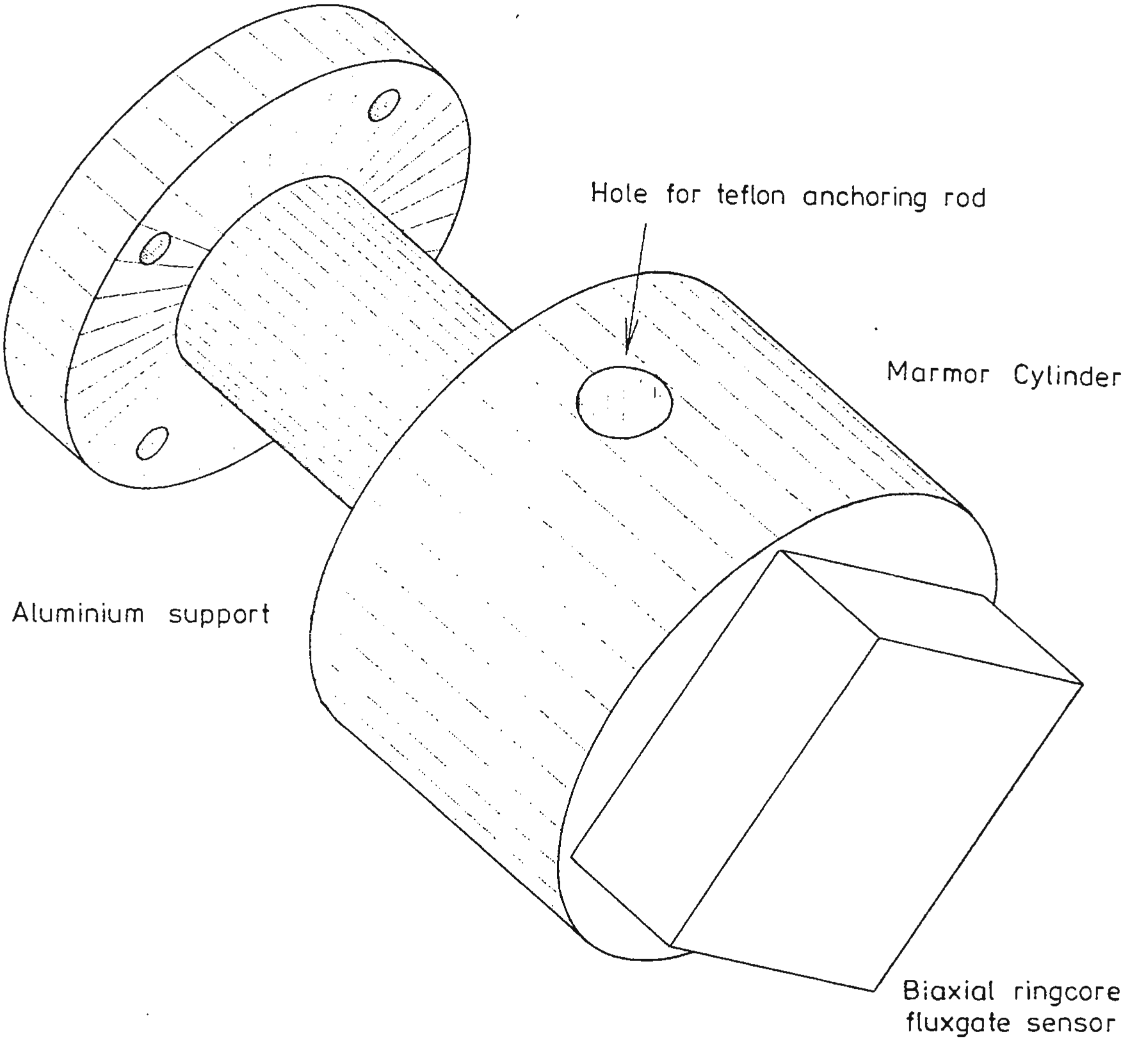

Fig. 2 – The aluminium-Teflon-marmor assembly. It allows the mounting of the biaxial fluxgate on an inclinometer frame. It is held by 4 screws at the rear. The hole in the marmor cylinder allows insertion of a Teflon rod on which the fluxgate is fixed by two screws (not shown). An axial screw in the aluminium support also clamps the marmor cylinder on the support by insertion in the Teflon rod.

Management of the Budgetary Aspects

It was decided that the instrumentation (except the recording PC) would be a free long term loan from the Royal Meteorological Institute of Belgium (RMIB) to the University of La Plata (UNLP). In this manner, we did not run into difficulties with the administration at RMIB since nothing was effectively removed from RMIB's estate. The instrumentation was mainly assembled from the unused pool of instruments belonging to the Belgian magnetic observatories of Dourbes and Manhay. Specifically new equipment was a custom fluxgate sensor, digitiser and parallel I/O interface cards, a dual power (24VDC 220VAC) PC and system power supply and battery charger. As the installation in Trelew was to be done directly after the 1993 IAGA assembly in Buenos-Aires, this equipment was transported as cabin and compartment luggage by one of us attending the assembly.

UNLP bought the PC and the batteries, cared for transport from Buenos-Aires to Trelew and for our living expenses during the two weeks necessary for the installation.

All those arrangements were registered in an "Acuerdo" undersigned by UNLP and RMIB before the operation began.

Instrumentation

4.1. The Variometer

The design goal was to realise a Declination-Inclination (DI) variometer for Trelew with a variational sensitivity of about 1 second of arc for both variables and a dynamic range of 2 degrees of arc. The long term stability should be better than 30 seconds of arc per year and the temperature coefficient lower than 10 seconds of arc per degree K.

We tried to achieve this by combining the following devices: The frame of an Askania rotating coil inclinometer. A biaxial ringcore fluxgate magnetometer.

The ringcore was a custom product made by the Special Design Division of the Institute of Physics and Mechanics in Lviv, Ukraine. The specifications called for a range of 2000 nT, 0.1 nT variational sensitivity, and nonorthogonality of the sensitive axis lower than 10 minutes of arc.

We removed all the rotating coil parts of the inclinometer and constructed an aluminium-Teflon-marble assembly (Fig. 2) destined at holding the fluxgate in the correct position at the centre of the now absent coil (Fig. 3).

netic field vector. As the ringcore has its two sensitive axes perpendicular to each other and in its plane, the next adjustment is done by rotating the marmor cylinder carrying the ringcore with respect to the aluminium support. The correct position is reached when one sensitive axis (this is the declination axis D) is perfectly horizontal, that is parallel to the horizontal rotation axis of the inclinometer. It is easy to check the correctness of this adjustment since any rotation around the horizontal axis of the inclinometer should give no change in the D output signal of the fluxgate electronics. Of course the other sensitive axis (this is the inclination axis I) is then optimally adjusted to record the variation in inclination.

It is noteworthy to point out that both the fluxgate sensors in the ringcore are working in "zero field" when set-up like that. The measurements are made around the null point of the sensors and no compensation field has to be generated. This removes one of the sources of thermal drift in the fluxgate variometer.

Another advantage stems from the fact that the two measured components of the geomagnetic field are identical to the ones measured by a DIflux. This en-

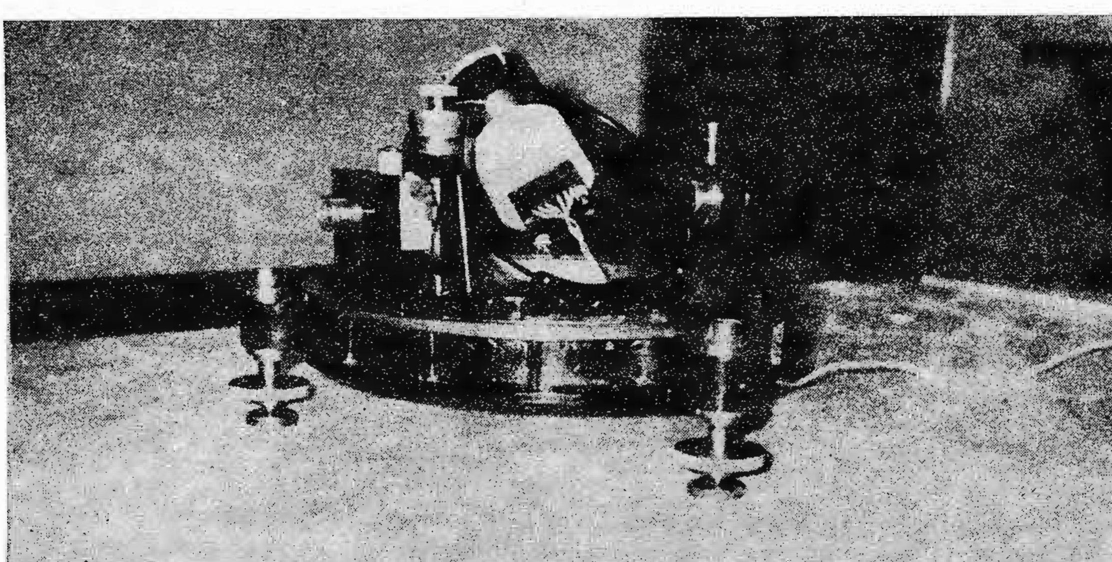

Fig. 3 – The biaxial fluxgate variometer as installed in the Trelew observatory. The frame of the inclinometer is clearly visible and the aluminium-Teflon-marmor assembly is shown holding the fluxgate sensor where the rotating coil was.

The inclinometer frame has a vertical rotation axis and a horizontal rotation axis, just like a theodolite. Levelling is done with the special Askania levelling device which is temporarily positioned on the horizontal axis journals and by obtaining equal readings of the level in orthogonal directions. The inclinometer frame provides all the mechanical controls and the slow motion adjustments necessary to position the ringcore correctly, i.e. with its axis aligned with the geomag-

sures complete independence in the data processing and the baseline determination. Should one channel of the variometer fail or should one measurement of the absolute session be bad or even should the proton precession magnetometer malfunction, it would leave the measurement of the other channel unaffected, valid and useful. This is not true for a XYZ variometer whose bases are determined with a DIflux and a proton precession magnetometer.

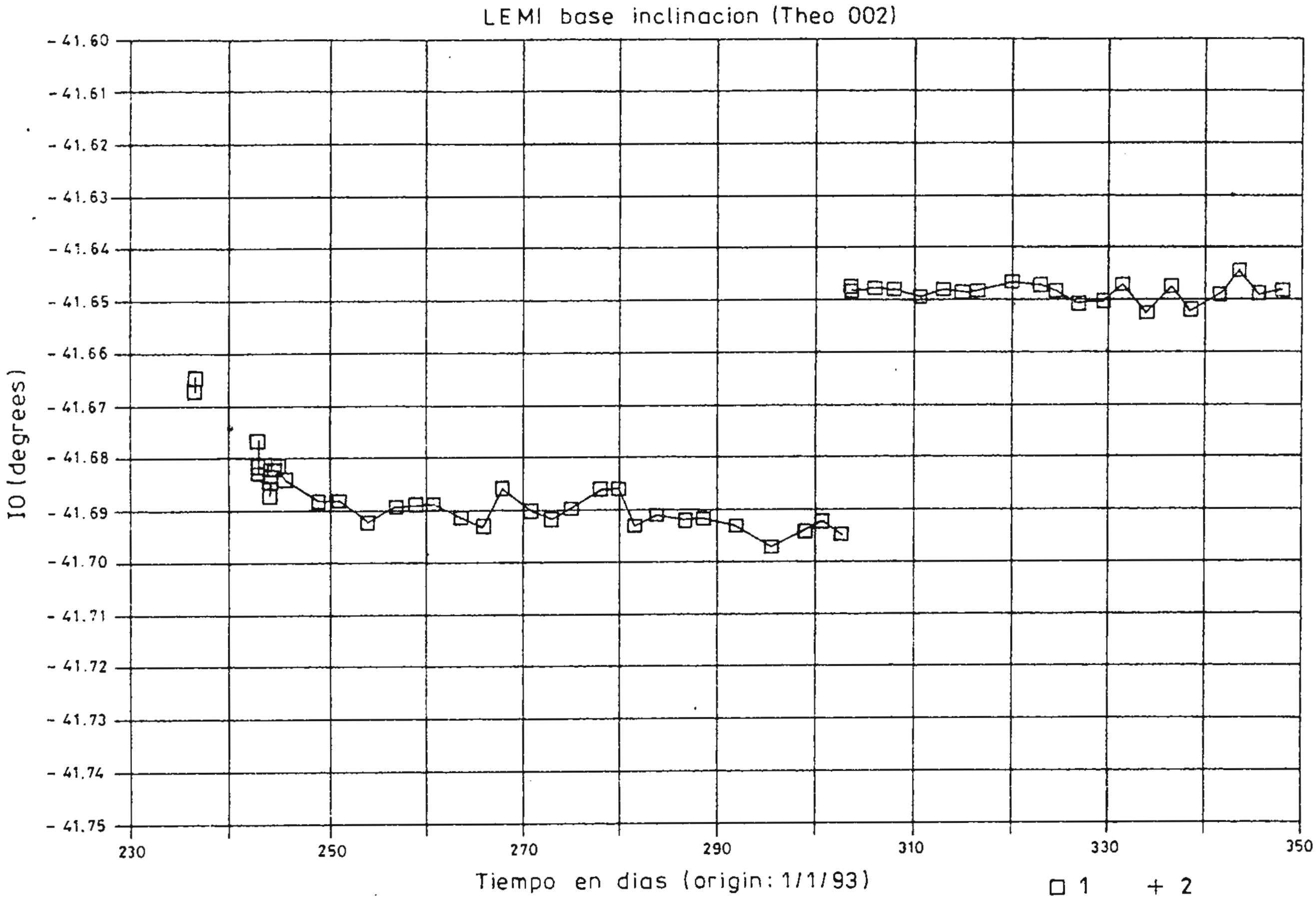

Fig. 4 - Evolution of the inclination baseline of the variometer as given by the DIflux for more than 100 days after the installation in Trelew. The jump on day 303 is due to a baseline adjustment.

The formula allowing to compute the variations in declination dD and in inclination dI in degrees from the data D and I stored on diskette is given by:

$$dD = \arcsin [(D/V)\ (1/H)]$$

and

$$dI = \arcsin [(I/W)\ (1/F)],$$

where H is the mean value of the horizontal and total component of the geomagnetic field in Trelew (typically H: 20000 nT, F: 27000 nT). V and W are the scale factors and were measured in Dourbes by comparing with other variometers having well-known scale value. They depend on the fluxgate electronics, the preamplifier gains and the AD converter gain. They were found to be given with an accuracy of about 2% by: V = 7. 6, W = 7.6.

4.2. The Recording Proton Precession Magnetometer

The proton precession magnetometer (ppm) is of ELSEC 880 type. It was set for continuous measurement. We suitably transformed it for communication with a parallel I/O PC card. Therefore the BCD and digit lines coming from the MC145345 decade counter chip in the ppm electronics along with some control lines where level-shifted to 5V and sent to the I/O card. This gave a compact interface unit allowing the ppm electronics to stay well away from the PC computer. This also left most of the acquisition job to be done by the software.

The ppm was tested in Dourbes (F = 48000 nT) in an artificially decreased field to confirm its satisfactory operation at around 27000 nT.

Upon installation in Trelew, considerable difficulties where experienced with this magnetometer. It would not make any reasonable measurement at the beginning. After extensive troubleshooting, it was noted that the PC was perturbing the ppm operation. Indeed, PC's are known to radiate a lot of electromagnetic noise. The problem was corrected by installing the ppm electronics as far as possible from the PC and by installing a ground (earth) plate with an earth line connected to the PC chassis.

The ppm will continuously measure the total magnetic field at the rate of one sample every 6 seconds with a resolution of 0.25 nT.

4.3. The DIflux

The DIflux was assembled from a F. W. Breithaupt & Sohn brass theodolite and an ELSEC type 810 fluxgate magnetometer. The theodolite has better than 1 second of arc accuracy but has no automatic height index like the Zeiss 010B. Hence, the horizontal reference for the vertical circle has to be observed with the height index bubble (Deumlich, 1980). The graduated circles are read by two separate microscopes at 180^0. The modifications done to the theodolite were:

- replacement of several magnetic parts by corresponding non-magnetic aluminium items;
- mirror-based lighting of the circles, compatible with the Zeiss requirements;
- mounting bracket on the telescope for the fluxgate sensor.

This instrument was tested for two years in the Manhay observatory. The tests were comparison measurements with a standard Zeiss 010B DIflux. A measurement protocol for the Breithaupt was found which led to no noticeable difference (< 5 seconds of arc) between the two instruments.

Figure 4 gives a drawing of the variometer inclination baseline measurement for more than 100 days of recording. After an initial drift following the installation, the instrument stabilised to a long term noise level of less than 10 seconds of arc. Note that this data includes absolute measurement noise and variometer noise.

4.4. The Data Acquisition

The acquisition is based on a IBM PC XT compatible computer equipped with real time clock, with one 360 kilobytes 5 1/2" and one 3 1/4" 720 kilobytes disk drive but without a hard disk. There is also a Hercules graphic adapter and display, a 14 bit 16 channel ADDA converter card and a digital 48 lines I/O card. The software for running the magnetometers and for the acquisition is the same as the one used for all Belgian observatories (Rasson, 1991) except for the acquisition of the ppm.

The dual input power supply (WEIR ADC1502400) is able to power the PC either from the mains or from a 24 V lead-acid battery. It also charges said battery at constant current. Moreover it powers the biaxial fluxgate electronics and the ppm. In this way an autonomy of two days is ensured for the digital magnetic observatory from mains failure.

Conclusion

It is shown in this paper how the IAGA resolution 2 (1991) could be implemented to "revaluate" the Trelew magnetic observatory. This has been achieved with a modest level of funding but nevertheless permitted the installation of a modern digital magnetic observatory with all facilities needed to produce high quality data.

We hope that in a near future we will be able to connect an INTERMAGNET transmitter to this equipment.

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LA DIRECTION DU CMT EN FRANCE, DURANT LES 21 DERNIERS SIÈCLES

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Key words: Archeomagnetism. France.

Abstract: *Direction of the TMF in France During the Last 21 Centuries.* The object of this paper is to present the complete directional archaeomagnetic data at present available for France from backed clay found *in situ*. Bivariate statistics have been used to draw the curves of the variation of the direction of the terrestrial magnetic field (TMF) for Paris during the last 21 centuries. These results should, on the one hand, contribute to a better understanding of the Earth's magnetic field and, on the other hand, allow an accurate assessment of the limits of the method of dating backed clay structures by archaeomagnetism.

L'exposé porte sur l'analyse de l'évolution, pendant deux millénaires, de la direction du champ géomagnétique, révélée par les informations conservées dans des structures archéologiques non déplacées depuis le temps du dernier refroidissement – fours et foyers –; c'est à dire, obtenue par des études archéomagnétiques.

La variation récente de la direction du CMT a été étudiée sur quelques dizaines d'années, à partir des enregistrements fournis par les observatoires magnétiques; elle a pu même être suivie plus loin dans le passé, grâce à des mesures directes ponctuelles, effectuées avec des boussoles depuis quatre siècles.

Apparemment, les courbes sont analogues, à un décalage près, du fait des différences de latitude de ces trois villes; elles présentent une régularité qui laissait penser que les ovales allaient se fermer; on a pu en déduire, trop rapidement, une périodicité de la variation séculaire (Fig. 1).

Ainsi, la connaissance de la variation séculaire de la direction du CMT se serait arrétée là, s'il n'y avait pas eu la remarquable propriété des terres cuites, leur "mémoire magnétique". Il a été démontré qu'une argile, chauffée au-dessus du point de Curie de ses minéraux constituants, puis refroidie jusqu'à la température ambiante en présence d'un champ magnétique, acquierait lors du refroidissement, une aimantation rémanente appelée "aimantation thermorémanente" (ATR); cette aimantation a la même direction que le champ magnétique qui régnait au moment du refroidissement, et dans le cas de plusieurs chauffes successives, au moment du dernier refroidissement.

L'argile a été utilisée depuis des milliers d'années dans la construction des fours et des foyers. Par conséquent, si de telles structures pouvaient être datées soit à partir des données archéologiques, soit par d'autres méthodes physiques de datation (dendrochronologie, thermoluminescence), en étudiant leur ATR, on pourrait obtenir la direction du CMT au moment du dernier refroidissement. L'ATR représente un enregistrement "indirect" de la direction du CMT à ce moment bien précis. Il est évident qu'il est indispensable que les structures soient bien "en place" (pas bougées par rapport à leur position au moment du dernier refroidissement).

L'étude de l'ATR des structures archéologiques bien datées, apparaît comme une source importante d'informations permettant de prolonger la courbe de variation séculaire de la direction du CMT, dans le passé plus lointain.

Les premières études systématiques d'archéomagnétisme ont été entreprises, en France notamment, par E. Thellier. Dand sa dernière publication (E. Thellier – Sur la direction du Champ Magnétique Terrestre en France durant les derniers millénaires. *Physics of the Earth and Planetary Interiors*, 24 (1981), . 89–132), il a présenté une courbe de la variation séculaire du CMT en France, durant les deux derniers millénaires. Depuis, environ 90 nouvelles structures archéologiques ont été étudiées; elles complètent la courbe de E. Thellier, et affinent certaines parties, et

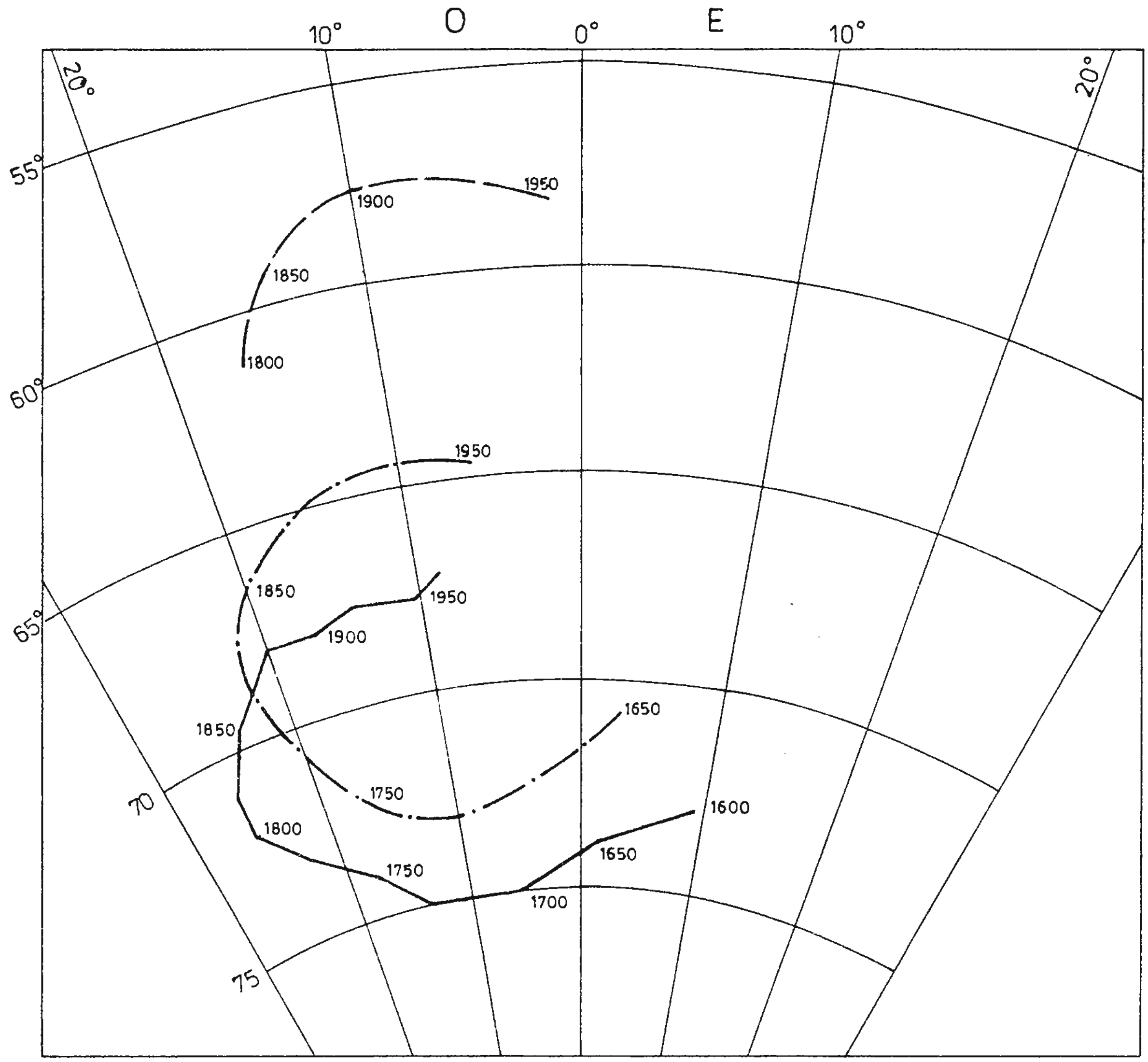

Fig. 1 – Variation de la diection du CMT tracée d'après des mesures directes: - à Londres jusqu'à 1600; - à Paris jusqu'à 1650; - à Rome jusqu'à 1800.

la prolongent d'un siècle dans le passé.

Bien que le nombre de sites étudiés à ce jour en France ait presque doublé par rapport à celui utilisé par E. Thellier, la répartition sur l'ensemble du pays reste très inégale dans l'espace. De ce fait, une seule courbe a été tracée pour tout le territoire (Fig. 2).

Les datations avancées par les archéologues ont été, dans l'ensemble, d'une précision médiocre: rarement fournies par des documents historiques, qui seuls donnent des fourchettes très serrées, elles ont été obtenues, dans beaucoup de cas, par d'autres méthodes physiques de datation, par la typologie de la céramique des tessons mis au jour, ou encore par des monnaies.

Par ailleurs, il aurait été souhaitable de disposer d'une dizaine de sites/siècle, du fait que toutes les directions d'ATR ne sont pas de fiabilité égale. Ceci n'a pas souvent été le cas, et ce manque, ajouté à certaines datations très imprécises, a souvent limité la précision du tracé de la courbe d'évolution de la direction du CMT.

La courbe de variation séculaire de E. Thellier, comme toutes celles établies dans les années '80 pour d'autres pays, ont été tracées à l'oeil; elles passaient, au mieux, au milieu des points représentatifs (Fig. 3). La représentation est faite sur une projection à surfaces égales. Chaque point représente une direction moyenne d'ATR (couple I, D), obtenue par calcul, en appliquant la statistique de Fisher à l'ensemble des directions individuelles mesurées sur chaque site.

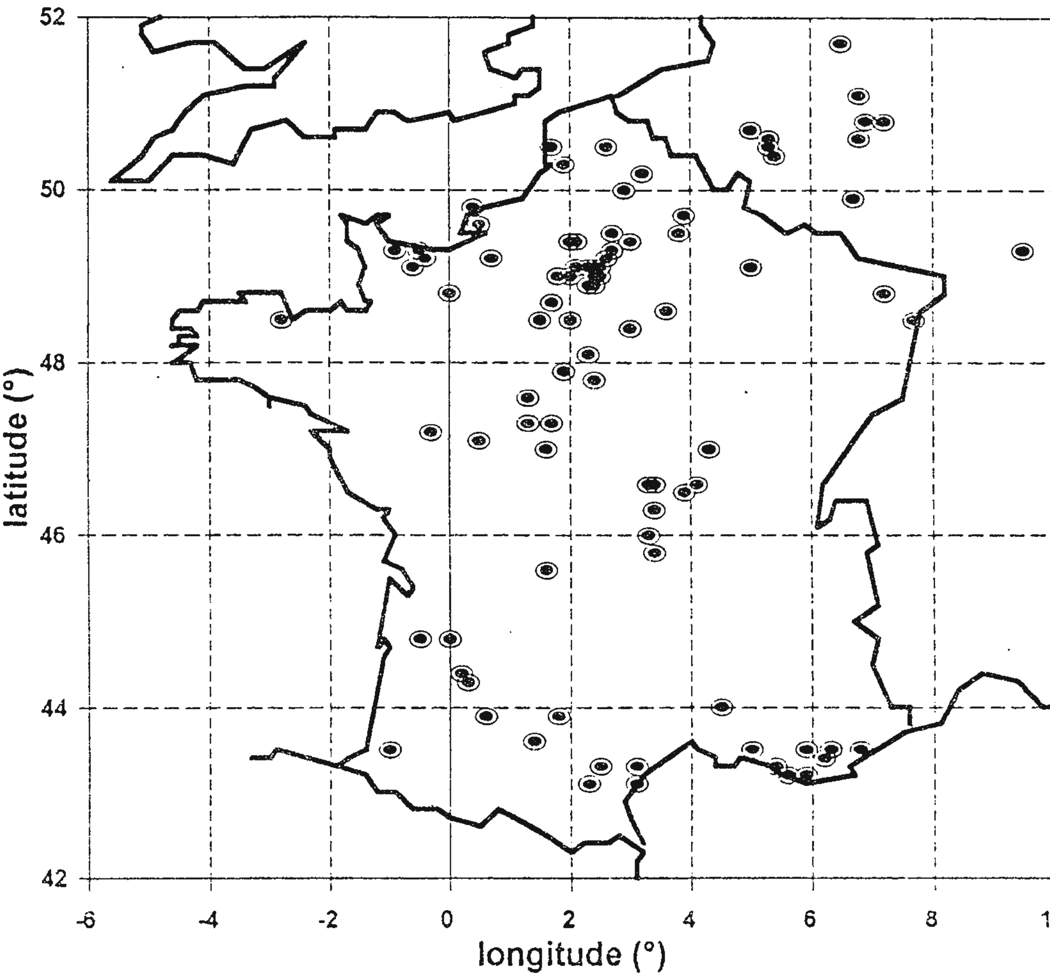

Fig. 2 – Répartition des sites sur le territoire de la France

Depuis, différentes approches statistiques ont été dévelopées. Actuellement, les courbes de variation séculaire apparaissent sous forme de bandes, dont les largeurs variables représentent l'incertitude sur le tracé.

Pour la courbe française actuelle[1] nous avons utilisé la méthode statistique bivariate de M. Le Goff. Cette méthode fournit l'ovale de confiance autour de la direction moyenne d'une somme pondérée de populations vectorielles. La pondération appliquée ici est fonction de la proportion de la durée d'âge attribuée à une structure, interceptée par une fenêtre mobile de 80 ans. La succession des ellipses trace le chemin probable de la direction du CMT réduit à Paris.

La réduction appliquée a été celle par passage au PGV (pôle géomagnétique virtuel): on a calculé d'abord les coordonnées géographiques du pôle géomagnétique virtuel, puis on a déduit la direction D, I correspondant à Paris, dans l'hypothèse du dipôle central incliné (Fig. 4).

Un examen bref de cette courbe, permet les observations suivantes:

– la non-régularité de la variation séculaire (forme non-circulaire et pas de périodicité évidente);

– une grande ampleur en déclinaison $\pm$ 20^0 (22^{0}E vers l'an 1000, 22^{0}W sous l'Empire);

– une certaine symmétrie par rapport au méridien géographique (la direction moyenne sur 2000 ans étant $\cong$ 65^0 en inclinaison et $\cong$ 4^{0}E en déclinaison), ce qui est très proche de la direction du dipôle axial centré. Les données archéomagnétiques sur les deux derniers millénaires, n'infirment pas l'hypothèse du paléomagnétisme qui considère que la configuration du CMT à l'échelle des temps géologiques, a été celle d'une champ crée par un dipôle axial centré;

– toutes les parties de la courbe n'ont pas un tracé d'égale finesse, mais, la partie comprise entre 1000 et 1400 après J.C., est actuellement bien précisée, avec

[1] I. BUCUR, The Direction of the Terrestrial Magnetic Field in France During the Last 21 Centuries. Recent Progress. *Physics of the Earth and Planetary Interiors*, 1994 (sous presse)

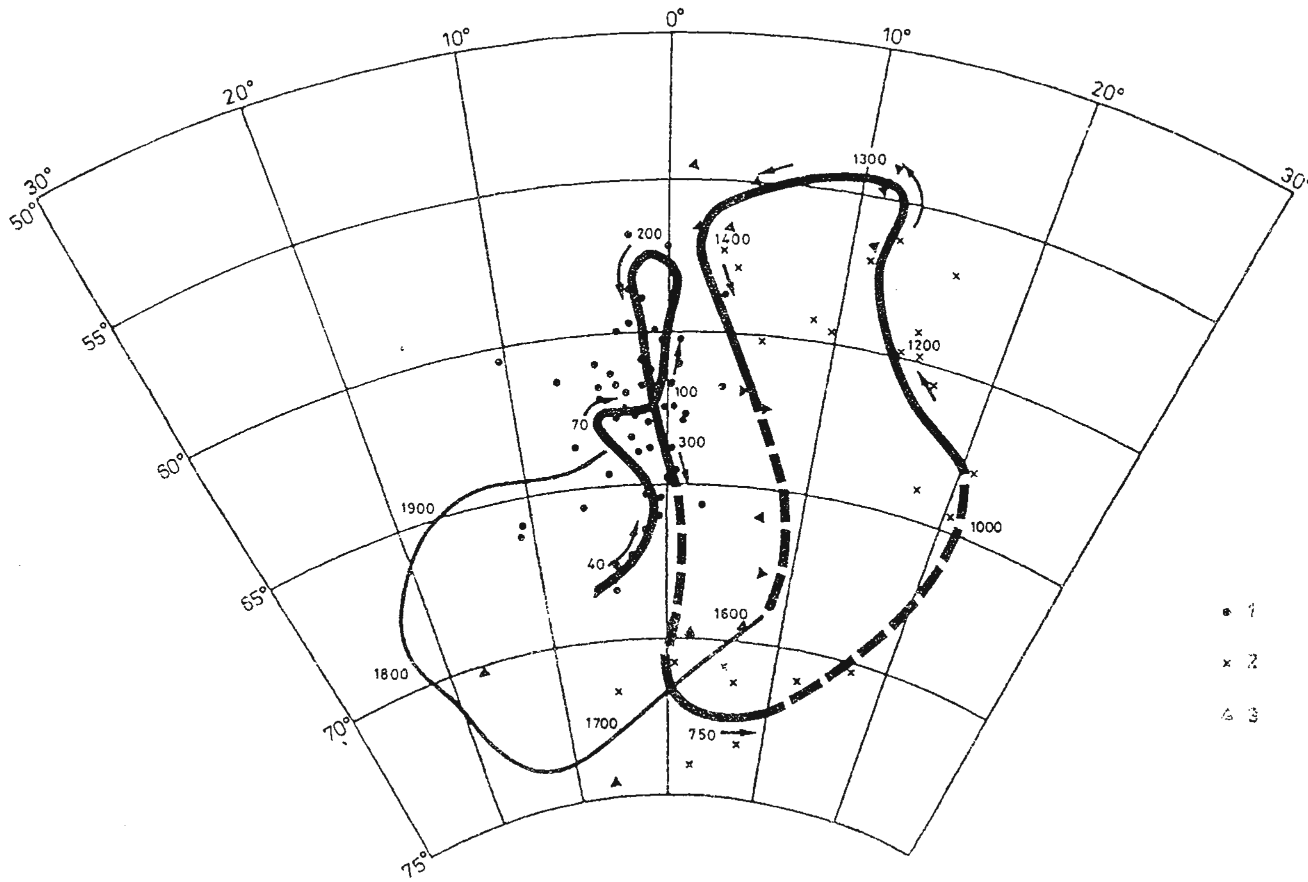

Fig. 3 – Variation séculaire de la direction du CMT en France (E. Thellier, 1981).
1, 0–400, 2, 400–1250; 3, 1250–1800.

un minimum très marqué situé entre la fin du 14ᵉ et le début du 15ᵉ siècle.

Conclusions

Bien que pour certaines périodes la courbe française nécessite des observations supplémentaires afin que tout son tracé soit d'égale finesse, elle apparaît comme assez complète, les valeurs de D et I couvrant de façon continue les 21 derniers siècles. Ces données devraient donc contribuer à améliorer notre connaissance du champ magnétique terrestre. Lorsque la variation séculaire du champ géomagnétique, sera aussi bien connue dans un grand nombre d'autres sites mondiaux (ces derniers sont actuellement en nombre réduit), des contraines plus réalistes pourront affiner les modèles théoriques, ce qui conduira certainement, à des progrès plus rapides dans la compréhension du CMT.

Par ailleurs, la courbe française présente aussi un intérêt au point de vue des applications de l'archéomagnétisme, et cela, en vue de la datation des structures archéologiques.

Les "limites" de la méthode de datation archéomagnétique sont les suivantes:

– durant l'intervalle 0 à 400 après J.C., l'inclinaison varie très vite selon une pente descendante de l'an 0 à 200, puis ascendante de 200 à 400, alors que la déclinaison conserve constamment des valeurs voisines de 0^0; pour une même inclinaison, deux dates apparaîtrons comme tout aussi probables;

– pour la période s'étendant de 700 à 900 après J.C., le tracé de la courbe est encore incertain. La fourchette de datation fournie par l'archéomagnétisme restera donc de l'ordre du siècle;

– par contre, pour la période 1000 à 1400 après J.C., dans des conditions expérimentales satisfaisantes, la précision de la méthode est de l'ordre du quart de siècle.

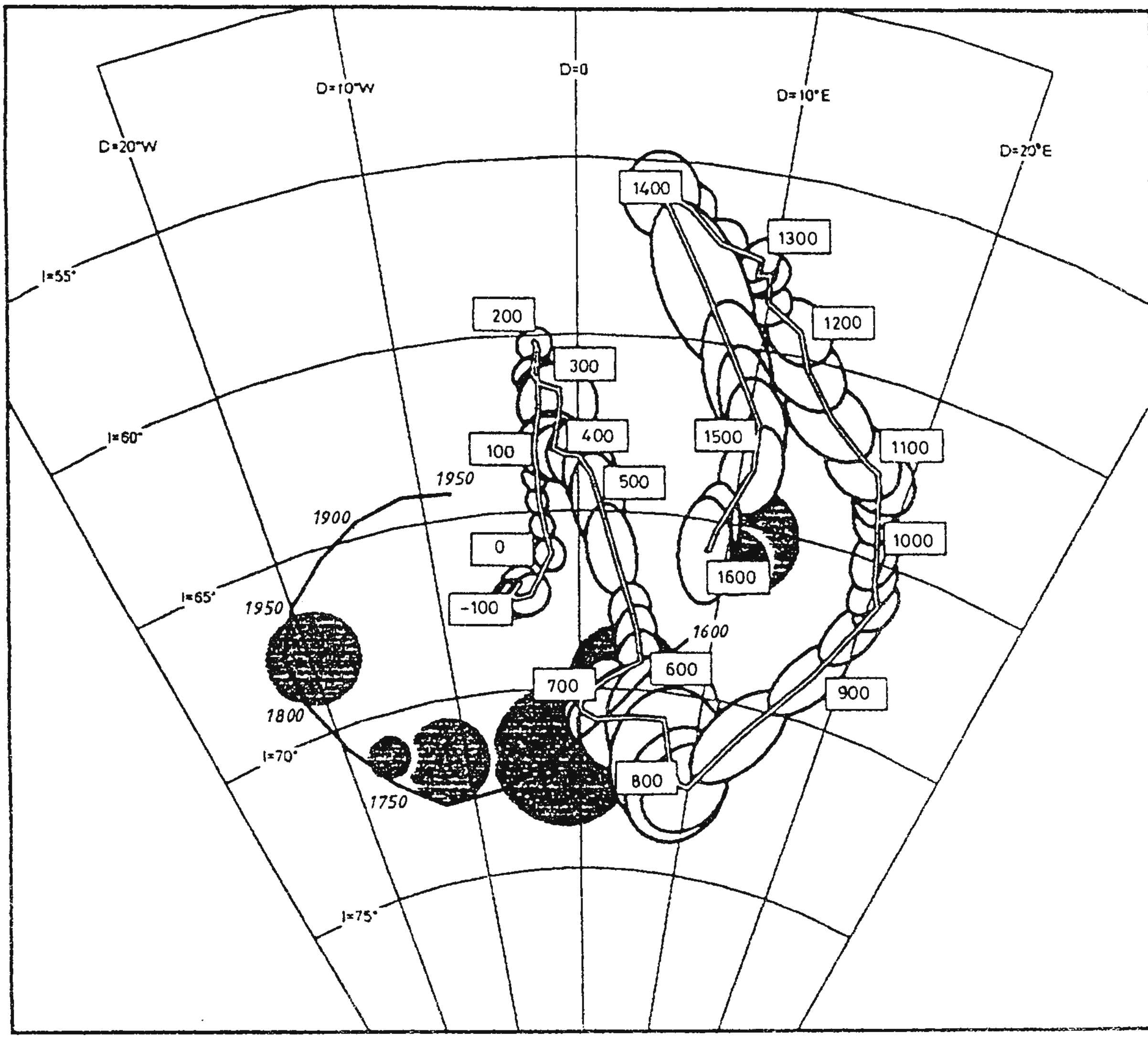

Fig. 4 – Direction du CMT au cours des 21 derniers siècles (réduit à Paris): – 100 à 1600 A.D. (courbe archéomagnétique (fenêtre glissante de 80 ans)); trait épais de 1600 à 1950 (variation séculaire à partir des observations directes); cercles gris foncé de 1500 à 1800 (cercles de confiance à 95% des directions individuelles obtenues sur structures archéologiques datées (période correspondant aux mesures directes)).

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OBSERVATORY MAGNETOMETER

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Key words: Flux-gate magnetometer. 3-Component Observatory.

Abstract: An observatory 3-component flux-gate reference magnetometer has been developed. There are two versions of the sensors: ring-cores with ceramic housing and racetracks mounted on a marble cube. Resolution: 0.1 nT. Range: ± 2000 nT. A 6-months test showed zero line fluctuations within a 5 nT range. Also two and one component magnetometers for geophysical and industrial applications have been developed.

The modern state of geomagnetic investigations needs very high precision of the data, obtained from magnetometers. Among various types of magnetometers the flux-gate version seems to be the most prospective in order to get high class results at relatively low cost. Special Design Division of Academy of Sciences of Ukraine and Eötvös Lorand Geophysical Institute of Hungary collaborate in the branch of the development of flux-gate magnetometers. As a result, three-component reference magnetometer DIMARS-LEMI for observatory use was designed. The most important part of the magnetometer is the three-axial flux-gate sensor. Two versions of such sensors were manufactured: ring-cores with ceramic housing and race-

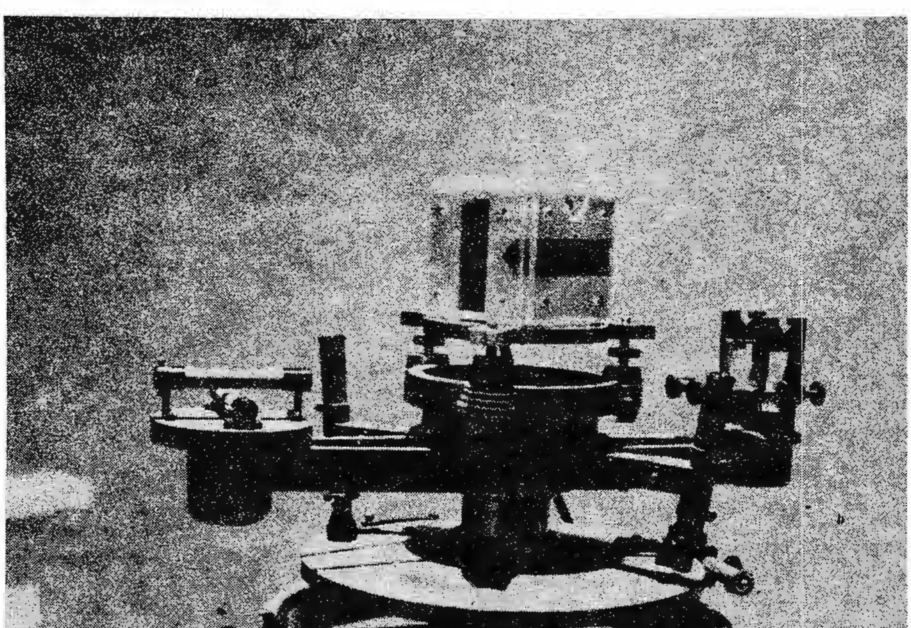


Fig. 1 – DIMARS-LEMI observatory magnetometer. Rigid fixation variant.

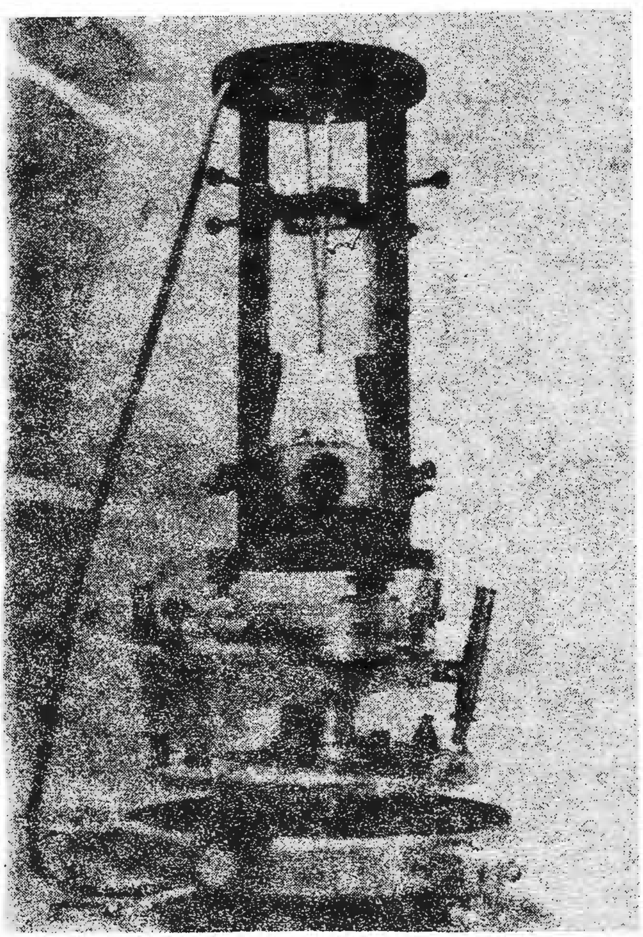


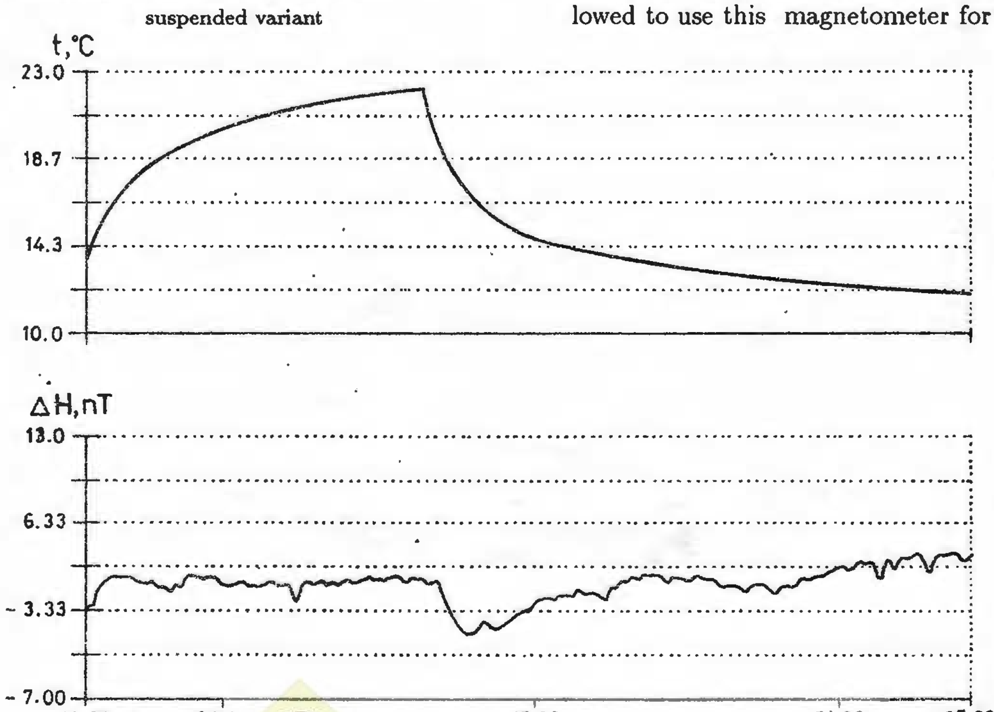
Fig. 2 – DIMARS-LEMI observatory magnetometer suspended variant

tracks, mounted on marble cube. Both these versions can be implemented as for a rigid fixation upon an observatory's pillar (Fig. 1), in the suspended variant for the compensation of tilts, provoked by small movements of the earth's surface (Fig. 2). The peculiarity of the sensor design is the use of the ferroresonance excitation mode of the core, when the amplitudes of current and voltage of the excitation signal are shifted by 90 degrees in phase. It allows to reach high current values and, correspondingly, high saturation of the sensor core with relatively moderate consumed power and, as a result, lower heat dissipation in the sensor volume. Such excitation mode gives also lower noise level: typical value is 20 pT rms in the frequency band 0. 03 – 1 Hz, the lowest values can be about 4 – 5 pT.

The electronic box consists of two parts: the measuring device, which transforms magnetic field components values into digital codes and the data acquisition system with floppy disk driver for data recording. Typical resolution of magnetic field measurements is about 0.1 nT, and full range of the measured deviation is ± 2000 nT.

The most important parameters of the observatory magnetometer are temperature and temporal stabilities. Some specimens of the magnetometers were manufactured and thoroughly tested at Tihany geophysical observatory. The temperature stability seems to be rather good. As can be seen from the Figure 3, it is about 0.1 nT/C except transition period.

The long-term tests of the DIMARS-LEMI magnetometer showed that for a 6 months period the zero line in the circumstances of the Tihany observatory was fluctuating within the limits of 5 nT. All that allowed to use this magnetometer for the Intermagnet



network service in the Tihany observatory.

Besides two- and one-components magnetometers are developed for different geophysical and industrial applications, the measurement range of which is from 0.1 to 500000 nT according to the version.

Both these have two modifications: with broad frequency band, which allows to use them also for A. C. magnetic field measurement to 1 kHz, and D. C. only with very deep A. C. fields compensation due to a special design of the sensor. The last modification is convenient for magnetic field measurements in industrial conditions: main frequency and pulse noise do not disturb its readings.

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L' INTERPRÉTATION GÉOLOGIQUE DES DONNÉES GRAVIMÉTRIQUES ET MAGNÉTOMÉTRIQUES DE LA ZONE DE MĂDĂRAŞ - SATU MARE

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Key words: Magnetics. Gravity. Apparent density. Interpretation. Intrusion. Hydrothermal transformation.

Abstract: *Geological Interpretation of the Gravity and Magnetic Data in the Mădăraş-Satu Mare Area.* The aim of the paper is to establish the geologic source of an aeromagnetic ΔT_a anomaly of great extension and an amplitude of more than 100 nT (also obvious in the ground magnetic ΔZ_a data) mapped in the Moftinu Mic - Doba - Sătmărel - Ruşeni - Mădăraş - Gelu - Terebeşti - Moftinu Mare area, south and south-west of Satu Mare. It is shown that the two magnetic anomalies cannot be explained entirely by the effect of the magnetic rocks of the sedimentary cover, so the main source must be an intrusive body. For a presumed magnetic susceptibility of $1800*10^{-6}$ uCGS, the 3D interpretation makes evident a body whose root is parallel to the North-Transilvanian fault (at about 5 km north of it) and reaches a depth of more than 8000 m. The body has its maximal horizontal extension at the depth of about 4000–5000 m and has its most elevated part in the Mădăraş area. It has also a possible hydrothermally transformed zone, magneticaly inactive, in the Hrip - Ruşeni - Cionchești - Amaţi area. The interpretation of the gravity data supports the conclusions provided by the magnetic data.

Introduction

L'intérêt pour l'interprétation géologique intégrée des données géophysiques de la zone de Mădăraş - Satu Mare a été suscité par l'existence d'une anomalie aéro-magnétométrique de grande extension et dont l'amplitude dépasse 100 nT, sur l'aire délimitée de manière approximative par les localités Moftinu Mic - Doba - Sătmărel - Ruşeni - Mădăraş - Gelu - Terebeşti - Moftinu Mare. Cette anomalie se retrouve également dans les mesures ΔZ faites au sol et est placée dans le proche voisinage de la Faille Nord-Transylvaine. Les travaux de forage exécutés dans cette région pour les hydrocarbures ont indiqué la présence, au sein de la couverture sédimentaire, des tufs, agglomérats et roches effusives, dont certaines à minéralisations de pyrite et chalcopyrite.

Au point de vue gravimétrique, cette zone se trouve justement au nord d'une anomalie intense de maximum se superposant au bloc cristallin élevé de Mădăraş.

L'étude des anomalies gravimétriques et magnétométriques a été réalisée sur une zone représentant un carré avec le côté de 30 km, délimité par les repères suivants: Căuaş - Eriu Sâncrai - Hodişa au sud, Hodişa - Viile Satu Mare - Botiz à l'est, Botiz - Doroltţ - Tyukod (Hongrie) au nord et Tyukod - Ghenci - Căuaş a l'ouest.

L'interprétation des données gravimétriques a été faite sur 6 profils orientés sud-nord, traversant toute la zone anomale. Vu que, selon les résultats des recherches faites sur un grand nombre d'échantillons récoltés de forages, la densité des formations sédimentaires pliocènes et miocènes est variable (croissante) avec la profondeur, l'interprétation a consisté en déterminer, sur chaque profil, la **densité apparente** (nous avons introduit ce terme par analogie avec la résistivité apparente de l'électrométrie).

L'interprétation des données aéro-magnétométriques a été faite dans une première phase sur quelques profils orientés sud-nord, en considérant une source bidimensionelle. Après avoir établi que les niveaux volcanogènes logés dans les dépôts sédimentaires sont susceptibles d'engendrer une anomalie aéro-magnétométrique pas plus grande que 20 nT, qui a été extraite de l'anomalie observée, la modélisation de l'anomalie non-justifiée par le sédimentaire a été faite sur 3 profils orientés sud-nord, dans l'hypothèse que la source de celle-ci soit un corps magmatique intrusif. À partir des résultats de l'interprétation 2D on a procédé à la modélisation 3D de l'anomalie aéro-magnétométrique. Les différences entre les valeurs ΔT calculées et celles observées sont moindres que 10 nT (précision supposée du levé aéro-magnétométrique) dans toute la zone modélisée.

Géologie de la région

Au point de vue géologique, la région étudiée se rattache à la Dépression Pannonienne.

La source de la description qui suit est la synthèse des données géophysiques (Visarion et al., 1977), qui comprend la plus récente présentation de la géologie de la région, à partir des données géophysiques et de forage disponibles à ce moment-là.

Le **socle cristallin** est constitué d'une suite de formations appartenant à la série de Someş. Il est représenté par des schistes cristallins mésozonaux (paragneiss, micaschistes, schistes quartzeux etc.) formant presque en totalité la bordure de la Dépression Pannonienne et affleurant sur de grandes surfaces dans les monts de Codru, Rez, Măgura Şimleului etc.

Le **Sénonien** repose directement sur le soubassement cristallin. Les formations sénoniennes, sous faciès de Gossau, ont une épaisseur de plus de 1000 m dans le grabben de Sânnicolau et sont représentées par des conglomérats et des brèches, partiellement calcaires, suivis par des calcaires noirs. Dans d'autres zones, le Sénonien est présent par une abondance de conglomérats calcaires, grès et schistes argilo-marneux, à intercalations de tuffites.

Le **Paléogène** est connu dans la Dépression Pannonienne particulièrement dans les forages situés au nord de la Faille Nord-Transylvaine et se rattache à la fosse de Maramureş. Il détient les caractéristiques d'une formation de flysch, formant une pile amplement développée sur la verticale, qui peut dépasser, par endroits, 1500 m.

Les formations sédimentaires néogènes, constituant le remplissage proprement dit de la Dépression Pannonienne, appartiennent au Badénien, au Sarmatien et au Pannonien. Ces dernières ont un large développement, qui peut atteindre dans les zones dépressionnaires profondes une épaisseur de 3000 m.

Le **Badénien**, marqueur du début du cycle sédimentaire néogène, présente une distribution non-uniforme; il est bien représenté dans les régions dépressionnaires les plus profondes, tel que le grabben de Sânnicolau où il atteint environ 800 m d'épaisseur.

Dans les secteurs où la succession est la plus complète (Abrămuţ, par exemple), on a pu séparer trois complexes principaux:

– le complexe inférieur, à caractère volcano-sédimentaire, dont la constitution comporte des grès, siltites, tufs et pyroclastites andésitiques ou rhyolitiques (300 m d'épaisseur);

– le complexe moyen, en général gréseux, renfermant des grès argileux, grès quartzitiques, marnes gréseuses et grès pyroclastiques, dont l'épaisseur totale ne dépasse pas 500 m et

– le complexe supérieur, représenté par une série marno-argileuse à rares intercalations de microconglomérats, grès et siltites (environ 200 m d'épaisseur).

Le **Sarmatien** (Volhynien - Bessarabien inférieur), disposé transgressivement sur les autres termes sédimentaires, est difficile à séparer par suite de sa ressemblance lithologique avec le Badénien. Il se présente, généralement, sous deux faciés: conglomératique - gréseux littoral dans la proximité de certaines zones d'élévation du soubassement et pélitique dans les zones de subsidence maximale.

Le **Pannonien** est largement développé en plan et sur la verticale. Du fait de son caractère transgressif, il arrive à se situer directement sur le soubassement cristallin. À l'échelle régionale, sa constitution a permis la séparation de deux horizons principaux: un horizon inférieur marneux (correspondant au Sarmatien supérieur - Pontien moyen) et un horizon supérieur plutôt sableux (Pontien supérieur - Dacien).

Le **Quaternaire** est représenté par des dépôts proluviaux (graviers, sables grossiers et argiles à stratification croisée), surmontés par un complexe de roches loessoïdes alternant avec argiles rouges.

La **TECTONIQUE** de la Dépression Pannonienne est compliquée, mais nous allons en souligner seuls quelques aspects locaux, ayant une liaison directe avec la zone étudiée.

Ce qui caractérise la tectonique de la zone c'est sa compartimentation accusée, le long de fractures orientées surtout E-O et NE-SO, ce qui a eu comme résultat une structure en blocs.

Ainsi, dans la partie sud-est de la zone on distingue le bloc élevé de Mădăraş, où le Pannonien, dont l'épaisseur ne dépasse guère quelques centaines de mètres, repose directement sur le cristallin.

À l'ouest et au sud-ouest de celui-ci, dans le grabben de Galoşpetreu - Mecenţiu, les forages n'ont pas traversé l'entière pile néogène, dont l'épaisseur dépasse 3000 m. La sismique montre que sous les formations néogènes se trouvent des formations plus anciennes, épaisses (plus de 2500 m) supposées d'appartenir au Sénonien.

Au nord de ces deux compartiments se trouve l'unité paléogène de Pişcolţ - Carei - Satu Mare qui se rattache au domaine des Carpates Orientales, représentant un prolongement de la fosse de Maramureş. Elle est séparée du bloc rigide de l'Autochtone de Bihor (qui se trouve au sud) par une fracture régionale majeure, connue sous le nom de Faille Nord-Transylvaine.

Pour l'interprétation des données gravimétriques et magnétométriques nous avons utilisé aussi les cartes à isobathes de la base du Pannonien et de la base du Miocène édifiées à partir des données sismiques et de forage (Visarion et al., 1977). Sur ces cartes apparaît de manière évidente le bloc de Mădăraş, dont le soubassement s'élève presque jusqu'à la surface dans la zone de Baba Novac - Ardud - Homorodu de Mijloc (même en affleurant au sud de Homorod), coupé au nord par la Faille Nord-Transylvaine sur la direction Terebeşti - Gelu - Mădăraş - Homorodu de Jos. Cette faille a un rejet de plus de 1500 m au niveau de la base du Pannonien et de plus de 2000 m au niveau de la base du Miocène, à l'est de Mădăraş. À l'ouest et au sud, ce bloc est délimité aussi par des failles, dont le rejet atteint 800 m dans la zone de Ghirişa - Craidorolţ.

Dans la région en question il y a beaucoup de forages, dont certains (1 Berveni, 1 Moftinu Mic, 955 Moftin, 10 Terebeşti, 7 Mădăraş, 220 Mădăraş, 110 Craidorolţ, 5 SV Curtuiuş, 1 Decebal, 1 Ambud, 1 NV Satu Mare, 5 Micula) ont intercepté (sous forme d'intercalations dans les formations sédimentaires sarmatiennes, badéniennes ou même paléogènes) des rhyolites, andésites, dacites, ainsi que des pyroclastites et des roches épiclastiques à divers degrés de transformation hydrothermale. Parfois, ces roches métamorphisées sont également pyritisées ou même minéralisées à pyrite et chalcopyrite (par exemple les rhyolites silicifiées interceptées par le forage 10 Terebeşti à la profondeur de 1450 m).

Données géophysiques initiales

Le point de départ de l'interprétation intégrée des données magnétométriques et gravimétriques de la zone de Mădăraş - Satu Mare est constitué par la carte aéromagnétique ΔT_a élaborée à l'IGPSMS (actuellement S.C. Prospecţiuni SA), la carte magnétique ΔZ_a au sol réalisée à l'IGG (actuellement l'Institut Géologique de la Roumanie) et la carte gravimétrique de Bouguer pour une densité de 2.67 g/cm^3 rédigée également à l'IGG.

Dans les deux images magnétométriques, l'anomalie positive principale s'étend sur la direction Terebeşti - Mădăraş - Ruşeni, mais avec des morphologies différentes (voir les figures 1 et 2). Les différences viennent autant du niveau auquel on a obtenu les mesures (au sol pour les anomalies ΔZ_a, à l'altitude de 400 m à l'ouest du méridien Porumbeşti - Odoreu - Stâna et a 600 m à l'est de celui-ci, pour le levé aéro), ainsi que des éléments du champ magnétique qui ont été mesurés (la composante verticale au sol, le champ total dans le levé aéro) et de la distribution en surface des points d'observation (un réseau assez rare au sol, contre profils continus nord-sud pour le levé aéro).

L'anomalie de Bouguer de cette zone (dont le croquis est présenté dans la figure 3) montre un très fort maximum régional dans la partie sud-est de la zone (Baba Novac - Ardud - Băiţa), accompagné d'une anomalie régionale de minimum vers l'ouest et le nord, à apex négatifs locaux à Mărişte, Sătmărel et Valea Vinului.

Propriétés physiques des formations géologiques

Dans ce qui suit, nous allons faire référence seulement aux densités et aux susceptibilités magnétiques, vu que l'objet de notre étude sont les anomalies gravimétriques et magnétométriques de la zone.

Les résultats des mesures de densité synthétisés par Visarion et al. (1977) nous portent à conclure que les formations pannoniennes lutitiques de cette région connaissent une augmentation non-linéaire de la densité avec la profondeur, de 1.75 g/cm^3 à la surface, jusqu'à 2.60 g/cm^3 à une profondeur de 2500 m, avec des variations locales provoquées par des variations de faciès (figure 4). La même courbe de variation est valable également pour le Miocène, puisque la densité des formations miocènes varie de 2.40 g/cm^3 à la profondeur de 1700 m jusqu'à 2.63 g/cm^3 à une profondeur de 2800 m (Ali Mehmed et al., 1969), ces valeurs s'inscrivant correctement sur la partie finale de la courbe qui correspond aux formations pliocènes.

Le gradient vertical moyen de la densité pour les formations miocènes et pliocènes est d'environ 0.20 g/cm^3/km pour les profondeurs de plus de 1500 m.

La présence des tufs et de pyroclastites, à densités entre 2.00 et 2.30 g/cm^3 (Marinescu, 1975), peut engendrer des anomalies locales.

Les formations pré-néogènes ont une densité moyenne de 2.62 g/cm^3 pour le Paléogène sous faciès de flysch, de 2.59 pour les formations crétacées et de 2.70 g/cm^3 pour le soubassement cristallin (Visarion et al., 1977).

La susceptibilité magnétique des formations sédimentaires est de l'ordre de $10*10^{-6}$ uCGS à l'exception des intercalations de tufs et de pyroclastites andésitiques qui atteignent $(600\text{-}700)*10^{-6}$ uCGS (Visarion et al., 1977).

Des mesures faites sur des carottes du forage 4064 Căpleni ont montré des susceptibilités de l'ordre de $2600*10^{-6}$ uCGS pour andésites à pyroxènes, de $900*10^{-6}$ uCGS pour dacites et de $300*10^{-6}$ uCGS pour agglomérats andésitiques, tandis que les roches magmatiques altérées fussent trouvées pratiquement non-magnétiques (Crahmaliuc dans Borcoş et al., 1993).

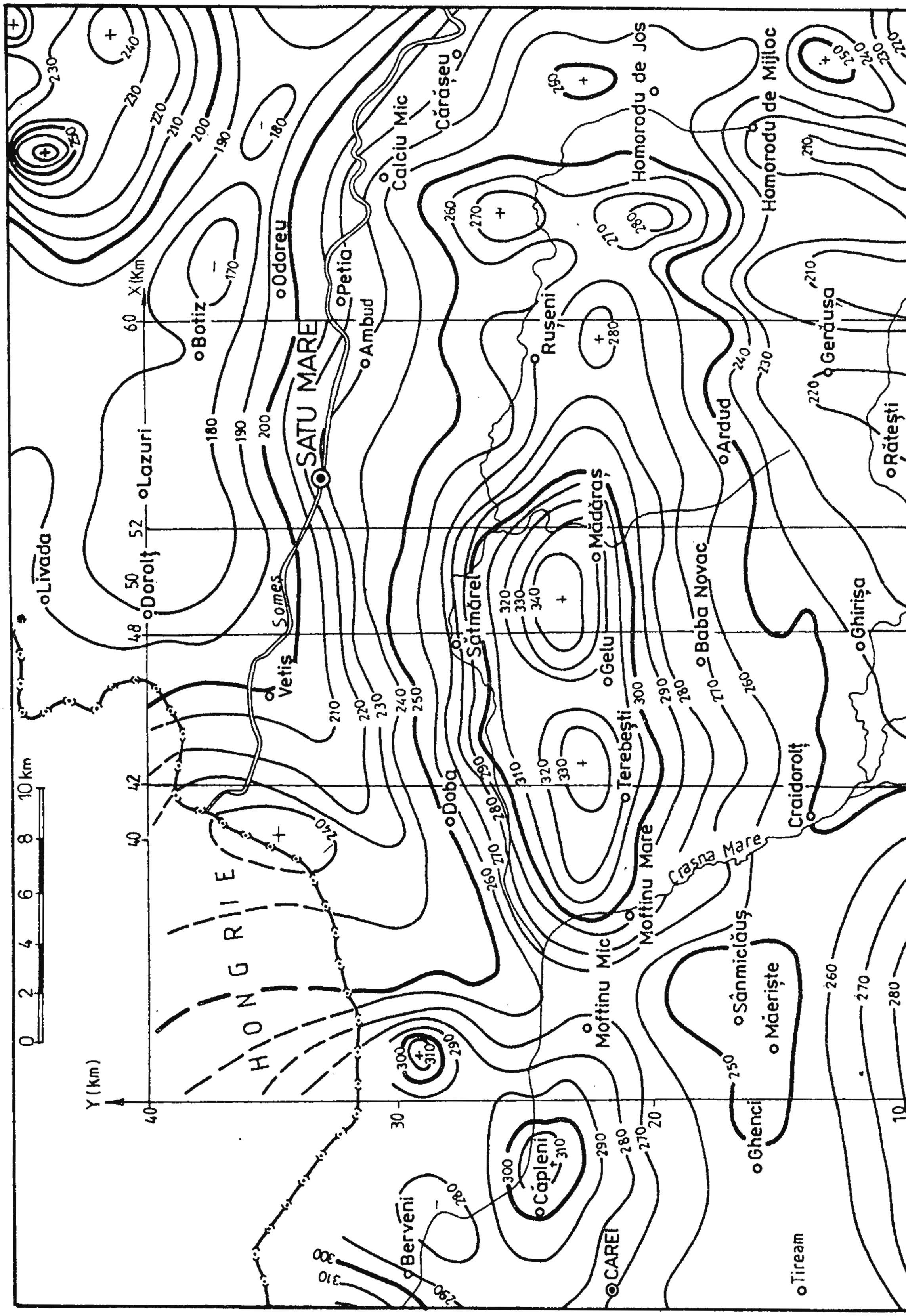

Fig. 1 – Carte de l'anomalie aéro-magnétométrique ΔT_a dans la zone de Carei-Satu Mare (d'après IGPSMS)

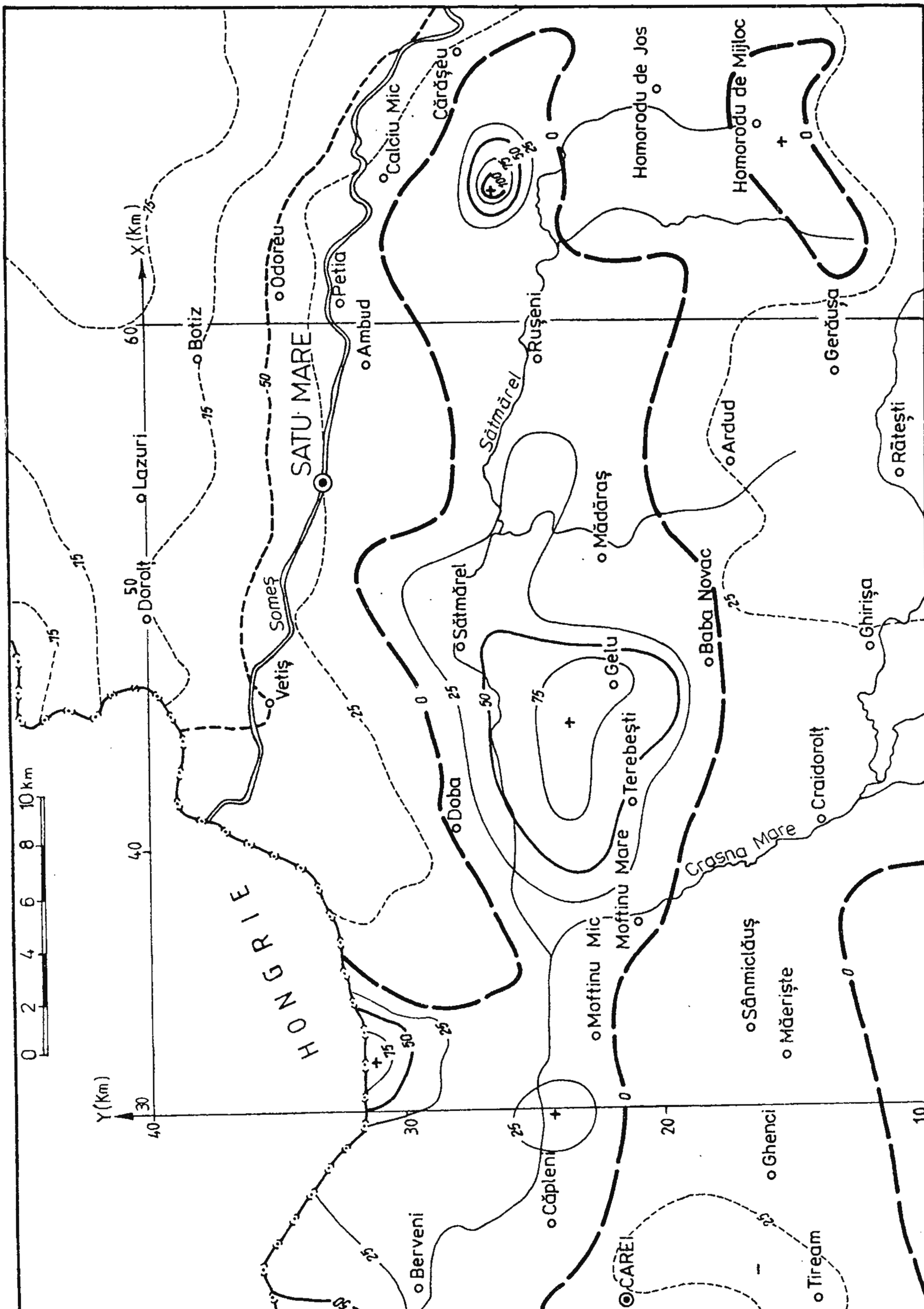

Fig. 2 – Carte de l'anomalie magnétométrique ΔZ_a , au sol, dans la zone de Carei - Satu Mare (d'après IGR)

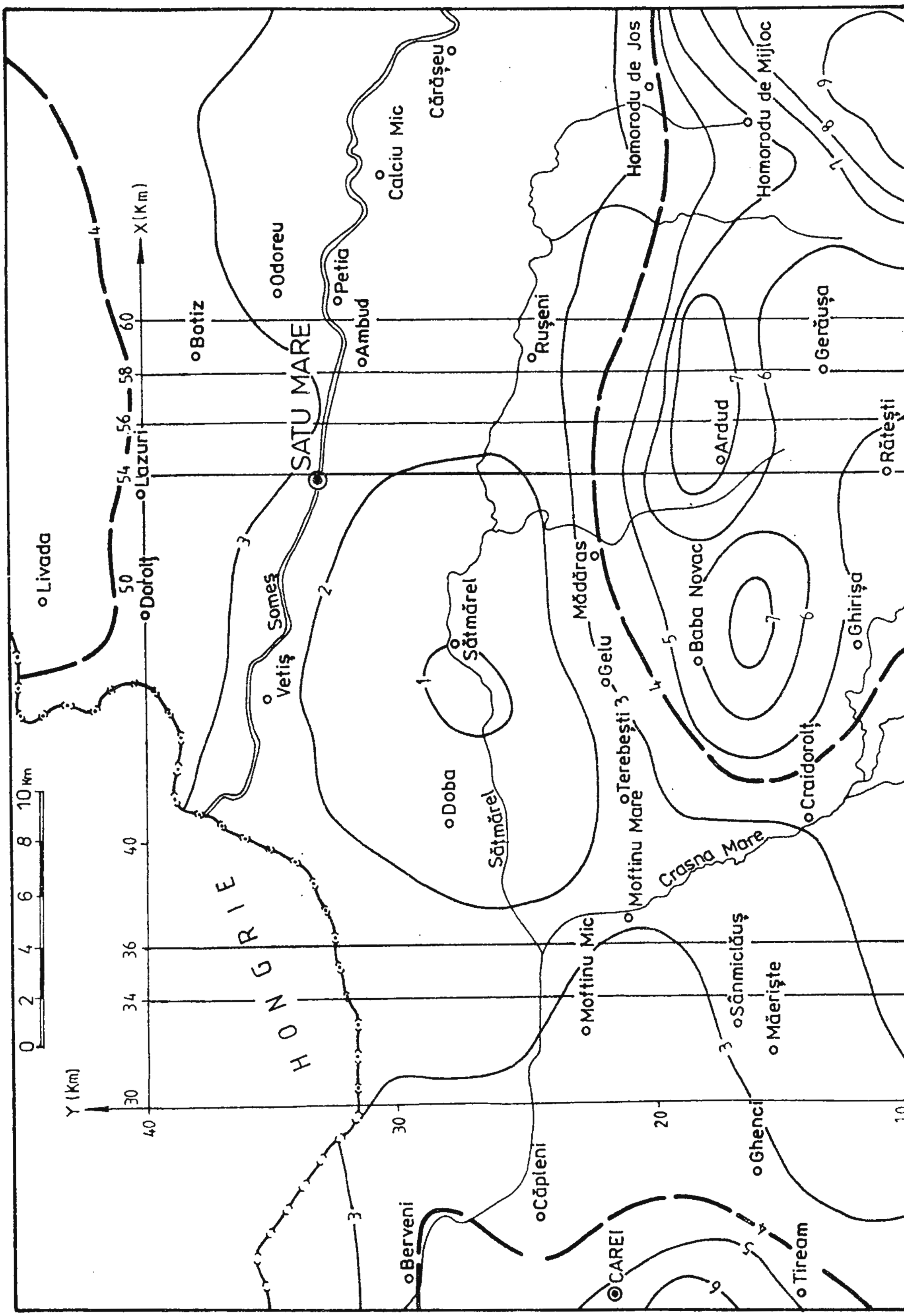

Fig. 3 – Esquisse de l'anomalie gravimétrique de Bouguer (densité 2.67 g/cm^3) de la zone Carei - Satu Mare (d'après IGR) - Isogales, à valeurs augmentant de 1 vers 9

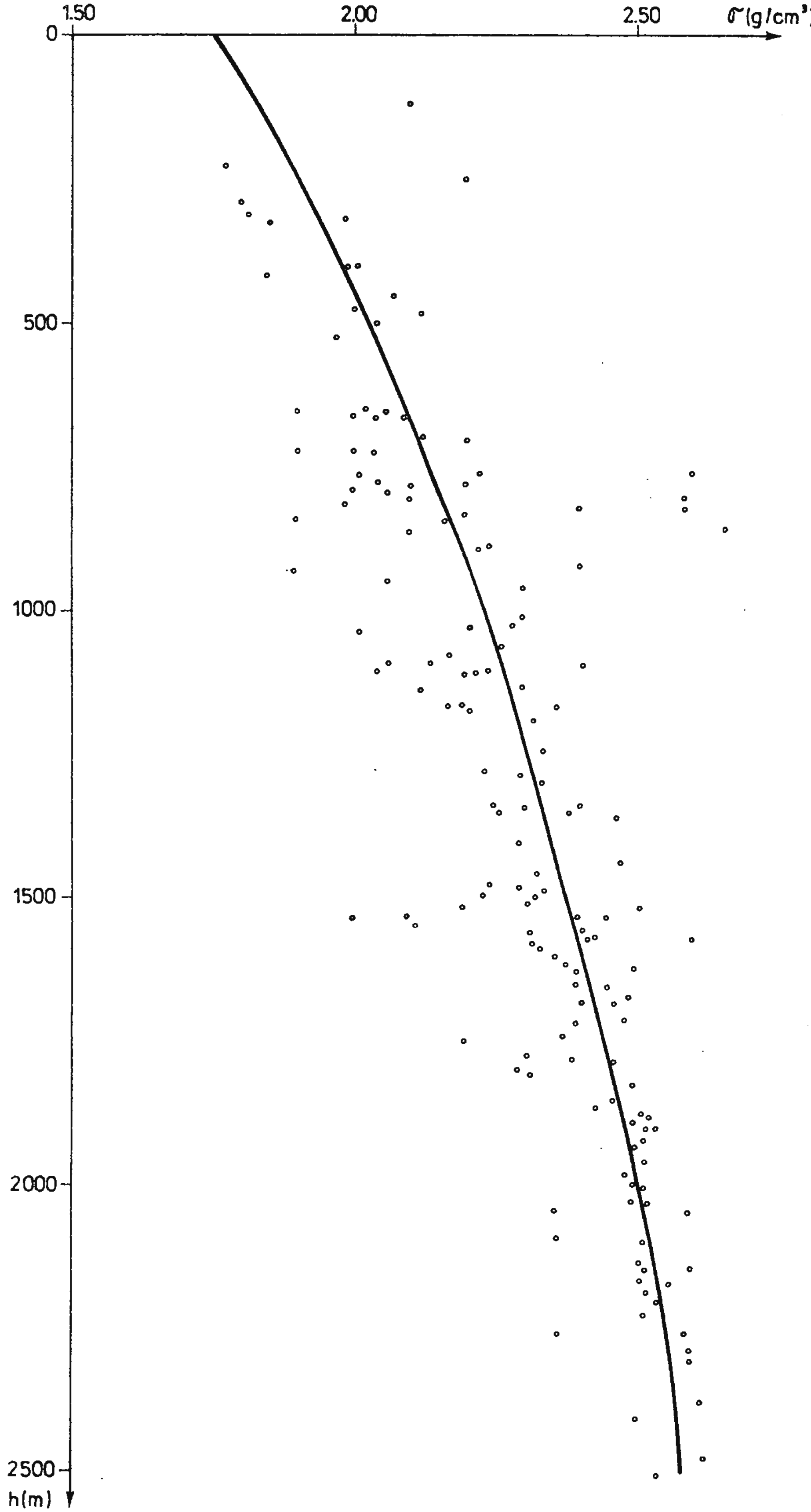

Fig. 4 - Variation de la densité des formations pliocènes de la Dépression Pannonique fonction de la profondeur (d'après Visarion et al., 1977)

Interprétation des données gravimétriques

Une première interprétation, qualitative, des données gravimétriques peut être faite directement sur la carte de l'anomalie de Bouguer, tenant compte du principal contraste de densité de la région entre le socle cristallin (densité moyenne environ 2.70 g/cm^3) et les roches sédimentaires en couverture (à densités entre 1.75 et 2.60 g/cm^3 en fonction de la composition lithologique et de la profondeur). À partir de ce contraste on peut placer, avec assez de certitude, la Faille Nord-Transylvaine dans la zone Terebeşti - Mădăraş - Homorodu de Jos, cette faille étant reflétée par une zone de gradient horizontal très fort de l'anomalie de Bouguer.

On ne peut pas faire une interprétation structurale directe des zones de minimum de Δg, à cause de la variation de la densité des roches avec la profondeur: cette variation provoque l'atténuation des anomalies engendrées par les dépressions profondes du relief pré-néogène, par suite de la diminution presque jusqu'à l'annulation du contraste de densité du sédimentaire par rapport au cristallin. Les zones de minimum peuvent aussi trouver partiellement leur origine dans l'augmentation du poids des pyroclastites et des roches arénitiques-ruditiques au sein des roches sédimentaires.

L'interprétation plus détaillée des données gravimétriques a été faite sur des profils orientés nord-sud, en considérant la structure bidimensionelle et ayant un seul contraste de densité entre le soubassement pré-néogène et le remplissage sédimentaire miocène et pliocène.

Dans ce but on a employé le procédé proposé par Qureshi et Mula (1971). Nous avons utilisé ce procédé sur plusieurs profils (34, 36, 54, 56, 58, 60, figure 3), en utilisant chaque fois un set de contrastes de densité Néogène - soubassement pré-Néogène variant de 0.20 à 0.80 g/cm^3. Les résultats nous ont permis de comparer la position réelle de la limite (résultant des données sismiques et de forage) avec les différentes positions résultées des divers contrastes de densité utilisés et d'établir ainsi la **densité apparente**. Celle-ci représente la densité constante qui, attribuée à l'entière structure modélisée, pourrait engendrer une anomalie de Bouguer la plus proche de l'anomalie observée. Cette densité n'est pas, bien sûr, la moyenne arithmétique des densités de la succession verticale des couches, mais elle en est un indice qualitatif de la pile sédimentaire néogène dans la zone en question.

Sur les profils ouest, 34 et 36, on remarque le fait qu'au nord de l'élévation de Mădăraş la base du Néogène résultée des données sismiques et de forage est assez bien designée pour un contraste moyen de densité de 0.35 g/cm^3 (donc pour la densité apparente du Néogène d'environ 2.35 g/cm^3), tandis qu'à l'extrémité sud, dans le grabben de Galoşpetreu - Mecenţiu, la comparaison avec les données sismiques nous conduit à un contraste de densité de 0.10-0.30 g/cm^3 (explicable par le fait que la densité du sédimentaire lutitique néogène en dessous de la profondeur de 2500 m tend à égaler la densité du soubassement cristallin et que la base du Néogène s'enfouit dans la zone du grabben jusqu'à la profondeur de 3500 m).

Dans le cas des profils est, 54, 56, 58 et 60, au nord de l'élévation de Mădăraş la meilleure superposition avec les données sismiques et de forage est obtenue pour un contraste moyen de densité de 0.25 g/cm^3, tandis qu'au sud de cette élévation le contraste moyen probable est de 0.40 g/cm^3.

On peut également constater qu'au nord de Mădăraş, sur les profils 54 et 56, la superposition se fait sur des portions pour des contrastes comprises entre 0.20 et 0.30 g/cm^3, bien que la profondeur de la base du Néogène ait de petites variations (figure 5). La raison du changement de la densité apparente du Néogène ne réside donc pas dans une différence de tassement du sédimentaire par suite de la profondeur différente, mais dans un contraste lithologique, dû soit à l'apport de matériel pyroclastique en quantités très différentes d'un point à l'autre, soit à une diminution de la densité des roches du soubassement pré-néogène pour des raisons lithologiques primaires ou par un degré différent d'altération. Selon ce qui résulte de ces profils, la diminution maximum de la densité apparente se trouve dans la zone située justement au nord du bloc de Mădăraş (points 24-32, entre Cionchești et Amaţi), ne dépassant probablement vers le nord le parallèle de Satu Mare.

Il est à remarquer aussi que dans la zone nord-est (Mădăraş - Satu Mare - Ambud, les profils 54 - 56) la densité apparente du sédimentaire est plus grande, environ 2.45 g/cm^3, par rapport à la zone nord-ouest (au nord de Moftinu Mic - Moftinu Mare, profils 34 - 36) où elle atteint environ 2.35 g/cm^3.

Interprétation des données magnétometriques

Afin de faciliter l'interprétation 3D des données magnétométriques, on a commencé par l'interprétation 2D sur quelques profils orientés nord-sud (les profils 42, 48 et 52). On a débuté avec le profil 42, où on a fait d'abord les opérations suivantes:

– on a déterminé le gradient régional de la courbe ΔT_a, en résultant une diminution régionale du champ magnétique ΔT_a de 0.35 nT/km du sud vers le nord;

– à partir des données sismiques et de forage on a construit les limites Pannonien/Miocène et Néogène/soubassement pré-néogène;

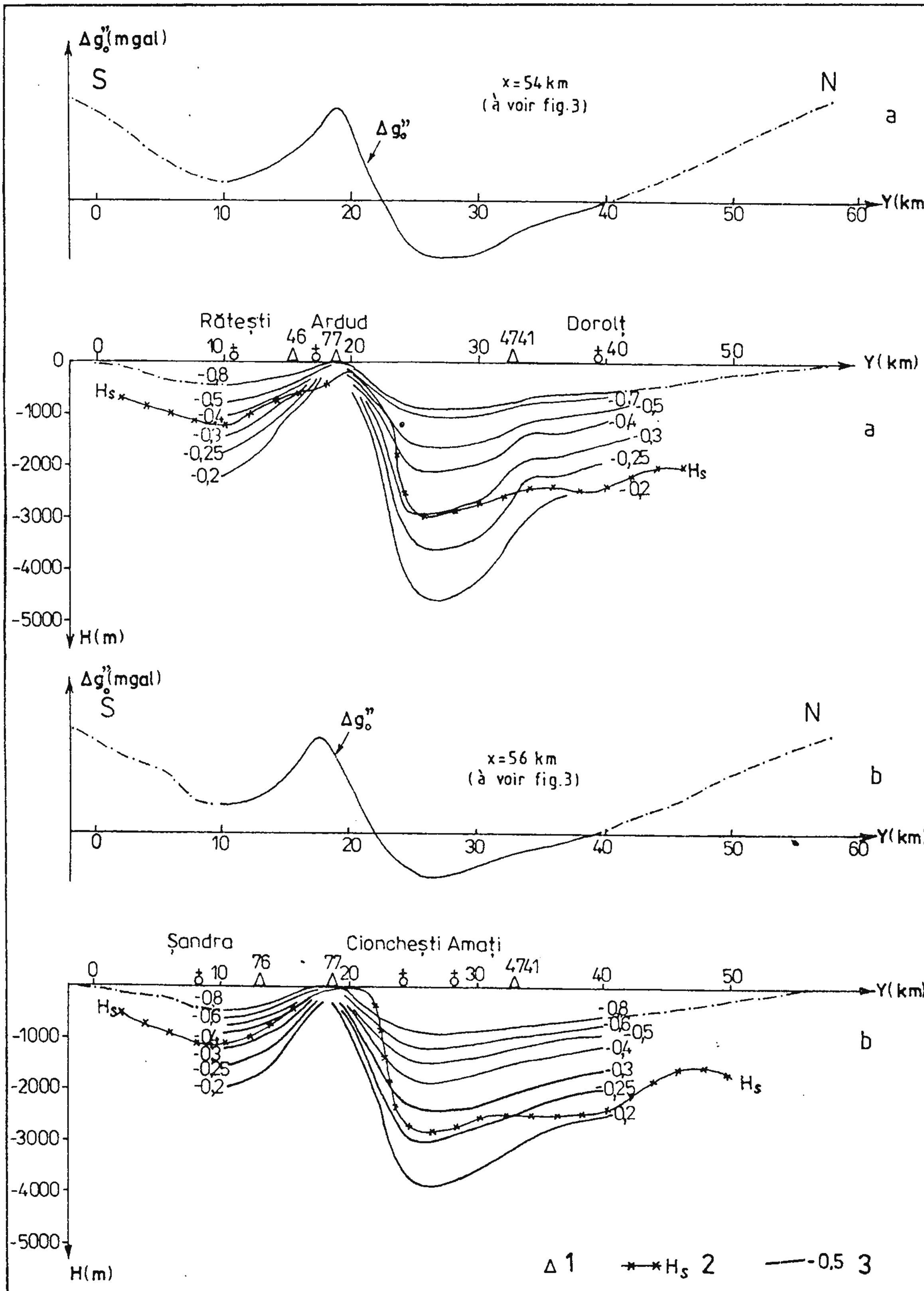

Fig. 5 Interprétation 2D des données gravimétriques sur les profils 54 (a) et 56 (b). 1, forages; 2, base du Néogène d'après les données sismiques et de forage; 3, base du Néogène résultant de l'interprétation des données gravimétriques, pour des contrastes de densité de 0.2 à 0.8 g/cm^3.

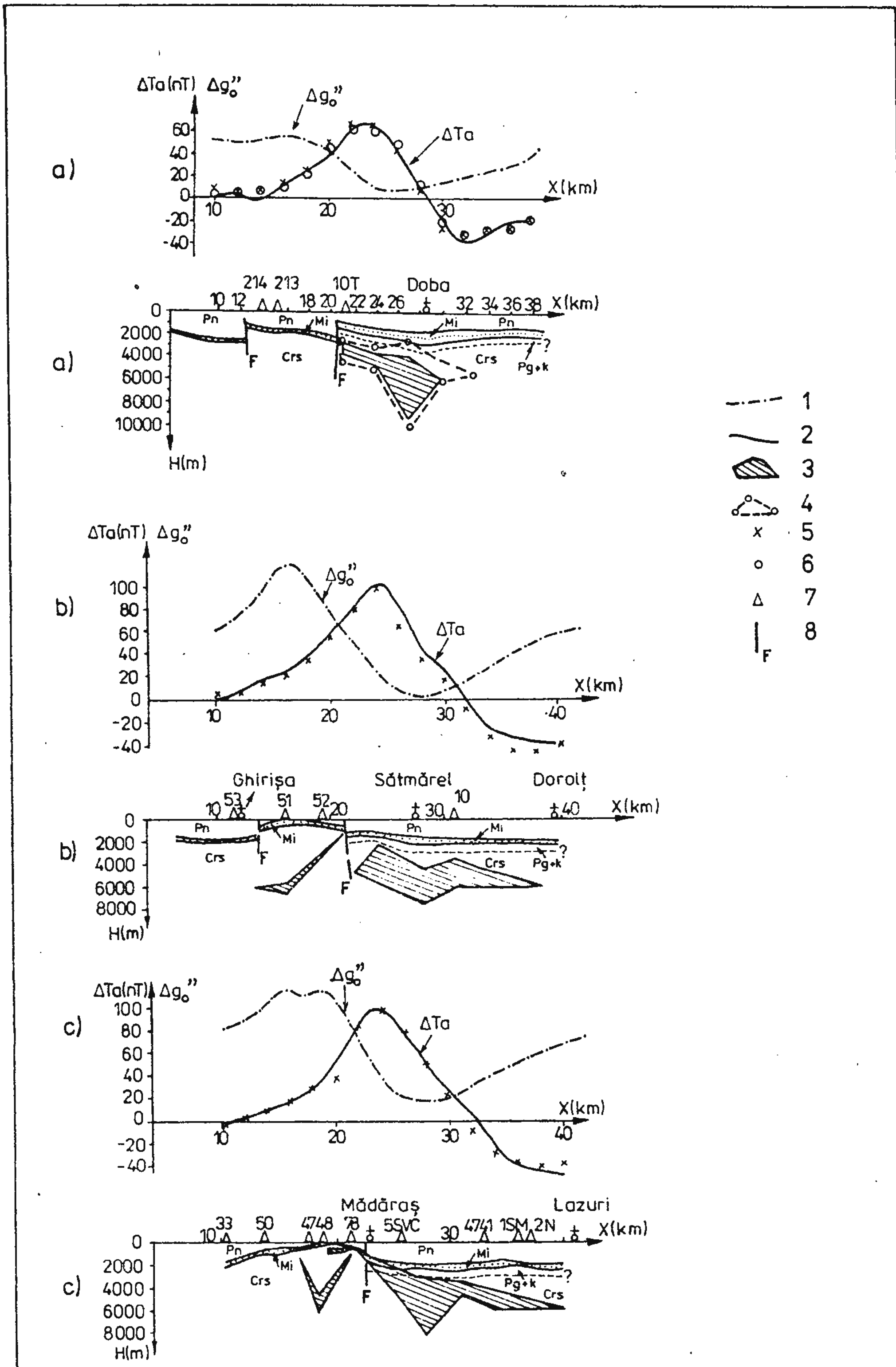

Fig. 6 – Résultats de l'interprétation 2D de l'anomalie aéro-magnétométrique ΔT_a sur les profils 42 (a), 48 (b) et 52 (c). Pn, Pannonien; Mi, Miocène; Pg+K, Paléogène + Crétacé; Crs, Cristallin; 1, courbe Δg_0; 2, courbe ΔT_a réduite; 3, modèle de la source pour $\chi = 1800*10^{-6}$ uCGS; 4, modèle de la source pour $\chi = 1000*10^{-6}$ uCGS; 5, valeurs ΔT_a calculées pour $\chi = 1800*10^{-6}$ uCGS; 6, valeurs ΔT_a calculées pour $\chi = 1000*10^{-6}$ uCGS; 7, forages; 8, failles.

– on a présumé que le soubassement pré-néogène incluait des formations paléogènes et crétacées avec une épaisseur presque constante, d'environ 500 m, et que le Miocène était constitué du Sarmatien et du Badénien en épaisseurs égales entre elles;

– on a estimé que le Badénien et le sédimentaire pré-néogène avaient une susceptibilité magnétique de $600*10^{-6}$ uCGS (ce qui est probablement beaucoup exagéré, d'après les données pétrophysiques disponibles), le reste du sédimentaire et le soubassement cristallin étant pratiquement inactifs au point de vue magnétique;

– on a calculé l'effet ΔT_a (à la côte + 400 m à laquelle on a obtenu les valeurs aéro-magnétométriques) des formations magnétiquement actives incluses dans l'empilement de roches sédimentaires, ce qui a donné un maximum de 18 nT dans le point où celles-ci approchaient le plus la surface (près du forage 10 Tereheşti) mais en diminuant au-dessous de 10 nT vers le sud et le nord à une distance de 1-3 km par rapport au point de maximum;

– on a extrait du champ ΔT_a le champ régional de 0.35 nT/km et aussi l'anomalie engendrée par les formations magnétiquement actives incluses dans la pile de roches sédimentaires;

– on est passé à l'interprétation 2D du champ resté non-justifié par les masses anomales du sédimentaire, qui a un maximum d'environ 70 nT à 2 km nord du forage 10 Terebeşti.

Pour interpréter cette anomalie, on a employé l'algorithme de modélisation de Won et Bevis (1987), avec les conditions supplémentaires suivantes:

1. – le corps perturbant a une section verticale qu'on peut approximer par un polygone dont les cotés ont une projection horizontale de 3 km chacune;

2. – toute droite verticale intersecte le polygone en maximum deux points;

3. – le corps se trouve entièrement au-dessous de la limite Pannonien/Sarmatien;

4. – la susceptibilité magnétique du corps est de $1800*10^{-6}$ uCGS;

5. – l'aimantation est purement inductive, dans le champ terrestre de 48000 nT avec l'inclinaison de 64^0.

Nous avons constaté que sur le profil 42 il fallait considérer comme niveau zéro de l'anomalie ΔT_a la valeur de 250 nT de la carte aéro-magnétométrique, tandis que sur les profils 48 et 52 il a les valeurs de 235, á savoir 225 nT, en résultant un gradient régional est-ouest de 2.5 nT/km positif vers l'ouest. Sur les profils 48 et 52, ainsi que sur le profil 42, on a trouvé également un gradient régional horizontal nord - sud de 0.35 nT/km positif vers le sud.

Dans la figure 6 nous présentons les résultats de l'interprétation 2D de l'anomalie aéromagnétométrique sur tous les trois profils (42, 48 et 52). On peut constater que:

– le corps perturbant déterminé dans les conditions (1-5) va s'enracinant dans la zone des points 27-28 à une profondeur dépassant 7500 m;

– le pendage général du corps est vers le nord, avec une pente plus grande du lit et plus petite du toit;

– le corps atteint son extension maximale sur l'horizontale autour de la profondeur de 5500 m;

– la partie la plus élevée du corps se trouve à la proximité de la surface sur le profil 52 (le plus à l'est).

Le profil 42 a été aussi interprété 2D pour une susceptibilité magnétique de $1000*10^{-6}$ uCGS. Dans ce cas-là le corps a une extension plus grande sur l'horizontale et, ce qui est plus important, il monte jusqu'à la base du Néogène (figure 6). Pour des susceptibilités (du corps tout entier ou de sa partie supérieure) encore moindres, le toit de la source peut monter encore plus vers la surface.

À partir des informations acquises sur ces trois profils, on a procédé à l'interprétation 3D de la carte aéromagnétométrique.

En considérant les niveaux zéro et les gradients horizontaux régionaux établis sur les trois profils, la carte aéro-magnétométrique ΔT_a brute a été corrigée avec ces valeurs, en obtenant la carte ΔT_a à modéliser, présentée dans la figure 7.

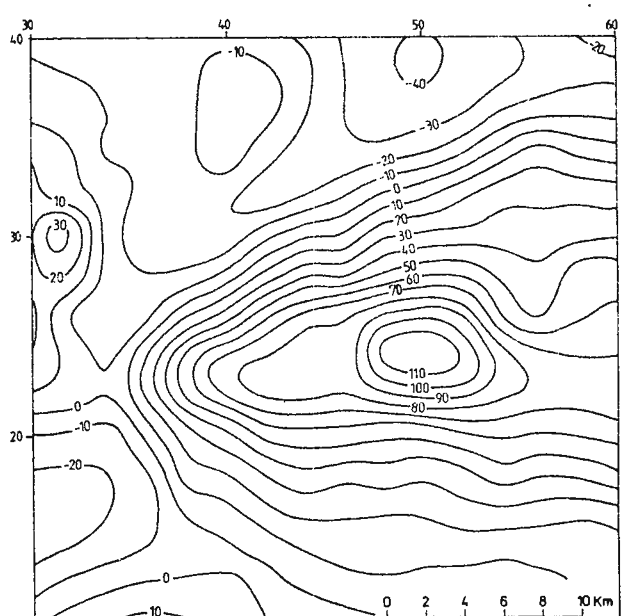

Fig. 7 – Carte ΔT_a corrigée avec l'effet régional

En vue de modélisation on a utilisé les formules établies par Plouff (1976) pour l'effet d'un prisme polygonale vertical. Le modèle obtenu finalement, en considérant la susceptibilité magnétique du corps de $1800*10^{-6}$ uCGS, est présenté dans la figure 8. Il faut mentionner qu'à l'est du profil 58 la forme du corps a

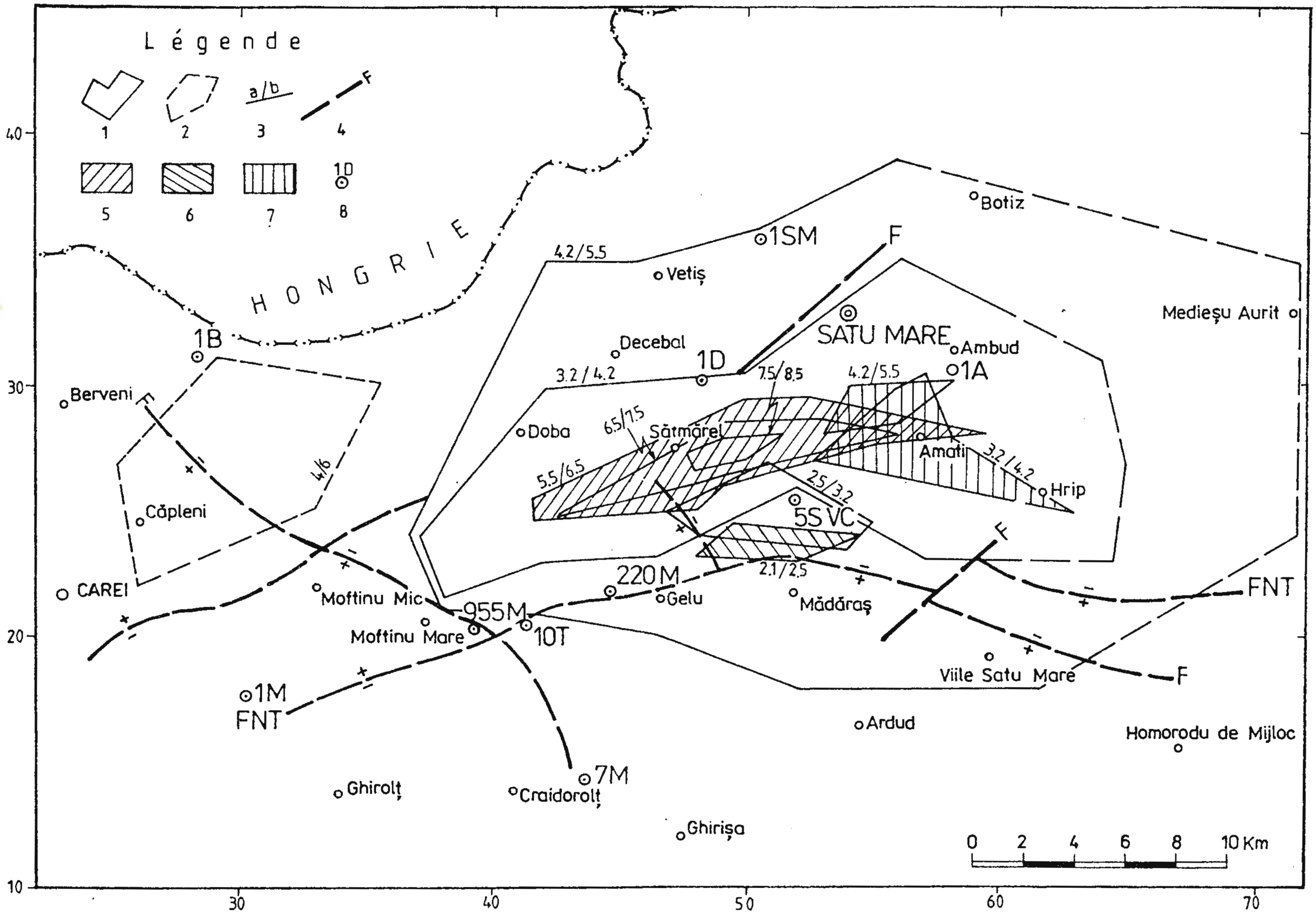

Fig. 8 – Modèle final du corps perturbant. 1, contours des plaques horizontales par lesquelles on a approximé le corps perturbant; 2, contour extrapolé; 3, profondeur de la face supérieure (a) / inférieure (b) de la plaque; 4, failles, d'après les données sismiques et de forage (FNT, Faille Nord-Transylvaine); 5, zone d'enracinement du corps; 6, apophyse; 7, zone d'altération hydrothermale; 8, forages ayant rencontré des roches magmatiques.

été seulement suggérée qualitativement tenant compte de l'allure des courbes de la carte ΔT_a, sans calculer effectivement le champ magnétique dans cette zone. L'effet ΔT_a du modèle a été calculé pour une hauteur de vol de 400 m, dans les noeuds d'une maille de 2 km x 2 km. Les petites différences, moins de 10 nT (présentées dans la figure 9) entre la carte obtenue et celle à modéliser n'ont pas été modélisées elles aussi, vu que la précision du levé aéro-magnétométrique fût de l'ordre de 10 nT et l'estimation de la susceptibilité magnétique du corps perturbant est en certaine mesure subjective. Les différences plus grandes que 10 nT apparaissant dans la partie ouest du périmètre étudié ont comme cause le fait de ne pas avoir modélisé les anomalies aéro-magnétométriques de cette zone, périphérique par rapport à la cible principale représentée par la zone de Moftin - Mădăraş.

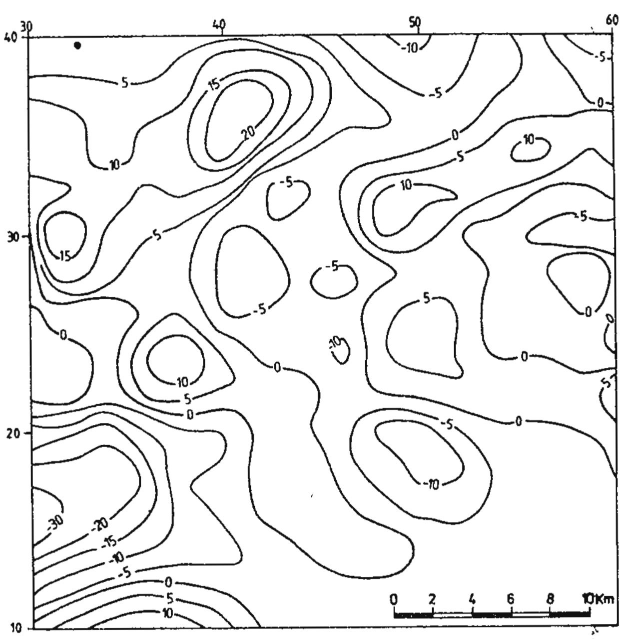

Fig. 9 - Carte des différences (en nT) entre la carte ΔT_a à modéliser et la carte ΔT_a résultée de la modélisation.

Interprétation géologique integrée des données magnétometriques et gravimétriques

Compte tenu aussi des données de forage et sismiques, l'examen des profils 42, 48 et 52 (figure 6) et de la carte du modèle physique résulté de l'interprétation 3D (figure 8) nous porte à conclure que l'anomalie magnétométrique (aéro et au sol) de la zone de Moftin - Mădăraş est engendrée par un corps magmatique intrusif, probablement lacolithique, enraciné sur l'alignement sud Tereboşti - Sătmărel - Mădăraş jusqu'à une profondeur d'environ 8000 m. Il a une apophyse qui approche la surface justement au nord de Mădăraş.

Dans l'hypothèse que sa susceptibilité magnétique est de $1800*10^{-6}$ uCGS, le corps atteint probablement son développement maximal autour de la profondeur de 4000–5000 m, sa limite nord passant de Moftinu Mare dans la partie ouest jusqu'à la ligne Doba - Vetiş - Botiz - Medieşu Aurit dans la partie est. Le toit de la partie principale du corps pend vers le nord sous un angle d'environ 20^0 et se trouve à une profondeur d'environ 1000 m en dessous de la limite Néogène/pré-Néogène.

Lorsque la susceptibilité magnétique du corps ou de sa partie supérieure est moins de $1800*10^{-6}$ uCGS, le toit de cette structure se trouve encore plus près de la surface.

Sur les profils 48 et 52 (figure 6) et dans la carte du modèle (figure 8) à l'est du profil 43 l'allure du champ magnétique a rendu nécessaire le prolongement des sources au sud de la Faille Nord-Transylvaine aussi, soit en tant que corps séparés du corps principal (dans ce cas elles sont susceptibles de représenter des lentilles d'amphibolites du soubassement cristallin), soit sous la forme d'une extension du corps principal dans cette zone.

L'image du corps perturbant nous indique aussi l'existence d'une zone magnétiquement inactive à l'intérieur du corps (sur les profils 53-60, points 25-31) qu'on peut considérer une zone d'altération hydrothermale. La même cause a pu déterminer aussi l'interruption vers l'est, dans la même zone, de la partie active de l'apophyse sur les profils 48-54, ainsi que l'arrêt vers l'ouest de la partie magnétiquement active du corps principal dans la zone des profils 34-38 (à l'intersection d'une faille orientée NO-SE avec une faille orientée ENE-OVO parallèle à la Faille Nord-Transylvaine). La possibilité que l'intrusion soit sujette à des transformations hydrothermales est suggérée par la présence de pareilles transformations au sein des roches éruptives intercalées dans la couverture sédimentaire, interceptées par les forages creusés dans la zone.

On remarque tout de suite le parallélisme entre l'alignement de l'enracinement du corps perturbant et la faille Nord-Transylvaine (à une distance d'environ 5 km au nord de celle-ci), entre les deux existant, selon toutes les probabilités, une liaison génétique aussi. En plus, la zone d'enracinement se trouve près d'un point de changement de direction de la faille Nord-Transylvaine (au nord de Mădăraş), ce qui a probablement déterminé aussi une fracture radiale orientée NNO-SSE, en facilitant l'accès du magma vers la surface.

La superposition de la zone d'enracinement du corps perturbant sur une anomalie gravimétrique de minimum peut être expliquée autant par: 1 – la densité plus réduite du corps par rapport à celle du cristallin, ainsi que 2 – par l'abondance du matériel pyroclastique (dans la situation que l'activité magmatique ait eu aussi un caractère extrusif) au voisinage de la zone la plus active et/ou 3 – par une altération hydrothermale plus intense dans cette zone, liée à la présence des voies d'accès ouvertes par l'intrusion. L'interprétation 2D sur le profil 54 (figure 5) est une bonne illustration de cette situation.

Conclusions

L'interprétation des données magnétométriques et gravimétriques de la zone de Mădăraş - Satu Mare fournit des informations tout à fait intéressantes, surtout sous le rapport scientifique, mais elle a également d'éventuelles implications économiques.

La première conclusion importante est que les formations magnétiquement actives de la couverture tertiaire ne sont pas suffisantes pour expliquer l'anomalie aéro-magnétométrique de plus de 100 nT de la zone de Moftin - Mădăraş. Cette première conclusion nous a poussé à chercher la source majeure de l'anomalie sous la forme d'un corps intrus, dont la forme, les dimensions et la position restaient à être établis par calcul.

En considérant une susceptibilité moyenne de $1800*10^{-6}$ uCGS et une aimantation purement inductive, l'interprétation 2D sur quelques profils nous a montré qu'on y avait affaire à un corps de plus de 1000 m d'épaisseur, situé de règle à une profondeur de plus de 3000 m, dont le toit a un faible pendage (moins de 25^0) vers le nord et l'enracinement (dans la zone Ghilvaci - Sătmărel - Amaţi) se place à une profondeur de plus de 8000 m. Si la susceptibilité du corps ou de sa partie supérieure est moindre, la profondeur au toit est plus réduite que celle obtenue dans la variante décrite en haut. Toute modification opérée sur les hypothèses de travail peut apporter seulement des changements quantitatifs, l'aspect du modèle résulté conservant l'empreinte de l'image obtenue de notre interprétation.

L'interprétation 3D de l'anomalie aéro-magnétométrique a mené aux mêmes conclusions, mais avec des précisions supplémentaires. On a constaté que l'enracinement du corps était parallèle à la faille Nord-Transylvaine, se situant à 5-6 km au nord de celle-ci, ce qui nous a porté à conclure qu'il s'agissait d'un corps magmatique intrus, probablement néogène, lié génétiquement à la Faille Nord-Transylvaine. Dans la zone Mădăraş, où cette faille change un peu de direction, le corps a une apophyse fraîche, qui s'approche beaucoup de la surface.

Dans les hypothèses présentées, l'extension maximale du corps sur l'horizontale est constatée autour de la profondeur de 4000-5000 m. La limite nord du corps passe par les localités Moftinu Mare - Doba - Vetiş - Botiz et elle arrive probablement jusqu'à Medieşu Aurit.

On constate aussi l'existence d'une zone magnétiquement inactive sur l'aire Hrip - Ruşeni - Cionchești - Amaţi (au nord-est de Mădăraş), probablement par suite d'une altération hydrothermale massive des magmatites constituant le corps perturbant. L'interruption apparaissant à l'ouest de Moftinu Mare peut représenter, elle aussi, une zone d'altération hydrothermale lorsque le corps se prolonge vers l'ouest par la source des anomalies aéro-magnétométriques qui se trouvent autour de la ville de Carei (Căpleni - Domneşti - Berveni - Foeni).

En ce qui concerne l'aspect régional, l'existence d'un gradient du champ géomagnétique positif vers l'OSO peut refléter soit une élévation de la couche basaltique dans cette direction, soit la présence des magmatites basiques des Transylvanides en dessous de la nappe des Dacides internes (Andrei dans Borcoş et al., 1992, 1993).

L'interprétation des données gravimétriques vient à l'appui des conclusions fournies par les données magnétométriques.

L'importance économique de cette zone réside dans la présence des roches magmatiques aux altérations hydrothermales, pyritisées et minéralisées parfois à chalcopyrite, rencontrées en plusieurs forages (figure 8) à des profondeurs minimales allant de 1200 à 1900 m, dont les moindres se trouvent le long de la Faille Nord-Transylvaine.

Remerciements

Les données concernant la lithologie détaillée des formations géologiques traversées par les forages ont été mises à notre disposition avec beaucoup d'amabilité par l'Institut de Recherches et Projets pour Pétrole et Gaz de Câmpina (le Groupe des Sections de Recherche de Bucarest), dont nous nous faisons un devoir de souligner et de remercier l'aide.

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UNELE SEMNIFICAŢII FIZICE ALE ELIPSEI DE POLARIZARE A CÂMPULUI TELURIC

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Key words: Telluric field. Polarization ellipse. Earthquakes.

Abstract: *Physical Significances of the Polarization Ellipse of the Telluric Field.* This paper presents the results of the processing of the data obtained as a result of the measurement of the telluric currents field, frequency range 0.01–0.1 Hz, in the main stations situated in Iaşi (1991) and Cluj (1992) areas. The study of the polarization ellipses parameters calculated for five-minute intervals (300 samples) stressed out a correlation between the variations of the size of the ellipse area and the variations of the dip angle of the polarization axis. The analysis of the natural or artificial factors that can influence the ellipse parameters revealed that the geological structure is the most important, a significant part being also played by the parameters of the external and/or internal source. It is of note the special significance of the study of the telluric field polarization, considering the latest interest in the sources of the electric/electromagnetic field related to the tectonic activity in the epicentre of a possible earthquake. Thus, new possibilities of studying the electric-electromagnetic phenomena, some of which with a precursor character, related to earthquakes are taken into consideration.

Introducere

Analiza proprietăţilor electrice ale atmosferei, ionosferei şi dinamicii magnetosferei, relevează sistemul de curenţi staţionari, magnetosferic-ionosferic, alimentat cu energie prin vântul solar. Variaţiile de densitate, viteză şi câmp ale acestuia, schimbă sistemul de curenţi în totalitate sau parţial, explicându-se astfel originea fluctuaţiilor geomagnetice la suprafaţa Pământului. Se aproximează că evoluţia câmpului electromagnetic natural se comportă ca o succesiune de unde plane care se propagă în direcţia verticalei coborâtoare, pătrunzând în subsol până la adâncimi care depind de frecvenţa oscilaţiilor şi rezistivităţii subsolului.

Introducerea unor ipoteze simplificatoare adecvate, privind sursele externe sau modul de interacţiune al acestor câmpuri cu scoarţa terestră, a condus la prelucrări şi interpetări din ce în ce mai precise ale datelor achiziţionate prin metode magnetotelurice, telurice sau geomagnetice.

Pe de altă parte, studiul unor fenomene electrice asociate seismelor a impus în ultima vreme ipoteza potrivit căreia activitatea tectonică poate schimba câmpul geoelectric prin procese în care Pământul creează o sursă de cîmp electric. Presupunând că cele două câmpuri (de sursă externă şi, respectiv, internă) coexistă într-un punct oarecare de pe suprafaţa scoarţei, autorii propun, în această lucrare, studiul comportării în timp a elipsei de polarizare a câmpului teluric, în domeniul de frecvenţe 0,01–0,1 Hz, specific pulsaţiilor şi micropulsaţiilor.

Prezentăm pe scurt câteva aspecte legate de aparatura folosită şi metoda de lucru. Două echipamente (R1 şi R2), de tipul TEM-80, permit măsurarea câmpului teluric prin intermediul dispozitivului în formă de L, ale cărui laturi X şi Y sunt orientate după direcţiile nord-sud, respectiv, est-vest, utilizându-se electrozi impolarizabili, de tipul Pb-$PbCl_2$. Semnalele electrice, corespunzătoare canalelor Ex şi Ey, sunt filtrate, amplificate, multiplexate şi convertite digital. Eşantionarea se face la fiecare secundă, iar un microprocesor permite însumarea variabilelor Ex şi Ey, calculează sumele şi diferenţele necesare realizării elipselor absolute şi controlează canalele analogice. Calculatorul de proces realizează sincronizarea măsurătorilor când sunt efectuate cu ambele staţii, asigurându-se controlul şi înregistrarea valorilor necesare calculului elipsei de polarizare la fiecare 300 de secunde. Pentru calibrarea respectivă şi controlul coeficienţilor de sensibilitate ai amplificatoarelor, Ex, Ey (R1) sau Eu, Ev (R2), se folosesc semnalele electrice sinusoidale de frecvenţă 0,03 Hz, generate de calibratoarele încorporate fiecărui echipament. Automatizarea prelucrării datelor primare, facilitată de utilizarea aparaturii TEM-80 şi a programului TELLUR livrat de firma constructoare (ELGI-Budapesta), pentru calculul parametrului J prin determinarea elipselor absolute, mai furnizează şi valori ale axei mici, axei mari, sau ale unghiului Φ făcut de direcţia de polarizare cu direcţia sistemului de referinţă.

1. Prezentarea rezultatelor

Faptul că observaţiile în staţia de bază sunt continue, uneori extinzându-se pe parcursul a 10-12 ore ale unei zile, oferă posibilitatea ca volumul de date rezultat să devină suficient de mare pentru descrierea dependenţei de timp a caracteristicilor câmpului teluric. Ca urmare, s-au determinat la fiecare cinci minute ariile elipselor absolute, iar prin raportare la aria elipsei calculată în acelaşi loc, pentru acelaşi interval de timp ales la începutul primei zile de observaţii a întregului sezon de înregistrări, s-a obţinut un parametru similar parametrului J. Ariile elipselor astfel normate, precum şi valorile unghiurilor Φ obţinute, au fost reprezentate în funcţie de axa tim-

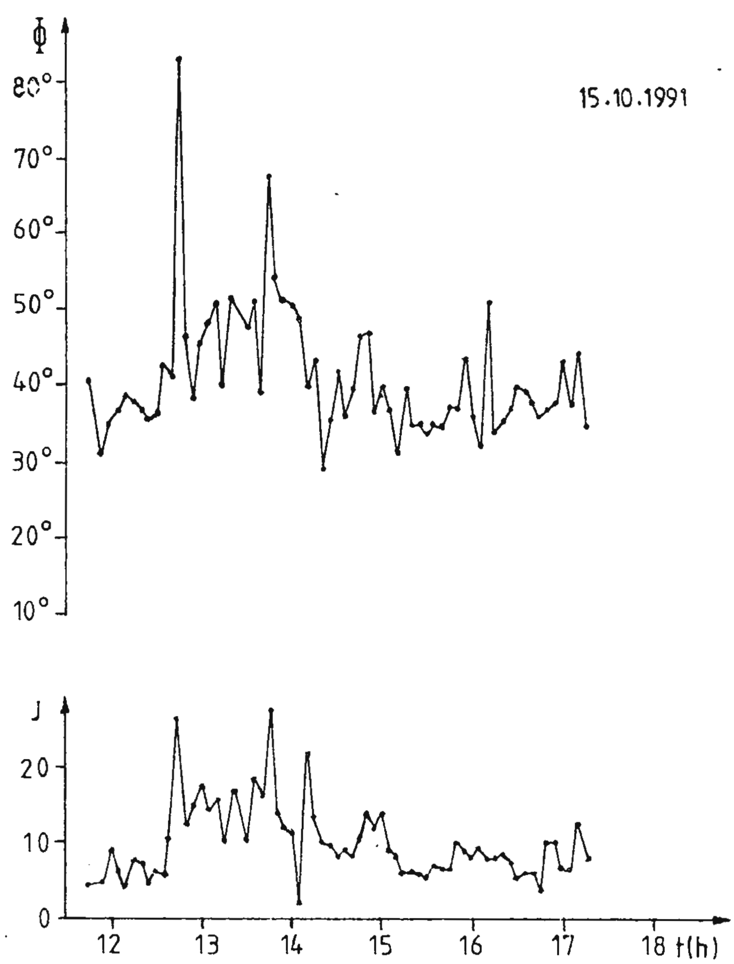

Fig. 1 – Variaţia parametrilor J şi Φ în baza Ţigănaşi

pului, două exemple fiind prezentate în figurile 1 şi 2, pentru variaţia parametrului **J**.

Parametrii **a** şi **b** (semiaxa mare şi semiaxa mică) ai elipselor normate, împreună cu unghiurile Φ corespunzătoare, au permis trasarea unor puncte care se situează la extremităţile axelor mari şi mici, într-un sistem de coordonate XOY asociat sistemului rezultat din orientarea dispozitivului de măsură în teren.

4. Diagramele construite pentru baza Ţigănaşi, demonstrează o bună corelaţie (uneori pozitivă, alteori negativă) între variaţia ariei normate şi variaţia unghiului Φ. Corelaţia se păstrează şi pentru variaţiile de perioadă mare, amintite anterior.

5. Diagramele aferente bazei Stavnic, manifestă o slabă corelaţie, ori aceasta lipseşte complet.

Figurile 3 şi 4 redau exemple de variaţie a polarizării

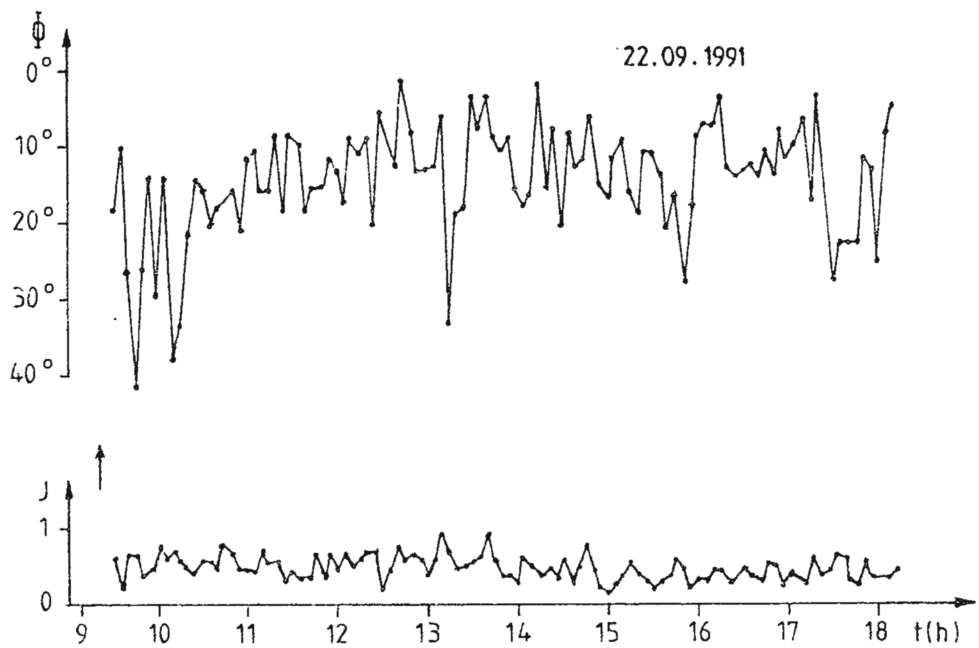

Fig. 2 – Variaţia parametrilor J şi Φ în baza Stavnic

Calculele s-au efectuat pentru datele achiziţionate în două baze de referinţă, folosite la realizarea hărţilor de curenţi telurici în zona Iaşi-Ştefăneşti: 1 – baza Ţigănaşi, amplasată la circa 20 km nord de Iaşi, cuprinde 10 zile de observaţii în perioada 26.06-27.11.1991 şi 2 – baza Stavnic, situată la circa 20 km sud-vest de Iaşi, cuprinde 15 zile de observaţii realizate în perioada 22.08.-6.11.1991.

Prin examinarea celor 25 perechi de diagrame (de exemplu figura 1 şi figura 2), s-au identificat atât trăsături comune, privind variaţia câmpului teluric în cele două baze, cât şi particularităţi:

1. Se observă aspectul agitat al graficului mărimii ariilor elipselor normate, dar mai cu seamă al valorilor unghiului Φ.

2. Există zile în care agitaţia atinge grade foarte înalte şi zile de un calm relativ.

3. Există o tendinţă în ambele diagrame (Φ şi **J**) ca variaţiile caracteristice pentru 300 de eşantioane să se grupeze în zone de amplitudini mai mari, ori mai mici, rezultând curbe de mediere cu perioade de ordinul orelor.

câmpului teluric faţă de direcţiile de măsură nord-sud şi est-vest. Totalitatea punctelor corespunzătoare elipselor înregistrate în fiecare zi, generează distribuţii mai mult sau mai puţin grupate. Fără excepţie, gruparea se face în jurul unor elipse, însă diferenţierea între baza Stavnic şi baza Ţigănaşi este semnificativă în ceea ce priveşte gradul de împrăştiere.

2. Discuţii asupra rezultatelor obţinute; factori care pot influenţa elipsa de polarizare a câmpului teluric

Manifestările anterioare nu surprind, ele fiind consecinţe normale ale comportării curenţilor telurici, în ipoteza existenţei sursei externe, însă nu contrazic nici ipoteza existenţei sursei de natură tectonică. Considerăm că o discuţie asupra evoluţiei în timp a elipsei de polarizare a câmpului curenţilor telurici poate fi făcută numai în paralel cu prezentarea unora dintre factorii naturali sau instrumentali care pot influenţa măsurătorile în teren.

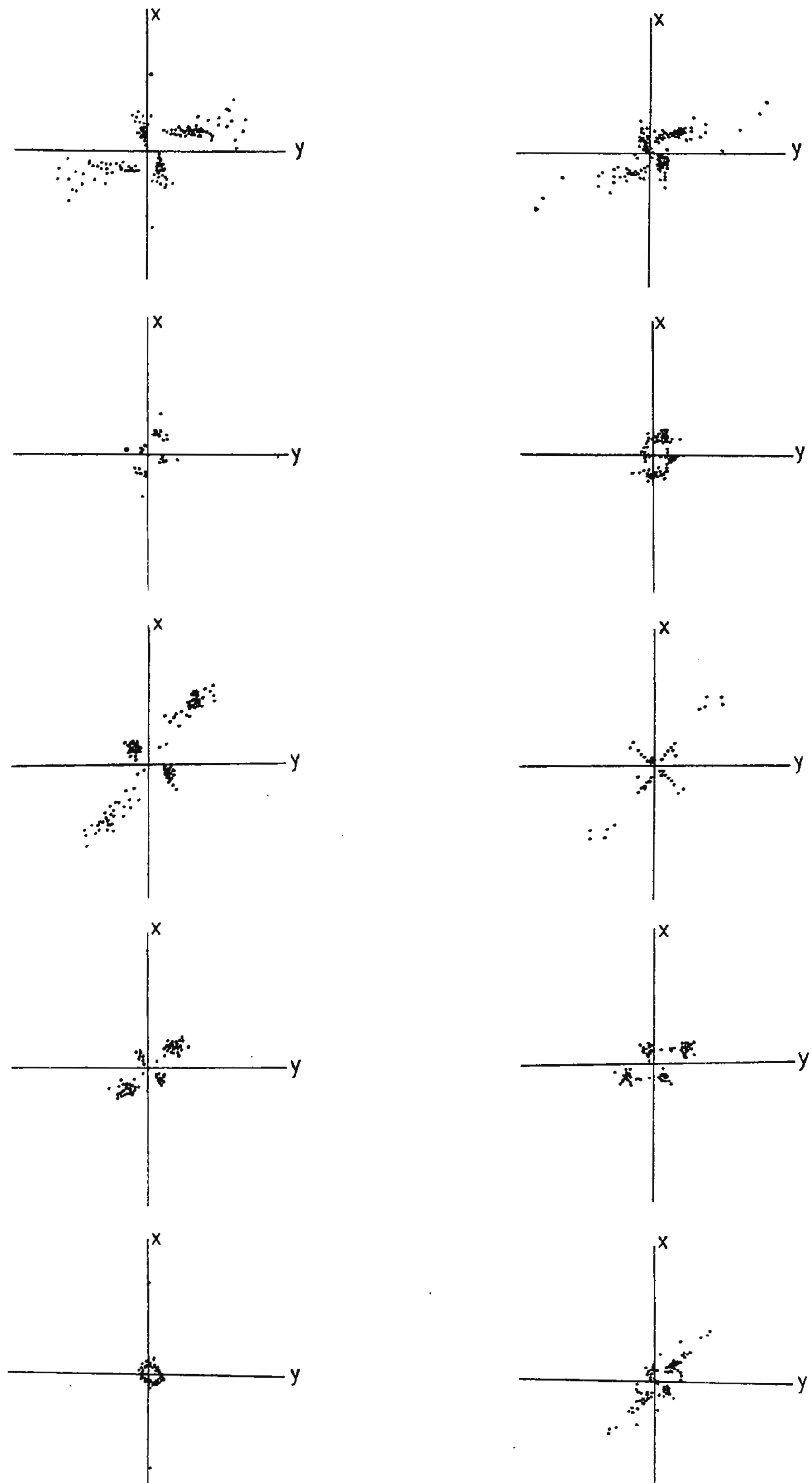

Fig. 3 – Grafice ale polarizării în baza Ţigănaşi, pentru zile diferite

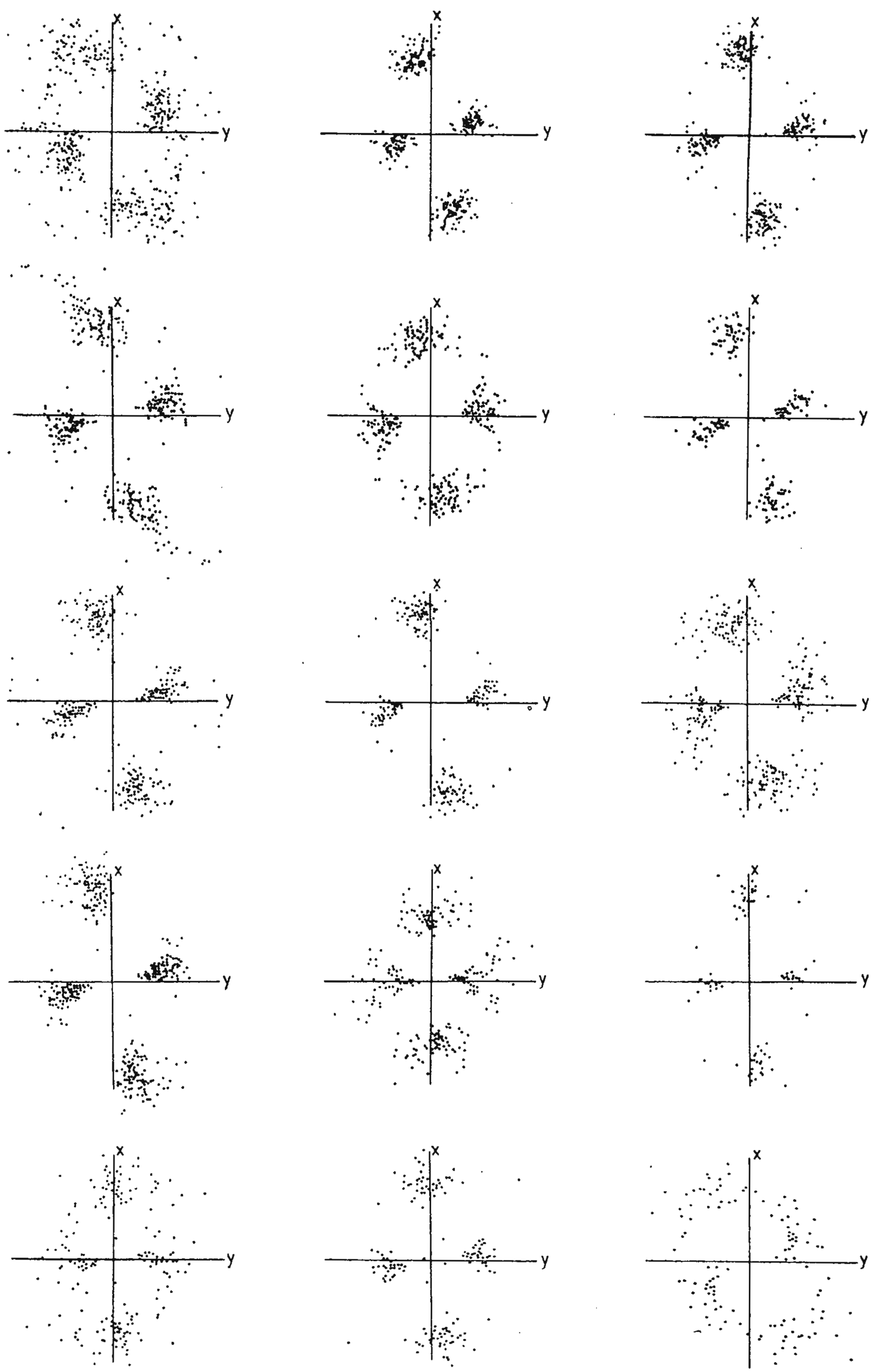

Fig. 4 – Grafice ale polarizării în baza Stavnic, pentru zile diferite

2.1. Condiţiile de relief

În general, problemele se referă la măsurile de precauţie care trebuie luate la amplasarea dispozitivului, în scopul înlăturării unor fenomene legate de prezenţa reliefului accidentat. O independenţă în fluctuaţii, mergând până la dispariţia corelaţiei între semnalele a două linii de aceeaşi direcţie, se manifestă uneori (Fatemi, 1963) pe pante şi în terenurile accidentate, astfel de perturbaţii nefiind observate pe câmpii sau în regiunile plate. Aceasta ar putea constitui unul dintre motivele pentru care nu există corelaţie între diagrama ariilor normate (**J**) şi diagrama unghiurilor Φ pentru baza Stavnic, unde intervin unghiuri verticale pe cele două direcţii de amplasare a liniilor de măsură. Baza Ţigănaşi se remarcă printr-o suprafaţă perfect plană, iar liniile de măsură au orientări similare celor din baza Stavnic.

2.2. Influenţe instrumentale prin dezechilibrarea amplificatoarelor electronice

În determinările noastre, considerăm că aceste influenţe sunt reduse la minim, aparatura TEM-80 având o serie de facilităţi în acest sens. Problema se reduce la o corectă etalonare a canalelor de amplificare, prin calculul sensibilităţilor Ex, Ey, Eu, Ev, precum şi printr-o verificare a acestora în timp.

2.3. Efecte ale factorilor meteorologici şi ale activităţilor umane

Influenţa factorilor meteorologici s-a eliminat, în general, prin evitarea zilelor improprii înregistrării câmpului teluric (vânt, ploaie, descărcări electrice etc.).

Rejectarea frecvenţei de 50 Hz şi a armonicelor acesteia, asigurată de aparatura TEM-80, îmbunătăţeşte mult posibilitatea de înregistrare a câmpului natural în zone relativ apropiate de amplasamente industriale.

Câmpurile curenţilor vagabonzi, rezultaţi din folosirea curentului continuu, precum şi undele atmosferice (câmpuri generate de descărcări electrice, care se propagă între ionosferă şi suprafaţa Pământului la distanţe foarte mari) pot influenţa rezultatele finale.

2.4. Importanţa skin-efectului

Una dintre cauzele care determină agitaţia omniprezentă în variaţia ariilor elipselor relative, ori a unghiurilor Φ, ar consta în faptul că aparatura recepţionează un domeniu de frecvenţe (0,01–0,1 Hz) destul de larg, pentru ca distanţarea faţă de proprietăţile unei unde monocromatice să fie suficient de mare. Astfel, este posibil ca o serie de frecvenţe să lipsească în anumite intervale de timp, răspunsul prin inducţie al structurii geologice fiind, în consecinţă, diferit.

2.5. Importanţa structurii geologice

Elipsa telurică, a cărei direcţie şi elipticitate depinde de condiţiile de sursă, precum şi de condiţiile geologice (Yungul, 1961), este o funcţie complicată de elipsa sursei, care variază în timp şi de elipsa geologică, considerată ca invariant.

Figurile 3, 4, 6 şi 7 sintetizează valorile parametrilor elipselor realizate pentru bazele Ţigănaşi şi Stavnic (zona Iaşi, 1991) ori Chinteni (zona Cluj, 1992) şi evidenţiază că oricât de mare ar fi împrăştierea punctelor caracteristice, acestea se dispun în jurul unei elipse, care depinde în principal de structura geologică. Toate celelalte cauze de variaţie, prezentate la punctele anterioare, produc influenţe minore, atât timp cât sunt luate toate precauţiile pentru evitarea lor.

2.6. Influenţa electrozilor de măsură

Diferenţele de potenţial se stabilesc între electrozi dispuşi la distanţe de ordinul sutelor de metri. În general sunt două tipuri de electrozi, polarizabili şi impolarizabili, între aceştia existând deosebiri importante din punct de vedere constructiv (Martel şi Meunier, 1963).

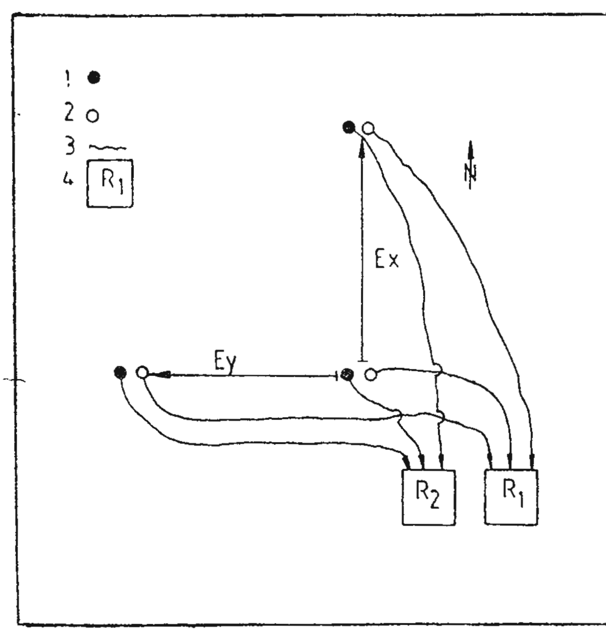

Fig. 5 – Amplasarea dispozitivelor de înregistrare în timpul experimentării tipurilor de electrozi. 1, electrod impolarizabil; 2, electrod polarizabil; 3, cabluri de conexiune; 4, echipamente pentru înregistrări telurice.

Descriem în continuare o experienţă realizată de noi, în scopul de a verifica influenţa unor electrozi polarizabili, din grafit, asupra parametrilor elipsei. Ambele echipamente TEM-80 s-au amplasat pe o suprafaţă topografică plană, în vecinătatea unui iaz, în condiţii meteorologice favorabile. Liniile electrice, de aceeaşi lungime, au fost orientate după direcţiile nord-sud şi

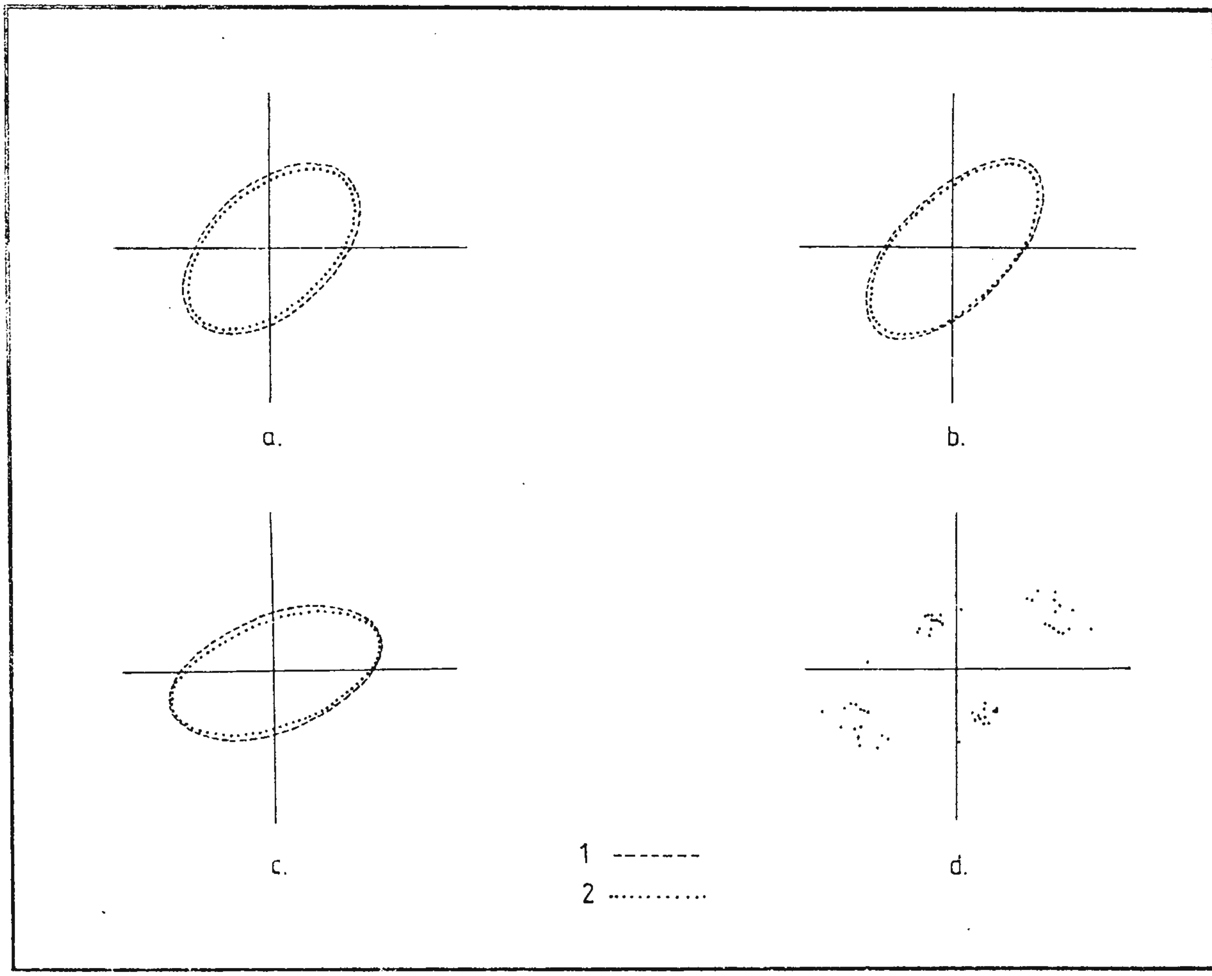

Fig. 6 – Elipse determinate pe baza potenţialelor măsurate între electrozi impolarizabili (Pb-$PbCl_2$). 1(a,b,c), elipse determinate cu echipamentul R1; 2(a,b,c), elipse determinate cu echipamentul R2; (d), nor de puncte corespunzător extremităţilor elipselor calculate pentru R1.

est-vest, având fiecare câte 150 metri. Prin aşezarea elecrozilor polarizabili şi impolarizabili la 10 centimetri unul de celălalt, s-a obţinut o identitate a condiţiilor de înregistrare pentru cele două dispozitive, menţinându-se însă independenţa lor din punct de vedere electric (fig. 5).

Experienţa s-a desfăşurat în luna august 1992, la circa 20 km nord de oraşul Cluj, între orele 13 h 45 min şi 18 h, în două etape. În prima etapă, ambele staţii, R1 şi R2, au măsurat sincron câmpul teluric, în condiţii identice, în intervalul de timp 13 h 45 min – 15 h 10 min. În cea de a doua etapă, păstrând ceilalţi parametri de înregistrare neschimbaţi, la R1 au fost înlocuiţi electrozii impolarizabili Pb–$PbCl_2$, cu electrozi polarizabili, din grafit. Inregistrarea a fost făcută între orele 15 h 30 min şi 18 h.

Rezultatele sunt exemplificate în figurile 6 şi 7. Pentru obţinerea lor s-a utilizat programul de calcul prin care se furnizează parametrii elipselor de polarizare (a, b, Φ), atât pentru R1, cât şi pentru R2. Figura 6 (a, b, c) reprezintă patru din cele 15 elipse calculate în condiţiile primei etape, în care s-au utilizat exclusiv electrozi impolarizabili. Gruparea foarte bună a norului de puncte (fig. 6d) în jurul unei elipse, reflectă gradul redus de variabilitate a parametrilor elipselor, calculaţi la fiecare cinci minute. Introducerea electrozilor polarizabili în dispozitivul lui R1, a avut ca efect variaţii deosebite ale parametrilor elipselor (fig. 7). Figura 7f reliefează gradul înalt de împrăştiere al punctelor care materializează maximele şi minimele elipselor, demonstrând că pe tot parcursul experimentului, răspunsul electrozilor polarizabili se deosebeşte uneori, în mod semnificativ, de răspunsul electrozilor impolarizabili.

Sunt câteva concluzii care se desprind:

– Elipsele calculate pentru înregistrarea simultană, folosind electrozii impolarizabili Pb–$PbCl_2$, sunt foarte asemănătoare, atât ca mărime, cât şi ca direcţie. În

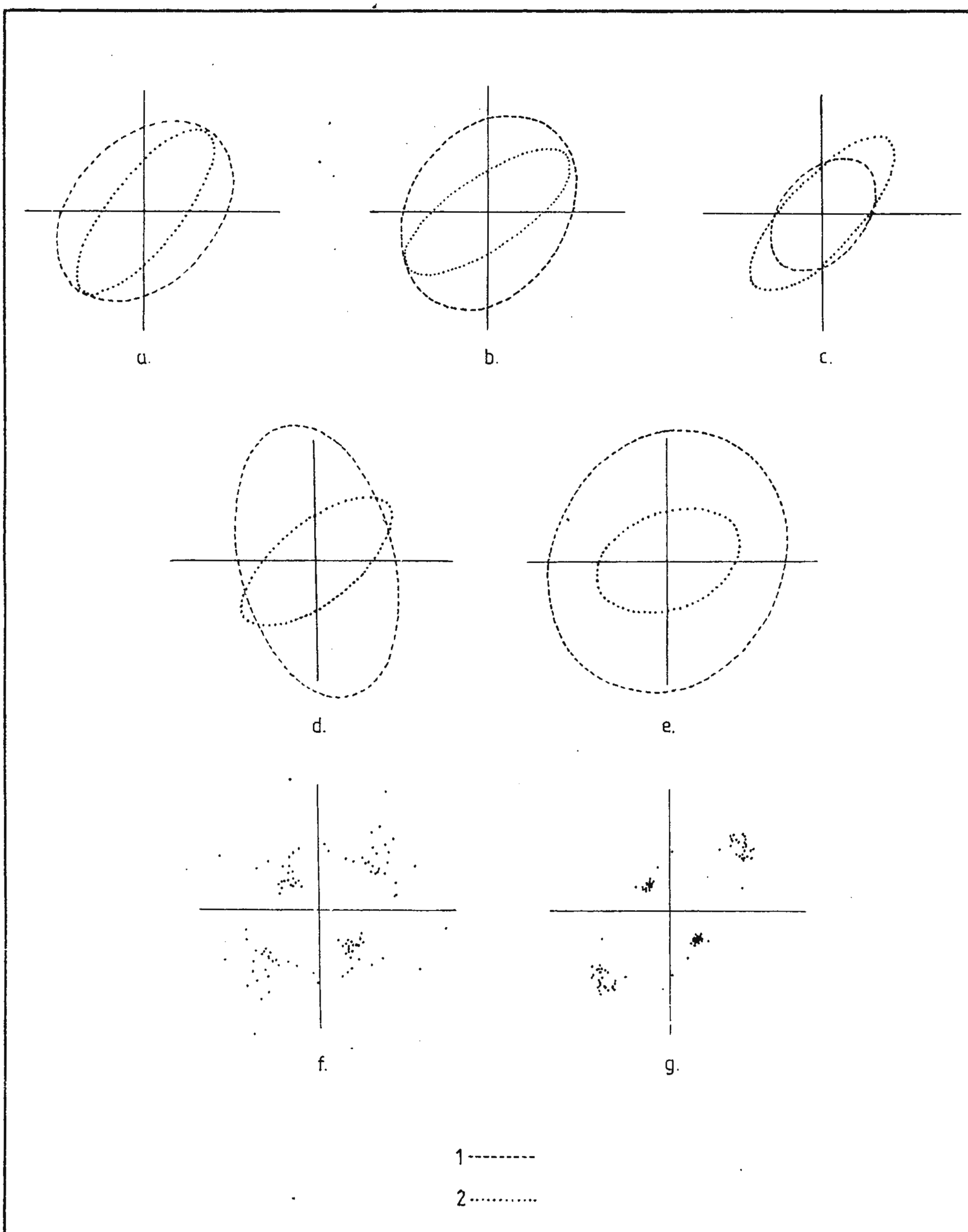

Fig. 7 – Elipse determinate simultan pe baza diferenţelor de potenţial măsurate între electrozi impolarizabili (R2) şi între electrozi polarizabili (R1). 1 (a,b,c,d,e), elipse determinate cu echipamentul R1 şi electrozi polarizabili; 2 (a,b,c,d,e), elipse determinate cu echipamentul R2 şi electrozi impolarizabili; (f), norul de puncte corespunzător extremităţilor elipselor calculate pentru diferenţe de potenţial măsurate între electrozi polarizabili; (g), norul de puncte corespunzător extremităţilor elipselor calculate pentru diferenţe de potenţial măsurate între electrozi impolarizabili.

consecinţă, punctele obţinute pentru parametrii tuturor elipselor sunt suficient de grupate, generând forma unei elipse medii, corespunzătoare întregului interval de observaţii (fig. 6d, 7g).

– Prin contrast cu situaţia de mai sus, în cazul folosirii electrozilor polarizabili, parametrii elipselor devin mult mai instabili. S-a constatat că ariile elipselor determinate de R1 au un caracter oscilant faţă de ariile determinate în acelaşi interval de timp pentru R2, oscilaţia având perioade de ordinul zecilor de minute.

– Variaţia unghiului corespunzător orientării axei mari a elipsei faţă de direcţia nord-sud, este mult mai amplă pentru electrozii polarizabili, comparativ cu variaţia pentru electrozii impolarizabili, fenomen care generează şi gradul înalt de împrăştiere a norului de puncte.

Cazurile de salturi (fig. 7d), atât în mărimea ariilor, cât şi a unghiurilor Φ, au fost analizate pe diagramele cu semnale analogice, corespunzătoare intervalelor de timp luate în calcul. S-a identificat astfel prezenţa unor "pulsaţii" de amplitudini mari, pe ambele canale ale staţiei R1 (fig. 8a). Cauza ar fi că electrodul de referinţă a suportat o descărcare electrică la nivelul contactului cu solul şi, în consecinţă, au fost influenţate diferenţele de potenţial pe ambele direcţii de măsură. Nu se poate explica în acest mod tipul de elipsă obţinut pentru cinci minute de observaţie, încheiate la 17 h 25 min (fig. 7e), în condiţiile unui semnal redus, care tinde să reflecte un fenomen natural, surprins cu intensităţi şi caracteristici de fază diferite, de către cele două categorii de electrozi utilizate (fig. 8b).

Urmare a celor arătate mai sus, noi considerăm că, pentru cazurile în care măsurătorile au beneficiat de condiţii naturale şi tehnice favorabile, unele comportări ale câmpului curenţilor telurici sunt explicabile şi prin activitatea unei surse de câmp electric de origine internă, probabil de natură tectonică.

Câteva aspecte legate de sursa internă de câmp electromagnetic asociat producerii cutremurelor de pământ

La nivelul experienţei mondiale, s-a evidenţiat că înregistrările câmpului electromagnetic natural conţin o serie de efecte anomale care pot fi asociate cutremurelor de pământ. Deoarece manifestările observate cuprind un domeniu larg de frecvenţe (0-zeci Mhz), fiind întâlnite la suprafaţa Pământului, în aer, precum şi la altitudinile de zbor ale sateliţilor, metodele de investigare sunt, în mod corespunzător, foarte diversificate. Metodele magnetotelurice şi telurice menţin sub observaţie domeniul frecvenţelor ultra-joase, la nivelul solului (Ralchovsky, 1990; Labeyrie, 1988; Maron, 1992, unpubl. data; Takahashi, Fujinawa, 1991; Mori et al., 1991). Interesul deosebit este trezit de valoarea de predicţie pe care o capătă semnalele înregistrate înaintea evenimentului seismic. O problemă importantă apare dacă se admite că sursa undelor electromagnetice se găseşte în hipocentru. Calculele arată că, plecând de la 10 km adâncime, numai undele de tip ULF (< 10 Hz) pot atinge supafaţa (Parrot et al., 1990, unpubl. data; Honkura, Kuwata, 1991).

Deci, se pune accentul pe identificarea formelor de manifestare a unei eventuale surse de câmp electric/electromagnetic interne, precum şi pe localizarea acesteia în spaţiu. Autorii prezentei lucrări consideră logică ipoteza conform căreia, în cazul existenţei unei surse interne, elipsa de polarizare a câmpului electric (electromagnetic) natural, să conţină şi informaţii asupra modului de manifestare al acesteia. De asemenea, ar exista posibilitatea ca activitatea electromagnetică asociată să fie cvasicontinuă în timp, putându-se detecta o creştere a intensităţii câmpului, pentru un observator care se apropie de sursă. În aceste condiţii, s-ar putea utiliza o serie de proprietăţi ale elipsei, legate în general de parametrii acesteia, care pot caracteriza direcţia şi sensul de propagare a câmpului, şi implicit, tipul de sursă care l-a generat (internă ori externă). Parametrii Stokes normalizaţi, ar putea furniza date mai apropiate de realitate, în ceea ce priveşte caracterizarea undei, ţinând seama de condiţiile naturale de aplicare (Moisil, Moisil, 1973).

O cale interesantă în încercările de determinare a poziţiei sursei interne, poate fi sugerată de unul din principiile de bază întâlnite în radiolocaţie. Acesta arată că polarizarea eliptică se poate obţine din interferenţa a două câmpuri ortogonale, de aceeaşi frecvenţă, însă defazate cu un unghi oarecare. Tensiunea indusă de o undă în antena de recepţie polarizată eliptic, depinde de parametrii de polarizare ai undei directe. Ea este maximă, dacă între polarizarea undei recepţionate şi aceea a antenei, în regim de emisie, există concordanţă, iar vectorii câmp electric au acelaşi sens de rotaţie şi minimă, dacă axele elipselor sunt perpendiculare, iar sensul celor două câmpuri este invers (Nicolau, Rogobete, 1978). În aplicaţia geofizică, rolul antenei în emisie cu semnal polarizat l-ar putea juca însăşi structura geologică, câmpul căutat fiind cel aparţinând sursei interne. Bineînţeles, situaţiile geofizice sunt mult mai complicate, iar dificultăţile ar putea fi insurmontabile. Totuşi, prin găsirea unor metode (de exemplu măsurarea inclusiv a componentei verticale a câmpului teluric) şi mijloace adecvate (aici putem reaminti factorii discutaţi în capitolul precedent), s-ar putea obţine unele rezultate încurajatoare.

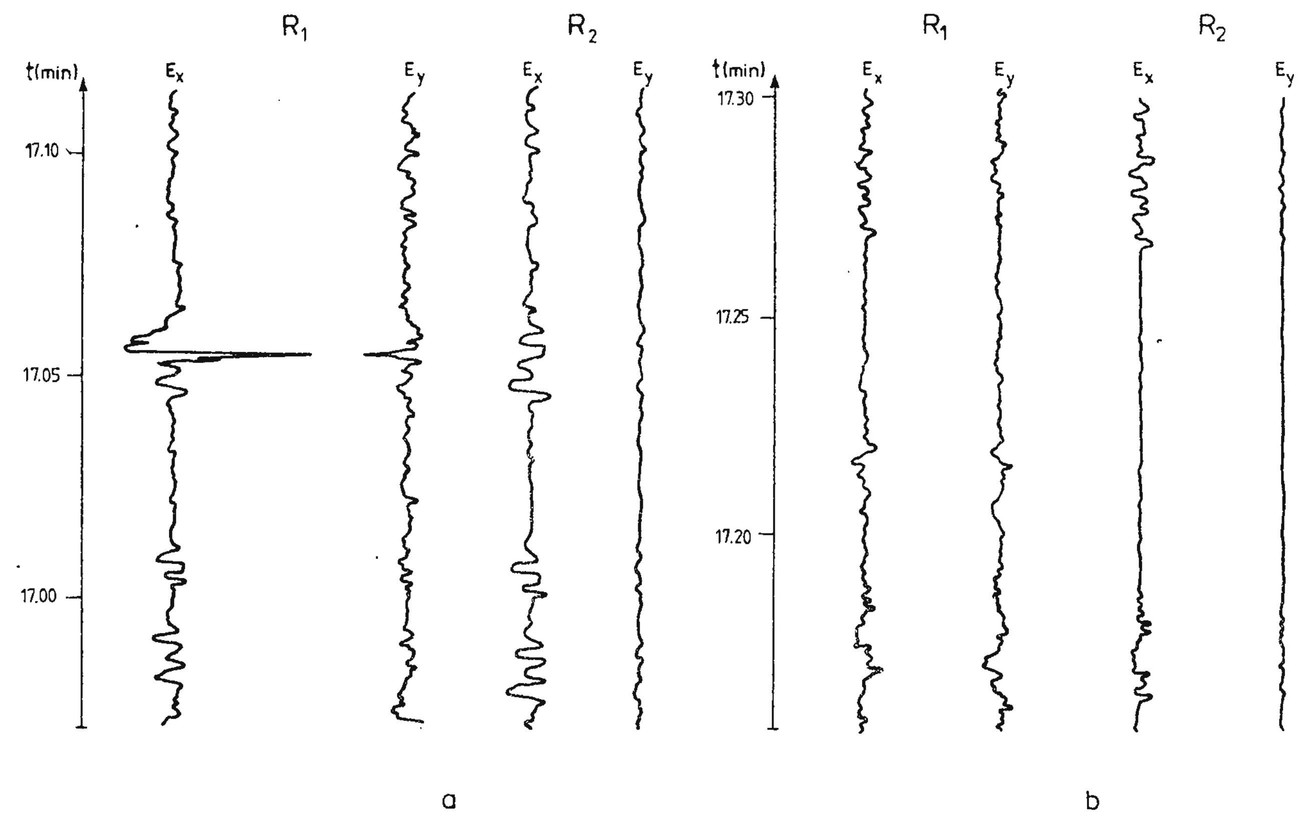

Fig. 8 – Înregistrări analogice efectuate cu echipamentele R1 şi R2 în acelaşi loc, însă cu electrozi polarizabili şi, respectiv, impolarizabili. a, efecte ale electrozilor polarizabili ?; b, fenomen electric surprins în mod diferit de către cele două tipuri de electrozi ?

4. Concluzii şi propuneri

Analiza parametrilor elipsei de polarizare a câmpului teluric, prin observaţii efectuate într-un singur loc, în domeniul de frecvenţe 0,01–0,1 Hz, conduce la câteva concluzii:

1. S-a evidenţiat o corelaţie bună, atât pozitivă, cât şi negativă, între variaţiile mărimii ariei elipsei şi a unghiului de înclinare a axei de polarizare faţă de direcţia nord-sud. În urma trecerii în revistă a unor factori care pot influenţa parametrii elipsei de polarizare şi bazându-ne pe rezultatele observaţiilor noastre, considerăm că ponderea cea mai mare în polarizarea câmpului teluric revine structurii geologice, nefiind exclusă şi influenţa unei surse de origine internă.

2. Experimentarea, în condiţii identice şi de simultaneitate, a două dispozitive de măsură independente, în care unul utilizează electrozi impolarizabili (Pb–$PbCl_2$), iar celălalt electrozi polarizabili (grafit) a relevat comportamentul diferit al elipselor de polarizare calculate pentru diferenţele de potenţial furnizate. Se remarcă instabilitatea elipsei construite pentru electrozii polarizabili. Comportamentul descris în figurile 7d şi 8 sugerează că deosebirile pot apare şi din cauza unui fenomen electric natural, posibil asociat unei activităţi tectonice, acesta fiind probabil surprins cu intensităţi şi caracteristici de fază deosebite, de către cele două tipuri de electrozi.

3. Recent, la nivel mondial, mulţi cercetători presupun că zona de focar a unui viitor seism se poate comporta ca sursă de câmp electric. În ipoteza că activitatea unei astfel de surse este cvasicontinuă, câmpul la suprafaţă devenind mai intens pe măsură ce distanţa la focar se micşorează, autorii consideră că elipsa de polarizare absolută poate conţine informaţii asupra modului de manifestare a undelor generate din cauze tectonice.

Propunem investigarea posibilităţilor care permit o exploatare a proprietăţilor elipsei de polarizare a câmpului teluric (sau magnetoteluric) în frecvenţe ULF ($<$ 10 Hz), în vederea identificării unor procedee de reperare a sursei de origine tectonică. Aplicaţiile pot include şi urmărirea semnalelor electrice sau electromagnetice cu caracter precursor cutremurelor de pământ.

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J. T. WEAVER : Mathematical Methods for Geo-electromagnetic Induction, Research Studies Press Ltd., Taunton, Somerset, England, ISBN 0 86380 165 X, 316 p.

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