Istituto Nazionale di Geofisica

Geomagnetic Survey of Italy at 1979.0 Repeat Station Network and Magnetic Maps

Geomagnetism Group

F. Molina, E. Armando, R. Balia, O. Battelli, E. Bozzo, G. Budetta, G. Caneva, M. Ciminale, N. De Florentiis, A. De Santis, G. Dominici, M. Donnaloia, A. Elena, V. Iliceto, R. Lanza, M. Loddo, A. Meloni, E. Pinna, G. Santarato and R. Zambrano

Pubblicazione n. 554

PREFAZIONE

A tutt'oggi la pubblicazione finale del lavoro svolto nall'ambito del Progetto Finalizzato Geodinamica del C.N.R. dal Gruppo Geomagnetismo, non è ancora stata effettuata. Il lavoro del Gruppo Geomagnetismo aveva portato alla realizzazione della nuova Rete Magnetica Italiana dei caposaldi e della Rete Magnetica del II ordine, coronata quest'ultima dalla stampa delle carte delle componenti intensive H, Z ed F nonchè della carta delle anomalie del campo totale. Il notevole ritardo accumulato dal C.N.R. per la stampa di questo lavoro, oltre ad aver avvilito i componenti del gruppo che negli anni 1977-1981 hanno effettuato materialmente le operazioni di campagna nonchè l'elaborazione dei dati, la riduzione all'epoca 1979.0 di tutte le misure e la compilazione delle mappe, ha privato il P.F.G. e gli autori della possibilità di divulgarne opportunamente i risultati e di citarli nelle successive pubblicazioni che necessariamente di essi hanno fatto uso.

L'Istituto Nazionale di Geofisica durante la realizzazione del Progetto oltre ad aver partecipato alle misure, ha coordinato tutto il lavoro delle varie unità operative e compilato le mappe prodotte. In questa occasione, stante la difficoltà di veder ancora pubblicati quei risultati, l'I.N.G. ha ritenuto, in pieno spirito di collaborazione, di effettuare la stampa del testo che fu concordato tra i vari autori nel 1986 quando fu prodotta l'ultima carta, quella delle anomalie crostali che rimane ancora il risultato più significativo. Questo lavoro viene quindi oggi stampato come Pubblicazione dell'Istituto Nazionale di Geofisica rimanendo, come testo, nella sua forma originale approvata dagli autori nel 1986. Si è infatti ritenuto corretto che comunque quel lavoro si volesse finalmente portare a conoscenza della comunità scientifica per poter inoltre essere correttamente citato nelle sedi opportune.

Il Gruppo Geomagnetismo
del Progetto Finalizzato Geodinamica
(C.N.R.)

PREFACE

Up to now the final publication of the work undertaken by the Geomagnetism Group within the frame of the Progetto Finalizzato Geodinamica (P.F.G.) of the Consiglio Nazionale delle Ricerche (C.N.R.), has not yet been made. One of the main results of this work was the updating of the repeat station network at 1979.0 and the accomplishment of the second order network, with the consequent preparation of the H, Z, and F magnetic elements charts and the F anomaly map as well. In the meanwhile the great delay taken by C.N.R. had mortified the components of the Geomagnetism Group who during 1977-1981 materially made field work, data processing, fixed epoch reduction and magnetic charts compilation. This delay has also deprived the P.F.G. and its components, of the possibility of making the results properly known and quoted in successive related publications.

During the progress of the project the Istituto Nazionale di Geofisica (I.N.G.) apart from its direct involvement in making field measurements, has coordinated all the tasks among all the operative units and materially compiled the final maps. Owing to the difficulty to see the results published in a close future, in the spirit of full cooperation, the I.N.G. has decided to publish the text which was prepared by all the authors in 1986 together with the crustal anomaly map of the total intensity, which is the most significant result obtained by the Geomagnetism Group. The work is now therefore finally published as an I.N.G. Publication and it remains in its original 1986 version, with all limitations, because the authors decided to present the results obtained as they were completed at that time.

The Geomagnetism Group
of the Progetto Finalizzato Geodinamica
(C.N.R.)

GEOMAGNETIC SURVEY OF ITALY AT 1979.0. REPEAT STATION NETWORK AND MAGNETIC MAPS

Geomagnetism Group

F. Molina (1), E. Armando (2), R. Balia (3), O. Battelli (1), E. Bozzo (4), G. Budetta (5), G. Caneva (4), M. Ciminale (6), N. De Florentiis (7), A. De Santis (1), G. Dominici (1), M. Donnaloia (11), A. Elena (4), V. Iliceto (7), R. Lanza (9), M. Loddo (6), A. Meloni (1), E. Pinna (10), G. Santarato (8) and R. Zambrano (7).

(1) Istituto Nazionale di Geofisica.
(2) Istituto di Arte Mineraria del Politecnico di Torino.
(3) Cattedra di Geofisica Mineraria dell'Università, Cagliari.
(4) Dipartimento Scienze della Terra, Università di Genova.
(5) Istituto Internazionale di Vulcanologia, Catania.
(6) Dipartimento di Geologia e Geofisica dell'Università, Bari.
(7) Dipartimento di Geol., Paleont. e Geofis., Università di Padova.
(8) Istituto di Mineralogia dell'Università, Ferrara.
(9) Dipartimento Scienze della Terra, Università di Torino.
(10) Dipartimento Scienze della Terra, Università di Pisa.
(11) Osservatorio di Geofisica e Fisica Cosmica, Bari.

ABSTRACT

A national network of 106 repeat stations for total field F, horizontal component H, vertical component Z and declination D has been undertaken in the frame of the 'Progetto Finalizzato Geodinamica' of the Consiglio Nazionale delle Ricerche.

From the observed magnetic elements the repeat station values were referred to 1979.0 and five normal fields in the form of a 2nd order polynomial in latitude and longitude were computed: GDN for the whole Italian area, GDN-N for northern Italy, GDN-C for central Italy, GDN-S for southern Italy and GDN-Sn for Sardinia. From comparisons made on F between GDN and two planetary reference fields it has been concluded that for total field the polynomial form can be well considered as representative of the main field in the Italian area.

A 2nd order network of 2500 stations for F, Z, H has been undertaken to produce geomagnetic maps of Italy. An anomaly map for F referred to the GDN normal field has been drawn. The main features of anomalies configuration are described.

RIASSUNTO

Nel quadro del Progetto Finalizzato Geodinamica è stata realizzata una rete di caposaldi magnetici che ha perfezionato l'antica rete dell'Istituto Geografico Militare con l'aumento a 106 del numero dei caposaldi e l'inclusione degli elementi F e Z e una rete del secondo ordine negli elementi F, Z, H. Dai valori degli elementi magnetici F, Z, H e D nei caposaldi, riferiti al 1979.0 sono stati calcolati cinque campi normali per elemento in forma di polinomi di secondo grado in latitudine e longitudine: GDN, per l'intero territorio italiano; GDN-N, per l'Italia settentrionale; GDN-C, per L'Italia centrale; GDN-S, per l'Italia meridionale; GDN-Sn, per la Sardegna.

Dal confronto, effettuato per l'elemento F, fra il GDN e due campi di riferimento planetari, si conclude che per l'intensità totale il GDN può con buona approssimazione essere considerato come rappresentativo del campo geomagnetico principale nella regione italiana. Dalla rete del secondo ordine sono state costruite le carte magnetiche dell'Italia per F, Z e H, e la carta delle anomalie di F, dedotte assumendo come riferimento il campo GDN. Vengono descritte e brevemente discusse le principali caratteristiche di queste anomalie.

1. INTRODUCTION

Starting in 1977, two major geomagnetic projects were undertaken in the frame of the 'Progetto Finalizzato Geodinamica' of the Consiglio Nazionale delle Ricerche:

1) a new national network of repeat stations for total field F, horizontal component H, vertical component Z and declination D.

2) a 2nd order network of stations for F, Z, H to produce geomagnetic maps of Italy.

The two projects were carried out by a 'Geomagnetism Group' made of 7 Operating Units, listed below (the codes on the first column of the list will be used through the text):

OPERATING UNIT	INSTITUTE
ING	Istituto Nazionale di Geofisica
FE	Istituto di Mineralogia dell'Università di Ferrara
BA	Istituto di Geodesia e Geofisica dell'Università di Bari
GE	Istituto Geofisico e Geodetico dell'Università di Genova Istituto di Arte Mineraria del Politecnico di Torino Istituto di Geologia dell'Università di Torino
PD	Istituto di Fisica Terrestre dell'Università di Padova
OV	Osservatorio Vesuviano Istituto Internazionale di Vulcanologia, Catania
CA	Cattedra di Geofisica Mineraria dell'Università di Cagliari

The field work ended in 1981. The ING Operating Unit coordinated the operations for both projects.

2. REPEAT STATION NETWORK

The repeat station network existing in Italy before 1977 had been established by the Istituto Geografico Militare more than 40 years ago, with 46 stations (Morelli, 1946). This old network was the base of the geomagnetic maps of H and D issued

and periodically updated by the Istituto Geografico Militare; the last updating was for 1973.0 (Talamo, 1975). The Geomagnetism Group decided to improve this old network by increasing the number of stations and including the elements F and Z.

Two major goals were in mind: a) the computation of normal fields in a simple mathematical form convenient for any user and objectively representative 1) of the whole Italian area, 2) of smaller regions of the country; b) a sufficient number of stations to monitor possible secular variation anomalies in the Italian area. A network of 106 stations was planned, 34 from the old network plus 72 stations, with mean distance between neighbouring stations of the order of 60 km.

The field work was carried out by Operating Units ING, FE, BA, GE, PD, OV. The operations started in spring 1977, when measurements were taken at about 20 stations. The remaining part of the field work was performed in summer 1978 and 1979; in this second part of the survey many of the 1977 stations were reoccupied.

The instruments used were:

for F : proton magnetometers
for H : QHM or proton magnetometer + GSI (Earth inductor)
for Z : proton magnetometer + GSI magnetometer
for D : GSI magnetometer.

The true north meridian was determined by means of known azimuth marks at existing stations, by means of Sun observations at the new stations.

The absolute values obtained in the field work at various epochs were reduced to 1979.0 according to the equation

$$E_s^{79.0} = E_{obs}^{79.0} + (E_s^t - E_{obs}^t) \qquad (1)$$

where:

E_s^t = value of element E observed at the station s at time t.
E_{obs}^t = value observed at the same time t at reference Observatory.
$E_{obs}^{79.0}$ = value at the Observatory at 1979.0.
$E_s^{79.0}$ = value of element at the station s reduced at 1979.0.

Equation (1) is valid only on the assumption that time variations at any station (daily variation, small perturbations, secular variations) are the same as those recorded at the reference Observatory. To ensure the validity of this assumption, 6 different Observatories were used: four existing permanent Observatories plus two installed for this purpose on a temporary basis. Three of the permanent Observatories are operated by ING Unit: L'Aquila (42° 23' N, 13° 19' E), Castel Tesino (46° 03' N, 11° 39' E), Gibilmanna (37° 59' N, 14° 01' E), the fourth by GE Unit (Istituto Geofisico e Geodetico, Genova University): Roburent (44° 18' N, 07° 53' E). Two Temporary Observatories were located in Southern Italy (Locorotondo 40° 48' N, 17°

22' E, operated by BA), and in Sardinia (Corongiu 39° 18' N, 09° 17' E, operated by CA).

The comparison of the instruments of the Observatories was carried out by the staff of ING Unit, who visited all the Observatories and checked the H and Z base lines by means of a proton magnetometer and a torsion magnetometer HTM calibrated at L'Aquila Geomagnetic Observatory according to the International Standard.

The reduction of data to 1979.0 was performed by ING.

In Table 1 (at the end of the text) we report the list of all repeat stations and Observatories with their geographic latitude, geographic longitude with respect to the meridians of Greenwich and Monte Mario (Rome), altitude above sea level, and values for the elements D, F, H and Z at 1979.0.

Estimated errors in the values of the geomagnetic elements at repeat stations, including measurements, time reduction and, for D, true meridian determination errors, are

$$\Delta F = \pm 8nT \qquad \Delta Z = \pm 8nT \qquad \Delta H = \pm 8nT \qquad \Delta D = \pm 2' \tag{2}$$

3. NORMAL FIELDS

From the values of the elements at the repeat stations, normal fields were computed for all elements. We mean here for normal field an analytic expression in X (latitude) and Y (longitude) that averages the general trend of the geomagnetic field in the survey area. If we suppose that the computed trend is due to sources deep in the earth well below the crust, the effect of sources located in the crust can be easily obtained by subtracting the normal field from any observed field value. A 2nd degree polynomial expression was chosen for each element E:

$$E = a_0 + a_1(X-X_0) + a_2(Y-Y_0) + a_3(X-X_0)^2 + a_4(Y-Y_0)^2 + a_5(X-X_0)(Y-Y_0) \tag{3}$$

where X_0 and Y_0 are the geographical coordinates of a point close to the center of the area of interest; coefficients a_0 ......a_5 were determinated from the station values by least squares fitting.

Actually, expression (3) is a purely mathematical definition; from a physical point of view this normal field could include not only the main field (originating in the Earth's core) but crustal field components too. Therefore, to interpret any crustal source a through inspection of the physical meaning of the normal field is necessary.

Five normal fields were computed; from now on they will be specified by the code GDN (from GeoDiNamics) followed by an abbreviation of the area for which they were computed. A global Italian normal field will be called GDN, other codes will be GDN-N, GDN-C, GDN-S, to mean respectively Northern, Central and Southern

Italy; a fifth normal field was computed for Sardinia: GDN-Sn. To reduce discontinuities between neighbouring fields (also with bordering nations) additional values of geomagnetic elements from outside the area of interest were used. However, not all the repeat stations included in the area of interest contributed to the final expressions for the normal fields; to minimize the effect of stations located in anomalous areas the Chauvenet criterion was used (Worthing and Jeffner,1943). At first, polynomial coefficients were computed by the least squares method using all the stations in that region and computing the standard uncertainty associated with each single station ($\sigma = \pm\sqrt{[vv]/(n-6)}$, where $[vv]$ is the sum of square differences between observed and computed values, n is the number of stations and 6 is the number of coefficients); then stations with residuals greater than 2σ were eliminated and the computation was made again with the remaining stations; this procedure was repeated until no residuals exceeded 2σ.

Normal fields are all referred to sea-level, that is, they were determinated after all station values were reduced to sea-level; the reduction ΔE of the element E, obtained considering only dipole field terms, is $\Delta E = 3Eh/R$, where R is the Earth's mean radius and h is the height above sea-level.

The coefficients of the normal fields are given in Table 2.

A) GDN - To deduce GDN polynomials, additional data from the Furstenfeldbrück German Observatory, 18 Austrian network stations, including the Wien-Kobenzl Observatory (Puhringer et al., 1975), 8 Swiss Network stations (Fischer, 1975; Fischer et al., 1979) and 7 stations from the French Network (2 of them in Corsica) (Courtillot et al., 1978) were used.

The difference in reduction epochs for the various networks was taken into account by reducing all of them to 1979.0 on the basis of a secular variation linear trend expressed as a function of X and Y computed from the data of L'Aquila, Furstenfeldbrück and Wien-Kobenzl Observatories.

Of the total of 146 stations, only 98 for F, Z, H and 102 for D were finally used after the Chauvenet criterion was applied. It is worth noting that this procedure eliminated 6 of the 11 Sardinia stations and the 2 Corsican stations of the French Network.

B) GDN-N - The area to which this field is considered to be applicable is the Northern part of Italy down to the 44th parallel. For this computation 86 stations were used: 34 of them are from the neighbouring national networks quoted above, 10 (between the 44th and 43rd parallels) belong, according to our subdivision, to the Central Italy area. The Chauvenet method left 58 stations for F, Z, H and 76 for D.

C) GDN-C - This normal field was computed for the region lying between the 44th parallel and a line connecting the point 41° N, 14° E with the point 42° N, 15° E; this line corresponds to the mouth of Volturno river in the West and the town of Termoli in the East. 23 stations are part of this region; 9 stations belonging to the

Northern Italy region (from the 44th to 45th parallels and meridian 9.5° E) and 9 stations from the Southern Italy region (from the border-line defined above to the line connecting Eboli and Cerignola) were added to compute the normal expressions. To the final expressions 33 stations contributed for F, Z, H and 30 for D.

D) GDN-S - This field was computed for the part of Italy south of the Volturno-Termoli line defined above, including Sicily. The area includes 33 repeat stations; to these 9 from the Central Italy region were added (in the region between the northern border and the Roma-Pescara line). After the Chauvenet method was applied, 34 stations for F, Z, H and 29 for D were finally used.

E) GDN-Sn - These expressions are valid in Sardinia. For the computation, the 11 repeat stations existing in the island were used plus 2 Corsican stations from the French Network. The final computation was made with 10 stations.

The use of the normal fields raises some difficulties. First, the values of F computed from normal expressions of H and Z do not coincide with the F expression itself; the difference amounts to only a few nT, but should be taken into account. The fact that the various elements were computed independently of each other is the cause of this disagreement. The consistency of the normal fields would involve heavy mathematical computations due to the nonlinearity of relation $F = \sqrt{H^2 + Z^2}$; this was not done.

A similar problem arises for H and D; the two horizontal elements are related by the curl $\mathbf{B} = 0$ condition; among others, Dawson and Newitt (1977) gave a simple treatment to impose such condition, but the procedure was not applied here because the improvement in the expressions of normal fields would have been negligible.

A major problem is the boundary discontinuity between the different expressions for the normal fields; this discontinuity was only reduced by using stations from outside the specified regions. In some places the differences amount to about 25 nT for F and H and about 0.5 nT/km for the gradients.

4. DISCUSSION ON NORMAL FIELDS

It is now necessary to give a physical meaning to the normal fields.

If we apply the concept of equivalent degree (Bullard, 1967; Armando et al., 1981) to our GDN, we find a characteristic length of the order of 700 km (computed on a 11^0 x 11^0 area exactly containing Italy); some suggestions are given, however, by Dawson and Newitt (1977) that polynomials in X and Y may be more smoothed than is estimated from Bullard's equivalent degree. According to the results of Alldredge et al. (1963), GDN could then be considered as representative of the main field in the Italian area; more recent studies (Bullard, 1967; Nomura, 1979; Harrison and Carle, 1981) and the first results from MAGSAT showed, however, the existence of crustal anomalies with wave-lenght of the order of 1000 km and more; considering, moreover, that GDN was computed on the ground of the same data from which the

trend should be subtracted, it is probable that our normal field includes a residual crustal component.

This crucial point is unfortunately not well clarified by a comparison between GDN and planetary reference fields built to best represent the main field. For this comparison we chose PGRF75 updated to 1979 (from now on called PGRF79) and IGS75. The former, officially adopted by the 4th General Scientific Assembly of I.A.G.A. held in 1981 in Edinburgh, is a spherical harmonic analysis up to 120 coefficients (n=m=10), updated to 1979 by linear interpolation between coefficients of DGRF75 and IGRF80; the latter (Barraclough et al. 1975) is a 168-coefficients (n=m=12) harmonic analysis, that was updated to 1979 by means of the secular variation coefficients included in the IGS itself. We will only examine F.

In Fig.1 differences between GDN and PGRF79 over Italy are reported; similarly in Fig. 2 for differences between GDN and IGS and in Fig. 3 for differences between IGS and PGRF79. It can be noted that differences between IGS and PGRF79 are of the same order of magnitude as those between GDN and the two planetary fields; moreover, the differences between GDN and PGRF79 are quite different from those with respect to IGS, indicating that no consistent crustal residual in GDN can be detected through this comparison. Lacking in more conclusive results, we assume that GDN looks very similar to planetary fields and can be used to represent the trend of the main field in the country.

The residual crustal field is apparent in the local normal fields. In Fig. 4 differences in F with respect to GDN of GDN-N, GDN-C, GDN-S are shown on a grid of points placed 30' apart in latitude and longitude. It is easy to see the different behaviour of regional fields. GDN-N is on the whole at a lower level than GDN, with a mean difference of -12.4 nT; we can see the beginning of a positive gradient from west to east with respect to GDN that is practically null at high latitudes and increases going south. This gradient becomes maximum in central Italy, where GDN-C shows remarkable negative differences along the Tyrrenian coast, and positive along the Adriatic coast. Differences between GDN-S and GDN show a complex distribution: they are positive and strong in the northern border of the region and in south-east of Sicily, and they have a negative minimum towards the border of Basilicata and Calabria; differences are negative also on north-west Sicily. These different features suggest real differences in the magnetic properties of the Earth's crust in Italian regions, but it is not possible to deduce from normal fields an exact location of physical sources; normal fields, in fact, represent a smoothing of single station values coming from a mathematical expression and from arbitrary spatial limits. For a more realistic analysis, the single station anomalies should be investigated.

In Figs. 5, 6, 7, 8 anomalies in F of repeat stations with respect to GDN, PGRF79, IGS and corrected IGS (IGS+10 nT) are reported. Corrected IGS is made in such a way that IGS - PGRF79 = 0 at the point (44.5° N, 11.5° E), where geological features and smoothness of the magnetic chart suggest lack of anomalies. The general trend of anomalies is very similar in all figures, showing the physical reality of the anomalous configurations and the very small influence of the differences between reference fields in this case.

Anomalies of F show some important features:

a) a few tens nT negative anomaly in northern Italy, in central and eastern Alps and Prealps;

b) a strongly anomalous character in northwest Italy (already known and reported by Elena et al., 1976 and Lanza, 1975);

c) a remarkable difference between the Tyrrenian and Adriatic sides of the Italian peninsula, with negative anomalies on the Tyrrenian side, and positive ones on the Adriatic side. Such a difference is the source of the above-mentioned features of GDN-C. The differences between east and west coast of Italy are in some cases over 100 nT with respect to the corresponding differences as given by the reference fields. The great extent of this anomalous configuration suggests the existence of a very deep source of anomaly (probably close to the Curie isotherm) on which some local and shallower effects are superimposed. To give a further insight into this anomaly it would be necessary to include in the study aeromagnetic and marine surveys of the area.

d) A fast transition from positive to negative anomalies around the 38th parallel, in both Calabria and Sicily.

e) A prevailing anomalous and rough character of Sardinia. This peculiarity was already shown by the areomagnetic survey made by Cassano et al. (1979).

A more detailed discussion on the magnetic anomalies is given in section 6.

Concerning the use of local normal fields as reference fields, the notes mentioned above on crustal residuals should always be kept in mind. Apart from fig. 4, the existence of such residuals could be argued from equivalent degree considerations as far as they are valid: for GDN-N and GDN-S the characteristic length is of the order of 300 km, for GDN-C it is 200 km. If so, subtracting the trend represented by a local field, the main field plus a part of the crustal field, (probably from the deepest sources) is removed (in GDN the smoothing makes the crustal residual small anyway, as seen above). We can then assume that the use of local fields as reference fields is valid only to detect anomalies of about 10 km lateral extension from shallow sources; obviously, areas close to borders should be avoided.

The validity of GDN-S and GDN-Sn as reference fields is rather doubtful: the very complex shape of GDN-S can be seen in fig. 4, with magnetically non-homogeneous areas, whilst in the case of GDN-Sn we should remember that it comes from a predominantly anomalous set of data.

We should add an obvious practical suggestion for future surveys: the use of spatial gradients deduced from the normal polynomials instead of the polynomials

themselves is recommended to eliminate trends. Through this procedure, which is valid because gradients are only scarcely affected by secular variations, the reduction of the survey data to 1979.0 can be avoided.

5. MAGNETIC MAPS OF ITALY

Magnetic maps of Italy of F, Z, and H representing the distribution of the geomagnetic elements in the Italian territory as deduced from measurements made at 2550 second order stations reduced, as for the 1st order stations, to 1979.0, were drawn. The mean density of stations is $1/100^2$ km; this leads to a mean distance of 10 km between stations.

All Operating Units of Geomagnetism Group contributed to the field work, operating in the following areas:

GE	Piedmont, Valle di Aosta, Western Lombardy, Liguria, North-Western Tuscany.
ING	Western Trentino-Alto Adige, Eastern Lombardy.
PD	Eastern Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia.
FE	Emilia-Romagna, North-Eastern Tuscany, Northern Marche.
OV	Central Italy between southern border of GE and FE and a line connecting Salerno (Tyrrhenian Sea) to Manfredonia (Adriatic Sea); Sicily.
BA	Southern Italy (south of the Salerno-Manfredonia line).
CA	Sardinia.

The central Italy stations occupied by OV were selected among those made by the Osservatorio Vesuviano in central Italy in the 60's and reduced to the epoch 1965.5 (Corrado et al., 1977).

The instruments used by the various Operating Units were the following:

ING	Proton Magnetometer + HTM (Z computed from F and H)
FE	Proton Magnetometer + Z fluxgate magnetometer (H computed from F and Z)
BA	Proton Magnetometer + GSI
GE	Proton Magnetometer + GSI Proton Magnetometer + QHM (Z computed from F and H)
PD	Proton Magnetometer + Z fluxgate magnetometer (H computed from F and Z)
OV	Proton Magnetometer + GFZ magnetometer (H computed from F and Z)
CA	Proton Magnetometer + HTM (Z computed from F and H)

The Z fluxgate magnetometer belonging to FE and PD was checked in the Castel Tesino Observatory (ING).

As for the 1st order network, the reduction to 1979.0 was made by means of equation (1) using the same reference Observatories. To reduce the 680 OV stations from 1965.5 to 1979.0 the variation at L'Aquila Observatory between 1965.5 to 1979.0 was added to each station.

The probable error in the reduced values was found by using the differences between the reduced values at repeat stations from the 1st order survey and the reduced values at the same stations from the 2nd order survey. This gave:

$$\triangle F = \pm 8nT \qquad \triangle Z = \pm 8nT \qquad \triangle H = \pm 14nT. \tag{4}$$

On the basis of the spatial gradients of the geomagnetic elements in Italy (which can be deduced from normal polynomials) the mean distance between stations would allow isolines to be drawn at 50 nT intervals for all three elements. For a scale 1:1,500,000 we preferred a 100 nT interval. This choice seems sufficient to map out the main features of the three elements in the Italian area; moreover, 100 nT is the smallest interval which can be used to make the shape of the isolines in anomalous areas clearly visible. Four well known strongly anomalous areas were excluded from the survey and from the maps: they are the ophiolitic belt of Voltri (Genoa), the Campanian volcanic district (Naples), the Mount Etna volcano, the West Sardinia tertiary volcanism.

To draw isolines in some anomalous areas in northern Italy, close to the border with Switzerland, 186 stations of the Swiss Network (Fischer et al. 1979) were used; they were reduced to 1979.0 by applying a secular variation trend estimated from Furstenfeldbrück and L'Aquila Observatories. In these areas isolines extend over Switzerland.

Concerning the accuracy with which the maps allow the deduction of the value (at 1979.0) of an element in any place, several contributing partial errors must be taken into account: a) measurements and reduction errors; b) interpolation error, which comes from a linear interpolation between stations for drawing isolines and from a linear interpolation between isolines to compute the value at the site; c) possible error for the altitude of location, due to the fact that isolines, which are drawn between stations that generally are at different altitudes, do not represent the field at a fixed height; d) localization error for the point on the map. Taking into account these factors we conclude that the estimated error of a value computed on the maps is ~ 20-30 nT.

The magnetic maps shown in Figs. 9, 10 and 11 for H, Z and F respectively, were reduced for this pubblication to a standard page size and represent contours to a 100 nT interval. The corresponding 1:1,500,000 maps are available on request.

6. MAGNETIC ANOMALIES OF ITALY

Several authors have already defined magnetic anomalies of total field F for restricted areas of Italy (Morelli et al. 1969; Morelli, 1970; Corrado et al. 1974; Corrado et al., 1977; Molina and Pinna, 1982; Bozzo et al., 1983). The computation of normal fields used to determine the anomalous field has been made in different ways for the different areas investigated in these previous studies. The residual aeromagnetic maps of Italy (Agip, 1981-83) have been obtained subtracting an average regional field whose gradients are, in the S-N direction, +3.25 nT/km and in the W-E direction +0.80 nT/km.

As reported in sections 3 and 4, on the basis of a first order network a global normal field has been computed now for the whole Italian area. This normal field (called GDN) represents, with a ± 10 nT uncertainty, the main field originating in the Earth's core. In Tavola 4 the enclosed 1:1,500,000 magnetic anomaly map of Italy for total intensity is shown; the map shows residuals of the 2nd order network computed subtracting the GDN normal field. The overall effect of errors in single measurements and uncertainty in determining the normal field and interpolating values on the map suggests a lower limit to significance of anomalies. The zero line is to be considered only as indicative and the very low value anomalies (20-30 nT) are not to be considered always real. We should also emphasize that the 1:1,500,000 scale chosen for this map excludes from our investigation wavelength anomalies lower than 10 km such as those originating in Voltri ophiolites belt and in volcanic areas of Roccamonfina, Phlaegrean Fields, Vesuvius, Etna, Bosano.

Looking at the geomagnetic field maps (Figs. 9, 10, 11) a remarkable aspect is the regularity of the observed field in certain areas; this can directly be associated with a very deep origin field that does not appear to be disturbed by any shallow source and that can be considered just the main field. This 'quiet' magnetic behaviour can be noted in Apulia, Romagna, in the Po Delta, and in Calabria. This implies that, independently from the field model used to compute anomalies, two different structures are not distinguishable on the basis of magnetic anomalies: these are the typical continental crust of normal thickness (Apulian platform) and that one characteristic of a 'melange' of crustal materials generated by the alpine deformation (Calabrian arc).

In the analysis of the anomalous field (Tavola 4) the principal aspect is the remarkable predominance of low value anomalies (values around ± 50 nT) like the southern Alps (excluding areas with plutonic or volcanic rocks), the southern part of Po Valley, the eastern border of the northern Apennines ridge. The lack of strong anomalies on a large area of the Italian territory was not expected considering the continental crust character and the complex geological history of Italy. This peculiarity can be explained suggesting a shallow sedimentary non magnetic layer of the upper crust and a middle lower crust made by metamorphic complex, granulite facies and plutonic intrusion all of acidic origin or however poor in magnetic terms.

It is probable that the above mentioned low anomalies have a deep origin and can be correlated with the Curie isosurface oscillations. Positive and negative anomaly values can be noted in the Adriatic and Tyrrhenian sides respectively; they are in agreement with the heat flow data observed by Loddo and Mongelli (1974), suggesting an uplift of the Curie isothermal surface going from the axis of the mountain ridge towards Tyrrhenian area. Using this information and assuming a normal assessment of the magnetic mineralogy in deep crustal regions characterized by low temperatures and hydrous conditions or by high temperatures and anhydrous conditions, the thickness of the magnetized crust can be determined; assuming a normal geothermal gradient in the Adriatic area and supposing the existence of nearly pure magnetites in the crustal rocks (about $Tc = 580°$ C) a thickness lower than 17 km can be estimated. In the southern Tyrrhenian basin a maximum depth of 8-9 km can be inferred on the basis of a 45-50° C/km thermic gradients with the occurrence of titanomagnetites (Dietrich et al., 1977).

Long period magnetic anomalies have been noted in the Italian area by several authors (Morelli et al., 1969; Morelli, 1970; Corrado et al., 1977; AGIP, 1981-83; Molina and Pinna, 1982; Bozzo et al., 1983). The magnetic anomaly picture shows long wavelength anomalies ($\lambda > 90$ km) in the Po plain, in the Adriatic foredeep, in the Bradano trough, in the Sicilian foredeep, as well as in the Genoa gulf and in Ogliastra (Sardinia). A few possible causes can be enumerated as responsible of such long period anomalies; we can mention:

a) different chemical physical conditions in the deep crust that determine the existence of different terms in the titanomagnetites series (that is variation in the Curie temperature);

b) large undulations of the Curie point isotherm due to different thermal gradient conditions;

c) noticeable crustal dislocations that recently modified large areas of the Italian peninsula.

In many areas of the country strong high-frequency anomalies are superimposed to the long period pattern; these short wavelength anomalies can be generated by upper mantle intrusions, ophiolite complex extensions, volcanic bodies, filling of large subsidence basins with very rich storage of high magnetic susceptibility minerals.

As a concluding remark it can be noted that many anomalies, particularly those that are connected with the Tertiary and Quaternary volcanism are of dipole type, with negative values towards north and positive values towards south with respect to the perturbing mass. This suggests a magnetization in agreement with the present geomagnetic polarity.

We will now discuss, only qualitatively, a few particular anomalies that appear in

the colour map (Tavola 4) in connection with the main geological Italian structural units.

ALPINE ARC. A remarkable contrast appears between the eastern Alps with a rather quiet magnetic behaviour and the central and western Alps with a strongly anomalous character. An intense and continuous anomalies belt follows the Piedmontese Ligurian ophiolites distribution. Particularly strong anomalies correspond to areas such as Valmalenco, Val d' Aosta, valleys of Lanza massif, Monviso, Maritime and Ligurian Alps up to the Voltri massif and Ligurian Apennine. A second anomalous belt can be seen in the Ivrea - Verbano area and particularly close to the middle north part of the 'Ivrea Body'. Three secondary maxima are clearly distinguishable: Locarno - Finero, medium Val Sesia and Ivrea (see also: Armando e Ratti, 1977; Wagner et al., 1978; Lanza, 1982). The only clear evidence of a plutonic intrusion that corresponds to an easy recognizable magnetic anomaly can be found in the Adamello massif probably because the intrusion stands in a rather non anomalous area.

In conclusion the magnetic character change in the areas where ultrafemic complex is absent does not appear significant, since the old crystalline nuclei, the plutonites, the metamorphites, the porphyrites and the two diorite-kinzigite units of the Alpine successions do not appear considerably magnetized. Other very local anomalies appear in connection with other sources like the Euganei, Lessini and Pasubio volcanics, the Adamello-Tonale pluton and the porphyritic Atesina platform.

APENNINE FOREDEEP. Peculiar anomalies which imply deep unknown sources appear in Po Basin between Casale M. and Como and between Mantua and Garda. They could suggest oscillations of the isotherm Curie point surface in a region where the plio-quaternary subsidence rate has been very high and where an isotherm distribution depression, at various depths, has been recognized (Della Vedova and Pellis, 1980).

In the Adriatic foredeep area a dipole type anomalies series aligned in the NW - SE direction with $\lambda > 80$ km, can be seen; they form a continuous belt of negative values in the Adriatic sea from the Po mouth to the Tremiti Islands (Morelli et al., 1969; Agip, 1983) and a positive values belt near the Adriatic coast, with maxima centered on Ancona, Pescara and Larino (Corrado et al., 1977). Such anomalies have been attributed to a crust more basic than normal near the Adriatic shore of central Italy and/or to a Curie isotherm depression from the Adriatic sea towards inland (Corrado et al., 1977). These interpretations don't seem appropriate, since relevant intrusion phaenomena of upper mantle materials are not confirmed by gravity data and since amplitudes of magnetic anomalies of 250 nT and more can only partially be explained with Curie isothermal surface variations (Gasparini et al., 1981). According to some studies on the crust and upper mantle magnetic petrology (Schilinger et al., 1983; Wasilewski, 1983) we can more realistically assume that such regional magnetic anomalies are imputable to deep crustal strata made of granulite rocks and characterized by titanium-poor titanomagnetites.

The Bradano trough has a similar NW - SE trend slightly shifted, with respect to the Adriatic foredeep trend, in the SW direction along the Tremiti fault. The anomalies belt stretches from Lucera to the Taranto gulf; the positive one marks the eastern border of the South Apennine chain, maxima are centred nearby Grottaminarda, Muro Lucano and Chiaromonte. In this area a peaked volcanic anomaly is superimposed: M. Vulture.

A similar bipolar trend of anomalies in the NW - SE direction with $\lambda > 90$ km can be noted in the Sicilian Foredeep also; in this case the origin can be associated to an uplift of the Curie isotherm on the Tyrrhenian side. In the Catania plain a dipole type anomaly with ~ 100 km wavelength and remarkably high in value can be noted; from stratigraphic informations on deep wells made by Agip, a basaltic body origin could be inferred. In this case the structure has a top at 4 km depth and extends in a north south direction for ~ 4 km.

APENNINES AND SICILY THRUST-BELT. A noticeable difference in the magnetic picture appears looking at the Adriatic and Tyrrhenian sides of the mountains chain; the relatively flat part of the division contrasts with the negative anomalies of the Tyrrhenian side. As said before the negative anomaly on the Tyrrhenian side can be related to an upwelling of the Curie isothermic surface. Localized anomalies of different sizes and intensities can be seen in the Latium and Campania volcanic areas; they extend towards the Tyrrhenian sea. The acidic magmatism of the Apennines appears little in the magnetic picture, while the border of the Latial-Campanian volcanic belt generates particularly intense anomalies. In the southern part of Latium and Campania wide anomalies suggest the existence of a deep crustal magmatism (Corrado et al., 1977).

CALABRIAN ARC. The Calabrian Arc shows unexpectedly a very quiet magnetic picture in high contrast with the strongly variate behaviour of the surrounding area. Only very low anomaly values are connected with the Calabride complex, in particular the Aspromonte unit. In conclusion the diorite-kinzigite unit, the plutonites and the schists that form the Arc appear very poorly magnetized like the deep crystalline substratum .

APULIAN PLATFORM AND RAGUSA ZONE. A completely different magnetic picture suggests a different evolution between the Apulian platform and the Ragusa zone. The Apulian platform is characterized by a high regularity of the magnetic field that can be related to the typically platform foreland structure, while the Ragusa zone shows intense anomalies connected with basaltic magma spreading phaenomena. Patacca et al. (1979) have in fact noticed a considerable submarine volcanic activity in the Middle-Upper Giurassic that originated the Scicli, Avola and Victoria seamounts, and a retour of volcanic activity in the Upper Cretaceous that originated

the Pachino seamount.

SARDINIA MASSIF. The overall magnetic picture of the Island appears quite complex; anomalous areas are however clearly visible. It's not always easy to correlate directly magnetic anomalies with the surface geological structure, but a deeper analysis plus hypotetical models can justify the existent anomalies in terms of magmatism (Cassano et al., 1979; Balia, 1980). Particularly evident are the Gallura anomalous area with Hercynian granites, the Logudoro with Oligo-Miocene volcanics, the Ogliastra shallow Hercynian basin and the M. Arcuentu, S. Antioco, and S. Pietro Islands Miocene volcanics. In conclusion it is interesting to note that the Sardinia basement is made of a crystalline massif interested by strong metamorphic phases of the Hercynian and Caledonian orogenic cycles and appears magnetically active. This behaviour is not found elsewhere in the Italian peninsula where crystalline rocks belong to napped units, so that no noticeable magnetic anomalies have been observed.

7. INFORMATION AND AKNOWLEDGEMENTS

All data from repeat stations as well as from 2nd order stations and maps can be obtained on request from the Istituto Nazionale di Geofisica, Geomagnetism Unit, Via di Vigna Murata 605 - 00143 Roma, Italy.

We thank Prof S.R.C. Malin for carefully reading a great part of the paper and for his most valuable comments. We also thank Miss. Anna De Santis for her assistance with programming and both Mrs. B. Giustini and S. Tucci for typing the manuscript.

8. REFERENCES

AGIP: Carta aeromagnetica d'Italia. 1981-1983.

Alldredge L.R., G.D. Van Voorhis, T.M. Davis, 'A magnetic profile around the world', Journ. Geoph. Res. 68, 3679, 1963.

Armando E. and the Geomagnetism Working Group, 'Sui campi normali degli elementi del campo geomagnetico in Italia', C.N.R. P.F. Geodinamica, Pubbl. n. 462, 1981.

Armando E., A. Ratti, 'Alcuni profili aeromagnetici in Piemonte', Boll. Ass. Min. Sub., 14(2), 233, 1977.

Balia R., 'Rilevamento magnetometrico della Sardegna', Atti Facoltà di Ingegneria-Università di Cagliari. Vol. 15, 409, 1980.

Barraclough D.R., J.M. Harwood, B.R. Leaton, S.R.C. Malin, 'A model of the geomagnetic field at epoch 1975.0', Geoph. Jour. R.A.S. 43, 465, 1975.

Bozzo E., G. Corrado, A. Elena, O. Faggioni, E. Pinna, 'Magnetic anomalies and deep crustal structure along the Elba-Levanto-Ottone-Varzi line', Boll. Geof. Teor. Appl., 1983.

Bullard E.C., 'The removal of trend from magnetic surveys', Earth Plan. Sci. Lett. 2, 293, 1967.

Cassano E., A. Marcello, R. Nannini, S. Pretti, G. Ranieri, R. Salvaderi, I. Salvadori, 'Rilievo aeromagnetico della Sardegna e del mare circostante. Carte di anomalie magnetiche in scala 1/250000', Boll. Serv. Geol. It., C, 199, 1979.

Corrado G., F. Iacobucci, E. Pinna, A. Rapolla, 'Anomalie gravimetriche e strutture crostali nell'Italia Centro-Meridionale', Boll. Geof. Teor. Appl., XVI (64), 271, 1974.

Corrado G., E. Pinna, A. Rapolla, 'The magnetic field of Italy: description and analysis of the new F, Z, and H maps between 40 N and 44 N.', Boll. Geof. Teor. Appl. XIX, 140, 1977.

Courtillot V., J.L. Le Moüel, B. Lepretre, 'Reseau magnetique de repetition de la France. Campagne 1977.', Inst. Phys. du Globe, 1978.

Dawson E., L.R. Newitt, 'An analytical representation of the geomagnetic field in Canada for 1975. Part. I: the main field', Canadian Journ. Earth Sci. 14, 477, 1977.

Della Vedova B., G. Pellis, 'Deep thermal trends for the Po valley from Agip temperature measurements in gas and oil wells', Boll. Geof. Teor. Appl. XXII (86), 129, 1980.

Dietrich V., R. Emmermann, J. Keller, H. Puchelt, 'Tholeitic basalt from the Tyrrhenian sea floor', Earth Plan. Sci. Lett., 36, 285, 1977.

Elena A., E. Bozzo, L. Cortesogno, 'Anomalie magnetiche sul Gruppo di Voltri', Boll. Soc. Geol. It. 95, 479, 1976.

Fischer G., Private Communication, 1975.

Fischer G., P. A. Schnegg, J. Sesiano, 'A new geomagnetic survey of Switzerland', Comm. Suisse de Geophysique, 1979.

Gasparini P., M.S.M. Mantovani, W. Shukowsky, 'Interpretation of long wavelength magnetic anomalies from the solution of inverse problem', in 'Geophysical Interpretation', edited by R. Cassinis. Plenum Press, 231, 1981.

Harrison C.G.A., H.M. Carle, 'Intermediate wavelength magnetic anomalies over ocean basins', Journ. Geoph. Res. 86, n.B12, 11585, 1981.

Lanza R., 'Profili magnetici e di gravità nelle Alpi Occidentali', Riv. It. Geof. Sci. Aff., II (2), 175, 1975.

Lanza R., 'Models for interpretation of the magnetic anomaly of the Ivrea body', Geologie Alpine 58, 85, 1982.

Loddo M., F. Mongelli, 'Tentativo di una mappa del flusso geotermico in Italia', Mem. Soc. Geol. It., XIII (suppl. n. 2), 1974.

Molina F., E. Pinna, 'Campo magnetico principale e regionale nell'area tirrenica', Ann. Geofisica, 35, 504, 1982.

Morelli C., 'La rete Geofisica e Geodetica in Italia nel suo stato attuale e nei suoi

rapporti con la struttura geologica superficiale e profonda', Pubbl. Ist. Naz. Geof., Trieste 1946.

Morelli C., M.T. Carrozzo., P. Ceccherini, I. Finetti, C. Gantar, M. Pisani., P. Schmidt di Friebderg, 'Regional Geophysical study of the Adriatic Sea., Boll. Geof. Teor. Appl., XI (41-42), 3, 1969.

Morelli C., 'Physiography, gravity and magnetism of Tyrrhenian sea', Boll. Geof. Teor. Appl., XII (48), 275, 1970.

Nomura M., 'Marine geomagnetic anomalies with intermediate wavelength in the western Pacific region', Bull. Earthquake Res. Inst. Tokyo Univ., 11, 1, 1979.

Patacca E., P. Scandone, G. Giunta, V. Liguori, 'Mesozoic Paleotectonic evolution of the Ragusa zone', Geol. Rom., 18, 331, 1979.

Puhringer A., W. Seiberl, E. Trapp, F. Pausweg, 'Die Verteilung der erdmagnetischen Elemente in Oesterreich zur Epoche 1970.0', Zentralanst. Meteor. und Geodynamik, Publ. n. 205 Wien 1975.

Schlinger C.M., B.D. Marsh, P.G. Wasilewski, 'The magnetic petrology of the deep crust and the interpretation of regional magnetic anomalies', Eos Trans. Am. Geophys. Union, 64, 214, 1983.

Talamo R., 'Le carte magnetiche d'Italia delle isodinamiche nella H e delle isogone, dell'Istituto Geografico Militare, e loro aggiornamento al 1973.0', Boll. di Geodesia e scienze affini, Anno XXXIV, n. 1, 1975.

Wagner J.J., R. Chessex, S. Dumortier, A. Espinosa, C. Cailay, Ph. Neri, J. Webel, 'The total field magnetic anomalies of the Ivrea zone: tentative model', Proc. 2nd Symp. Ivrea-Verbano. Mem. Ist. Geol. Min. Padova, XXXIII, 256, 1978.

Wasilewski P.J., 'Magnetic mineralogy of the crust and upper mantle', Eos Trans. Am. Geophys. Union, 64, 214, 1983.

Worthing A.G., J. Jeffner, 'Treatment of experimental data', John Wiley, New York, 1943.

TABLE 1 *(continued)* Repeat Station Values at 1979.0

STATION (*Observatories underlined*)	LATITUDE	GREENWICH LONGITUDE	MONTE MARIO LONGITUDE	ALT. (m)	D	F (nT)	H (nT)	Z (nT)
Rasun di sotto	46° 46' 51"	12° 03' 15"	-0° 23' 53"	1065	-0° 49'	46877	21516	41648
Castel d'Ultimo	46° 35' 51"	11° 05' 53"	-1° 21' 15"	770	-1° 06'	46768	21634	41463
Cima Sappada	46° 35' 00"	12° 43' 30"	+0° 16' 27"	1400	-0° 34'	46877	21624	41591
Sella di Bartolo	46° 33' 04"	13° 36' 23"	+1° 05' 44"	1200	-0° 17'	46904	21646	41611
Preguzzon - Bormio	46° 28' 42"	10° 14' 52"	-2° 12' 16"	1950	-1° 20'	46598	21646	41265
Bevola - Baceno	46° 16' 11"	8° 18' 44"	-4° 08' 24"	800	-1° 51'	46648	21752	41266
Vigo d'Anaunia	46° 16' 08"	11° 04' 38"	-1° 22' 30"	473	-1° 02'	46683	21822	41269
Rivamonte Agordino	46° 15' 26"	12° 01' 38"	-0° 25' 30"	971	-0° 56'	46715	21798	41317
Malghe Grua	46° 09' 54"	10° 16' 23"	-2° 10' 45"	988	-1° 33'	46695	21898	41242
Tesis - Maniago	46° 07' 06"	12° 48' 38"	+0° 21' 30"	160	-0° 32'	46739	21872	41306
<u>Castello Tesino</u>	46° 02' 51"	11° 39' 01"	-0° 48' 07"	1175	-0° 56'	46611	21901	41146
Croce di Salven - Breno	45° 57' 05"	10° 09' 04"	-2° 18' 04"	1175	-1° 20'	46498	21969	40981
S. Martino in Culmine	45° 55' 35"	8° 44' 38"	-3° 42' 30"	1087	-1° 47'	46439	22008	40893
Col di Medea	45° 55' 27"	13° 25' 58"	+0° 58' 50"	130	-0° 21'	46708	21970	41218
Longara Davanti	45° 55' 00"	11° 32' 51"	-0° 54' 13"	1600	-0° 58'	46548	21939	41054
Chaffiery	45° 45' 16"	7° 04' 42"	-5° 22' 26"	1390	-2° 23'	46260	22052	40666
Bosco Chiesanuova	45° 37' 42"	11° 03' 36"	-1° 23' 32"	1100		46460	22091	40872
Scorzè	45° 34' 47"	12° 07' 03"	-0° 20' 05"	14	-0° 48'	46562	22163	40949
Pont	45° 33' 39"	7° 06' 46"	-5° 20' 22"	1800	-2° 25'	46172	22138	40519
Casa del Guardiacaccia	45° 32' 20"	8° 29' 47"	-3° 57' 21"	215	-1° 59'	46342	22138	40712
Mirauda - Borgiallo	45° 26' 18"	7° 39' 09"	-4° 47' 59"	1330	-2° 05'	46070	22149	40396
Campo S. Maria	45° 14' 49"	10° 04' 57"	-2° 22' 11"	45	-1° 24'	46314	22286	40600
Casa del Lupo	45° 10' 48"	9° 28' 46"	-2° 58' 22"	130	-1° 41'	46282	22371	40516
Ponte Merlano	45° 07' 23"	10° 53' 04"	-1° 34' 04"	25	-1° 12'	46389	22395	40625
San Michele	45° 06' 40"	8° 13' 59"	-4° 13' 09"	330	-2° 02'	46177	22387	40387
Balboutet	45° 02' 58"	7° 00' 50"	-5° 26' 18"	1550	-1° 55'	46216	22422	40412
Morosina - Lendinara	45° 02' 54"	11° 33' 21"	-0° 53' 47"	7	-0° 58'	46335	22413	40553
I Gessi - Retorbido	44° 56' 16"	9° 03' 44"	-3° 23' 24"	330	-1° 48'	46243	22566	40363

TABLE 1 *(continued)* Repeat Station Values at 1979.0

STATION (*Observatories underlined*)	LATITUDE	GREENWICH LONGITUDE	MONTE MARIO LONGITUDE	ALT. (m)	D	F (nT)	H (nT)	Z (nT)
La Risaia - Mesola	44° 55' 09"	12° 17' 20"	-0° 09' 48"	4	-0° 41'	46368	22529	40527
Cascina Predassi	44° 46' 16"	8° 30' 55"	-3° 56' 13"	185	-1° 53'	46063	22640	40115
Montalbano	44° 44' 28"	11° 34' 49"	-0° 52' 19"	8	-1° 06'	46287	22611	40388
Malalbergo	44° 43' 16"	11° 33' 06"	-0° 54' 02"	20	-0° 57'	46280	22616	40378
Chiabrand	44° 36' 23"	7° 16' 27"	-5° 10' 41"	1280	-2° 16'	45995	22639	40038
Monte Cassio	44° 35' 26"	10° 03' 09"	-2° 23' 59"	928	-1° 22'	46112	22707	40134
Bergolo	44° 33' 08"	8° 11' 16"	-4° 15' 52"	646	-1° 50'	45816	22517	39901
Possessione	44° 28' 08"	10° 51' 32"	-1° 35' 36"	447	-1° 07'	46150	22784	40134
Villanova	44° 27' 46"	12° 02' 32"	-0° 24' 36"	9	-0° 45'	46201	22754	40209
Monte Caucaso	44° 27' 21"	9° 13' 33"	-3° 13' 35"	1236	-1° 47'	45945	22709	39941
Casa Madonnina - Peveragno	44° 18' 46"	7° 38' 28"	-4° 48' 40"	620	-2° 12'	45959	22901	39847
<u>Roburent</u>	44° 17' 45"	7° 53' 18"	-4° 33' 50"	824	-1° 55'	46009	22936	39884
Monte Santa Croce - Follo	44° 09' 58"	9° 48' 56"	-2° 38' 12"	581	-1° 12'	45981	22951	39843
Borghetto di Chiozza	44° 09' 24"	10° 25' 59"	-2° 01' 09"	943	-1° 12'	45988	22939	39859
Cà Bruciata - Bruscoli	44° 08' 54"	11° 14' 11"	-1° 12' 57"	835	-0° 53'	46051	22947	39923
Colle Tre Faggi	43° 55' 33"	11° 40' 22"	-0° 46' 46"	930	-0° 49'	45998	23059	39801
S. Giovanni - Ceriana	43° 52' 00"	7° 46' 30"	-4° 40' 38"	787	-1° 57'	45726	23070	39480
Cavallino di Urbino	43° 45' 42"	12° 36' 43"	+0° 09' 35"	420	-0° 31'	46005	23150	39756
Casa Turchino	43° 45' 38"	10° 46' 24"	-1° 40' 44"	44	-1° 01'	45870	23125	39614
Croce al Termine	43° 37' 56"	13° 00' 01"	+0° 32' 53"	248	-0° 06'	46017	23220	39729
Monte Venanzio	43° 35' 51"	13° 33' 04"	+1° 05' 56"	185	-0° 13'	46101	23247	39811
Monte Fili	43° 34' 37"	11° 16' 34"	-1° 10' 34"	548	-0° 54'	45854	23226	39537
La Vallina	43° 26' 24"	11° 49' 25"	-0° 37' 43"	267	-0° 47'	45853	23303	39490
Casale Marittimo	43° 17' 20"	10° 38' 33"	-1° 48' 35"	160	-1° 07'	45658	23385	39215
Casale di Mecciano - Camerino	43° 10' 22"	13° 02' 52"	+0° 35' 44"	433	-0° 21'	45842	23471	39378
Monte Castellano	43° 00' 56"	13° 46' 10"	+1° 19' 02"	410	-0° 11'	45880	23609	39339
S. Casciano dei Bagni	42° 52' 54"	11° 52' 32"	-0° 34' 36"	655	-0° 46'	45646	23616	39062
Poggio la Guardia - Follonica	42° 52' 17"	10° 47' 45"	-1° 39' 23"	48	-1° 03'	45567	23621	38967

TABLE 1 *(continued)*

Repeat Station Values at 1979.0

STATION *(Observatories underlined)*	LATITUDE	GREENWICH LONGITUDE	MONTE MARIO LONGITUDE	ALT. (m)	D	F (nT)	H (nT)	Z (nT)
Misciano - Norcia	42° 46' 08"	13° 05' 29"	+0° 38' 21"	645	-0° 24'	45730	23655	39137
Montagnola - Le Pianacce	42° 33' 40"	14° 03' 39"	+1° 36' 31"	286	-0° 05'	45791	23782	39131
Poggio della Ficona	42° 26' 56"	12° 01' 59"	-0° 25' 09"	340	-0° 47'	45495	23845	38745
Configni	42° 25' 30"	12° 37' 48"	+0° 10' 40"	600	-0° 22'	45558	23871	38804
L'Aquila	42° 22' 56"	13° 18' 59"	+0° 51' 51"	682	-0° 17'	45581	23910	38806
Ponte S. Martino	42° 16' 04"	13° 48' 18"	+1° 21' 10"	360	-0° 04'	45667	24023	38838
Punta del Cimitero - Tremiti	42° 07' 39"	15° 30' 46"	+3° 03' 38"	30	+0° 11'	45669	24034	38833
Morgitella - Gissi	42° 02' 50"	14° 34' 14"	+2° 07' 06"	158	-0° 02'	45650	24132	38750
Cagnano	41° 54' 21"	13° 06' 26"	+0° 39' 18"	530	-0° 27'	45418	24163	38457
Lama la Vita - Vieste	41° 53' 46"	16° 05' 25"	+3° 38' 17"	100	+0° 21'	45666	24215	38717
Le Serre - Morrone nel Sannio	41° 42' 16"	14° 48' 23"	+2° 21' 15"	750	+0° 01'	45678	24346	38649
Masseria Coppa Salsola	41° 36' 40"	15° 37' 01"	+3° 09' 53"	20	+0° 12'	45537	24376	38463
Cerasuolo Vecchio	41° 35' 44"	14° 01' 23"	+1° 34' 15"	810	-0° 04'	45382	24361	38289
Pisterzo	41° 29' 33"	13° 16' 00"	+0° 48' 52"	500	-0° 30'	45292	24434	38136
Monte Lapillo	41° 18' 12"	13° 36' 49"	+1° 09' 41"	800	-0° 18'	45240	24519	38020
Fonte di Stella	41° 16' 52"	14° 51' 55"	+2° 24' 47"	500	+0° 02'	45360	24553	38140
Masseria Boschetto	41° 13' 52"	15° 35' 14"	+3° 08' 06"	260	+0° 08'	45395	24564	38175
Cala Garibaldi - La Maddalena	41° 13' 09"	9° 27' 34"	-2° 59' 34"	11	-1° 32'	45046	24563	37760
Masseria di Messere	41° 07' 54"	16° 11' 16"	+3° 44' 08"	357	+0° 22'	45382	24614	38127
Casino Vecchio - Caserta	41° 06' 49"	14° 18' 34"	+1° 51' 26"	265	-0° 11'	45242	24643	37941
Vaddi Niedda	40° 52' 36"	9° 08' 47"	-3° 18' 21"	620	-1° 12'	45070	24789	37641
Madonna della Neve	40° 51' 44"	14° 37' 25"	+2° 10' 17"	520	-0° 12'	45194	24790	37788
Cacasivo	40° 48' 25"	16° 19' 52"	+3° 52' 44"	375	+0° 22'	45279	24794	37887
Locorotondo	40° 47' 48"	17° 22' 18"	+4° 55' 10"	200	+0° 36'	45391	24774	38034
Masseria Ramundo	40° 46' 03"	17° 06' 26"	+4° 39' 18"	410	+0° 37'	45353	24828	37953
Masseria Petraccone	40° 43' 43"	15° 32' 34"	+3° 05' 26"	533	+0° 13'	45246	24840	37818
Monte Tintiri - Siniscola	40° 36' 18"	9° 43' 42"	-2° 43' 26"	40	-1° 28'	44838	24967	37244
Punta del Giglio - Alghero	40° 34' 06"	8° 12' 14"	-4° 14' 54"	70	-1° 44'	44550	24836	36985

TABLE 1

Repeat Station Values at 1979.0

STATION *(Observatories underlined)*	LATITUDE	GREENWICH LONGITUDE	MONTE MARIO LONGITUDE	ALT. (m)	D	F (nT)	H (nT)	Z (nT)
Osservatorio Solare - Capri	40° 32' 45"	14° 13' 43"	+1° 46' 35"	476	-0° 13'	45015	24925	37485
Masseria Lamia	40° 24' 44"	18° 15' 26"	+5° 48' 18"	4	+0° 51'	45340	25053	37790
Masseria Maserino	40° 21' 26"	17° 38' 34"	+5° 11' 26"	88	+0° 40'	45238	25049	37670
Buttacarro - Pertusillo	40° 17' 32"	15° 57' 17"	+3° 30' 09"	600	+0° 44'	45104	25060	37501
Vignale lo Monte	40° 14' 39"	15° 17' 24"	+2° 50' 16"	500	+0° 04'	44963	25062	37330
Santa Maria d'Anglona	40° 14' 37"	16° 33' 11"	+4° 06' 03"	240	+0° 20'	45118	25078	37506
Punta Sasisorgiu - Ollolai	40° 10' 01"	9° 10' 13"	-3° 16' 55"	1075	-1° 37'	44514	25060	36790
Nuraghe Crichidoris - Cabras	39° 54' 45"	8° 27' 55"	-3° 59' 13"	6	-1° 34'	44426	25295	36522
Tescere - Ilbono	39° 53' 51"	9° 35' 44"	-2° 51' 24"	160	-1° 28'	44544	25270	36682
Presicce	39° 51' 58"	18° 13' 08"	+5° 46' 00"	90	+0° 48'	45130	25306	37368
Talleri - Villamar	39° 38' 13"	8° 58' 27"	-3° 28' 41"	137	-1° 34'	44329	25380	36344
Corongiu	39° 18' 20"	9° 16' 50"	-3° 10' 18"	100	-1° 43'	44244	25566	36110
Lago Arvo	39° 14' 00"	16° 28' 26"	+4° 01' 18"	1360	+0° 47'	44756	25665	36666
Serra Santa Caterina	39° 06' 02"	9° 31' 09"	-2° 55' 59"	70	-1° 27'	44197	25651	35992
Casa Seddas de Sa Murta	39° 01' 04"	8° 26' 56"	-4° 00' 12"	27	-1° 59'	43991	25704	35701
Isola di Capo Rizzuto	38° 58' 25"	17° 07' 08"	+4° 40' 00"	172		44735	25831	36524
Lanzaro	38° 41' 05"	16° 10' 44"	+3° 43' 36"	288	+0° 16'	44559	25966	36211
Milazzo	38° 16' 08"	15° 13' 46"	+2° 46' 38"	70	0° 00'	44169	26156	35592
Pizzolungo	38° 04' 03"	12° 34' 12"	+0° 07' 04"	10	-0° 35'	44002	26265	35304
Ferruzzano	38° 01' 41"	16° 07' 05"	+3° 39' 57"	50		44264	26319	35589
Portella Pantano	38° 00' 51"	15° 39' 56"	+3° 12' 48"	234	+0° 15'	44195	26282	35531
Gibilmanna	37° 59' 35"	14° 01' 26"	+1° 34' 18"	1000	-0° 18'	44038	26310	35314
Portella Ginestra	37° 58' 26"	13° 15' 28"	+0° 48' 20"	850		43984	26272	35276
Ceraml	37° 48' 48"	14° 29' 52"	+2° 02' 44"	900	-0° 17'	43929	26297	35188
Sant'Anna	37° 33' 05"	13° 14' 24"	+0° 47' 16"	272	-0° 28'	43888	26500	34984
Contrada Misteci	37° 26' 19"	14° 02' 57"	+1° 35' 49"	385	-0° 13'	43871	26566	34913
Casa Farrugia	37° 02' 23"	15° 17' 56"	+2° 50' 48"	11	-0° 03'	44028	26893	34860
Quartarella - Modica	36° 48' 36"	14° 45' 43"	+2° 18' 35"	380	-2° 27'	43979	27139	34607

Table 2

NORMAL FIELDS

$$a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 y^2 + a_5 x y$$

	F(nT)	Z(nT)	H(nT)	D(')
GDN x= (lat. - 42°) in minutes; y= (long. Greenw. - 12°) in minutes				
a_0	45388.4	38451.7	24104.2	-44.70
a_1	5.70878	12.46703	-9.04300	-0.00041
a_2	1.11079	1.25918	0.10973	0.28870
a_3	-0.00153	-0.00444	0.00036	-0.00004
a_4	0.00049	0.00060	0.00004	-0.00007
a_5	-0.00068	-0.00069	-0.00042	0.00014
GDN-N x= (lat. - 45°) in minutes; y= (long. Greenw. - 12°) in minutes				
a_0	46358.4	40543.6	22477.5	-46.97
a_1	5.08175	10.77693	-8.93118	-0.04561
a_2	1.07413	1.17897	0.07035	0.31361
a_3	-0.00079	-0.00356	0.00129	0.00012
a_4	0.00066	0.00070	0.00006	0.00000
a_5	-0.00144	-0.00110	-0.00117	0.00009
GDN-C x= (lat. - 42°) in minutes; y= (long. Greenw. - 12°) in minutes				
a_0	45346.0	38409.0	24103.8	-42.27
a_1	6.41016	13.25662	-9.08775	0.03548
a_2	1.78201	1.90898	0.28323	0.28326
a_3	-0.00361	-0.00689	0.00028	-0.00035
a_4	0.00164	-0.00149	-0.00059	-0.00011
a_5	-0.00601	-0.00529	-0.00302	0.00020
GDN-S x= (lat. - 39°) in minutes; y= (long. Greenw. - 12°) in minutes				
a_0	44279.5	36019.6	25751.7	-43.45
a_1	6.14390	13.79024	-8.68572	-0.00514
a_2	1.32721	1.50371	0.16531	0.21755
a_3	0.00100	-0.00111	-0.00118	0.00009
a_4	0.00043	0.00061	-0.00007	0.00005
a_5	-0.00095	-0.00074	-0.00113	0.00016
GDN-Sn x= (lat. - 40°) in minutes; y= (long. Greenw. - 12°) in minutes				
a_0	44597.1	36690.0	25372.8	-131.33
a_1	7.93198	13.60779	-5.93829	-0.39010
a_2	-1.68368	-2.78380	1.29403	-0.64295
a_3	-0.00838	-0.00979	-0.00495	-0.00099
a_4	-0.01196	-0.01579	0.00213	-0.00236
a_5	0.00663	-0.00291	0.01516	-0.00283

Fig. 1

Isolines of differences between GDN and PGRF79 over Italy ; units are nT

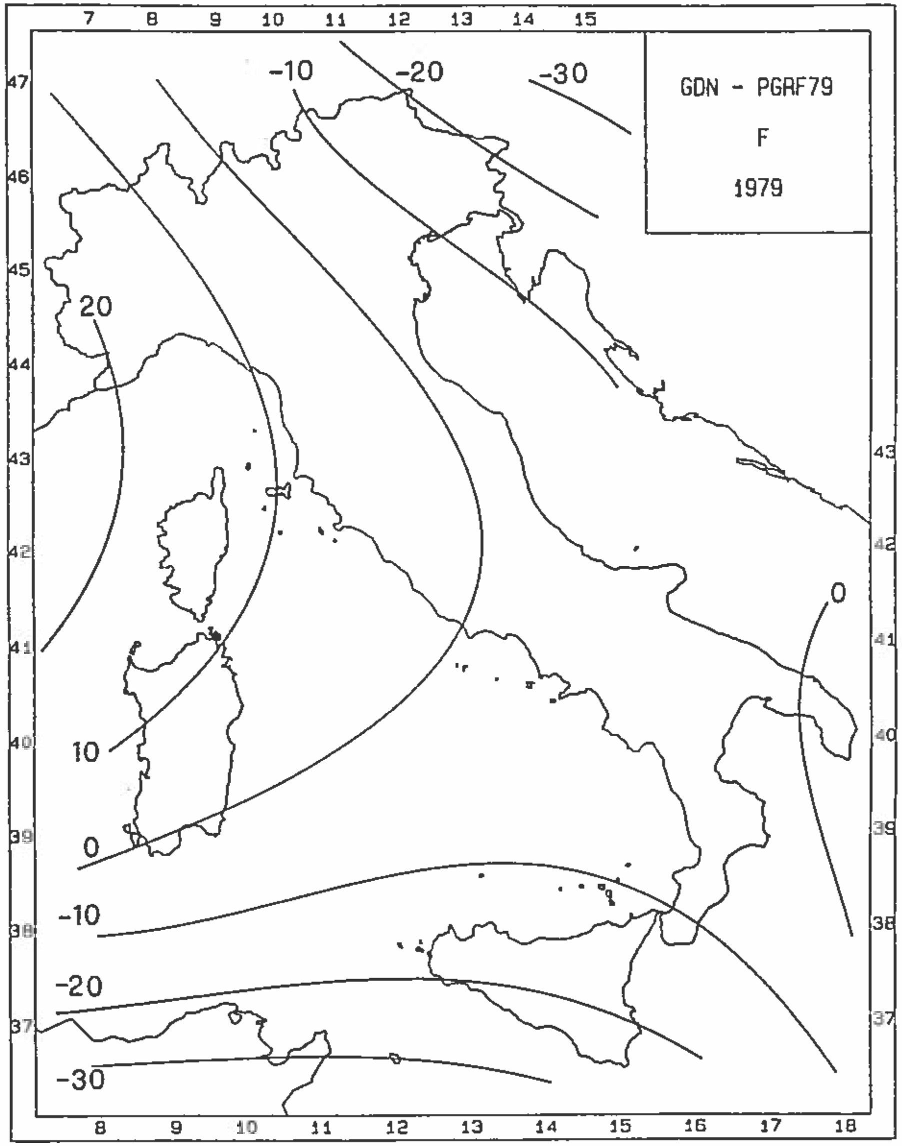


Fig. 2

Isolines of differences between GDN and IGS over Italy; units are nT

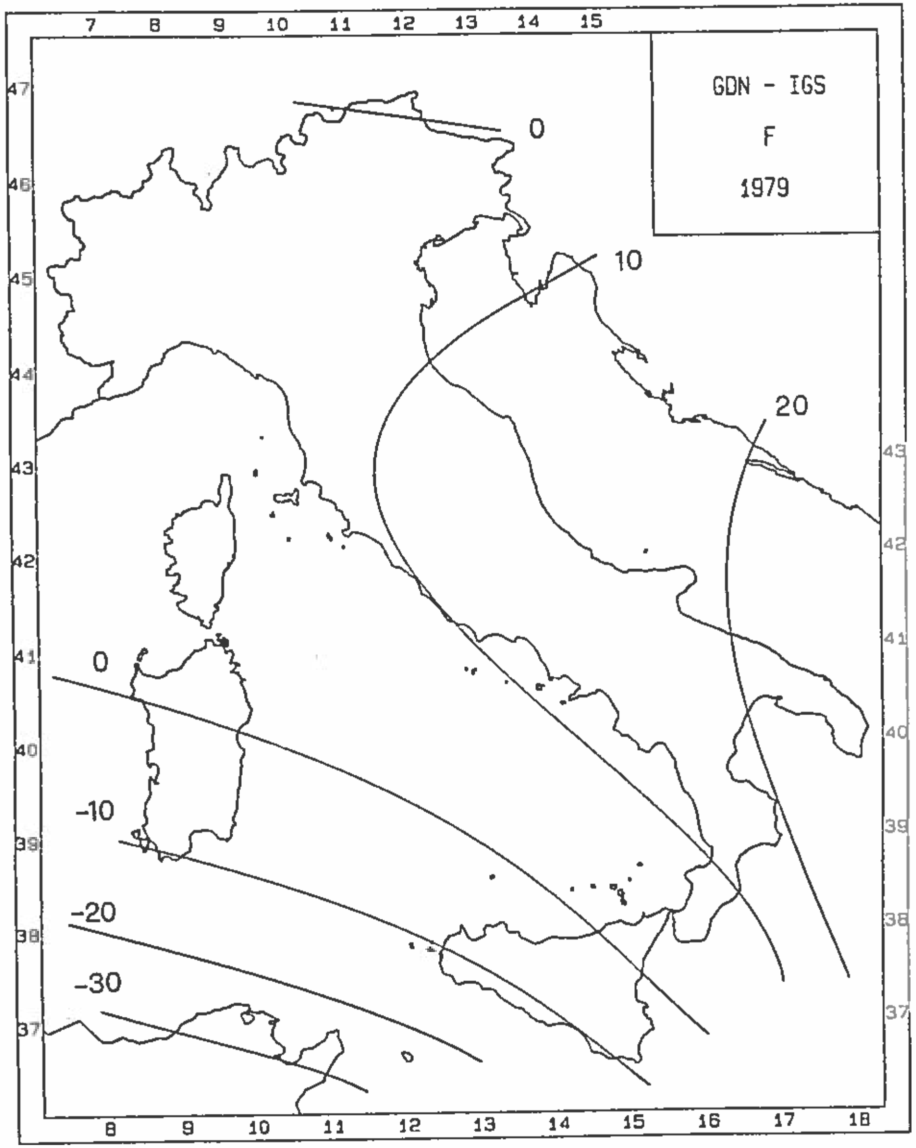


Fig. 3

Isolines of differences between IGS and PGRF79 over Italy; units are nT

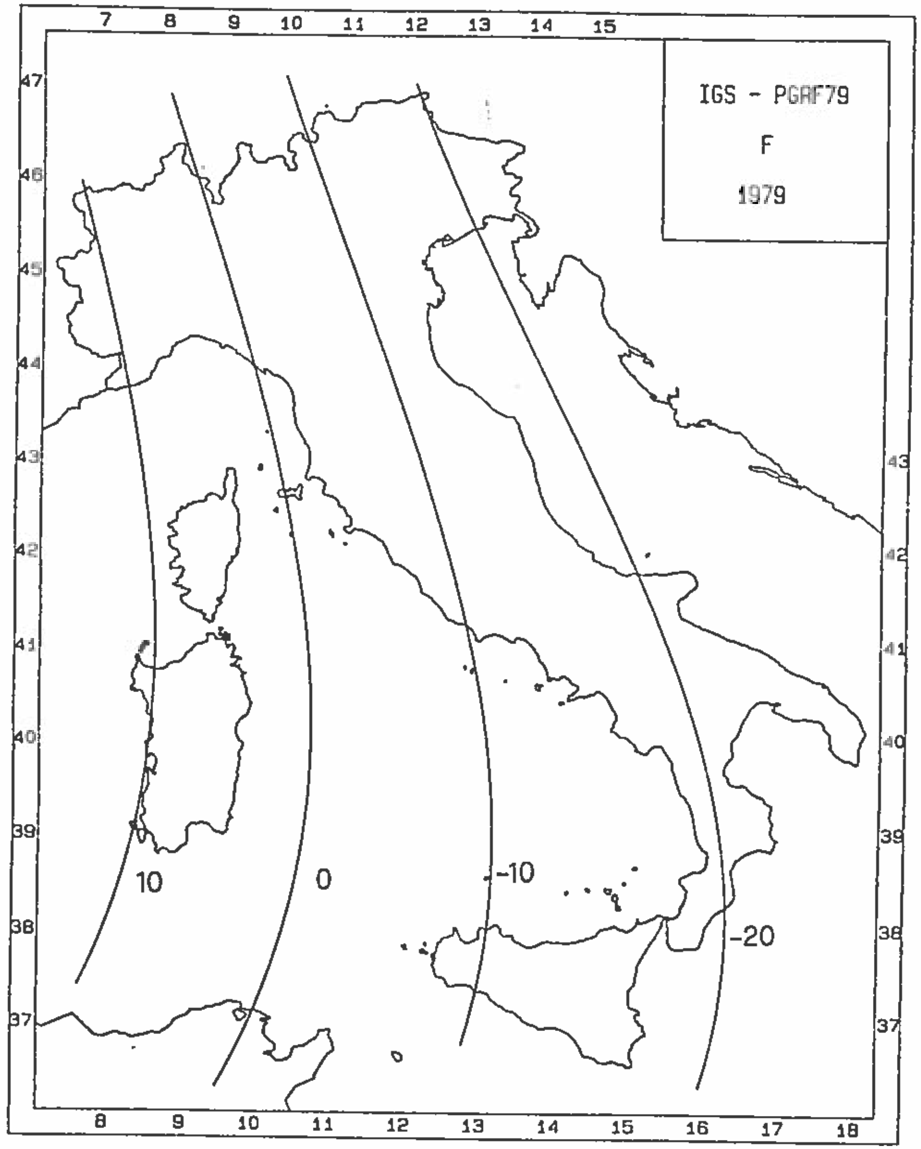


Fig. 4

Differences in F of GDN-N, GDN-C, GDN-S with respect to GDN over Italy; units are nT

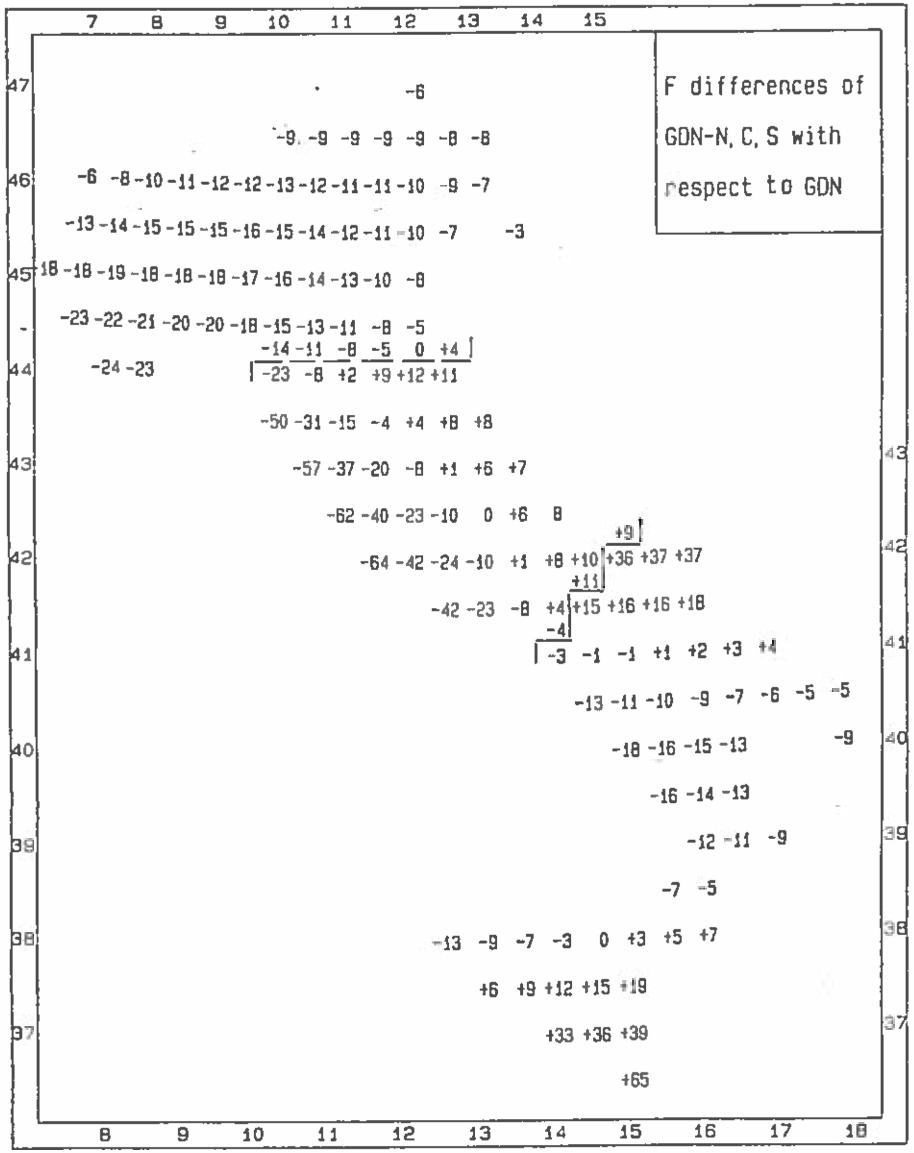


Fig. 5

Anomalies of F repeat stations with respect to GDN; units are nT

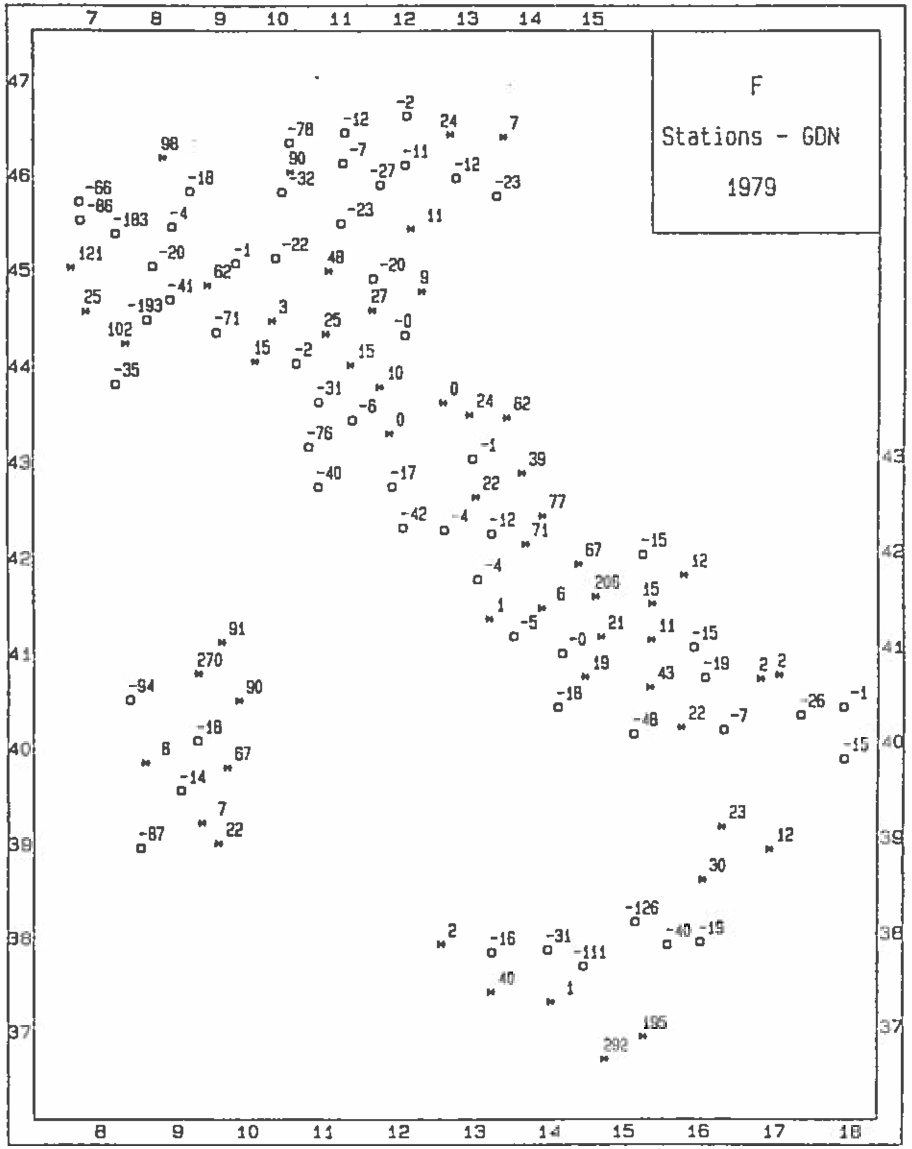


Fig. 6

Anomalies of F repeat stations with respect to PGRF79; units are nT

** indicate positive anomaly values, o indicate negative anomaly values*

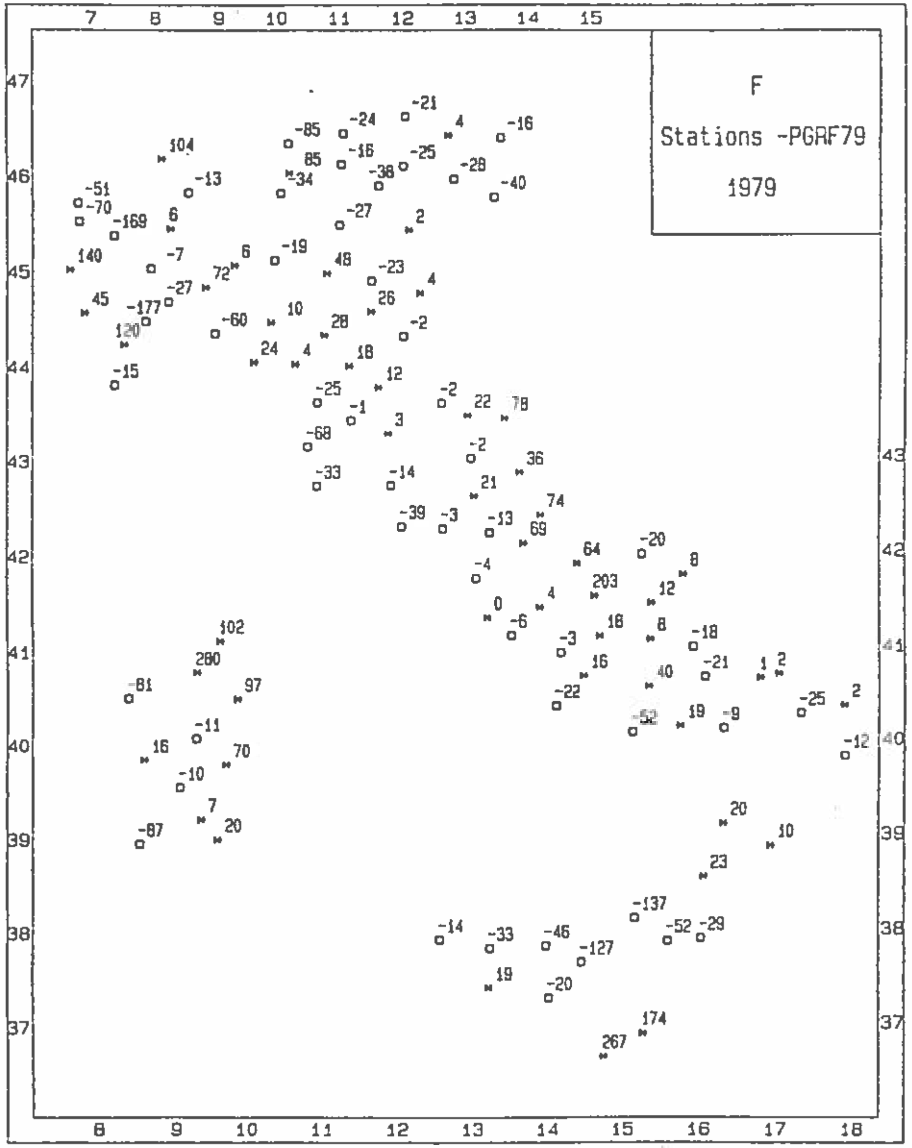


Fig. 7

Anomalies of F repeat stations with respect to IGS; units are nT

** indicate positive anomaly values, o indicate negative anomaly values*

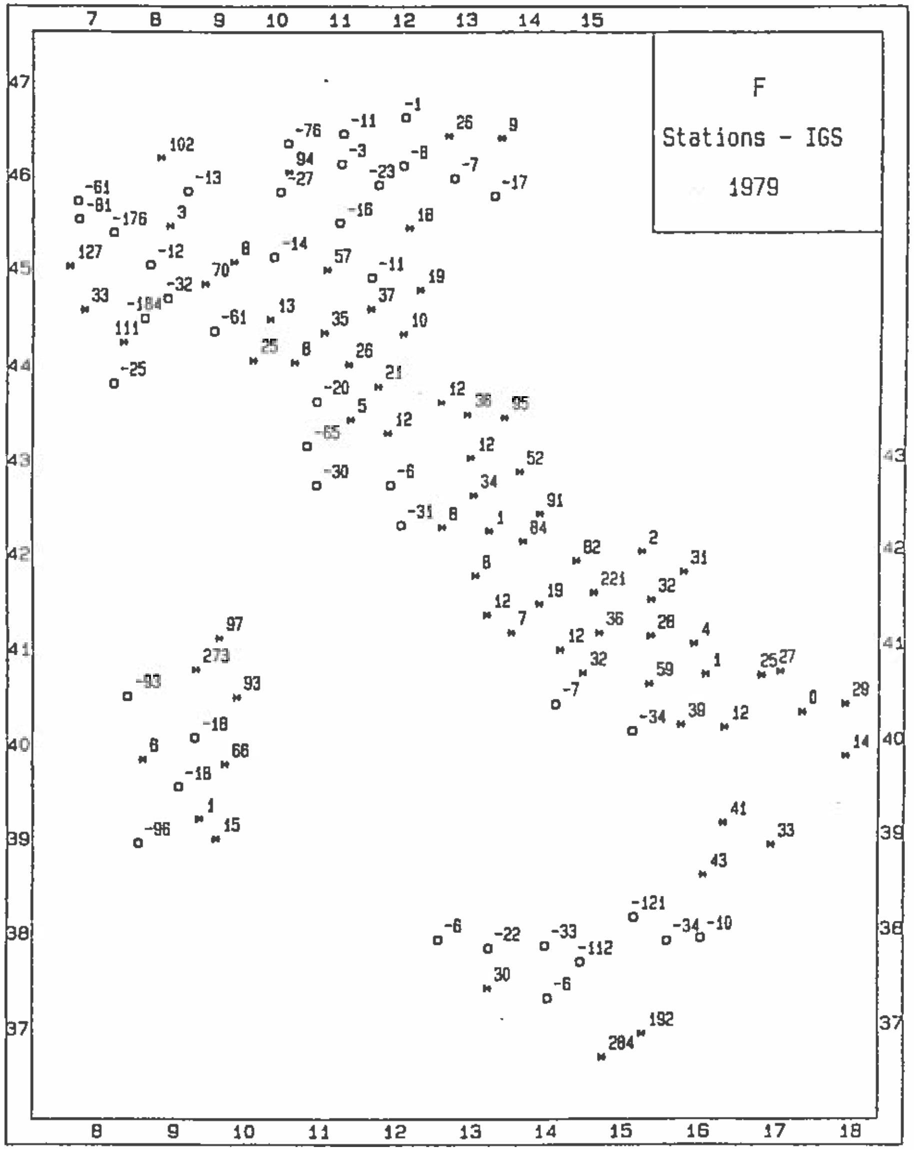


Fig. 8

Anomalies of F repeat stations with respect to IGS-C; units are nT

**: indicate positive anomaly values, o: indicate negative anomaly values*

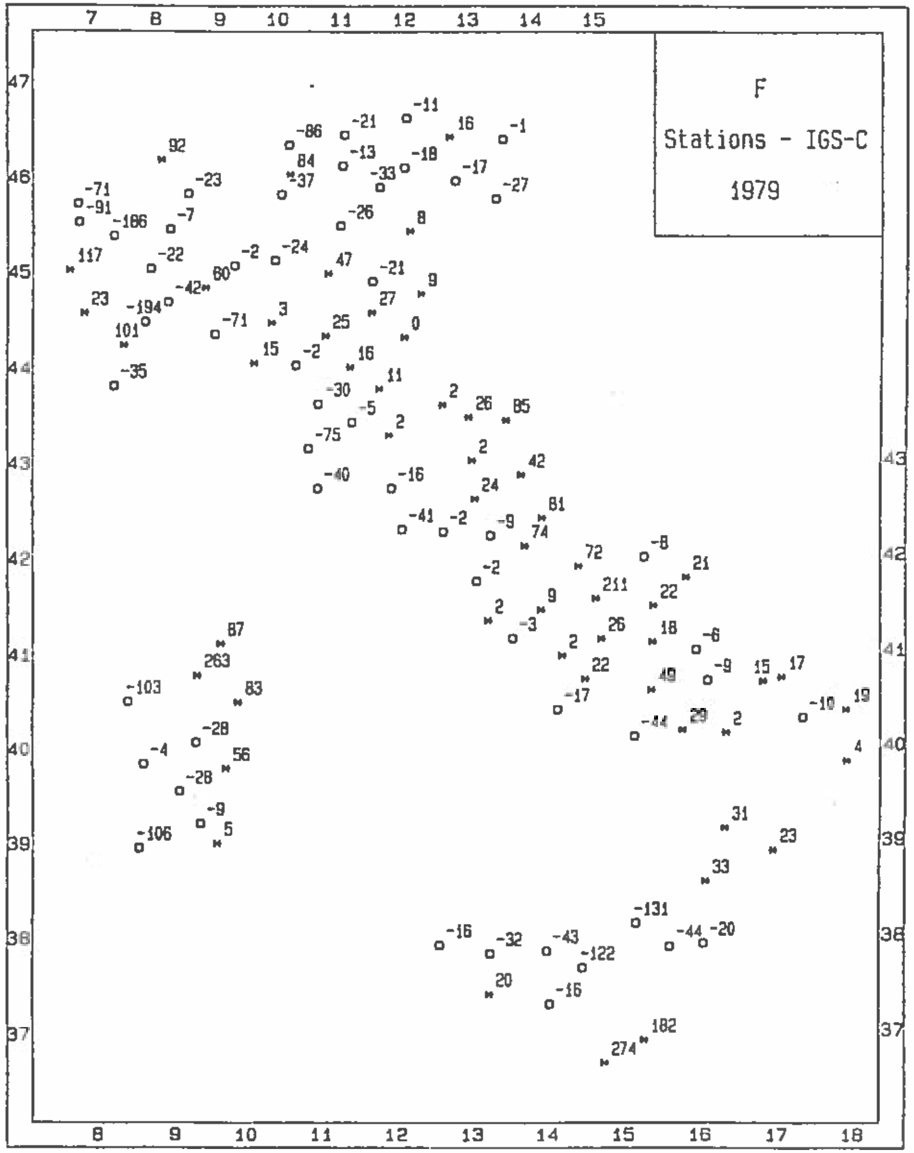


Fig. 9

Geomagnetic Field Map
Horizontal component at 1979.0 (20.000 nT +)

Fig. 10

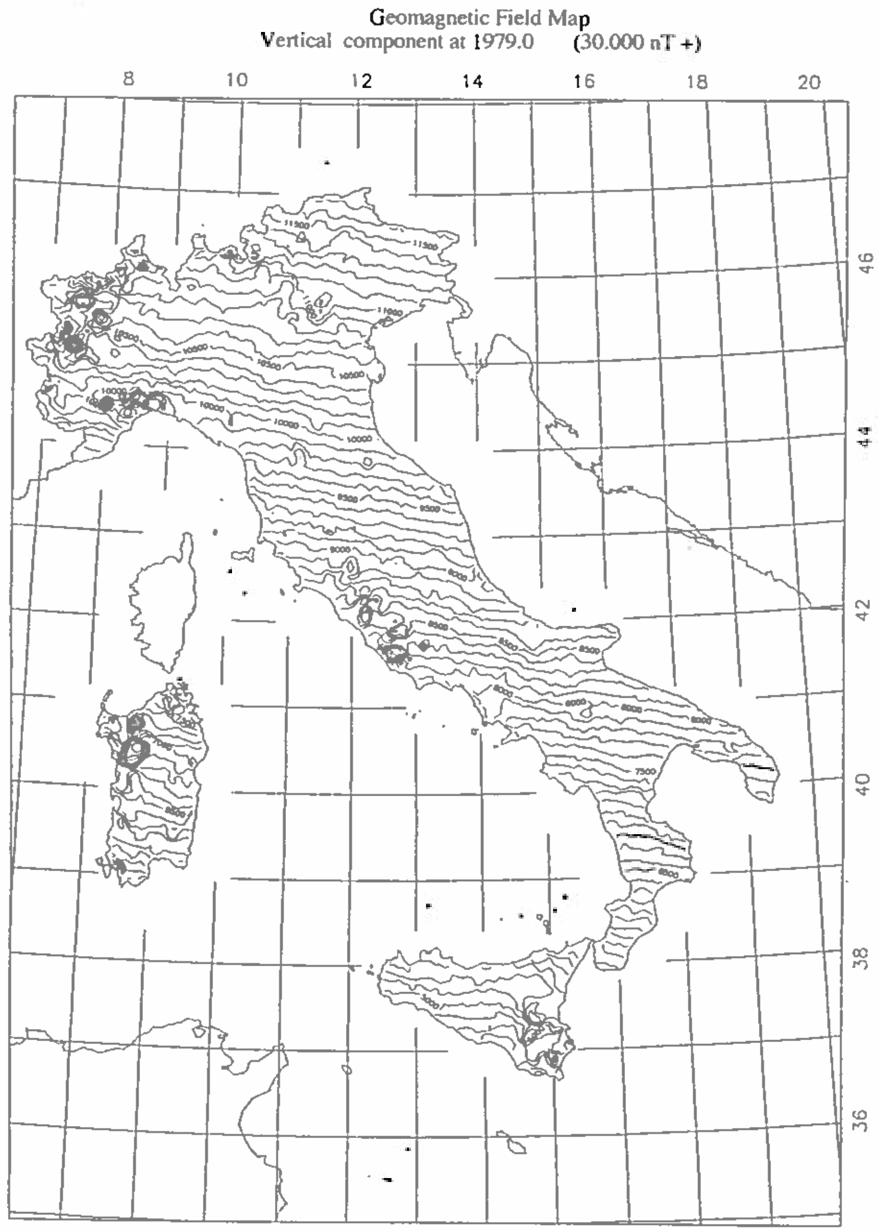
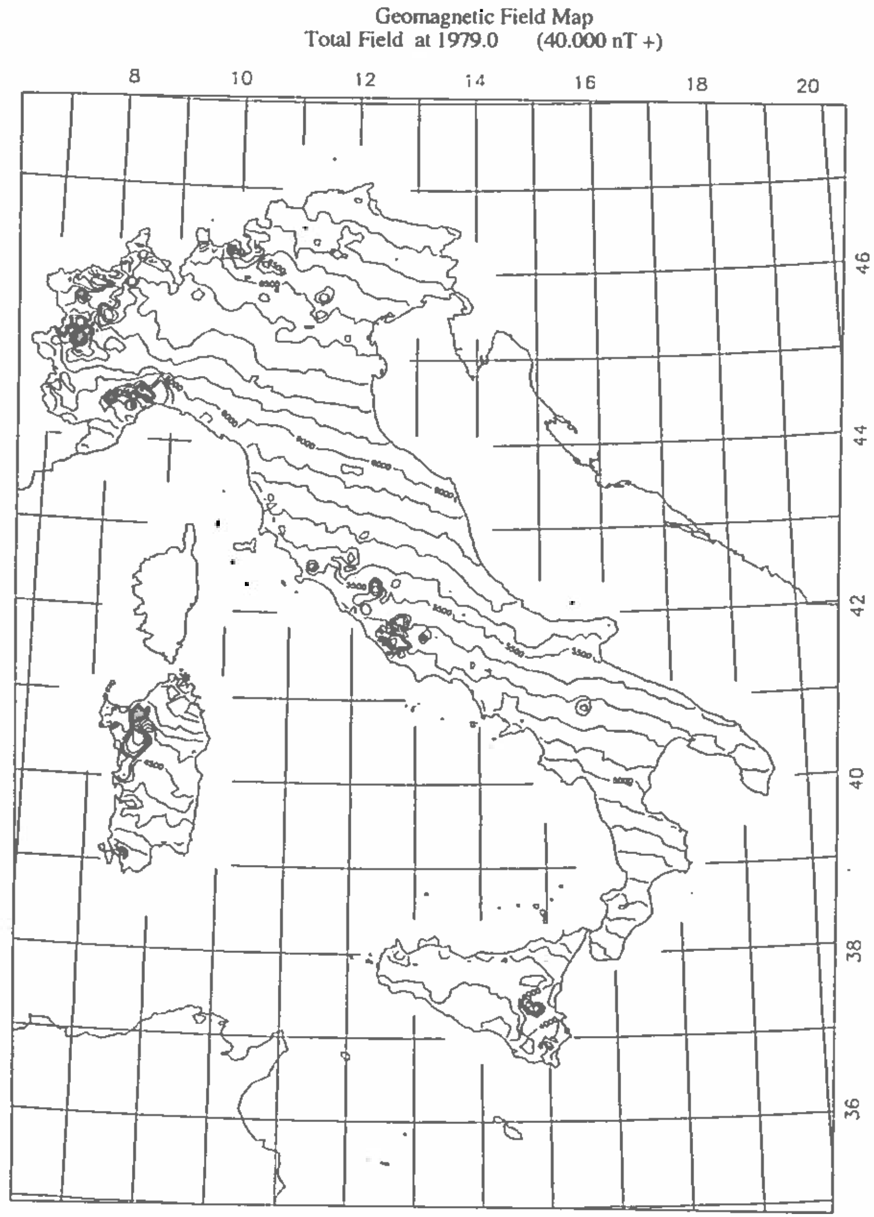

Geomagnetic Field Map
Vertical component at 1979.0 (30.000 nT +)
8
10
12
14
16
18
20
46
44
42
40
38
36

Fig. 11



Geomagnetic Field Map
Total Field at 1979.0 (40.000 nT +)
8
10
12
14
16
18
20
46
44
42
40
38
36