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# MAGNETIC FABRIC OF PLIO-PLEISTOCENE CLAYEY SEDIMENTS FROM THE FOOTWALL OF THE AVEZZANO EARTHQUAKE FAULT (CENTRAL APENNINES, ITALY)

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RIASSUNTO - "Fabric" *magnetico delle argille presenti al letto della faglia del terremoto di Avezzano (Appennino centrale, Italia)* - Il Quaternario *Italian Journal of Quaternary Sciences*, 9(1), 1996, 145-154 - Vengono riportati i risultati di uno studio sulla anisotropia della suscettività magnetica basata su campionamenti effettuati in otto località del bordo nord-orientale della Conca del Fucino (Italia centrale). Il settore studiato è caratterizzato dalla presenza di strutture ad attività quaternaria e costituisce l'area epicentrale del disastroso terremoto che distrusse Avezzano (Ms = 6.9) nel 1915. Lo studio è stato condotto per determinare il *fabric* magnetico e le cause della sua formazione nei sedimenti continentali argillosi plio-pleistocenici affioranti al letto della faglia responsabile del terremoto. Il *fabric* magnetico osservato è tipico di sedimenti scarsamente deformati o che non hanno subito deformazioni. I siti campionati per lo studio sono stati suddivisi in tre gruppi principali a seconda del grado di anisotropia. La lineazione magnetica accertata nei siti dove l'anisotropia è più elevata ha un andamento praticamente orizzontale con orientazione N302°, che è praticamente parallela alla traccia della faglia del 1915 e agli assi delle larghe flessure che si riscontrano al letto della faglia stessa. Questo fatto viene interpretato come il risultato di una debole "sovraimpressione" di tipo tettonico sul *fabric* legato alla compattazione dei sedimenti. Tuttavia, la natura di questo fatto non è chiara; può essere l'effetto sia di originari processi distensivi lungo faglie dirette a direzione NE-SW, sia di una deformazione localizzata nella parte sollevata della struttura sismogenica del 1915 in risposta a più eventi tettonici cosismici simili a quelli del terremoto in questione.

ABSTRACT - *Magnetic fabric of Plio-Pleistocene clayey sediments from the footwall of the Avezzano earthquake fault (Central Apennines, Italy)* - Il Quaternario *Italian Journal of Quaternary Sciences*, 9(1), 1996, 145-154 - The paper reports the results of a study on the anisotropy of the magnetic susceptibility at eight localities along the north-eastern edge of the Fucino basin (Central Italy). This area has been affected by widespread Quaternary tectonics and was struck by the catastrophic 1915 Avezzano earthquake (Ms = 6.9). The aim of this study is to determine the rock magnetic fabric and to investigate its possible origin. The Pliocene-Pleistocene continental clayey sediments exposed at the footwall of the fault responsible for the 1915 earthquake have been studied. The magnetic fabric is typical of undeformed or weakly deformed sediments. Sampling sites have been grouped into three main classes according to their degree of anisotropy. In the most anisotropic sites a nearly horizontal magnetic lineation oriented N302° was identified. This lineation is parallel to the trace of the 1915 fault and to the axes of broad flexures in the footwall; it is interpreted as the result of a weak tectonic overprint on the sedimentary-compactional fabric. Its origin is however not well constrained: it may have been produced either during early extensional processes along NE-SW normal faults or may be correlated to the localized deformation within the uplifted footwall of the 1915 seismogenetic structure in response to repeated 1915-like events.

Key words: Magnetic fabric, anisotropy of magnetic susceptibility, sediments, Fucino, central Italy
Parole chiave: *Fabric* magnetico, anisotropia della suscettività magnetica, sedimenti, Fucino, Italia centrale

## 1. INTRODUCTION

The study of the anisotropy of low-field magnetic susceptibility (AMS) is a non-destructive technique used for petrofabric determination. In general the AMS analysis is employed to study the imprint of a fabric on a rock by various geological processes, both during lithogenesis and during subsequent deformation (see reviews by Hrouda, 1982; Lowrie, 1989; Jackson & Tauxe, 1991; Rochette *et al.*, 1992; Tarling & Hrouda, 1993). In this latter case AMS provides valuable information on the strain experienced by a weakly deformed sedimentary body.

The AMS of a rock is represented by a second rank symmetric tensor and is visualized using an ellipsoid constructed on the basis of the magnitude of principal susceptibilities ($k_{max} > k_{int} > k_{min}$). The original fabric of an undeformed sediment is usually characterized by an oblate susceptibility ellipsoid having the $k_{min}$ axis perpendicular to the bedding plane. Strain overprints a tectonic fabric on the sedimentary-compactional fabric. Observations from several rock types and various structural settings suggest that during progressive deformation the AMS ellipsoid responds to an applied stress field in a manner analogous to the strain ellipsoid (for a detailed description of this process see, for example, Graham, 1966; Kligfield *et al.*, 1981; Hrouda, 1982; Lowrie, 1989; Tarling & Hrouda, 1993). It has been shown that the acquisition of a magnetic lineation in a sediment may be related to two different processes. The first has been recognized in undeformed sandy sediments subjected to significant hydrodynamic currents acting during the deposition (Hamilton & Rees, 1970; Hrouda, 1982); in this case $k_{max}$ lies in the direction of the water flow. The second process relates to the initial stages of tectonic deformation. In this case the first effect is the alignment of $k_{max}$ axis in the bedding plane following a direction perpendicular to the maximum shortening, where-as the $k_{min}$ axis remains on the bedding pole (see *e.g.* Lowrie, 1989). AMS analyses recently performed on clayey sediments from different structural settings indicate that AMS data are very sensitive to the strain affecting very weakly deformed sediments (*e.g.* Kissel *et al.*, 1986; Lee *et al.*,

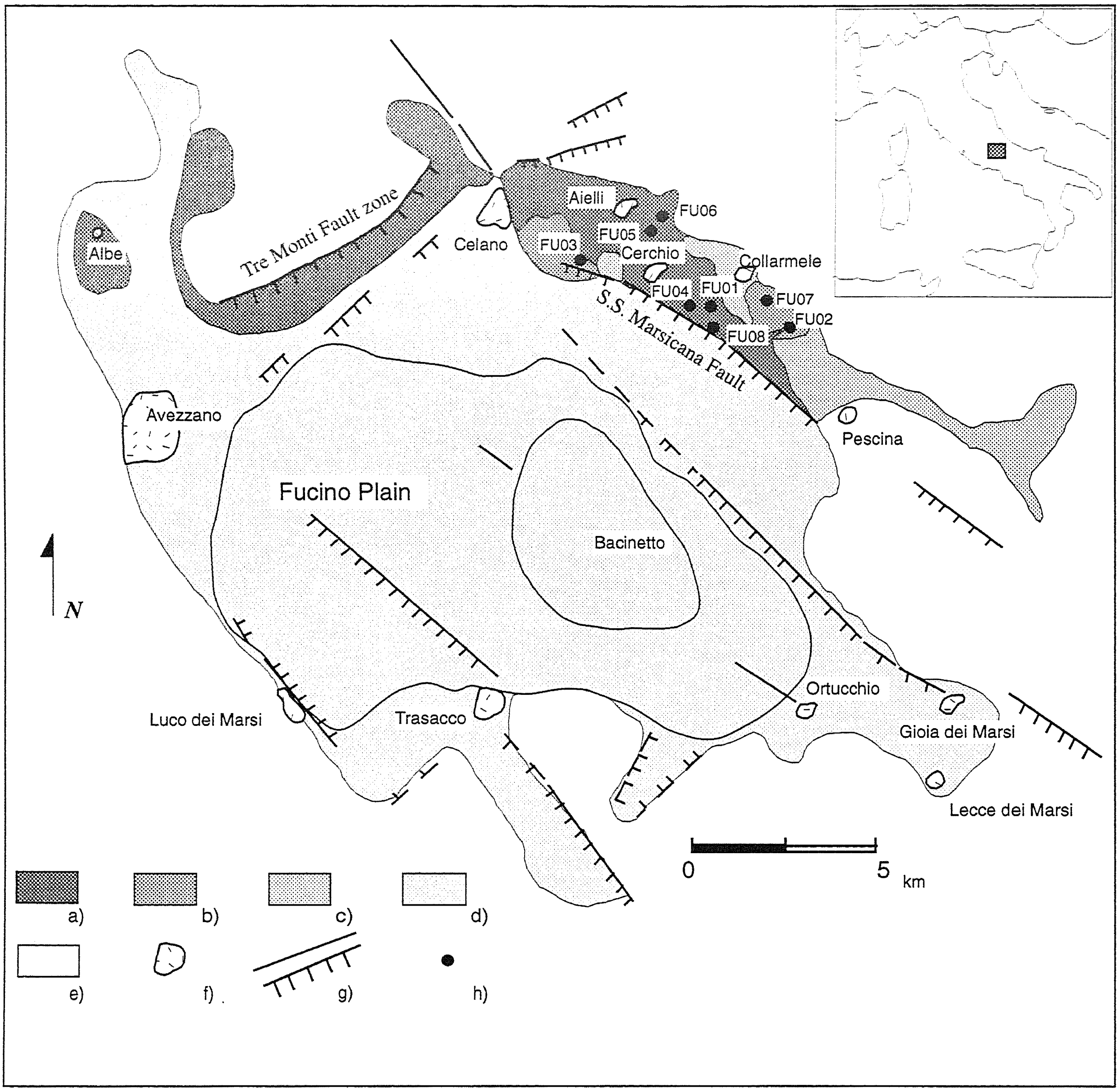



Fig. 1 - Simplified structural and geological sketch of the Fucino basin (from Bosi *et al.,* 1993, modified); a) Aielli complex (Pliocene); b) Cupoli complex (Lower Pleistocene); c) Pescina, Pervole, and Boscito formations, undifferentiated (Middle Pleistocene); d) Upper Pleistocene - Holocene sequences; e) Meso-Cenozoic limestones or Pleistocene breccias and Holocene cover; f) villages; g) fractures and faults; h) location of the sampling sites.

*Schema geologico e strutturale semplificato del bacino del Fucino (da Bosi et al., 1993, modificato); a) complesso di Aielli (Pliocene); b) complesso di Cupoli (Pleistocene inferiore); c) Formazioni di Pescina, Pervole e Boscito, non differenziate (Pleistocene medio); d) sequenze del Pleistocene superiore - Olocene; e) calcari meso-cenozoici, o brecce del Pleistocene e copertura olocenica; f) centri abitati; g) fratture e faglie; h) siti di campionamento.*

1990; Sagnotti & Speranza, 1993; Sagnotti *et al.,* 1994).

Building on the great potential of AMS analyses for petrofabric determination, in this paper we analyze the AMS of Plio-Pleistocene clayey rocks exposed at the north-eastern edge of the Fucino basin, in the Central Apennines (Italy). This is an area with widespread evidence of remarkable Quaternary tectonics and corresponds to the epicentre of one of the most destructive earthquakes of this century (the Avezzano earthquake of January 13th, 1915). The purpose of this work is to investigate possible relationships between the magnetic fabrics of clayey sediments and the Quaternary main structural elements.

## 2. GEOLOGICAL AND STRUCTURAL SETTING

During the Pliocene and Quaternary, the Central Apennines underwent extension leading to the dissection of the newly formed chain. During these phases several sedimentary intermontane basins developed all along the

Apennines, one of which was the Fucino Plain, a broad depression filled with lacustrine sediments (Fig. 1).

The Fucino basin hosts an important seismogenic structure and was struck by the destructive Avezzano earthquake of 1915. This event had an estimated magnitude Ms = 6.9 (Ward & Valensise, 1989) and its effects were especially severe: nearly every building in the area was destroyed and there were more than 30,000 casualties. Surface faulting accompanied by major surface deformations was produced during the main shock. Reconnaissance surveys carried out soon after the earthquake focused on the distribution of coseismic surface ruptures (Oddone, 1915). A series of recent investigations constrained the seismogenic structure to the E-NE edge of the Fucino basin with a NW-SE (N135°) orientation (Serva *et al.,* 1986; Ward & Valensise, 1989) and contributed to a better definition of the characteristics of the earthquake causative fault by identifying older and previously unknown surface faulting events (Giraudi, 1988; Brunamonte *et al.,* 1991). Recent studies (Galadini *et al.,* 1995) recognize four NW-SE faults affecting the basin floor, interpreted as direct surface expression of the seismogenic fault.

On the basis of seismological and geodetic data the geometry and kinematics of the 1915 fault were constrained to pure dip-slip normal motion (Ward & Valensise, 1989). Based on structural analyses carried out along the northern and southern extensions of the 1915 structure outside the Fucino basin, Galadini & Messina (1995) however, suggested the presence of a significant left-lateral strike-slip component in addition to the dip-slip motion.

Other major tectonic elements with a significant role in the Quaternary structural evolution of the basin are the Tre Monti fault, that runs along its northwestern side with a NE-SW orientation, and a set of NW-SE subparallel faults cutting its eastern and south-eastern edges (Fig. 1).

The Pliocene-Pleistocene continental sequences of the Fucino basin have been extensively studied in the past few years (Bertini & Bosi, 1976; Bosi & Messina, 1990; 1991; Zarlenga, 1990) and can be subdivided into five main sedimentary cycles (Bosi *et al.,* 1993). The first and oldest cycle is represented by the Aielli complex, which is mainly composed of lacustrine deposits, often tilted and deformed, tentatively dated to the Pliocene. This complex consists of clays, with subordinate sandy silt layers in its lower part and of gravels and breccias in its upper part. The second is the Cupoli complex, represented by gravels and sands with interbedded clayey sediments, which deposited in a predominantly fluvial environment. This cycle, which is held in the Aielli deposits, is attributed to the lower Pleistocene. A calcareous silt lacustrine sequence cropping out in the southeastern part of the basin was correlated with and considered equivalent to the Cupoli complex. The remaining three subsequent sedimentary cycles are represented by coarse-grained sediments of Middle Pleistocene age deposited in a fluvio-lacustrine environment. These sequences are exposed in the uplifted footwall of the north-easternmost fault scarp produced by the 1915 earthquake (S.S. Marsicana Fault in Fig. 1). Unfortunately, due to the local morphology, the corresponding units in the hanging-wall are buried beneath the Fucino Plain.

Some of these sequences exhibit tilting and flexuring. In particular, the Aielli complex is deformed by flexures with a NW-SE axial orientation that clearly do not match the expected direction of extensional stress revealed by 1915-type faulting. Significant uplift of the studied sector is also documented by Pliocene lacustrine deposits (Aielli complex) exposed about 350 m above the present elevation of the Fucino plain.

## 3. SAMPLING AND MEASUREMENTS

Eight sites in the Plio-Pleistocene clayey continental units for AMS analysis were identified and samples were collected from the only suitable outcrops located along the north-eastern edge of the Fucino basin. Site FU08 is the closest to the S.S. Marsicana Fault (Galadini & Messina, 1995), whereas the other sites are sparsely distributed but always located within the footwall of the 1915 fault (Fig.1). Six sites (FU01, FU02, FU04, FU05, FU06, FU08) belong to the Aielli complex. Site FU03 is a thin purple-reddish clayey level in a conglomerate se-quence of the Cupoli complex, and site FU07 was drilled in calcareous silty lacustrine sediments stratigraphically correlated with the Cupoli complex (Bosi *et al.,* 1993). A coarse clastic component was found within the clayey matrix at sites FU03 and FU04, while at all the other sites the lithology is consistently fine-grained. Samples were collected and oriented by *in-situ* drilling. A total of 83 cores were sampled (7 to 16 cores/site). Sampling of sites FU01, FU02 and FU04 took advantage of trenches excavated for the construction of a gas-pipeline, while the other sites were located on the basis of suitable outcrops. Bedding was detectable at all sites and is variably oriented. Other sedimentary features, such as current markers, were observed only at site FU08.

The AMS was measured in the paleomagnetic laboratory of Istituto Nazionale di Geofisica (Roma) using a KLY-2 Kappabridge. Measurements were taken on one standard specimen (cylinder 25 mm diameter x 22 mm height) per core. The susceptibility tensor of each specimen was computed using an updated version of the Aniso 11 programme (Jelinek, 1977). To evaluate statistically groups of specimens we used the ANS 21 programme (Jelinek, 1978).

Magnetic mineralogy was also investigated on representative specimens. The Isothermal Remanent Magnetization (IRM) was produced on a pulse magnetizer in progressively increasing magnetic fields up to 1.6 T. Natural and artificial remanences were measured on a JR-4 spinner magnetometer inside a magnetically shielded room. Stepwise thermal demagnetization was obtained in a shielded electrical oven. In addition, X-ray diffraction analyses were performed on a specimen from each site at the University of Rome using a CPW1729 diffractometer (Phillips generator CuK$\alpha$, 40 Kvolt and 20$\mu$A).

## 4. RESULTS

### 4.1 AMS Data

For each specimen the mean susceptibility ($k_{mean}$) and the most common anisotropy factors (Table 1) (magnetic lineation, L; magnetic foliation, F; corrected aniso-

Table 1 - List of anisotropy factors computed at each site.
*Parametri di anisotropia per i vari siti.*

| Sites | n | $k_{mean}$ | P' | L | F | T | q |
|---|---|---|---|---|---|---|---|
| P' ≤ 1.01 | | | | | | | |
| FU03 | 7 | 143.7 (11.3) | 1.006 (.002) | 1.001 (.001) | 1.004 (.002) | .612 (.137) | .218 (.085) |
| | | | 1.005 | 1.001 | 1.004 | .774 | .120 |
| FU04 | 10 | 134.9 (13.2) | 1.008 (.004) | 1.004 (.001) | 1.004 (.003) | -.071 (.432) | .791 (.442) |
| | | | 1.006 | 1.004 | 1.002 | -.387 | 1.063 |
| FU05 | 12 | 144.8 (7.6) | 1.010 (.003) | 1.002 (.001) | 1.007 (.002) | .461 (.213) | .321 (.157) |
| | | | 1.009 | 1.003 | 1.006 | .423 | .338 |
| 1.01<P'<1.04 | | | | | | | |
| FU01 | 16 | 129.7 (15.0) | 1.029 (.003) | 1.009 (.002) | 1.018 (.003) | .326 (.145) | .414 (.110) |
| | | | 1.028 | 1.009 | 1.018 | .336 | .402 |
| FU07 | 7 | 43.3 (4.4) | 1.020 (.006) | 1.006 (.006) | 1.013 (.002) | .466 (.282) | .326 (.223) |
| | | | 1.017 | 1.005 | 1.012 | .422 | .340 |
| FU08 | 10 | 113.5 (8.2) | 1.034 (.006) | 1.015 (.004) | 1.018 (.004) | .113 (.132) | .581 (.110) |
| | | | 1.031 | 1.014 | 1.017 | .085 | .600 |
| P' > 1.04 | | | | | | | |
| FU02 | 10 | 203.0 (27.9) | 1.071 (.007) | 1.015 (.004) | 1.051 (.007) | .534 (.106) | .273 (.070) |
| | | | 1.068 | 1.015 | 1.050 | .542 | .266 |
| FU06 | 11 | 227.2 (98.8) | 1.067 (.022) | 1.019 (.004) | 1.046 (.018) | .363 (.220) | .398 (.175) |
| | | | 1.061 | 1.019 | 1.042 | .374 | .380 |
| **Total** | 83 | 146.2 (61.2) | 1.031 (.025) | 1.009 (.007) | 1.021 (.018) | .338 (.297) | .423 (.255) |
| | | | 1.026 | 1.006 | 1.018 | .473 | .307 |

The upper line for each locality shows the arithmetic means of single specimen values (standard deviation in parenthesis); the lower line shows the site tensorial means (for values, see text), as calculated by the ANS 21 program (Jelinek, 1978).

n = number of samples;

$k_{mean} = (k_{max} + k_{int} + k_{min}) / 3$ (mean susceptibility, in $10^{-6}$ SI units) ;

$P' = \exp\sqrt{\{2[(\eta_1 - \eta)^2 + (\eta_2 - \eta)^2 + (\eta_3 - \eta)^2]\}}$ (corrected anisotropy degree);

$L = k_{max} / k_{int}$ (lineation);

$F = k_{int} / k_{min}$ (foliation);

$T = 2(\eta_2 - \eta_3) / (\eta_1 - \eta_3) - 1$ (shape factor);

$q = (k_{max} - k_{int}) / [(k_{max}+k_{int}) / 2 - k_{min})]$ (shape factor);

$\eta_1 = \ln k_{max}$ ; $\eta_2 = \ln k_{int}$; $\eta_3 = \ln k_{min}$; $\eta = (\eta_1 + \eta_2 + \eta_3)/3$

tropy degree, P'; and shape factors, T and q) were computed . See Table 1 for the mathematical expression of each factor. The mean susceptibility ($k_{mean}$) of the sampled rocks is 146.2 x $10^{-6}$ SI units; the averaged degree of anisotropy (P') is 1.031 and the mean shape factor (T) is positive and equal to 0.473. The observed value range for AMS parameters is typical of weakly deformed or nearly undeformed sediments. However, different sites exhibit significant variations. In order to visualize the changes of the AMS parameters listed above, Figure 2 gives the T-P' plot. The anisotropy parameters indicate that sites can be grouped into three main classes characterized by different degrees of anisotropy (P') and ellipsoid shapes:

1) almost isotropic, with P'<1.01 (FU03, FU04, FU05);

2) weakly anisotropic, with 1.01<P'<1.03 and susceptibility ellipsoids mainly triaxial to oblate (FU01, FU07, FU08);

3) anisotropic, with 1.03<P'<1.07 and susceptibility ellipsoids essentially oblate (FU02, FU06).

Based on a comparison of the variation of the anisotropy degree and of the ellipsoid shapes, it is concluded that higher anisotropies are typical of specimens where foliation prevails. This would suggest a major role of sedimentary and compactional processes in the acquisition of a magnetic fabric in the studied rocks. Indeed, the $k_{min}$ axes are clustered around the bedding pole at all the anisotropic sites. At four sites (FU01, FU02, FU06, FU08; see Fig. 3b, c) a well defined magnetic lineation with small differences in azimuth and plunge was identified. This lineation is given by the cluster of the $k_{max}$ axes in the bedding plane. Even at sites where the ani-

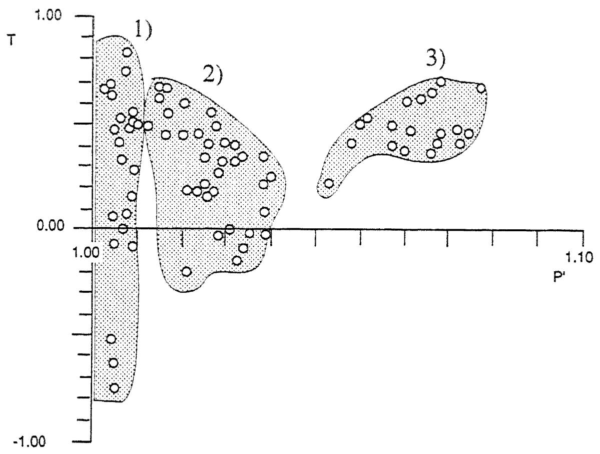



Fig. 2 - Magnetic anisotropy plot: Shape factor (T) versus corrected anisotropy degree (P'). 1) P' < 1.01, isotropic specimens (FU03, FU04, FU05); 2) 1.01 < P' < 1.03 and ellipsoid shape oblate to triaxial (FU01, FU07, FU08); 3) 1.03 < P' < 1.07 and oblate ellipsoid (FU02, FU06).

*Diagramma dell'anisotropia magnetica: fattore di forma (T) in funzione del grado di anisotropia corretta (P'). 1) P' < 1.01, campioni isotropi ((FU03, FU04, FU05); 2) 1.01 < P' < 1.03 e forma dell'ellissoide oblata fino a triassiale (FU01, FU07, FU08); 3) 1.03 < P' < 1.07 ed ellissoide oblato (FU02, FU06).*

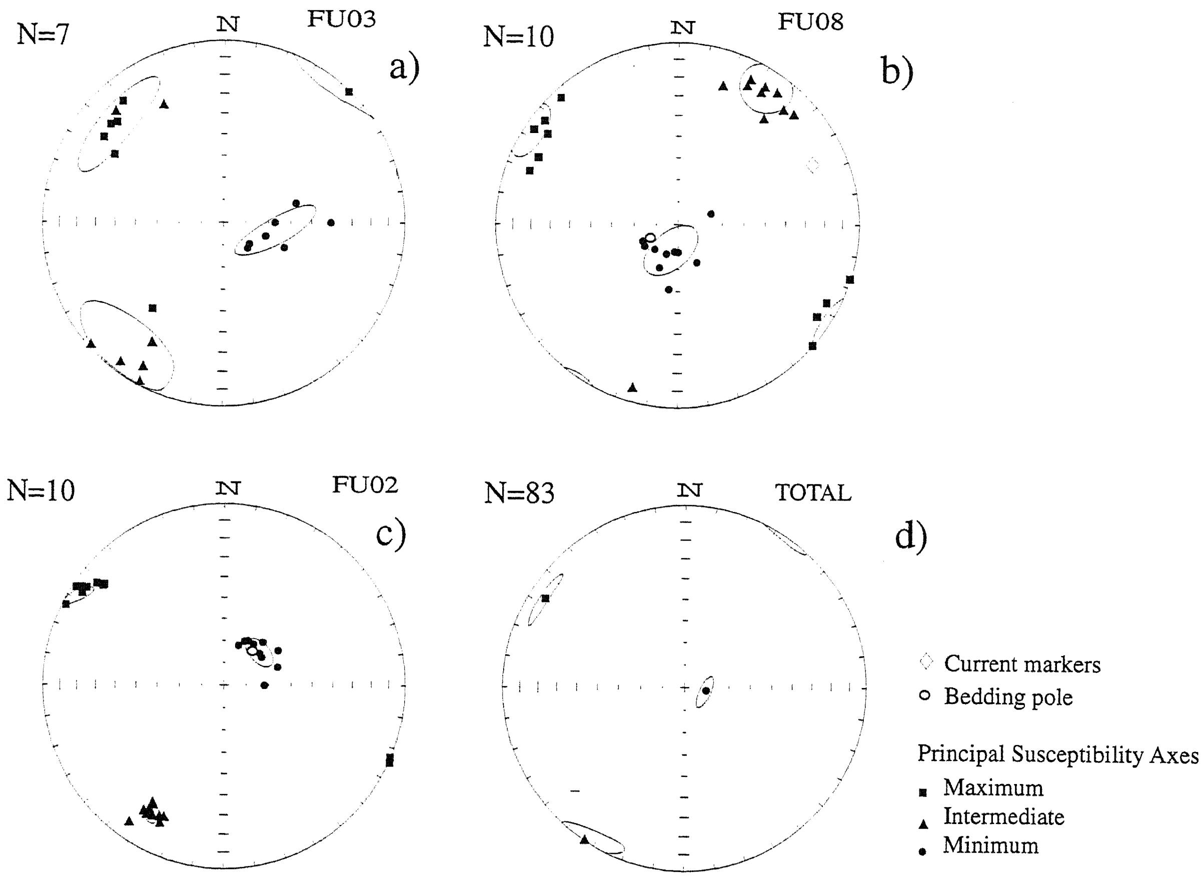
sotropy degree is very low, we could detect a magnetic lineation (FU03, FU04, FU05; see Fig. 3a) that is variably oriented. The overall direction of $k_{max}$ resulting from the tensorial statistics computed using 83 samples (Fig. 3d) is N302° with nearly horizontal dip (9°).

## 4.2 Magnetic mineralogy

The very low values for the mean susceptibility of these sediments (in the range 22 x $10^{-6} \div 213$ x $10^{-6}$ SI) indicate that the magnetic susceptibility and its anisotropy are mainly controlled by a paramagnetic fraction (Rochette, 1987; Tarling & Hrouda, 1993). The nature of the main mineralogical components has been discriminated by X-ray diffraction for one sample each site.

Fig. 3 - Representative AMS data results. Schmidt equal-area projections, lower hemisphere. a) Site FU03 (almost isotropic); b) site FU08 (weakly anisotropic); c) site FU02 (anisotropic); d) total (only mean susceptibility axes and 95% confidence ellipses are shown).

*Risultati dei dati AMS rappresentativi. Proiezioni di Schmidt, emisfero inferiore. a) Sito FU03 (praticamente isotropo); b) sito FU08 (debolmente anisotropo); c) sito FU02 (anisotropo); d) tutti i siti (sono indicati solamente gli assi a suscettività media e le ellissi di 95% di confidenza).*



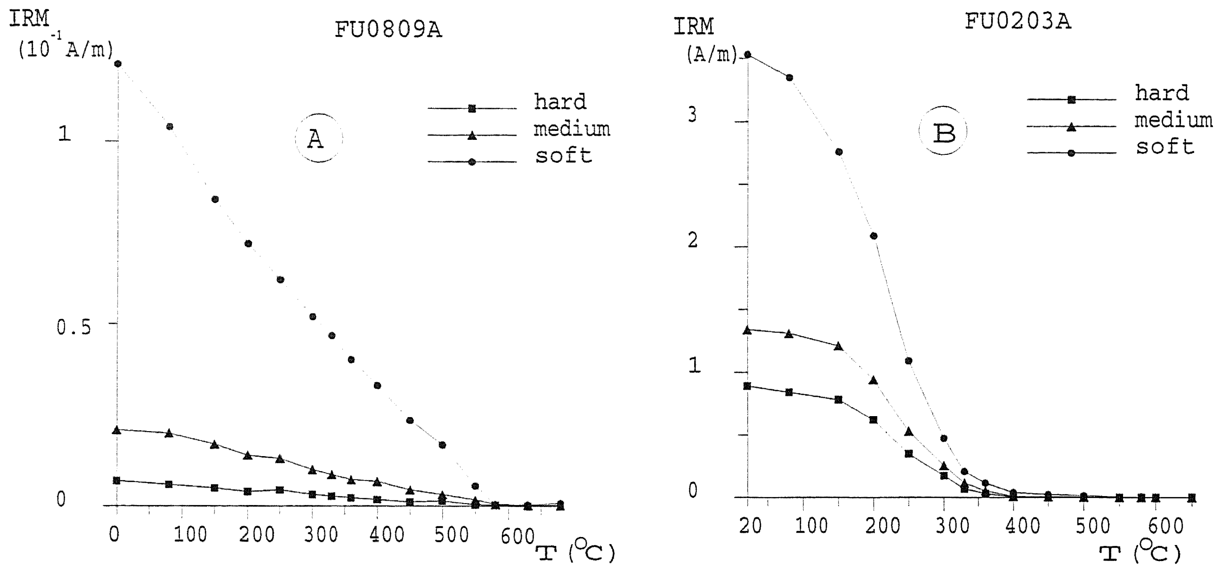



Fig. 4 - Stepwise thermal demagnetization of a three component IRM produced by applying 1.6 T along the z-axis, 0.6 T along the y-axis and 0.12 T along the x-axis of the specimen, for two representative specimens.

*Livelli di demagnetizzazione termica di una IRM a tre componenti ottenuta applicando un T pari a 1.6 lungo l'asse z, 0.6 lungo l'asse y e 0.12 lungo l'asse x del campione; prova eseguita su due campioni rappresentativi.*

Table 2 - Rock magnetic parameters

*Parametri magnetici della roccia*

| Specimen | NRM (μ A/m) | k (x $10^{-6}$ SI) | SIRM (A/m) | $H_{cr}$ (mT) | Tb (°C) | SIRM/k | S-ratio (A/m) |
|---|---|---|---|---|---|---|---|
| FU0114A | 500 | 110 | 1.2 x 10-1 | -42 | 580 | 1091 | -0.65 |
| FU0203A | 2400 | 213 | 4.9 | -65 | 330 (580) | 22846-0.56 | |
| FU0301A | 270 | 122 | – | -73 | 580; >650 | – | -0.18 |
| FU0409A | 380 | 114 | 1.2 x 10-1 | -48 | 300; 580 | 1053 | -0.57 |
| FU0507A | 300 | 130 | 9.1 x 10-2 | -40 | 580 | 700 | -0.64 |
| FU0608A | 770 | 151 | 1.7 x 10-2 | -48 | 580 | 1113 | -0.56 |
| FU0610A | 24000 | 315 | 11 | -64 | 330; 400 | 34921 | -0.63 |
| FU0705B | 110 | 36 | 2.5 x 10-2 | -45 | 300; 580 | 694 | -0.6 |
| FU0809A | 320 | 101 | 1.4 x 10-1 | -40 | 580 | 1416 | -0.79 |

NRM: Natural Remanent Magnetization; k = mean low-field magnetic susceptibility; SIRM = Saturation Isothermal Remanent Magnetization; $H_{cr}$ = coercivity of remanence; Tb = maximum unblocking temperatures; S-ratio = IRM(-0.1Tesla)/IRM(1 Tesla)

Results indicate that in all samples paramagnetic clayey minerals belong to the illite and chlorite groups. Common minerals such as quartz, feldspars, calcite and dolomite have also been identified. No correspondence between variations in the distribution and abundance of common minerals and variations in magnetic anisotropy types was identified.

Finally, at least one specimen per site underwent specific analyses to investigate the nature of the ferromagnetic minerals. Initially the stepwise acquisition of the isothermal remanent magnetization (IRM) and the coercivity of the remanence (Hcr) were analyzed. Then, the blocking temperatures of magnetic phases, separated according to their coercivity spectra, were investigated performing a stepwise thermal demagnetization of three orthogonal IRMs, following the method described in Lowrie (1990) (Fig. 4). Results of these analyses are summarized in Table 2. Magnetite is the predominant remanence carrier at all the sites (maximum unblocking temperature around 580°C). Low coercivities and blocking temperatures around 300-350°C, identified at sites FU02, FU04, FU06 and FU07, are probably related to the additional presence of iron sulphides. High coercivity minerals were detected only at site FU03. A maximum unblocking temperature > 650°C for the hard and intermediate fractions shows that hematite is the main remanence carrier at this site.

## 5. DISCUSSION AND CONCLUSIONS

The magnetic fabric of the clayey rocks at the north-eastern margin of the Fucino Plain is typical of undeformed or weakly deformed sediments. The values obtained for AMS parameters suggest a subdivision of all sampled sites into three groups. Some sites exhibit isotropic behav-

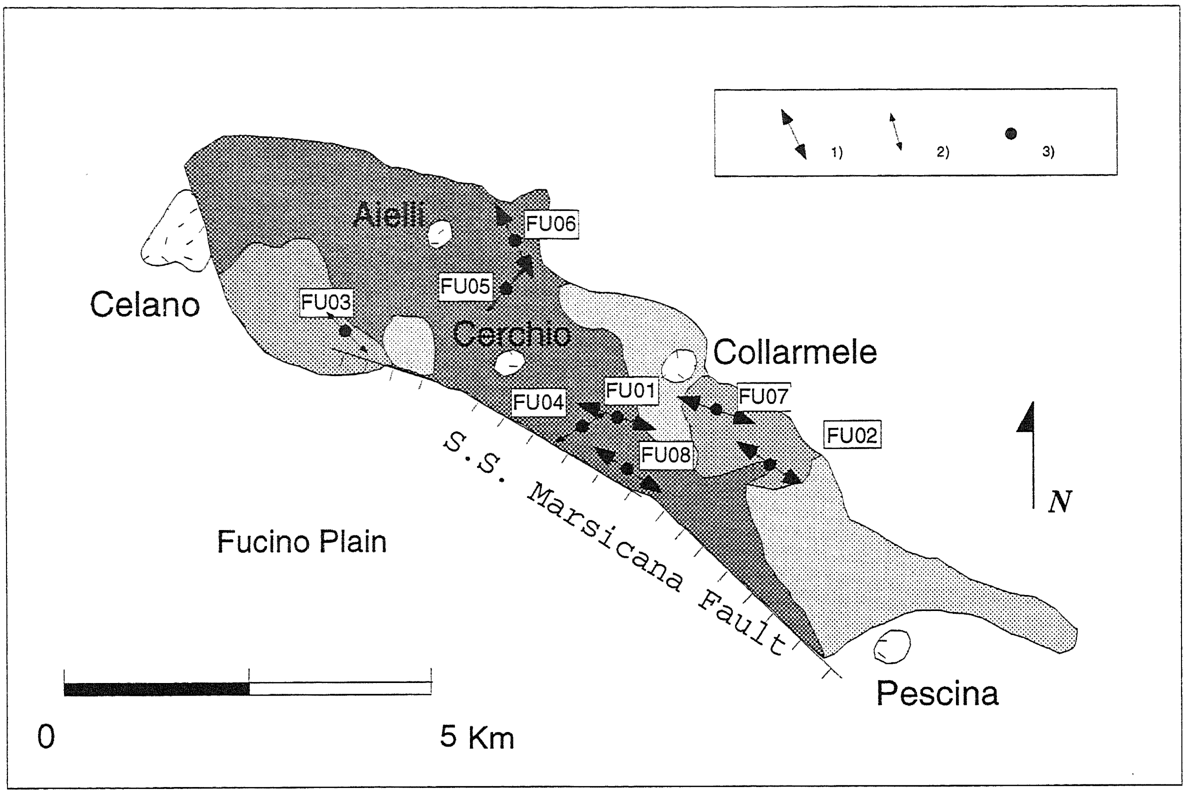



Fig. 5 - Simplified sketch reporting the magnetic lineation detected in the studied area. 1) magnetic lineation trend for sites having P' > 1.01; 2) magnetic lineation trend for sites having P' < 1.01; 3) location of the sampling sites. Other symbols as in Fig. 1.

*Schema semplificato della lineazione magnetica della zona studiata. 1) direzione della lineazione magnetica per i siti con P' > 1.01; 2) direzione della lineazione magnetica per i siti con P' < 1.01; 3) siti di campionamento. Per gli altri simboli vedi la Fig. 1.*

iour or very low AMS definition (FU03-FU04-FU05), which is possibly due to specific lithological characteristics, such as the presence of a considerable coarse clastic component (FU03-FU04). The mean magnetic lineation recognized at the anisotropic sites (FU01, FU02, FU06, FU08) is nearly horizontal and trends N302°.

The ferromagnetic content of these clays is scarce and no clear relationship between variation in ferromagnetic mineralogy and anisotropy of low-field magnetic susceptibilty was observed. This implies that AMS data are mostly controlled by paramagnetic clayey minerals of the rock matrix, which is in agreement with the very low values of mean susceptibility. The sedimentological features of this clayey sediments suggest a calm water continental (lacustrine) depositional environment, and no evidence of hydrodynamic currents was generally found. Sedimentary current markers have been detected only at one site (FU08), where they lie at a high angle with respect to the magnetic lineation (nearly 60°; Fig. 3b). This additional observation indicates that, at least at this site, the magnetic lineation does not reflect hydrodynamic currents during deposition but instead must be related to post-depositional events. Considering the strong neotectonic activity in the study area and the vicinity of all sampling sites to an important active fault, a possible interpretation is that the observed magnetic lineation originated in response to tectonic processes that affected this portion of the Fucino basin.

Detailed studies have shown that deformation occurring along the eastern edge of the basin is the result of several tectonic events, some of which were recognized along parts of the 1915 surface rupture (Brunamonte *et al.,* 1991).

The magnetic lineation might have originated in response to a weak tectonic effect on the primary magnetic fabric and be therefore related to the deformation pattern of the studied sequences. However, in this case the magnetic lineation would suggest a NW-SE direction of maximum stretching in the uplifted footwall (Fig. 5), parallel to the 1915 fault and to the axes of flexures found in the Aielli complex deposits.

A first alternative explanation is that the tectonic contribution to the fabric was superimposed onto the primary fabric at an early stage as a result of activity along the NE-SW normal faults (*i.e.* the Tre Monti Fault in Fig. 1) In this scenario, subsequent tectonic activity along NW-SE faults would not further affect the fabric of these sediments. This is in agreement with the indication that the fabric is more easily affected by strain when sediments are relatively soft and unconsolidated (Graham, 1966), and is hardly overprinted by subsequent tectonic phases.

A second alternative explanation is that magnetic lineation has in fact recorded localized deformation of sediments that have undergone tilting and flexuring associated with fast uplift of the footwall of the NW-SE structures. This would justify the parallelism between the magnetic lineation, the fault trace and the flexure in the footwall. A magnetic lineation parallel to the trend of a broad flexure in the uplifted footwall of a transverse extensional structure has been recently observed in Pliocene marine sediments from the Tyrrhenian margin of Central Italy (Sagnotti *et al.,* 1994). Theoretical models indicate that motion of a dip-slip fault in an extensional setting imposes a negative load on the footwall, thus generating uplift of the footwall itself (King *et al.,* 1988; Stein *et al.,* 1988; Wernicke & Axen, 1988). The uplift is generally expressed through folding and flexuring. Under this hypothesis magnetic lineation would follow localized deformation directly associated with the uplift and would not be representative of the regional strain field. Tectonic magnetic lineations are expected to be perpendicular to the main normal fault in the hanging wall and at greater distances from the fault in the footwall.

Unfortunately, the lack of suitable outcrops does not allow to discriminate between the two hypotheses and further investigations in areas characterized by more favorable exposures are needed to solve the dispute.

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