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MESOSTRUCTURAL ANALYSIS IN A CONGLOMERATIC DEPOSIT ALONG THE MT. CASTELLO-MT. CARDOSA NORMAL FAULT ZONE IN THE SOUTHERN UMBRIA-MARCHES APENNINES (CENTRAL ITALY)

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ABSTRACT - *Mesostructural analysis in a conglomeratic deposit along the Mt. Castello-Mt. Cardosa normal fault zone in the southern Umbria-Marches Apennines (central Italy)* - Il Quaternario, **8**(1), 1995, 229-234 - Kinematic indicators recognized on pebble surfaces in a Quaternary fluvio-glacial deposit (presumably Middle Pleistocene in age) placed on the hanging wall of a normal fault belonging to the Mt. Castello-Mt. Cardosa fault zone are described. Fault planes in the bedrock show two different extension directions: N50°÷60°E and N-S to N20°E. The aim is to check the consistency of kinematics both along master faults and in Quaternary deposits. The conglomerates under investigation present a N-S to N20°E extension direction: the N-S extension direction is younger than the N60°E one, no longer active after sedimentation. Compressive striae in the conglomerates oriented N-S could have originated in an extensional regime. Cyclic load application during seismic events may have developed these structures by reducing conglomerate shear strength.

RIASSUNTO - *Analisi mesostrutturale di un deposito conglomeratico situato nella zona delle faglia normali di M. Castello-M. Cardoso nell'Appennino umbro-marchigiano meridionale (Italia centrale)* - Il Quaternario, **8**(1), 1995, 229-234 - In questo lavoro si analizzano gli indicatori cinematici nei ciottoli di un deposito fluvio-glaciale (probabilmente riferibile al Pleistocene medio) situato al tetto di una della faglie normali quaternarie appartenenti al fascio M. Castello-M. Cardosa (dorsale appenninica umbro-marchigiana). Lo scopo è di verificare la compatibilità tra i dati cinematici raccolti su piani di faglia nel substrato e quelli nei ciottoli e di tentare una cronologia relativa tra le cinematiche osservate. I risultati ottenuti mostrano che la faglia di M.Cardosa è una struttura rimasta attiva dopo la sedimentazione dei conglomerati fluvio-glaciali (Pleistocene medio); le faglie nel substrato registrano due direzioni di estensione: N50°-60°E e N-S-N20°E. L'estensione a direzione circa N-S è successiva a quella orientata N60°E; quest'ultima è stata attiva prima della sedimentazione dei conglomerati in quanto essi non la registrano. I conglomerati registrano anche indizi di compressione — ugualmente orientati N-S — che sono da ascrivere, a nostro avviso, a deformazioni indotte localmente nell'*hanging wall* della faglia di M.Cardosa durante la tettonica estensionale. Tali strie inverse sono dovute ad accomodamenti nell'ambito di un sistema confinato in cui si è avuto incremento della pressione dei fluidi per applicazione di carichi ciclici di natura sismica.

Key words: Striated pebbles, Quaternary normal faults, mesostructural analysis, Umbria-Marches Apennines ridge
Parole chiave: Ciottoli striati, faglie normali quaternarie, dorsale appenninica umbro-machigiana

1. INTRODUCTION

During the last years, detailed studies have been carried out on the geometry and kinematics of Quaternary normal faults in the Umbria-Marches Apennines (Brozzetti *et al.*, 1991; Pizzi, 1992; Calamita & Pizzi, in press). These faults are believed to date from Lower-Middle Pleistocene (Calamita *et al.*, 1982; Coltorti *et al.*, 1989), and their activity is suggested by morphotectonic and geological evidence and widespread seismicity occurring in this area.

Structural analysis of kinematic indicators on bedrock fault planes shows a main extension direction N50°÷60°E and, subordinately, a N-S to N20°E extension direction for these faults. The relationships between different extension directions and their respective chronology are not well defined.

2. GEOLOGICAL SETTING

The studied deposit is placed just south of Mt. Cardosa (southern Umbria-Marches Apennine ridge), very close to a normal fault evidenced by a bedrock (*Scaglia rossa* Formation, Upper Cretaceous-Middle Eocene) scarp trending NNW-SSE and belonging to the Mt. Castello-Mt. Cardosa fault zone (MCC). The Umbria-Marches Apennines is a Neogene fold and thrust belt with arcuate shape and a NE convexity (Calamita & Deiana, 1987). Since the Lower-Middle Pleistocene (Calamita *et al.*, 1982; Coltorti *et al.*., 1989), extensional tectonics have overlain the Neogene compressive tectonics from west to east (at a larger scale this characterizes all the Northern Apennines: Lavecchia *et al.*, 1984; Boccaletti *et al.*, 1986). In fact, folds and thrusts have been displaced and/or inverted by NNW-SSE trending extensional faults. The latter are generally organized in fault zones with a length of up to 30÷40 km. Single faults dip mainly WSW and are arranged in *en-échelon* array, sometimes linked by transfer faults.

The MCC fault zone extends approximately 15 km from Mt. Castello (west of the Castelluccio basin) to Mt. Cardosa, running between the parallel fault zone of Mt. Vettore-Mt. Bove to the east and that of Nottoria-Preci-Mt. Fema to the west (Fig. 1). The MCC fault zone is made up of three main segments with a right-stepping *en-échelon* pattern and is characterized by WSW downthrow. Estimated throws (Calamita *et al.*, 1992) for these

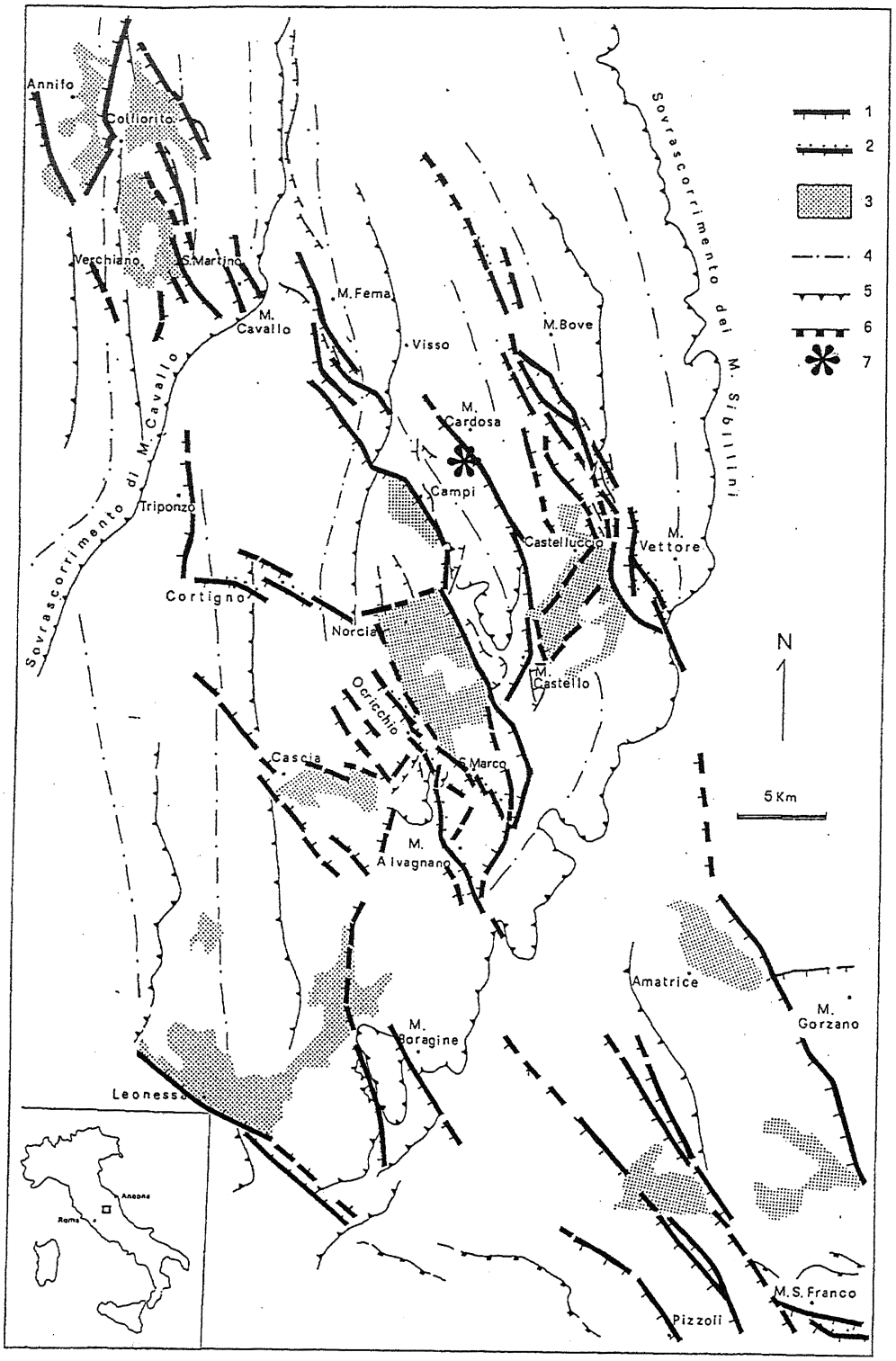

Fig. 1 - Structural sketch of the southern Umbria-Marches Apennine ridge: 1) Quaternary normal fault; 2) active fault; 3) Quaternary continental basin; 4) macroanticline; 5) thrust; 6) thrust in the Latium-Abruzzi Domain; 7) Mt. Cardosa fluvio-glacial deposits (from Pizzi, 1992).

Schema strutturale della dorsale appenninica umbro-marchigiana: 1) faglia normale quaternaria; 2) faglia attiva; 3) bacino colmato da depositi continentali quaternari; 4) macroanticlinale; 5) sovrascorrimento; 6) sovrascorrimento nel Dominio laziale-abruzzese; 7) ubicazione del deposito fluvio-glaciale di M. Cardosa (da Pizzi, 1992).

faults reach several hundreds of meters with a maximum of 600 m along the southernmost segment. The central part of the MCC fault zone offsets the Mt. Patino-Mt. Vetica thrust plane with downthrow of 400 m (Fig.1). The northernmost segment (Mt. Lieto-Mt. Cardosa) is characterized by a maximum estimated throw of 500 m along its central part. The amount of throw decreases progressively, moving northward; in the studied area the fault places the *"Sca-*

Fig. 2 - Northwestward view of the Mt. Cardosa deposits: f) fault plane in the *Scaglia rossa* Formation (the spatially rapid change in azimuth is evident); c) inchoesive cataclastic rocks; d) Quaternary fluvio-glacial deposits.

Veduta da NO del deposito di M. Cardosa: f) piano di faglia nella Scaglia rossa (è evidente la geometria curva del piano di faglia); c) volume di roccia cataclastica incoesiva associato alla faglia; d) deposito fluvio-glaciale.

glia rossa" Formation in contact with the *"Scaglia cinerea"* Formation (Oligocene) with a throw of about 300 m. A 3 to 4-m-wide band of incohesive cataclastic rock and gouge separates the fault plane from the studied Quaternary continental deposit. The latter is placed in a flat narrow area at an elevation of 1300 m, 1.7 km south of Mt. Cardosa (Croce della Lago, Fig. 2). A well-exposed section crossing the deposit was obtained by a 20-m-long anthropic excavation dug parallel to the fault, with a height ranging from 2 m to 5 m. The exposed sequence (Fig. 3) is characterized by calcareous and calcareous-marly, from subangular to well-rounded, heterometric pebbles (resulting from the *Scaglia rossa* and *Scaglia cinerea* Formations). They are accompanied by a mass of matrix and arranged in nearly horizontal beds with interbedded sandy levels, several centimeters thick. These materials have been interpreted as a remnant of a fluvio-glacial deposit presumably Middle Pleistocene in age (Coltorti & Farabollini, pers. comm.), although more accurate dating is under way.

3. STRUCTURAL ANALYSIS

A structural analysis has been carried out both a-long the bedrock fault planes and on the pebble surfaces in order to compare data.

The MCC fault zone is characterized by a quite var-iable and spatially rapid changes in azimuth. The variation is evident in Figure 2, where azimuths range from N135° (to the south) to N-S (to the north). Slip data indicate two different extension directions: one trending N50°-60°E and the other N-S to N20°E. These data agree with those obtained along the entire MCC fault zone (Fig. 4). Furthermore, the striae related to the N 50°-60°E extension are very well marked, whereas those indicating the N-S extension are slighter but superimposed onto the former.

Mechanical and slikholite striae on the pebble surfaces found in the deposit have been measured (Fig. 5) as linear elements. Some were measured *in situ*, others on samples in the laboratory. Mesostructural analysis on pebbles was carried out using methods described in the literature (Bernini, 1986; Calamita *et al.*, 1987; Calamita & Invernizzi, 1991; Schrader, 1989). Data are plotted on the Schmidt net, lower hemisphere (Fig. 6). Most of the striae show steep dips and have a normal sense of shear: the maximum shortening axis is subvertical and the maximum extension direction ranges between N10°W and N10°E. Striae with a reverse sense of movement are also found, but rarely transcurrent ones: these are compatible with a horizontal shortening axis still oriented

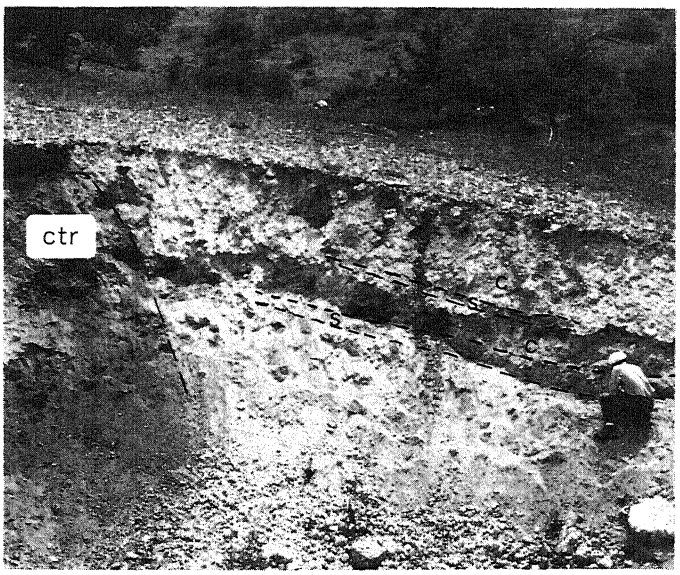

Fig. 3 - Heterometric pebbles (c), and sandy levels (s) forming the main sedimentary facies of the Mt. Cardosa deposits; (ctr): inchoesive cataclastic rocks.

Particolare del deposito fluvio-glaciale del M. Cardosa costituito, prevalentemente, da ciottoli eterometrici (c), a cui si intercalano sottili livelli sabbiosi (s). Sulla sinistra: ammasso di roccia cataclastica incoesiva (ctr).

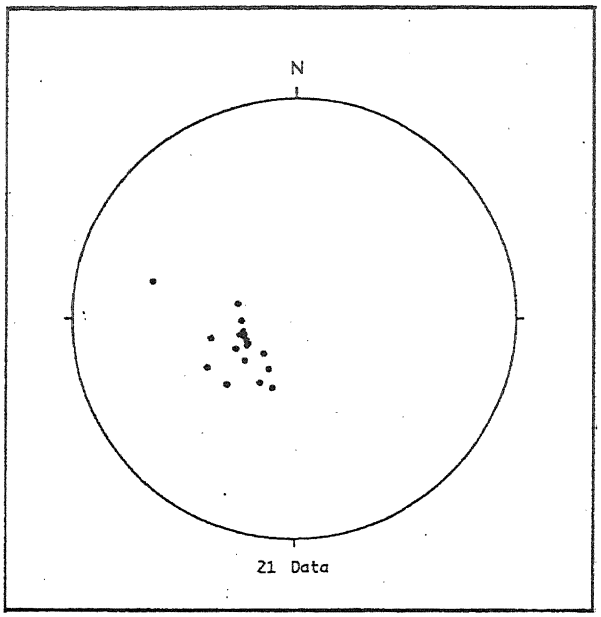

Fig. 4 - Equal-area stereoplot (lower-hemisphere projection) of the kinematic indicators measured along the master fault plane (bedrock) throughout the MCC fault zone.

Proiezione stereografica equiangolare (emisfero inferiore) degli indicatori cinematici misurati lungo la zona di faglia di M. Castello-M. Cardosa.

N10°W-N10°E. Furthermore, few fractures cutting single pebbles occur due to the abundance of fine-grained matrix which reduces stress influence between pebbles. Measured fractures are subvertical and oriented E-W, perpendicular to the maximum extension direction and presumably related to the cyclic load application during seismic events (Moretti, 1990).

4. CONCLUSIONS

A mesostructural analysis on a conglomeratic deposit adjacent to a Quaternary normal fault plane belonging to the Mt. Castello-Mt. Cardosa fault zone is presented. Results give rise to some considerations:

i - the Mt. Cardosa fault is a young structure, still active after conglomerate sedimentation.

ii -studied conglomerates present a N-S to N20°E extension direction: this supports the hypothesis that the N-S extension direction is younger than the N60°E one (as suggested by the relationships of kinematic indicators on the fault plane); the N60°E one was no longer active after deposit sedimentation.

We propose that the existence of compressive striae oriented N-S in the conglomerates could have originated in an extensional regime. Increased fluid pressure in the system, related to the cyclic load application during seismic events, could be a mechanism behind the development of these structures, reducing conglomerate shear strength. The required 90° change of stress field orientation in order to obtain compressive striae (with the same orientation as the extensional ones) may be favoured by the lateral confining pressure of the system.

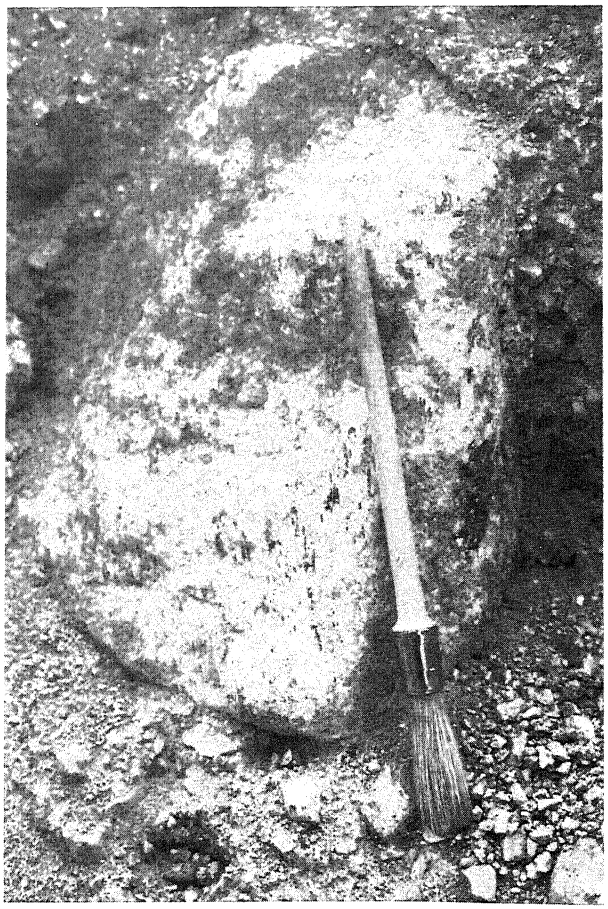

Fig. 5 - Detail of a striated pebble. Striae are often evidenced by smearing of oxides .

Particolare di un ciottolo striato. Le strie sono spesso evidenziate da spalmature di ossidi lungo la superficie del ciottolo.

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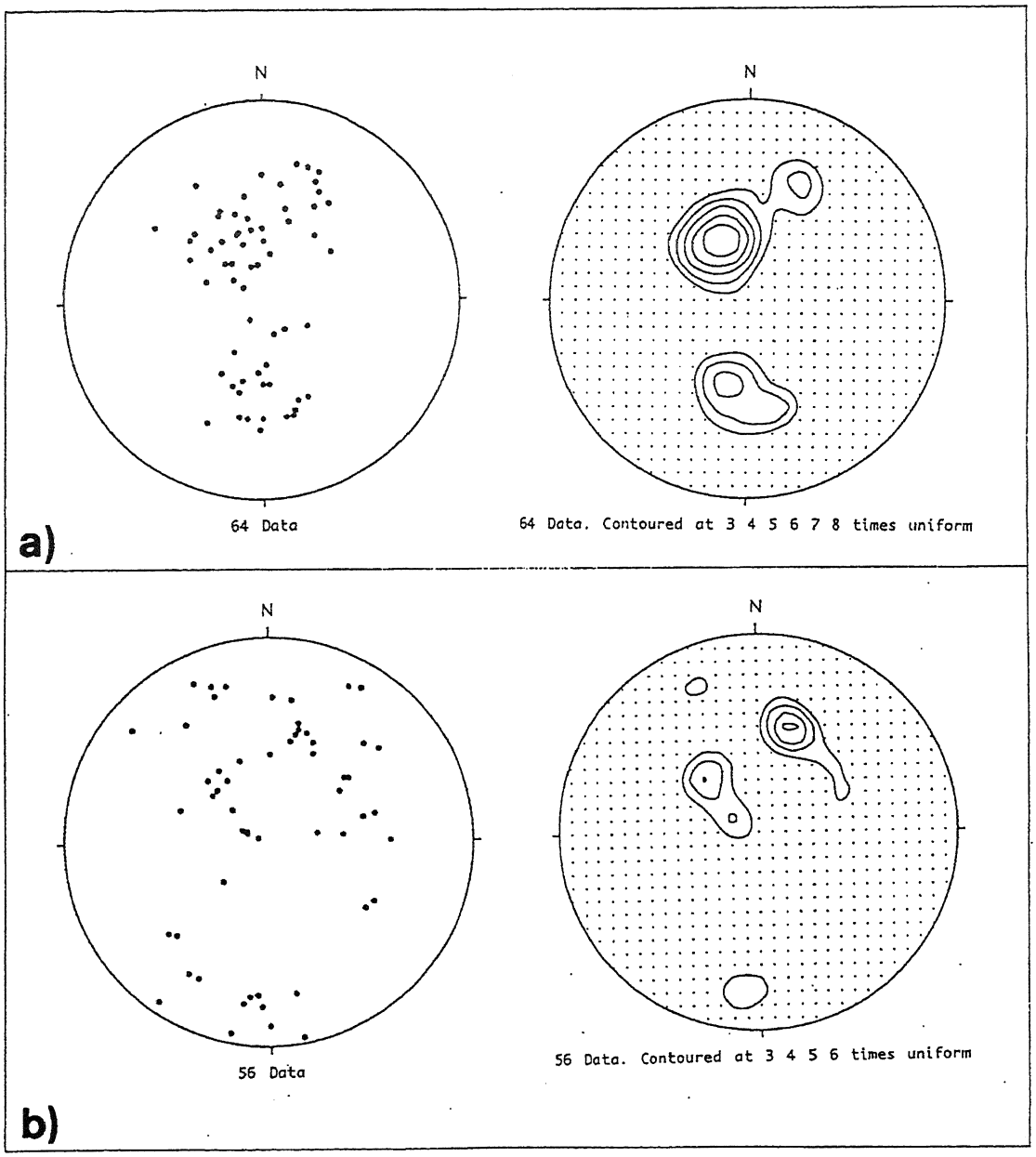

Fig. 6 - Equal-area stereoplots (lower-hemisphere projection) and contour diagrams of the kinematic indicators measured on the pebble surfaces: (a) striae with normal kinematics; (b) reverse striae.

Proiezioni stereografiche equiangolari (emisfero inferiore) e diagrammi di densità delle strie misurate sulla superficie dei ciottoli: (a) strie con cinamatica normale; (b) strie inverse.

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