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PALEOEARTHQUAKES ALONG THE IRPINIA FAULT AT PANTANO DI SAN GREGORIO MAGNO (SOUTHERN ITALY)

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ABSTRACT - *Paleoearthquakes along the Irpinia fault at Pantano di San Gregorio Magno (Southern Italy)* - Il Quaternario, **4**(1a), 1991, p. 121-136 - We excavated trenches across the causative fault of the 23 November 1980, Campania-Lucania earthquake, named Irpinia Fault. The first experiment was performed in 1989 at Piano di Pecore, along the middle section of the fault (Pantosti *et al.*, 1989a, 1989b, 1991). Two new trenches were excavated in 1990 at Pantano di San Gregorio Magno, a closed elongated depression located near the southern end of the fault and filled with Quaternary and Holocene sediments. A careful study of the stratigraphic sequence exposed in the trenches (that is extensively described in the paper) allowed us to recognize the geologic records of four paleoearthquakes that occurred prior to 1980. The four events share a similar dislocation magnitude and geometry with the most recent earthquake. Radiometric dating of organic samples collected at different levels of the stratigraphic sequence yielded a time interval of occurrence for individual paleoevents and allowed us to calculate a fault slip rate and repeat time for 1980-type earthquakes of 0.3 mm/yr and 1,950 yr, respectively. The positive agreement between these results and those obtained at the Piano di Pecore site indicates that the 23 November 1980 earthquake is strictly characteristic for the Irpinia Fault (in the sense of Schwartz & Coppersmith, 1984). The new observations provide an unprecedented tool for understanding the main characteristics of seismicity in the southern Apennines, but also highlight a basic discrepancy with the historical evidence: based on the Italian catalogue of historical seismicity, earthquakes of magnitude ≅ 7 occur every 300÷500 years, whereas the repeat time suggested by paleoseismology is four to six time larger. The paper suggests a number of possible explanations and delineates research avenues that could be followed to address this paradox.

RIASSUNTO - *Paleoterremoti avvenuti lungo la Faglia dell'Irpinia a Pantano di San Gregorio Magno (Italia meridionale)* - Il Quaternario, **4**(1a), 1991, p. 121-136 - Sono stati condotti studi paleosismologici in corrispondenza dell'emergenza superficiale della faglia responsabile del terremoto campano-lucano del 23 novembre 1980, denominata *Faglia dell'Irpinia*. Il primo esperimento è stato effettuato nel 1989 a Piano di Pecore, nella parte mediana della faglia (Pantosti *et al.*, 1989a, 1989b, 1991). Altre trincee sono state aperte nel 1990 a Pantano di San Gregorio Magno, un bacino a sedimentazione recente e attuale situato all'estremità meridionale della faglia. Lo studio della sequenza deposizionale osservata in questo sito, che viene descritta nel dettaglio, ha permesso di riconoscere le registrazioni geologiche di almeno quattro eventi sismici precedenti al terremoto del 1980 ma ad esso simili per dimensioni e stile deformativo. La datazione di campioni di materiale organico raccolti a vari livelli della successione stratigrafica esposta ha permesso di determinare gli intervalli temporali entro cui si sono verificati i paleoeventi riconosciuti. E' stato quindi possibile calcolare lo *slip rate* locale e il tempo di ricorrenza medio per eventi *tipo 1980*, rispettivamente è pari a 0.3 mm/anno e 1950 anni. La concordanza dei risultati ottenuti nei siti di Piano di Pecore e di Pantano di San Gregorio Magno consente di considerare il terremoto del 23 novembre 1980 come strettamente *caratteristico* per la *Faglia dell'Irpinia* (nel senso di Schwartz & Coppersmith, 1984). I risultati ottenuti forniscono un nuovo e fondamentale contributo alla comprensione della sismicità di questo settore dell'Appennino, ma al tempo stesso mettono in luce importanti contraddizioni con le parallele indicazioni fornite dalla sismicità storica. Il più vistoso esempio di tali contraddizioni è costituito dalla discrepanza tra il tempo medio di ricorrenza ottenuto su basi paleosismologiche, pari circa a due millenni, e quello di 300÷500 anni suggerito dai cataloghi sismici esistenti. Il lavoro propone possibili spiegazioni del fenomeno e indica alcune delle linee di ricerca che potrebbero essere seguite per venire a capo di questo paradosso.

Key-words: Holocene deposits, active tectonics, 1980 Campania-Lucania earthquake (Italy)
Parole chiave: Depositi olocenici, tettonica attiva, terremoto campano-lucano del 1980

1. INTRODUCTION

A close interaction between seismological and geological studies during the last two decades allowed to achieve significant progresses in the understanding of the seismogenic processes. This interaction gave birth to Paleoseismology, a discipline developed to investigate the past behavior of seismogenic structures using traditional tools of field geology. Paleoseismology is based on the recognition of surface faulting as the direct expression of coseismic deformation at seismogenic depth, and on the correlation between repeated seismic activity and the evolution of geological structures.

It is normally observed that coseismic slip associated with large earthquakes ($M_S > 6.5$) may affect the surface by producing distinctive dislocation features named *fault scarps*. Most authors agree that the geometry of the scarp follows that of the seismogenic fault at depth, while the surface throw is related to the seismic moment released by the source. In practice, empirical laws can be used to infer seismic release parameters from surface observations and viceversa (Bonilla *et al.*, 1984).

The earthquake deformation involves buried deposits in form of simple dislocation, while the depositing sediments record the event as a sharp alteration of the erosion-deposition process. Under favorable conditions, these geological records can be preserved by overlying younger sediments. Every large earthquake occurring along a specific seismogenic structure will produce

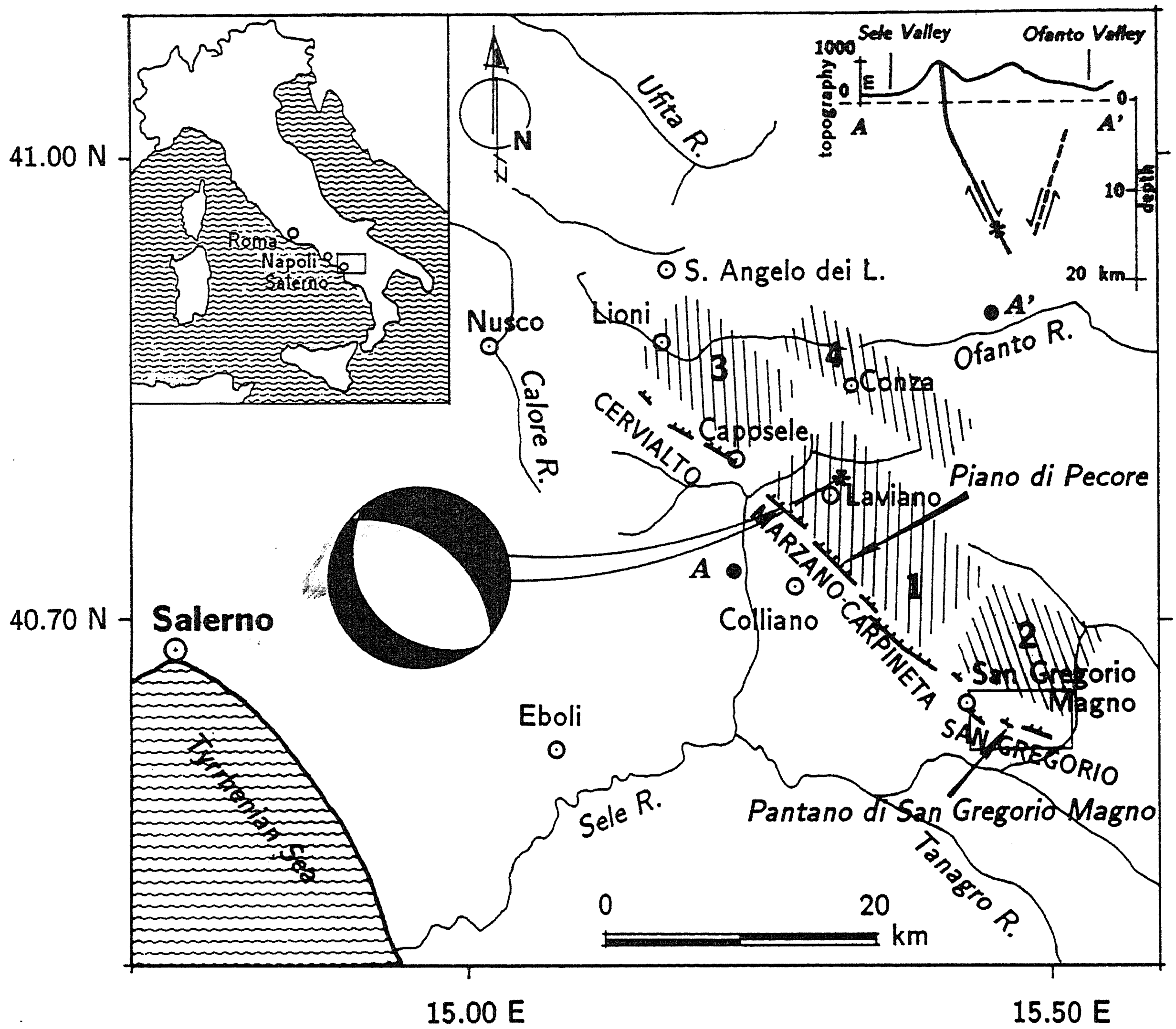


Fig. 1 - Location of the sites selected for paleoseismological investigations along the November 23, 1980 fault scarp. The heavy line represents the trace of the scarp. The ticks along the line indicate the downthrown block. The location of 1980 mainshock is taken from Westaway & Jackson (1987) and is marked by an asterisk. The focal mechanism taken from Giardini *et al.* (1984) indicates a pure normal faulting rupture geometry. The dashed areas represent the projection on the ground surface of the four fault fragments that ruptured during the earthquake (numbered 1 to 4 following the rupture sequence: Westaway & Jackson, 1987; Bernard & Zollo, 1989). The intersection with the topographic surface of the fragments 1, 2 and 3 corresponds to the observed fault scarp, while the antithetic fault fragment 4 did not produce surface faulting. The simplified section in the upper right corner of the figure shows the 1980 graben-type rupture geometry and the topography of the area. The two sites selected for trenching, Piano di Pecore and Pantano di San Gregorio Magno, are marked by arrows. The small rectangle centered on the San Gregorio section of the scarp outlines the area shown in Fig. 2.

Ubicazione dei siti per ricerche paleosismologiche lungo la scarpata di faglia del terremoto del 23 novembre 1980. La traccia della scarpata è riportata a tratto spesso con i dentini che indicano il settore ribassato. L'asterisco indica la localizzazione epicentrale della scossa principale dell'evento del 1980 (da Westaway & Jackson, 1987). Il meccanismo focale calcolato indica una rottura per faglia normale pura (da Giardini et al., 1984). Le aree a tratteggio rappresentano la proiezione in superficie dei quattro frammenti di faglia attivati nel terremoto del 1980, numerati secondo l'ordine temporale di rottura (Westaway & Jackson, 1987; Bernard & Zollo, 1989). L'intersezione con la superficie topografica dei primi tre frammenti (1, 2 e 3) è rappresentata dalla scarpata di faglia mentre per il quarto frammento (4), che ha giacitura antitetica rispetto ai precedenti, non sono state osservate rotture di superficie. La sezione nell'angolo in alto a destra della figura schematizza la geometria a Graben della stuttura sismogenetica responsabile del terremoto del 1980 e la topografia dell'area. I siti prescelti per l'apertura delle trincee, Piano di Pecore e Pantano di San Gregorio Magno, sono indicati da una freccia. Il riquadro centrato sul frammento di faglia di San Gregorio Magno racchiude l'area rappresentata in Fig. 2.

nearly identical surface effects; cumulation of coseismic deformation over time will give rise to peculiar fault-controlled landforms. Careful investigation of such records allows to reconstruct the recent history of a seismogenic fault and emphasize the repetitive nature of the seismic release cycle. Eventually the investigated paleoearthquakes will be recognized as the largest possible events occurred along the given fault and hence regarded as *characteristic* (in the sense of Schwartz & Coppersmith, 1984). Dating of the identified paleoearthquakes will allow the evaluation of the average slip-rate of the fault and of the average repeat time for the largest observed magnitude.

In the Mediterranean area the study of past earthquakes for seismic hazard assessment is traditionally based on the remarkable patrimony of historical accounts. On the other hand, the recognition of the actual location of the main active faults is still at a very early stage. In Italy, for example, this results from the combination of the inherent weakness of the historical accounts with the structural complexity of the Apennines (Boschi *et al.*, 1990). Even though in the past few years several authors have described surface faulting and dislocation of Holocene deposits (Basili & Valensise, 1986; Serva, 1986; Giraudi, 1988; Frezzotti & Giraudi, 1989; Galadini & Giraudi, 1989; Calderoni *et al.*, 1991), only seldom the tectonic origin of these features could be positively ascertained by association with a known and throughgoing active fault or with a large historical earthquake. On the other hand, the traditional geomorphic indicators of Holocene tectonic activity, such as range-bounding fault scarps, deflected streams and linear features in young deposits, are generally not clearly expressed geomorphically or difficult to decipher.

The most common paleoseismological approach is that of excavating trenches across historical fault scarps where they cross recent and poorly consolidated sediments. By analyzing the deformation history recorded by the stratigraphic sequence exposed in the trenches, one can recognize the effects of the most recent earthquakes that occurred along the investigated fault.

The 23 November 1980, Campania-Lucania normal faulting earthquake ($M_S = 6.9$) lent a unique opportunity to begin paleosesimological investigations across a historical fault scarp, mainly because this was the first large Italian earthquake for which sizable and unequivocal surface faulting has been documented (Westaway & Jackson, 1984; Funiciello *et al.*, 1988; Pantosti & Valensise, 1990).

2. THE 1980 CAMPANIA - LUCANIA EARTHQUAKE

The November 23, 1980 normal faulting earthquake struck a wide area of the southern Apennines 50 to 90 km east of Naples. Based on good quality seismological, geological and geodetic observations the earthquake source was recognized as being extremely complex. At least three subevents occurred within 40 seconds of the origin time (Westaway & Jackson, 1987; Bernard & Zollo, 1989). The first two subevents ruptured a 40 km-long, northwest-trending, northeast dipping main fault (1, 2 and 3 in Fig. 1), which following Pantosti *et al.* (1991) is referred to as the Irpinia Fault. The last subevent occurred along a 15 km-long antithetic fault located 10 km to the northeast (4 in Fig. 1), such that the overall geometry of the 1980 seismogenic structure is that of a symmetric Graben.

The earthquake produced a 0.5 to 1.0 m-high fault scarp with the northeastern side down, consistently with the focal mechanism of the mainshock (Giardini *et al.*, 1984; Westaway & Jackson, 1987) and with elevation differences observed along a 200 km-long stretch of the first-order national Italian leveling network (Arca & Marchioni, 1983). Even though parts of this scarp were tentatively interpreted as surface faulting right after the earthquake (Bollettinari & Panizza, 1981; Cinque *et al.*, 1981), it was not until 1984 that a 10 km-long stretch of the fault centered on Mt. Marzano was positively related to the main parameters of the earthquake source (Westaway & Jackson, 1984). The rest of the scarp was later described in detail by Funiciello *et al.* (1988). The main reason for the delayed recognition is that the scarp runs at high elevation on the Mt. Valva - Mt. Marzano - Mt. Carpineta range, and exhibits little or no direct relationships with the preexisting topographic setting (Pantosti & Valensise, 1990) cutting at a low angle older NW and W-trending structural features (Salvi & Nardi, 1991). For most of its length the scarp cuts modern soil and slope debris that overlies the Cretaceous limestone forming the backbone of the mountain range. Polished limestone facets and the associated fault breccia also appear at a limited number of sites along the scarp (Pantosti & Valensise, 1990).

Detailed field observations allowed the identification of three main scarp sections separated by two gaps where no surface faulting was observed. The three sections were named (northwest to southeast) *Cervialto scarp*, *Marzano-Carpineta scarp* and *San Gregorio scarp*. The average strike of the scarp is 308°. The middle section strikes 314°, while the northern and southern sections exhibit a slightly more westerly orientation (Fig. 1). These features were seen to match the complexity of the earthquake and were later used by Pantosti & Valensise (1990) to propose a model of the source mechanism solely based on field observations.

3. PALEOSEISMOLOGY ALONG THE IRPINIA FAULT

Based on the uniqueness and on the quality of the field observations of coseismic ruptures, the 1980 earthquake represented an extremely good opportunity to start paleoseismological investigations of deformation rates and earthquake repeat times in the Apennines. Two trenches (named Trench 1 and Trench 2) were excavated in summer 1989 along the Marzano-Carpineta scarp in the small intermontane basin of Piano di Pecore (Fig. 1; Pantosti *et al.*, 1989a; Boschi *et al.*, 1990). The trenches

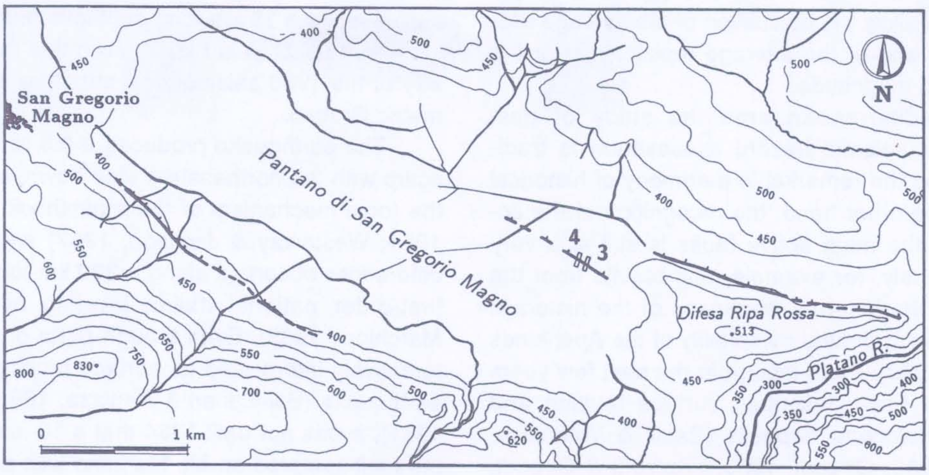


Fig. 2 - Pantano di San Gregorio Magno: location of Trench 3 and 4. The heavy line marks the trace of the 1980 scarp. The ticks along the line indicate the downthrown block.

Pantano di San Gregorio Magno: localizzazione delle trincee 3 e 4. La traccia della scarpata di faglia del 1980 è riportata a tratto spesso; i trattini indicano il settore ribassato.

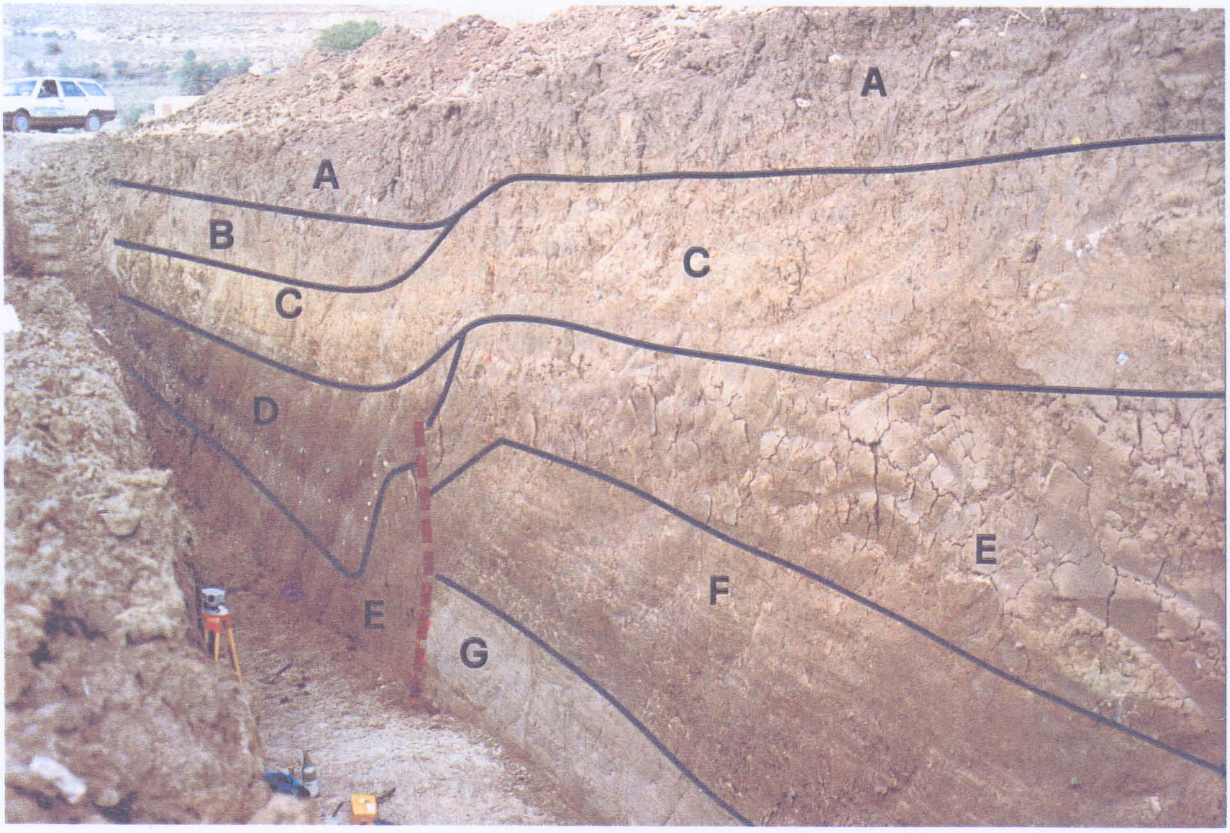


Fig. 3 - The eastern wall of Trench 3 (north is to the left). The units exposed by trenching are faulted and folded consistently with the geometry and location of the 1980 fault scarp. The degree of vertical offset across the fault increases proportionally to the age of the beds, suggesting that the oldest deposits have been deformed several times. For instance, the dislocation of the base of unit *A*, which is entirely related to the occurrence of the 1980 earthquake, adds up to approximately half of the dislocation recorded by unit *C*. Furthermore, the base of unit *E* which, together with the units *F* and *G*, was not reached by the excavation on the downthrown side of the fault, must have undergone an even larger dislocation.

Parete est della trincea 3; il nord è alla sinistra della foto.I sedimenti messi in luce dallo scavo, profondo circa 5 m, sono fagliati e piegati in corrispondenza e con geometria concordante alla scarpata di faglia del 1980. L'entità della deformazione aumenta proporzionalmente all'età dei sedimenti, indicando che i depositi più antichi sono stati interessati da più eventi deformativi.Si può notare, infatti, che la dislocazione della base dell'unità A, causata solo dall'evento del 1980, ammonta a circa la metà di quella registrata da C e che la base dell'unità E, come anche le unità F e G, non essendo state raggiunte dallo scavo nel settore ribassato della trincea sono state evidentemente dislocate di un'entità ancora maggiore.

Table I - Based on the radiometric age of the samples collected in the trenches, for each earthquake we determined a time interval of occurrence. Stratigraphic arguments (discussed in the text) led to consider the age shown in bold face as the most probable. See text for the uncertainty associated with the ^{14}C dates. All the dates but that estimated as the oldest possible age for Event 6 were calibrated.

Sulla base dell'età radiometrica dei campioni prelevati nelle trincee sono stati valutati i limiti cronologici dell'intervallo entro cui ha avuto luogo ciascun paleoterremoto. Considerazioni stratigrafiche (discusse nel testo) permettono di indicare come data più probabile quella riportata in grassetto. Per gli errori associati alle misure ^{14}C si veda il testo. Tutte le date, tranne la più antica tra quelle stimate per l'evento 6, rappresentano età calibrate.

	Piano di Pecore		Pantano di San Gregorio	
Event	Age (yr B.P.)	Vertical throw (cm)	Age (yr B.P.)	Vertical throw (cm)
1	**1980 A.D.**	85	**1980 A.D.**	60
2	1415-**2754**	65	1720-**2570**	80
3	3507-**4283**	55	2570-6620	65
4	4411-**6736**	55	?	
5	> 7900	70	6620-**9420**	50
6	—	—	11180-19660	?

forming the object of this paper (Trench 3 and Trench 4) were excavated one year later at Pantano di San Gregorio Magno, along the San Gregorio scarp (Fig. 1). While Trench 1 and 2 are mostly representative of the largest moment release subevent of the 1980 mainshock, Trench 3 and 4 were essentially excavated to investigate whether the southernmost section of the Irpinia Fault always slips in conjunction with rupturing of the main asperity, as it did in 1980, or instead if it bears an independent earthquake potential.

Before describing in detail the new results, we summarize results from the previous trenching work that are relevant to the understanding of the long-term behavior of the Irpinia Fault.

3.1 Trenches at Piano di Pecore

Piano di Pecore is one of the sites where the 1980 surface effects were most obvious and spectacular. In this area the 1980 scarp changes progressively from an abrupt step in the mountain slope to a gentle warp in the central part of the Piano, that was divided into two nearly flat but distinctly separated portions. Two conditions led to hypothesize that the site was especially favorable for investigating the effects of large earthquakes that occurred prior to 1980: (1) the convenient setting and location of the basin and therefore the suitability of the basin filling for preserving records of dislocation events of the past; (2) the peculiar setting of the scarp in relation to the basin, suggesting that the basin itself undergoes a cycle of damming-flooding-filling that is strictly associated with the occurrence of coseismic dislocation.

The stratigraphy and deformation revealed by the trenches at Piano di Pecore fulfilled the most optimistic expectations. After the sequence was analyzed in great detail, ^{14}C dating was carried out on several charcoal and humic soil samples in order to establish a reliable frame of reference for all the deposition and deformation events. The 3÷4 m-high walls of the trenches showed a sequence of lacustrine beds and colluvial deposits ranging in age between 7,900 yr cal B.P. and present (for a detailed description see Pantosti *et al.*, 1991). In both trenches the sequence is faulted and warped directly underneath and consistently with the 1980 scarp. Restoration of the original geometry of several displaced horizons at different stratigraphic levels allowed to single out the deformation effects of four dislocation events that occurred prior to the 1980 earthquake. Each of these events was interpreted as a paleoearthquake comparable in size with the 1980 earthquake (Table I). The combination of the paleoearthquake chronology with the inferred scarp heights yielded an average fault slip-rate and repeat time of 0.4 mm/yr and 1950 yr, respectively (Pantosti *et al.*, 1991).

3.2 Trenches at Pantano di San Gregorio Magno

The Pantano di San Gregorio Magno is a wide, E-W-trending closed depression filled with recent colluvial and lacustrine deposits (Fig. 2). Around the turn of the last century the area was reclaimed, and a net of artificial channels was built to promote modern agriculture. The excess water was diverted toward the Platano River using a buried tunnel that is now used to regulate the channel system. The Pantano has a large ($\cong$ 60 km^2) drainage basin, but since its surroundings are mostly made up of highly fractured and karstified Cretaceous limestones surficial drainage is strictly limited to the rainy season.

The 1980 earthquake did not form a single, continuous scarp in the Pantano area, but instead a number of different fragments, suggesting a strong control by the preexisting geologic texture (Pantosti & Valensise, 1990). The northernmost fragment runs along the southern boundary of the Pantano east of the village of San Gregorio Magno and can be followed for about 2 km before dying out. The scarp then appears in the middle of the basin and can be followed for about 500 m until it abuts the calcareous ridge (Difesa Ripa Rossa) bordering the eastern side of the Pantano. The scarp continues along the northern slope of the ridge for about 2 km until it dies out near the Platano River (Fig. 2). According to Pantosti & Valensise (1990), this site also represents the southernmost tip of the 1980 rupture and hence the boundary between the Irpinia and Val d'Agri (1857) segments identified by Pantosti & Valensise (1988). The scarp height varies between 50 and 80 cm, although due to the obvious structural control these observations is probably the least reliable among all those collected along the 1980 fault scarp.

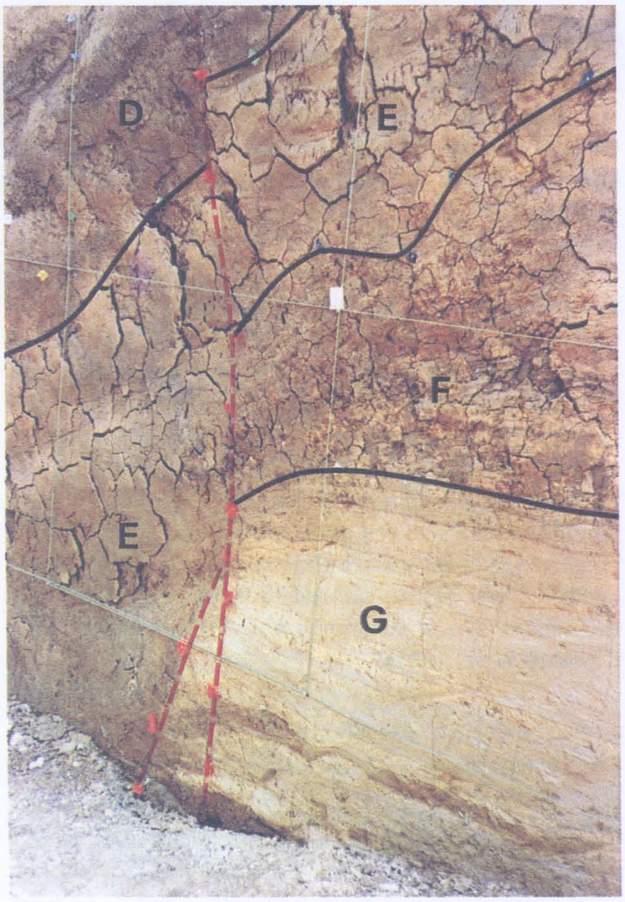


Fig. 4 - Detail of the fault zone in Trench 3. This photograph shows both the deformation styles, brittle and plastic, that characterize the fault zone. The beds are sharply faulted at the base of the trench and tightly folded in its upper part. The picture also shows details of the lacustrine units *E*, *F*, and *G* and those of the colluvial unit *D*. Colored flags mark the different faults and the boundaries between units. The reference square net is 1 m wide.

Particolare della zona di faglia della trincea 3. Sono riconoscibili nella foto i due stili deformativi, fragile e duttile, che la caratterizzano. Infatti nella parte inferiore della trincea i depositi sono evidentemente dislocati da una faglia, mentre verso l'alto essi sono essenzialmente piegati. Si riconoscono anche dettagli dei sedimenti lacustri (E, F e G) e colluviali (D). Le discontinuità tettoniche ed i limiti tra le unità sono messi in evidenza da bandierine di diverso colore. Il reticolo di riferimento ha lati di un metro.

The site selected for trenching is located along the scarp fragment running in the middle of the Pantano. The selection of this site followed the same basic criteria and working hypotheses outlined for the Piano di Pecore trenches (see § 3.1). In spite of ten years of intense agricultural activities, the scarp still appears as a clear warp in the ground surface. However, the net local throw (65 cm) can be precisely measured only by leveling a transect perpendicular to the scarp.

The two trenches (Trenches 3-4 in text and figures) were excavated at a distance of ≅ 35 m from each other with an average strike of 20° (perpendicular to the local trend of the scarp) (Figs. 2, 3 and 4). Each trench was about 30 m long, 3.5 m wide and 5÷6 m deep. First the main wall of each trench was cleaned up to emphasize the main sedimentary and deformational features of the sequence, and covered with a regular grid of cotton rope to help drawing. Then the section was interpreted and a 1:20 log was hand-drawn as a basis for further analyses (such as the restoration of tectonic dislocation). Finally, organic samples (charcoal, concentrations of organic substances) from different horizons at various stratigraphic intervals were collected for ^{14}C dating. All the analyses were performed by the Beta Analytic Laboratories (Miami, Florida).

3.2.1 Sedimentary sequence at Pantano di San Gregorio Magno

The trenches excavated at Pantano di San Gregorio Magno exhibit a sequence of lacustrine and colluvial deposits partly resulting from remobilization of volcanites (Figs. 3, 4 and 5). These are most likely associated with explosive activity of the Vesuvium and Phlegrean Fields volcanoes, located 100 km or less to the northwest. Extensive subaerial reworking before the final sedimentation is suggested by peculiar depositional structures, by the association with other materials, and by the physical and chemical weathering of the grains. Volcanic materials, in particular pumices, are well preserved only in the lower units. Based on its lithological and sedimentological characteristics, we then divided the stratigraphic sequence into seven distinct units. Each unit is identified by a letter *(A-G)* and, when necessary, subdivided into secondary layers, indicated by the same letter followed by a number (Fig. 5). The sequence described can be regarded as representative of both trenches (Fig. 6).

Soil A. The top of the sequence is formed by a dark, fine-grained soil containing weathered volcanic materials and rare limestone pebbles near its bottom. The upper part of the soil (about 40 cm) exhibits a lighter color probably due to a lower degree of humidity and to agricultural works that may have modified its original texture. The thickness ranges between 65 and 95 cm. A charcoal sample (TR4A) that was collected in the lower part of this unit in Trench 4 was dated at 1,720±90 yr cal B.P.

Colluvium B. This unit was found on the downthrown side of the fault in both trenches. It is a brown massive deposit formed by fine slopewash sediments. It also contains a large quantity of lapilli, weathered pumices and pottery fragments. Thickness is in the range 0÷85 cm. Charcoal fragments (sample TR3B) collected at the base of this unit in Trench 3 were dated at 2,570±70 yr cal B.P., that hence represents a maximum age of deposition for this unit.

Lacustrine C. This unit can be divided in two different layers.

C_1. The upper lacustrine deposit is mainly made up of a yellowish laminated fine sand rich in weathered volcanic materials. It also contains pottery fragments. A 5÷10 cm-

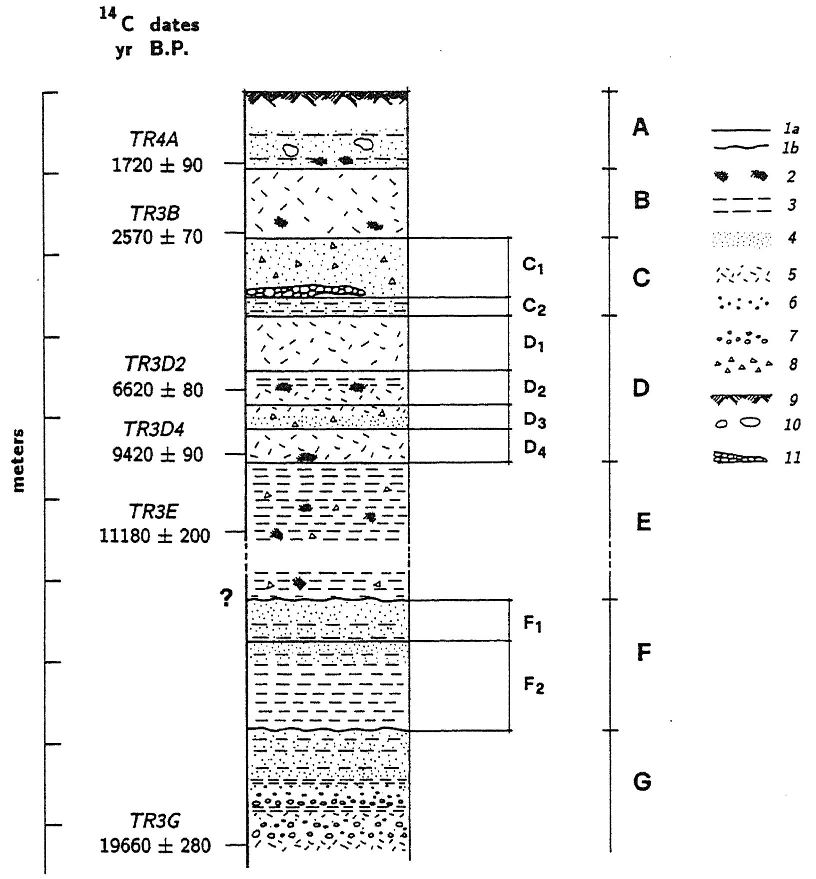


Fig. 5 - Stratigraphy of the trenches excavated at Pantano di San Gregorio Magno. We observed a 9 m-thick sedimentary sequence deposited during the past 20,000 years. Symbols: 1a) conformable contact; 1b) angular or erosive disconformity; 2) organic substance; 3) clay; 4) silt; 5) colluvium; 6) sand; 7) pumices; 8) volcanic materials; 9) ground surface; 10) limestone pebbles; 11) conglomeratic layer.

Colonna stratigrafica delle trincee di Pantano di San Gregorio Magno. Correlando i depositi presenti su entrambi i lati della zona di faglia è stata ricostruita una sequenza sedimentaria spessa almeno 9 m deposta durante gli ultimi 20.000 anni. Simbologia usata: 1a) contatto stratigrafico; 1b) contatto con discordanza angolare o erosivo; 2) materiale organico; 3) argilla; 4) silt; 5) colluvio; 6) sabbia; 7) pomici; 8) materiale vulcanico; 9) superficie topografica; 10) ciottoli carbonatici; 11) livello conglomeratico.

thick discontinuous level of limestone pebbles is found about 2÷3 cm above the base of this bed; the pebbles are poorly sorted and strongly oxidized. Total thickness is about 70 cm.

C_2. The lower bed is made up of massive coarse sand in a clayey matrix also containing small limestone pebbles. Thickness is about 20 cm. No samples suitable for dating could be found within this unit.

Colluvium D. This unit was only found on the downthrown side of the fault because it pinches out against the scarp. We divided this unit in four main beds based on their texture, on the humic content, on the abundance of volcanic fragments, and on their state of deformation, although the transition from one bed to the following is generally gradual.

D_1. Massive ochreous clayey silt with volcanic materials and pottery fragments. In the vicinity of the fault zone this bed is warped and stretched and partly overlies unit *E*. Its thickness ranges between 0 and 70 cm.

D_2. Dark clay with weathered pumices and organics. Within this bed we found a large pottery fragment. Dating of these fragments, as well as of those found in the overlying units, is in progress. Thickness is in the range 0÷40 cm. A bulk sample (TR3D2) from this bed in Trench 3 was dated at 6,620±80 yr cal B.P.

D_3. Whitish sandy silt, mainly made up of oxidized pumices and small pebbles of different origin. Thickness does not exceed 30 cm.

D_4. Massive brownish silty clay containing coarse weathered pumices and blanketed by a thin oxidized layer. The maximum thickness of this layer (40 cm) is found close to the fault zone. A sample of this bed (TR3D4) was dated at 9,420±90 yr cal B.P.. This age is most probably representative of the age of organics synthesized somewhere in the drainage basin prior to the deposition of this bed.

Lacustrine E. This brownish unit is mostly made up of compact plastic feebly laminated clay. Dark spots locate concentrations of organics. A layer of pebbles in a sandy matrix can be found at the base of the clayey layers. Thin branching roots, probably in a living position, are frequent throughout the whole unit. All the beds are dis-

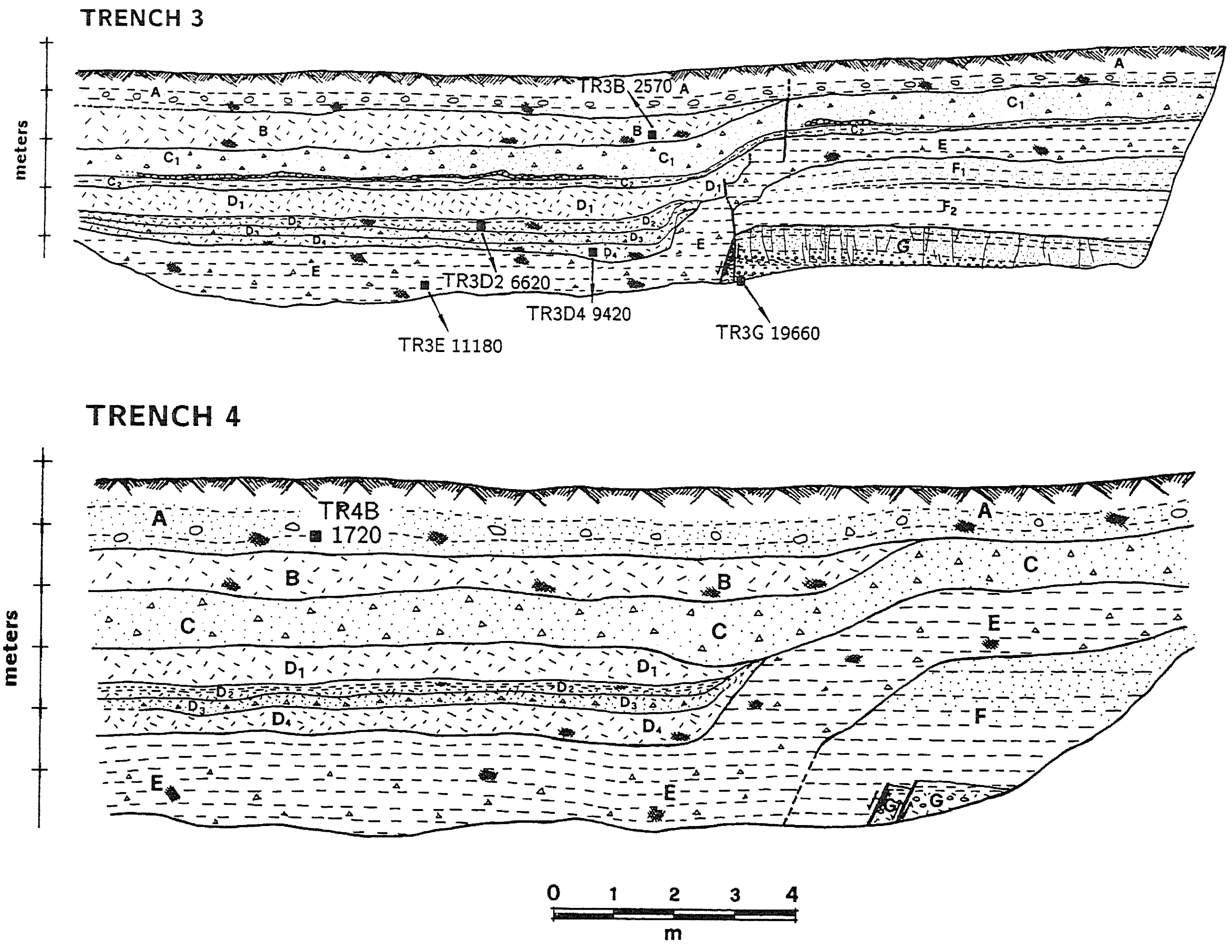


Fig. 6 - Sections of the eastern walls of Trench 3 and 4. The symbols are the same used in Fig. 6. Heavy lines outline major faults and fractures. Black squares mark the location of the samples collected for ^{14}C dating; the dates are in yr cal B.P.

Sezioni delle pareti est delle trincee 3 e 4. Per la simbologia delle litologie si faccia riferimento alla Fig. 6. Le linee a tratto spesso rappresentano le principali faglie e fratture. I quadratini pieni indicano la localizzazione dei campioni su cui sono state effettuate le datazioni con il metodo del ^{14}C; le date sono riportate a fianco in anni cal B.P.

located and stretched as they cross the fault zone. The maximum thickness of the unit in the upthrown block is 85, while on the downthrown side a minimum figure of 120 cm can be estimated; the uncertainty arises from the fact that on this side of the fault the base of the unit was not exposed by trenching. A bulk sample (TR3E) collected in Trench 3 was dated at 11,180±200 yr cal B.P.

Lacustrine F. This unit can only be seen on the upthrown side of the fault. We divided it into two beds that can be clearly distinguished only away from the fault zone.

F_1. The upper bed is made up of a sequence of 2÷3 cm-thick oxidized layers and 5÷6 cm-thick ochreous clay beds that become progressively more silty toward the top. Total thickness is of about 50 cm.

F_2. The lower bed is an ochreous laminated sequence with a large clay component. Some cylindric oxide-rich concretions in a vertical position can be seen within the bed. Maximum thickness is 115 cm. The lower part of the unit is dissected by a net of randomly oriented small fractures; their origin is most likely non-tectonic but rather related to the trenching operations and to the consequent rapid loss of humidity of the deposits. Since the F_2 beds are characterized by an onlap (progradational) geometry, the transition to the underlying unit *G* is unconformable. No sample for radiometric dating could be found in this unit.

Lacustrine G. The lowest deposit only appears on the upthrown side of the fault. Its composition reflects widely changing sedimentation conditions. From top to bottom we distinguished:

- 25 cm of silty clay layers alternated with thin layers of dark clay;
- 35 cm of whitish, irregularly laminated diatomitic silt and sand with a few thin layers of brownish clay;
- 5 cm of whitish clay with a silt level at its base;
- 25 cm of irregularly laminated diatomitic silty sand;
- 8 cm of whitish clay;
- 0 to 10 cm of brownish colluvium;
- 20 cm of grayish coarse sand;
- 20 cm of brownish colluvium.

The lower beds are rich in well preserved alkaline-potassic pumices. Many vertical fractures filled with dark silt and clay intersect the whole unit but do not propagate in the overlying beds. Since the base of this unit was not exposed by trenching, we can only evaluate a minimum thickness of about 150 cm (measured on the western wall of Trench 4). An organic-enriched sample (TR3G) from the bottom of the unit in Trench 3 was dated at 19,660±280 B.P.. This date could not be calibrated because it falls beyond the range of known natural variations of the ^{14}C content of the atmosphere, and is therefore poorly constrained in comparison with the remaining ones. However, the sample is by far the oldest of all those analyzed and it will be used only as a first approximation of the age of the exposed sequence.

3.2.2 Tectonic deformation of the sequence

For a few months after the 1980 earthquake the fault scarp at Pantano di San Gregorio Magno appeared as a sharp rupture of the soil, much in the same fashion as at most other locations along the fault (Bollettinari & Panizza, 1981; Carmignani *et al.*, 1981). Ten years of intense farming have flattened the scarp berm so that tectonic dislocation is now distributed over a 10 m-long band. However, the original width of the deformation zone can still be fully appreciated in the trenches, where most of the dislocation is accommodated within a 2 m-wide band centered around the site were the 1980 scarp was observed prior to its degradation (Fig. 3).

The dislocation zone in the trenches exhibits two distinct deformation styles. The lower half of the sequence (units *G*, *F* and part of *E*) is displaced by a well defined, 305°-striking, 70-80°NE-dipping fault plane causing relative subsidence of the northeastern block, whereas in the upper half (top of unit *E* through unit *A*) the beds form a tight flexure mimicking the setting of the underlying faulted units (Figs. 3, 4 and 6). The geometry of the main fault plane is more complicated within the unit *G*. In Trench 3 a secondary subvertical fault intersects the main rupture at the top of the unit causing its further displacement, while in Trench 4 a secondary fault parallels the main rupture causing an additional 15 cm dislocation of the top of the unit and the back-rotation of the block in between the two shear planes (Fig. 6). Besides being gently tilted toward the upthrown side of the fault (Fig. 6), the top of unit *G* is also tilted lengthwise, somewhere between the two trenches. This complication was clearly recognized in Trench 4, where on the eastern wall the top of G is 90 cm lower than on the western wall and on both walls of Trench 3. The overlying unit *F* lies unconformably on *G* and levels all the irregularities of its top surface. The upper part of *F* is warped and stretched near the fault zone and is partly eroded as it represents a buried scarp free-face. The unit *E* is partially displaced by the fault but its deformation style is essentially plastic, as suggested by extreme stretching of the beds near the fault. The unit *D*, that crops out only on the downthrown side of the fault, is warped against the fault zone where it also exhibits a larger thickness. Thickening is related to the combination of piling produced by warping with back-rotation of the underlying deposits prior to the deposition of the unit.

With the exclusion of the unit *G*, where numerous vertical fractures dissect all the beds, all the deposits are virtually undeformed away from the fault zone. Only a single extensional fracture affects the younger deposits on the footwall of the fault in Trench 3, about a meter away from the scarp (Fig. 6).

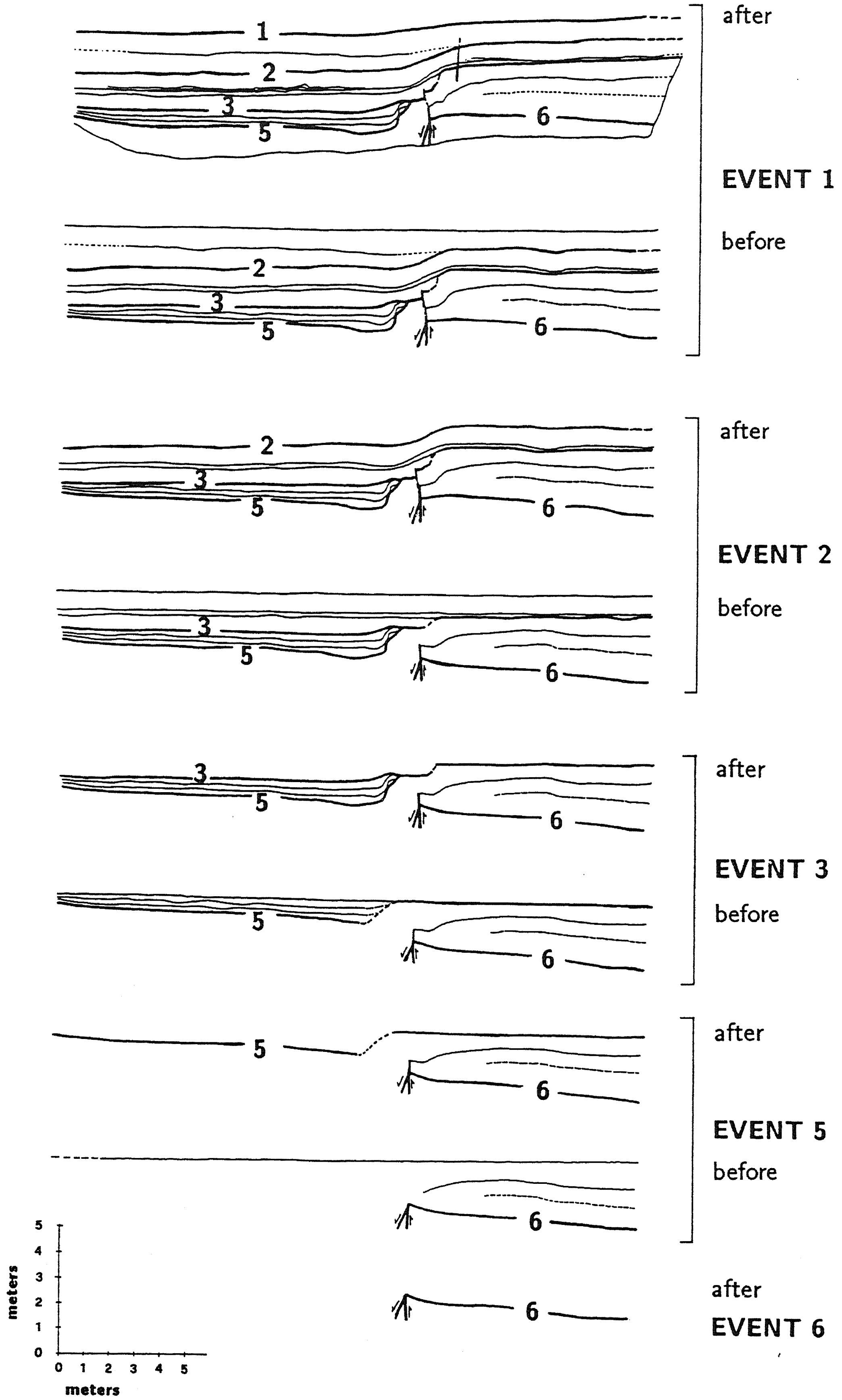
3.2.3 Reconstruction of the deformation history

The existence of several units that could be followed across the fault zone allowed a precise evaluation of the cumulated fault displacement as a function of time (Fig. 6). In particular, the total offset observed for the units *A*, *C* and *E* showed that tectonic displacement increases with depth. However, the increase does not occur in a continuous fashion but rather by discrete amounts comparable with the height of the 1980 scarp. For example, both the top and the base of unit *C* are offset by about twice the offset characterizing the ground surface (top of unit *A*).

Based on these observations and on the analogy with similar evidence from the Piano di Pecore trenches (see § 3.1), the observed total offset was interpreted as the effect of the repetition of distinct dislocation events. However, in order to single out discrete earthquakes and constrain their time of occurrence it is necessary to unravel the series of sedimentological and tectonic events written on the trench walls.

The occurrence of a large earthquake suddenly offsets the deposits lying across the fault and disrupts the equilibrium of sedimentary processes in the vicinity of the scarp. After the earthquake sedimentation resumes with generally different characteristics, thus delineating a boundary surface between different units. When seen within a trenched sequence, such a surface becomes representative of the ground surface at the time of the earthquake occurrence. The sediments overlying this surface will be deformed only by subsequent earthquakes (if any), while the underlying layers are deformed by a number of earthquakes that increases as a function of depth.

The identification of all the surfaces bounding sets of layers characterized by the same offset leads to the recognition of a number of units corresponding to discrete increments of tectonic dislocation. Each of this units can be associated with a paleoearthquake that displaced the ground surface by the amount of the corresponding increment in total offset. Similarly the presence of colluvial sediments pinched out against the fault on its downthrown side is suggestive of the existence of a scarp that has been leveled by deposition rather than by erosion to restore the pre-earthquake topography. For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example, the offset increase recorded at the top of unit *C* (Fig. 6) was interpreted as the effect of an earthquake that occurred prior to 1980; sedimentation of *B* on top of *C* and against the newly formed scarp started right after, and continued until the elevation contrast between the two sides of the fault was compensated.

Based on these observations we recognized the effects of four different earthquakes besides that of 1980. Each paleoearthquake was characterized in terms of geometry, size, and time of occurrence (Table I, column 2) using a graphic technique for the reconstruction of the deformation history written in the trenches. Assuming that the lacustrine units were deposited in horizontal beds, the effects of each earthquake were graphically subtracted from the total observed offset starting from the youngest event (Fig. 7). Repetition of this procedure for older events permitted to restore what the geometry of the trench sections would have looked like just before and right after each event, and for all of them yielded a reliable estimate of the geometry and extent of dislocation. For those paleoearthquakes for which we could not use beds extending across the fault zone, a minimum scarp height was assumed to be represented by the thickness of the colluvium deposited after the scarp was formed. The timing of each earthquake is constrained by the estimated age of the sediments that were deposited soon after and immediately before the event. The associated uncertainty represents a combination of (1) the inherent analytical uncertainty, (2) the sedimentary history of the dated sample, and (3) the vertical separation between the dated samples and the surfaces marking the occurrence of a paleoearthquake.

Table I (column 2) summarizes the main characteristics of the paleoearthquakes recognized in Trenches 3 and 4 at Pantano di San Gregorio Magno. The events are identified by progressive numbers referring to those used for Trench 1 and Trench 2 at Piano di Pecore (Table I, column 1); the same number is assigned to events occurring within a comparable interval of time at both sites.

Event 1 is the 1980 earthquake. The recognition of Event 2 and the estimation of the offset it produced was simply based on the restoration procedure delineated above. The recognition of Event 3 instead was quite difficult because the unit *D*, that was presumably emplaced around the time of its occurrence, is not at present continuous across the fault (Figs. 6, 7); on the other hand the unit *E*, which can be followed on both sides of the fault in both trenches, was clearly deformed by some older event (Figs. 6, 7). However, two lines of evidence testify the occurrence of Event 3: (1) the geometry of D1, that overlies both the older D beds and part of the unit *E*, by doing so leveling one of the two steep scarps that cut the latter unit along the fault zone; and (2) the observation that the removal of the offsets associated with Event 1 and 2 flattens the bed D1 but leaves the beds D2, D3 and D4 still warped against the fault zone. Therefore Event 3 most likely occurred when the upper part of D2 was deposited on the downthrown side of the fault; at the same time the unit *E* cropped out on the upthrown side and possibly underwent erosion. Similarly, Event 5 occurred prior to deposition of the D2, D3, D4 colluvial sequence. As noted above, the unit *D* is not

Fig. 7 - Graphic reconstruction of the sequence of dislocation events recognized in Trench 3. We reconstructed the conditions of the section preceding and following the occurrence of each recognized paleoearthquake. To do so we substracted the deformation effects produced by all the events that occurred prior to the one under consideration. This reconstruction allowed us to determine the geometry and magnitude of the deformation effects produced by each event and to understand their influence on the sedimentary and erosional processes. The trace of the ground surface at the time of occurrence of each earthquake is marked by a heavy line and by the number identifying that particular event in Table I. The deposits underlying each surface were deformed by the earthquake that occurred when that surface represented the topographic surface and by previous events, whereas the overlying deposits were deformed only by younger events, if any. The vertical throw associated with Event 2 was evaluated based on the vertical offset of the base of unit *C* across the fault zone. The surfaces displaced by Event 3 and 5 can only be seen on the downthrown side of the fault. For this reason, we could estimate only a minimum figure for the vertical throw associated with these earthquakes. This estimate is based on the thickness of the colluvial sediments filling the depression that was produced by each surface faulting event (D1 for Event 3; D2, D3, D4 for Event 5). This is done assuming that following each paleoevent sedimentation took place within this depressions, similarly to what was observed following the 1980 earthquake. Sedimentation resumed over the whole area only after these surface depressions were leveled.

Ricostruzione grafica della sequenza degli eventi deformativi della trincea 3. Per ogni terremoto riconosciuto sono state "restaurate" graficamente le condizioni della sezione immediatamente precedenti e successive all'evento in esame, sottraendo di volta in volta le deformazioni legate a tutti gli eventi che lo hanno preceduto.Su questa base è stato possibile valutare l'entità e la geometria della deformazione legata a ciascun terremoto ed evidenziare le eventuali alterazioni all'equilibrio deposizionale innescate dalla deformazione stessa. La traccia della superfice topografica al momento in cui ha avuto luogo un evento è indicata da una linea spessa e dal numero identificativo del terremoto, corrispondente a quello riportato in Tabella I. I depositi al di sotto di ognuna di tali superfici sono stati deformati dall'evento che ha avuto luogo in corrispondenza di tale superficie, ed eventualmente da terremoti precedenti, mentre quelli che la ricoprono sono indeformati o deformati solo da eventi successivi. Il rigetto causato dall'evento 2 è stato assunto pari allo spostamento verticale necessario a giustapporre la base dell'unità C attraverso la faglia. Per gli eventi 3 e 5, che hanno dislocato superfici esposte solo sul lato ribassato della faglia, è stato possibile valutare un valore minimo di dislocazione sulla base dello spessore dei depositi che colmano la depressione creatasi di fronte alla scarpata di faglia a seguito di ciascun evento (D1 per l'evento 3; D2, D3, D4 per l'evento 5). Infatti, successivamente ad ogni evento la sedimentazione aveva luogo principalmente all'interno di tale depressione, a somiglianza di quanto si osserva oggi per la scarpata del 1980. Una volta colmata la depressione la sedimentazione riprendeva omogeneamente su tutta l'area.

continuous across the fault and hence the vertical offsets evaluated for Event 3 and 5 must be regarded as a minimum estimate. Theoretically, the true displacement associated with these paleoearthquakes might be evaluated based on the total offset of the unit *F* and *G*, but none of the trenches was deep enough to expose them on both sides of the fault. Borehole drilling in the vicinity of the trench site has been planned to address this ambiguity and perhaps collect information on older events.

Event 4 of Piano di Pecore (Table I) was not recognized at all. The occurrence of Event 6 in correspondence with the top of unit *G* was hypothesized based on the unconformity between this unit and the overlying ones. Several fractures and faults affecting unit *G* but filled by the overlying sediments suggested that a major tectonic event occurred during its deposition, thus indirectly confirming the existence of Event 6. Possible occurrence of an additional event after the deposition of *F* (between Event 5 and 6) was suggested by the erosion of part of the top of this unit near the fault. The crest of the scarp formed by the earthquake was eroded off and deposited in form of a colluvial wedge on the downthrown side of the fault before being buried and leveled by the unit *E*. However, as the unit *F* and the bottom of the unit *E* were only found on the upthrown block of the fault, the plausibility of this hypothesis can not yet be tested. This aspect of the site's tectonic history will be also addressed by the planned drilling operations.

The recognition of these paleoearthquakes and the evaluation of their timing and characteristic offset yielded an average slip-rate and repeat time of respectively about 0.3 mm/yr and 2,000 yr for the Irpinia Fault. Assuming that the average fault dip is 60°, the obtained slip-rate converts into a fairly slow extension-rate of about 0.2 mm/yr.

4. PALEOEARTHQUAKES ALONG THE IRPINIA FAULT

Table I shows that the results obtained from trenching at Pantano di San Gregorio Magno are in good agreement with the observations from the site of Piano di Pecore. At both sites, all the recognized paleoearthquakes were found to be comparable to each other, both in terms of surface offset and deformation style.

Based on stratigraphic and sedimentological observations, we hypothesize that surface faulting associated with the events 2, 3 and 5 was synchronous at both sites, and therefore that the Marzano - Carpineta and the San Gregorio fragments (Fig. 1) of the Irpinia Fault ruptured during a single complex earthquake as they did in 1980. In particular, the age of Event 2 (2,570±70 ÷ 2,750±50 yr cal B.P.) is well constrained at both sites because we know the age of the sediment that was being formed at the time of the earthquake or immediately after it. The well-constrained age of Event 3 from Trench 1-2 (4,000 yr B.P.; Pantosti *et al.*, 1991), also agrees with the time-range estimated for the same events in Trench 3-4.

The lack of records of Event 4 at Pantano di San Gregorio Magno (see § 3.2.3) can be explained in four different ways: (1) the southernmost section (San Gregorio: Fig. 1) of the Irpinia fault did not rupture at all during this earthquake; (2) it ruptured but the coseismic slip was too small for the fault scarp to be formed; (3) it ruptured at the same location as in 1980 but its geologic records could not be deciphered; (4) it did rupture and produce surface faulting but not at the same location as the 1980 scarp. The latter hypothesis was ruled out because field evidence strongly suggests that, at least at the time-scale explored by trenching, surface deformation along the Irpinia fault took place always at the very same location, and that the influence of changing climatic and sedimentologic conditions was very limited. Hypothesis (3) might be accepted assuming that the scarp produced by Event 4 at this site was quickly eroded, and that the resulting deposits should be found within the unit *D*. In fact, we recognized three distinct depositional episodes beetween Event 3 and 5, which suggests changes in the sedimentological evolution of the area, but no evidence supports the hypothesis that these changes could have been caused by surface faulting.

Event 5 occurred prior to the Mercato Plinian eruption of Mt. Vesuvius (Pantosti *et al.*, 1991) dated at 7,900 yr cal B.P. (Arnò *et al.*, 1987). This time constraint is in agreement with the age interval estimated for this event from Trench 3-4 (6,620±80÷9,420±90 yr cal B.P.). Event 6 was recognized only at Pantano di San Gregorio Magno, where sediments older than 10,000 yr were exposed thanks to the larger depthof Trench 3-4 in comparison with Trench 1-2. This event occurred in the interval 11,180±200-19,660±280 yr cal B.P.

5. DISCUSSION

The results of trenching along the 1980 fault scarp represent the first observations of surface faulting associated with repeated large paleoearthquakes to be obtained in Italy and in the central Mediterranean. The new accomplishments allow to address a number of questions of primary relevance for the understanding of seismogenic processes and recent tectonic evolution in the Italian peninsula.

A strictly seismological conclusion that can be drawn sheds light on whether the complexity of the rupture process of the 1980 earthquake should be regarded as a random occurrence, or instead if it represents a permanent characteristic of the source. The good match between the timing of the paleoevents recognized at Piano di Pecore and those recognized at Pantano di San Gregorio Magno (with the exclusion of Event 4) suggests that the 1980 earthquake complexity is in fact a source feature that is permanent at the time scale spanned by the investigation (≅10,000 yr). This would imply that not only the 1980 earthquake is characteristic in the sense formalized by Schwartz & Coppersmith (1984), but also that the energy tends to be radiated by the same regions of the seismogenic zone. Unfortunately, no inference can be made on the long-term behavior of the small antithetic fault that ruptured in the 1980 earthquake (4 in Fig. 1) but did not produce surface faulting. In other words, there is no evidence that this fault does not rupture independently from the main Irpinia Fault, as suggested by some moderate historical events (Postpischl, 1985), in addition to participating in 1980-type earthquakes.

A second, twofold conclusion may affect our ideas on how to recognize the field effects of large historical earthquakes. One of the key observations from all the excavated trenches is the highly repetitive nature of surface faulting, both in terms of geometry and extent of deformation. The time link that was created between two largely separated trenching sites confirms that the events summarized in Table I are *the large earthquakes* that ruptured the Irpinia Fault during the Holocene, and that we are not missing other surface faulting events just because their field evidence is offset relative to the trench sites. On the other hand, the similarity between the height of the scarp observed in 1980 and that inferred for older earthquakes indicates that very little or no slip is released between large earthquakes, either aseismically or through moderate magnitude events. By supporting some of the keystones of paleoseismology, these findings grant legitimate optimism on the development of this discipline in southern Italy.

The average fault slip-rate obtained at the two trenching sites shows a good agreement, the somehow lower figure obtained at Pantano di San Gregorio Magno (0.3 mm/yr) being mainly attributable to the lack of deformation associated with the Event 4 at this site. Hence the overall contribution of the Irpinia Fault to the extension of this portion of the Apennines is nearly constant over the fault length. The estimated 0.2 mm/yr rate could be increased up to 0.3 mm/yr assuming that the above mentioned antithetic fault always participates in *1980-type* events. As the total cumulated stratigraphic throw across the Irpinia Fault was estimated 500 m or less (Pantosti & Valensise, 1990), the age of the fault itself and thus the time of inception of the modern extensional tectonic regime can be set at about 1 Myr or younger. The main implication of this conclusion is that the active tectonic regime has not yet had a chance to modify the landscape to the extent that the active faults stand out and can easily be recognized. This simple concept may explain with remarkable simplicity why so far the recognition of active tectonic features along the Apennines has been especially slow and controversial (for a discussion of this topic in relation to the 1980 earthquake see Pantosti & Valensise, 1990).

The conclusion that is most relevant to long-term seismic prediction and risk assessment is the estimated repeat time of 1,950 years for *1980-type* earthquakes. Based on the combination of historical macroseismic data and limited geomorphic evidence Pantosti & Valensise (1988) suggested that the Irpinia Fault may represent one of the segments of a 200 km-long seismogenic belt named Southern Apennines Fault. Under the assumption of a constant deformation rate across this belt the repeat time obtained for a magnitude ≅ 7 earthquake along the Irpinia Fault can as a first approximation be extrapolated to the adjacent segments. Further investigations along these segments will hopefully confirm and strengthen this estimate. However, for the time being we need to address the large discrepancy between the paleoseismological repeat time (≅ 2,000 yr) and the much shorter repeat time suggested by historical data (300÷500 yr). To address this paradox, that is central to any seismic risk analysis conducted along this stretch of the Apennines, Boschi *et al.* (1990) suggested two possible explanations:

(1) the size of the historical earthquakes on which the computations of the repeat time were based was systematically overestimated;

(2) antithetic seismogenic structures (such as the one that ruptured during the 1980 earthquake) may be responsible for part of the observed large earthquakes, as their characteristic damage pattern is similar to that typical of the main (synthetic) structures.

The absence of geologic records of the 1694 earthquake is another and maybe the most striking paradox, as this event is commonly regarded as an ancestor of the 1980 earthquake (Serva, 1981). Also for this *paradox* three hypotheses were put forward by Boschi *et al.* (1990):

(1) the 1694 earthquake was not large enough to produce surface faulting (a magnitude of 6.5 is commonly assumed as the lower threshold for a normal fault to produce unequivocal surface ruptures);

(2) the 1694 earthquake occurred on an adjacent seismogenic structure (such as the antithetic fault that ruptured in 1980);

(3) surface deformation associated with the 1694 earthquake does not occur at the very same location nor within meters of the fault scarp produced by the 1980 earthquake.

The last of this hypotheses can now be safely ruled out based on the conclusions discussed above on the repeatability of the surface expression of the Irpinia Fault. Further paleoseismological investigations and a specific study aimed at the reevaluation of the damage pattern associated with the 1694 earthquake should help addressing the ambiguities involved in the first two hypotheses.

A further *paradox* raised by the paleoseismological results is represented by the 0.2÷0.3 mm/yr estimate for the extension-rate across the Irpinia Fault. This figure is extremely small in comparison with published estimates of 2÷4 mm/yr based on instrumental earthquake data (Anderson & Jackson, 1987; Jackson & McKenzie, 1988; Westaway *et al.*, 1989). We could hypothesize that:

(1) The Irpinia Fault is paralleled by several similar faults spread within the 100-200 km band between the Tyrrhenian and Adriatic seas;
(2) The Irpinia Fault is paralleled by a few similar faults concentrated along the axis of the Appenines chain;
(3) most of the extension takes place aseismically.

The last hypothesis (3) must be ruled since the 2÷4 mm/yr estimate relies entirely upon observations of modern seismicity. The hypothesis (1) is in contrast with historical observations made as early as eighty years ago (Omori, 1909), showing that almost all the largest historical earthquakes that occurred along the Apennines were located in a relatively narrow band along the axis of the chain. Due to the limited resolution of historical data, the hypothesis (2) could be accepted. However, field evidence from several areas of regional extension around the world suggest that the spacing between parallel large normal faults is generally of the same order of magnitude of the local thickness of the seismogenic layer. For the southern Apennines, this ideal wavelength could be represented by the 10-12 width of the Graben formed by the Irpinia fault and its antithetic counterpart.

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