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A major seismogenic fault in a 'silent area': the Castrovillari fault (southern Apennines, Italy)

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SUMMARY

Large historical earthquakes in Italy define a prominent gap in the Pollino region of the southern Apennines. Geomorphic and palaeoseismological investigations in this region show that the Castrovillari fault (CF) is a major seismogenic source that could potentially fill the southern part of this gap. The surface expression of the CF is a complex, 10–13 km long set of prominent scarps. Trenches across one scarp indicate that at least four surface-faulting earthquakes have occurred along the CF since Late Pleistocene time, each producing at least 1 m of vertical displacement. The length of the fault and the slip per event suggest $M=6.5$–7.0 for the palaeoearthquakes. Preliminary radiocarbon dating coupled with historical considerations imply that the most recent of these earthquakes occurred between 380 BC and 1200 AD, and probably soon after 760 AD; no evidence for this event has been found in the historical record. We estimate a minimum recurrence interval of 1170 years and a vertical slip rate of 0.2–0.5 mm yr^{-1} for the CF, which indicates that the seismic behaviour of this fault is comparable to other major seismogenic faults of the central–southern Apennines. The lack of mention or the mislocation of the most recent event in the *historical seismic memory* of the Pollino region clearly shows that even in Italy, which has one of the longest historical records of seismicity, a seismic hazard assessment based solely on the historical record may not be completely reliable, and shows that geological investigations are critical for filling possible information gaps.

Key words: palaeoseismicity, seismicity gap, seismogenic fault, Southern Italy.

1 INTRODUCTION

Most large earthquakes in the Italian Peninsula are located along the central and southern Apennines seismogenic belt (Valensise *et al.* 1993), which is a ≈50 km wide, 800 km long zone straddling the crest of the chain (Fig. 1). The earthquakes have almost pure dip-slip focal mechanisms and occur along 20–40 km long adjacent normal fault segments. These faults accommodate the present NE–SW to E–W extension perpendicular to the axis of the chain, which was initiated less than 1 Myr ago (Pantosti & Valensise 1990; Cinque *et al.* 1993; Westaway 1993; Hyppolite, Angelier & Roure 1994). However, within the belt, there are sections where no earthquakes with $I \geq$ VIII Mercalli Cancani Sieberg (MCS) have been reported in the catalogue of strong Italian earthquakes since 461 BC (Boschi *et al.* 1995), so the earthquake-free areas could be interpreted as seismic gaps. The most prominent of these possible gaps is in Southern Italy in the Pollino region (Fig. 1). The gap is bounded on the north by the $M=7$, 1857 Agri Valley earthquake, and on the south by seismicity in the Crati Valley. Seismicity during the last 10 years has been relatively rare and diffuse throughout the gap and does not show any significant clustering in time or space. The largest seismic event in the area during this century is the $M=5.5$, 1913 Roggiano earthquake ($I=$ VIII MCS), which was near the southern border of the gap (Fig. 1). Detailed studies of historical records for the Pollino area have confirmed the lack of important historical seismicity (Storia Geofisica Ambiente 1994).

The simplest interpretation for seismicity gaps, such as the one in the Pollino area, is that they represent zones where the active deformation occurs aseismically because of unique local geological conditions. However, as shown by recent palaeoseismological studies in other parts of Italy, these gaps may *contain seismogenic faults that have been relatively quiescent* during historical time. The apparent lack of historical seismicity in these gaps (1) may be due to fault-specific return periods for large events of more than one millennium, which is comparable to the length of the historical record (Valensise &

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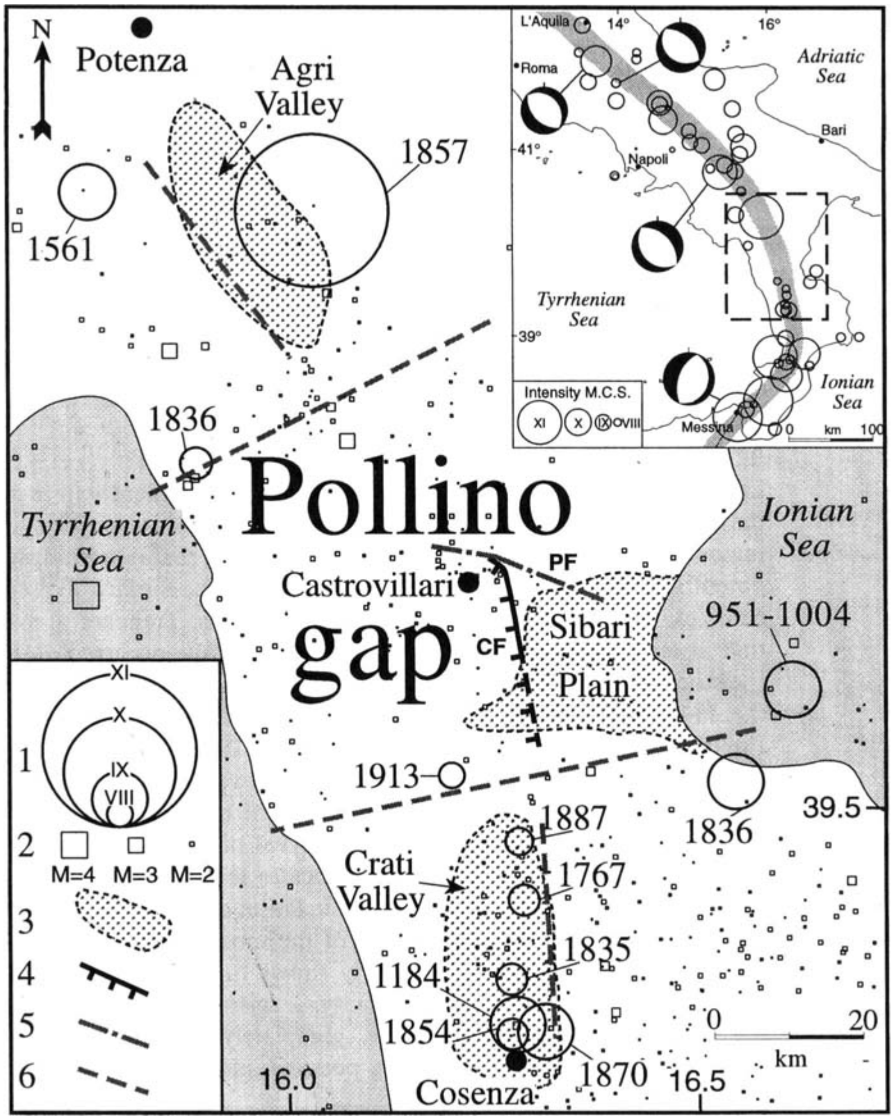

Figure 1. Historical and instrumental seismicity in the Pollino gap and surrounding regions of the southern Apennines, Italy. The inset locates the Pollino area (dashed rectangle) within the Apennines seismogenic belt (shaded area) where most of the $I \geq$ VIII MCS, historical earthquakes have occurred (from Valensise *et al.* 1993). Available focal mechanisms are also shown. Key: 1. historical earthquakes scaled according to MCS intensity from 461 BC to 1980 AD (from Boschi *et al.* 1995); 2. instrumental earthquakes between 1984 and 1994 (from the Earthquake Monthly Bulletin of the Istituto Nazionale di Geofisica, Rome); 3. major alluvial valley; 4. Castrovillari fault (CF), dashed where inferred; 5. Pollino fault (PF); 6. other structures within the seismogenic belt (from Valensise *et al.* 1993).

Pantosti 1992; Pantosti, Schwartz & Valensise 1993; Michetti *et al.* 1996; Pantosti, D'Addezio & Cinti 1996) or (2) might reflect the low density of population and the settlement pattern in some parts of the peninsula (D'Addezio, Cinti & Pantosti 1995; Valensise & Guidoboni 1995). Thus, it is possible that the Pollino area could have experienced large earthquakes in historical time but the records of these events were lost or misinterpreted.

To examine this possibility and to understand better the true seismic potential of this region, geological studies of recent faulting (*sensu lato*) provide a powerful tool. These studies are independent of historical and instrumental seismicity, and are warranted because a prominent fault scarp in Quaternary deposits, hereinafter referred to as the Castrovillari fault (CF), and a major regional structure whose activity is uncertain (the Pollino fault) are present in the area. Both these faults, first described by Bousquet (1973), are located in the southern part of the gap (Fig. 1) and may be potential seismogenic sources in the region.

In this paper, we describe our preliminary results from geological and geomorphic studies in the area, and palaeoseismological investigations along the Castrovillari fault.

2 THE CASTROVILLARI FAULT

Aerial photographs and ground-based observations were used to map in detail the surface expression of the Castrovillari fault and to analyse the recent geomorphology of the area. The Castrovillari fault is located on the southwest side of the Pollino Range and is composed of three main NNW-trending, southwest-facing normal-fault scarps that extend for 10–13 km (Fig. 2). The scarp traces have a complex geometry: they are

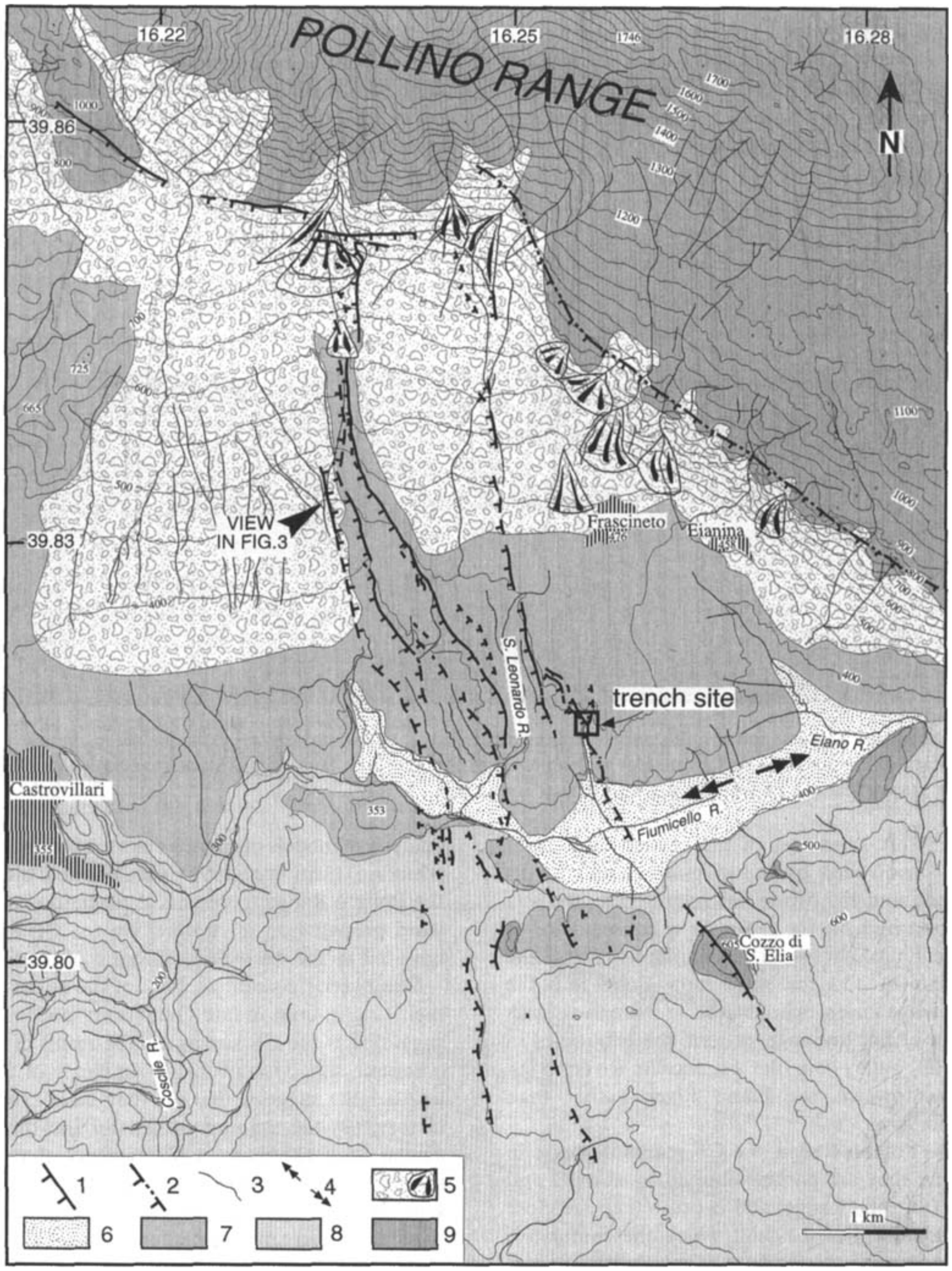

Figure 2. Map of the Castrovillari fault scarps based on aerial photos and field studies. Key: 1. Castrovillari fault scarp, dashed where mapped only on aerial photos; 2. Pollino fault; 3. active stream; 4. drainage divide in the Fiumicello Valley; 5. modern and active slope debris and alluvial fan; 6. Holocene alluvium and colluvium; 7. late Pleistocene fan-delta deposits (gravel, sand, silt and clay); 8. middle to late Pleistocene marine sand and conglomerate; 9. Meso–Cenozoic calcareous bedrock.

parallel to each other across a 1–2 km wide zone and form a left-stepping *en echelon* pattern. Antithetic scarps are particularly prominent west of the westernmost fault trace. The scarps offset fan-delta, fluvial, lacustrine and colluvial deposits of middle to late Pleistocene and Holocene age. In general, the scarps produce abrupt changes in the local topography that, in the central part of the structure, are as high as 25 m (Fig. 3). The total vertical separation across the entire fault zone is 100–150 m on the youngest top-set beds of the late Pleistocene fan-delta sequence (Colella 1994). The CF scarps are oriented obliquely to the WNW-trending Pollino Range, which is the major physiographic feature of the area. As a result, the local drainage is generally parallel to the scarps and causes erosion at their bases rather than burying the scarps; this erosion may locally enhance the scarp height. Other than a few ephemeral streams that cut across the scarps, the Fiumicello River is the only important watercourse flowing perpendicular to the structure. Near the river the evidence for the long-term activity of the CF is reflected in the geomorphology and drainage pattern. The drainage divide between the Fiumicello and Eiano rivers,

Figure 3. Photograph of the western and central scarps of the Castrovillari fault (white arrows show the scarp crests). The scarps interrupt abruptly the flat surface of the fan delta and form steps as high as 25 m. An antithetic fault scarp (black triangles show the top) faces the main scarps and bounds a graben that is a preferential site for drainage in the area.

which is located about 2 km east of the eastern fault trace (Fig. 2), is directly controlled by the long-term uplift in the footwall of the fault, and the divide has migrated to the east as repeated slip occurred on the fault. As a consequence of this migration, the Fiumicello River has captured part of the Eiano River catchment and the water now flows into the Coscile River drainage basin, whose area is increasing with time. Reflecting an earlier drainage pattern, the tributaries in the high Fiumicello Valley join the Fiumicello River in an eastward direction towards the Eiano River, rather than towards the Coscile River.

Approaching the Pollino Range, the CF scarps decrease in height both because they are partially buried by alluvial and colluvial deposits from the Range, and because they are close to the northern boundary of the fault where the cumulative slip is expected to decrease. At the base of the Pollino Range, the scarps turn westwards and join in a single E–W-trending, $\approx$3 km long scarp cutting late Pleistocene–Holocene deposits (Fig. 2). This part of the scarp seems to overprint the trace of the Pollino fault, a major crustal structure transverse to the CF (Figs 1 and 2) that was active as a left-lateral strike-slip fault until the lower Pleistocene, when prevalent extensional activity was initiated (Russo & Schiattarella 1992; Colella 1994). Vittori *et al.* (1995) suggested that normal faulting is still active, interpreting the W-trending scarp described above as evidence for Holocene movement along the Pollino fault. However, assuming that both the Castrovillari and the Pollino structures are prevalently normal faults, their geometry and kinematics are not consistent with the same stress field. The recent geomorphology of the area is the result of repeated movements along the CF and does not necessarily reflect the current activity of the Pollino fault, as also suggested by the analysis of models of surface deformation induced by a CF-type structure (Cinti *et al.* 1995). One possible interpretation is that the Pollino Range represents a geometric barrier to the northward propagation of ruptures on the CF fault and may also have led to the westward deflection of the CF at the surface.

The overall geomorphology of the scarps, their length and their height, even in late Quaternary unconsolidated deposits, suggest that the CF scarps are the result of multiple events of coseismic slip. Moreover, the similarity of the scarps' profiles and heights suggests that (1) they have experienced a similar history, (2) the amount of slip on the three main scarps is similar, and (3) there is no evidence that any of the three scarps have been abandoned yet. To investigate the possible seismogenic behaviour of the CF, we conducted exploratory trenching in search of geological evidence of past surface-faulting earthquakes.

3 PALAEOSEISMICITY OF THE CASTROVILLARI FAULT

The trenching site is located at the major NW-trending step-over along the eastern scarp (Fig. 2). To the south of the site, the main scarp bounds the eastern edge of a seasonal stream; at the trench site, the scarp offsets recent alluvial sediments because of its left-stepping geometry. As previously mentioned, because most streams flow parallel to the scarps, the change in strike of this section of the scarp from the general trend provides one of the few favourable settings where the CF displaces modern alluvial deposits and a record of faulting events is likely to be preserved. Dating of an organic-rich alluvium from a nearby quarry and stratigraphic correlations suggest that these alluvial deposits are younger than ≈30 000 years.

Topographic profiling and mapping along the seasonal stream has revealed important complex details of the fault zone, which has been extensively modified by human activity (Figs 4a and b). The fault zone contains a 3 m high, human-modified main scarp and several subparallel secondary scarps within a 200 m wide zone. The minimum total vertical separation across the scarps along the stream bed is 5–6 m. The stream across the main and secondary fault zones does not show clear evidence of lateral offset. The site topography and the complexity of the drainage pattern on the downthrown block mainly reflect the effects of individual scarps and local subsidence.

We excavated four trenches at this site: two crossed the NW-trending stepover zone and two were parallel to it (Fig. 4a).

3.1 The cross-fault trenches

Trenches 1 and 2 were excavated across the fault zone (Fig. 4a). Trench 1 crossed the two southern secondary scarps along the central part of the active dry stream. The trench was about 40 m long and exposed a 6 m thick sequence of fan-delta, lacustrine and alluvial deposits and palaeosols. The stratigraphic sequence was divided into nine units (indicated by numbers), and each unit contains deposits from the same sedimentary event (Figs 5a and b). The complete stratigraphic sequence is preserved better on the west wall because the east wall is closer to the stream axis, where there is intense erosion. Both trench walls exhibit a complex 8 m wide main fault zone formed by a series of normal and reverse high-angle faults. Varying thicknesses of the deposits across the faults, the presence of apparent normal and reverse separation on the same fault trace, and wide complex shear zones suggest a component of horizontal slip. This is to be expected since the site is a stepover between adjacent fault strands. Structures and stratigraphic relations such as increasing displacements, upward-terminating faults, faulted colluvial wedges, flexured and onlapping layers and slumps in lacustrine deposits provide evidence of at least four surface-faulting earthquakes (Fig. 5a). Most of the faults have been active during multiple deformation events. The depositional history of the site is strongly controlled by the location and the geometry of the coseismic scarps; the formation of a relatively low area on the downthrown block after each earthquake became the preferred site for alluvial and lacustrine deposition.

Trench 2 was located at the western edge of the stream, about 30 m west of trench 1 (Fig. 4a). The trench was about 60 m long and crossed the main and a secondary fault scarp. The stratigraphic sequence in this trench was similar to that in trench 1 and was divided into the same units. The trench did not provide a complete record of the faulting history because intense human activity affected the main fault zone, even at the depth of the trench. However, the excavation exposed a 7 m wide secondary fault zone composed of high-angle, low-angle and antithetic faults (Fig. 6). Upward-terminating faults, fissure infills and backtilted lacustrine

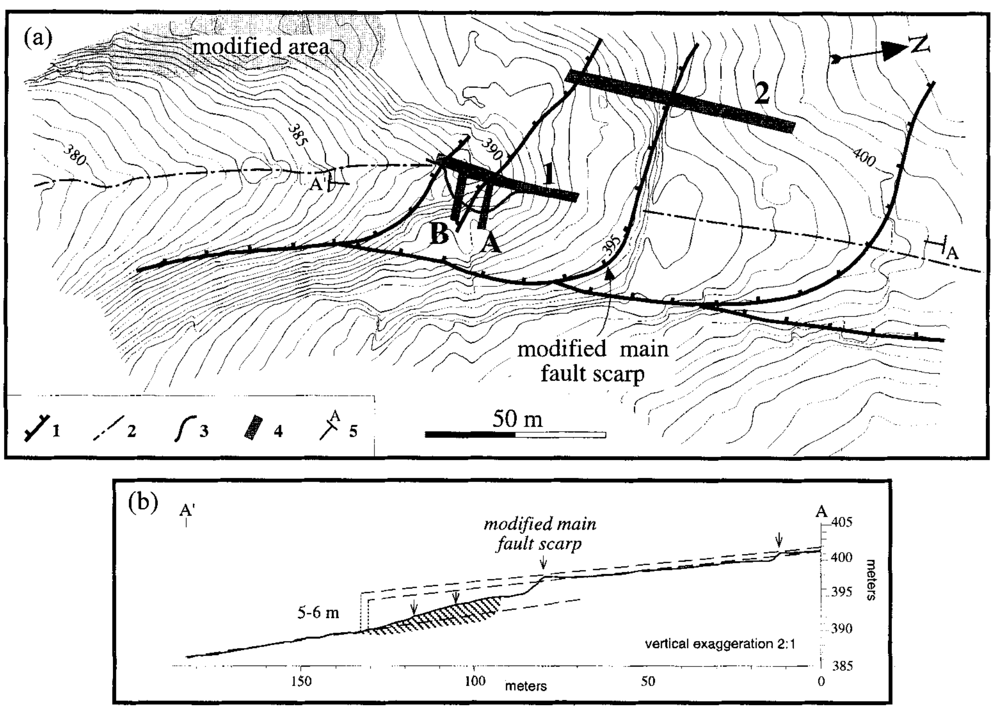

Figure 4. (a) Microtopographic map of the trench site, contour interval 0.5 m. Key: 1. fault scarp; 2. stream axis; 3. axis of the palaeochannel in unit 4; 4. trench; 5. trace of the profile shown in (b). (b) Topographic profile along the stream bed showing a total vertical separation of 5–6 m. This value should be a minimum because of possible erosion of the upthrown side and deposition on the downthrown side of the scarp. Arrows indicate the intersection of the profile with the fault scarps. The location of trench 1 is indicated by the striped area. Horizontal scale is the same as in (a).

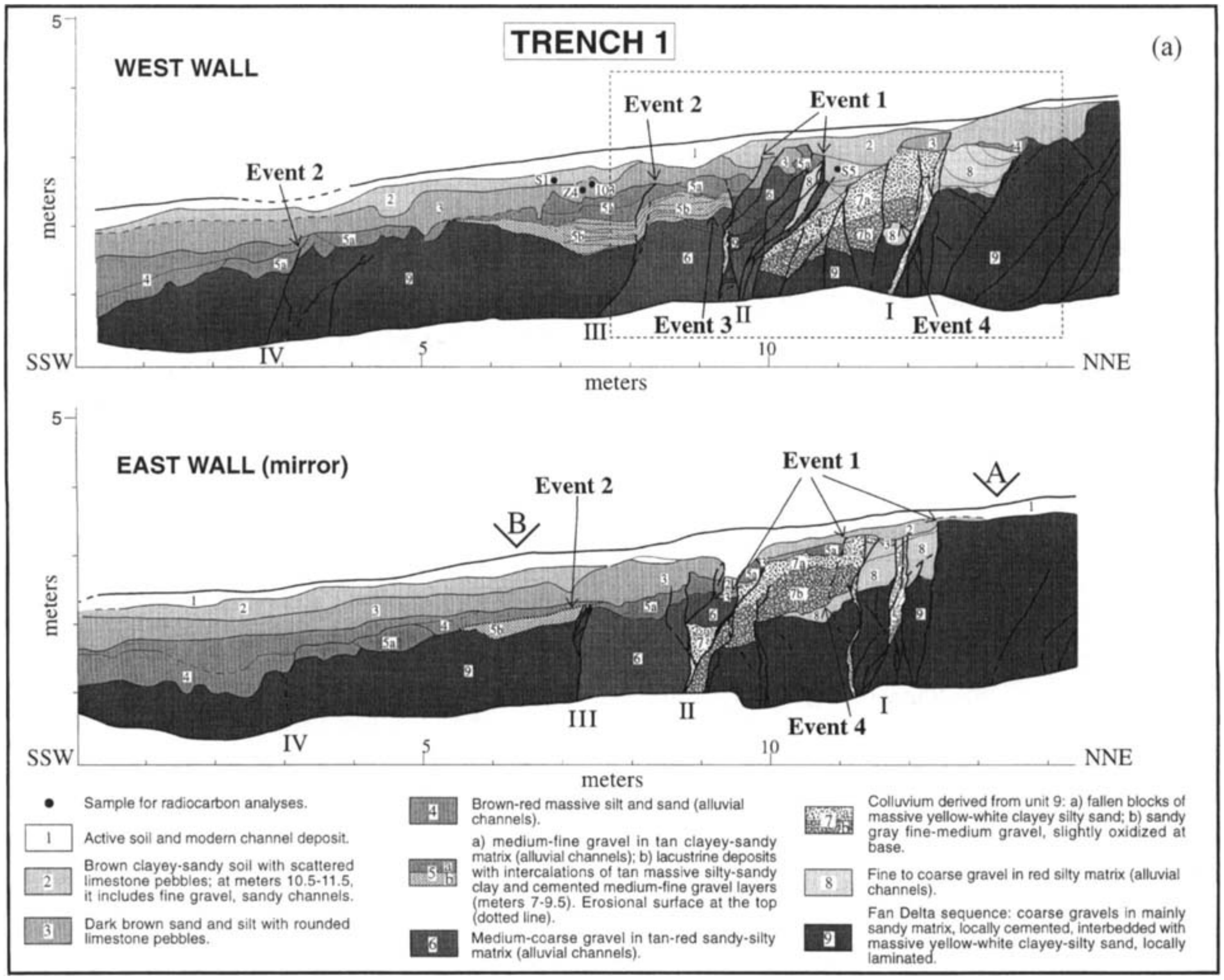

Figure 5. (a) Schematic logs from 1:20 detailed mapping of the fault zone exposed in trench 1 (see Fig. 4a for location). Main fault zones are indicated by Roman numerals I, II, III and IV. Arrows indicate the event horizon recognized for each palaeoearthquake. Uncertain contacts and the modified ground surface are represented by dashed lines. Letters A and B indicate the intersection with the fault-parallel trenches (logs in Fig. 7). Ages of the samples are listed in Table 1. The dashed rectangle encloses the section of trench wall shown in (b). (b) Photograph of central part of the fault zone exposed in the west wall of trench 1; unit numbers are the same as those used in the logs, arrows show fault scarps.

deposits provided evidence of at least three deformation events, which were correlated to those documented in trench 1.

3.2 The fault-parallel trenches

To investigate a possible lateral component of slip on the fault, we excavated trenches A and B parallel to the main fault zone and roughly perpendicular to trench 1 (Figs 4a and 7). The walls on both trenches exposed a series of unfaulted distinct fluvial channels that can be correlated to units 1–4 in trench 1. Trench A exposed palaeochannels with a regular, almost symmetric geometry, whereas trench B exposed palaeochannels with a more complex geometry that appears to be the result of a braided drainage pattern. This change in the depositional complexity across the main fault zone may reflect the sudden decrease in the energy of water flow once the stream crossed the scarp and spread over a wider area. We did not find convincing evidence of horizontal movement across the fault. In fact, the net offset of the channels (see in particular channel 4 in Fig. 4a) is within the variability of the natural diversion of streams.

3.3 Recognition of palaeoearthquakes

On the basis of stratigraphic relations between trench units, we correlated the most recent palaeoearthquake in trench 1 with a similar event in trench 2. We recognized evidence for three other events in the trenches. The palaeoearthquakes are referred to as Event 1 to Event 4, from youngest to oldest (Fig. 5a).

Evidence of the oldest event, Event 4, is recognized in trench 1 as a well-developed, scarp-derived colluvium about 1 m thick (unit 7) that contains blocks of the lacustrine deposits of unit 9. Following the formation of the colluvial wedge, the depression at the base of the main scarp was a preferred site for channel deposits, as indicated by channel sequence 6, which post-dates Event 4. The event horizon of this palaeoearthquake corresponds to the top of the channel sequence 8. Unit 8 is clearly displaced across fault zone I with an apparent vertical throw of as much as 0.9 m on the west wall. The deformation related to Event 4, or to an older event, is probably also expressed in trench 2, where lacustrine deposits of unit 9 in the upthrown block are clearly backtilted.

Evidence for Event 3 is found on the west wall of trench 1.

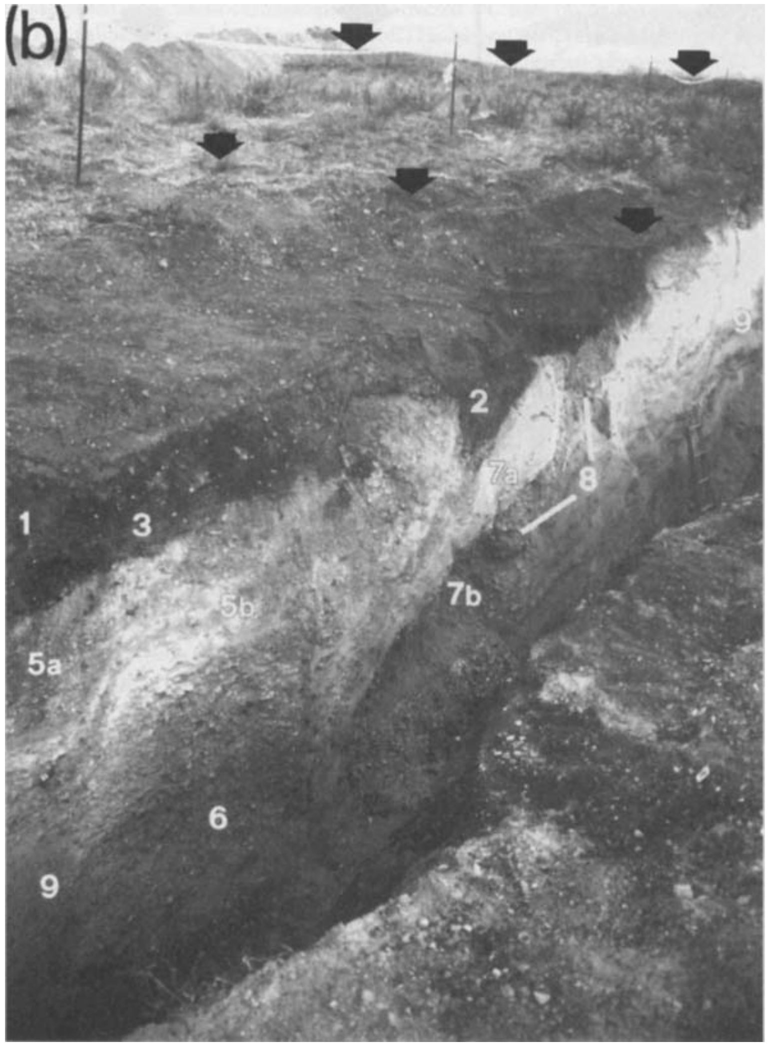

Figure 5. *(Continued.)*

This event produced intense faulting and shearing of the channel sequence 6, mainly in the ≈ 1 m wide complex fault zone II. Although this event horizon is the most poorly constrained, it is mainly inferred from the presence of the lacustrine deposits of unit 5b, which are interpreted as post-event. The nature of these deposits and their position with respect to fault zone II suggest that, similar to the previous event, they represent the sudden ponding of a depression formed by the coseismic subsidence during Event 3.

The penultimate palaeoearthquake, Event 2, is recognized in both trenches; however, the event horizon is clearly at the top of unit 5 in trench 1, and it is uncertain in trench 2. In trench 1, the event horizon corresponds to a sharp erosional surface on the top of unit 5, which is very clear on the east wall. On this wall, unit 5 appears clearly faulted by fault zone III and buried by the unfaulted deposits of unit 4. On the west wall, unit 5 has an apparent total vertical separation of ≈ 0.8 m across fault zones III and IV.

The most recent event, Event 1, is recognized in trench 1 because it reactivated fault zones I and II. In trench 2, the evidence of Event 1 is preserved as upward-terminating faults and fissure infills in the secondary fault zone. In both trenches, the stratigraphic sequence is faulted up to the lower part of unit 2 (Figs 5a and 6), suggesting that the event occurred during the deposition of this unit. In trench 1, Event 1 produced a total apparent vertical throw of 1.2–1.6 m at the base of unit 2.

3.4 Dating of palaeoearthquakes

Preliminary radiocarbon dating provided initial constraints on the age of the palaeoearthquakes at the study site. Unfortunately, most of the radiocarbon samples were bulk soil samples and thus their ages are mean residence time (MRT) dates of organic carbon in soils. Therefore, the ages of these samples contain important uncertainties because they represent an average age of carbon accumulating in the soil throughout the entire period of humic enrichment; this age is always older than the top of the sampled layer. On the other hand, because of the sample locations with respect to the surface and the permeability of the overlying deposits, the samples could be contaminated by young carbon as a result of leaching and bioturbation. In the following discussion, all reported ^{14}C ages are the 2σ range of dendrochronologically calibrated ages (see Table 1) adjusted to the nearest decade.

At present, units 2 and 3 have been dated (Table 1). Because

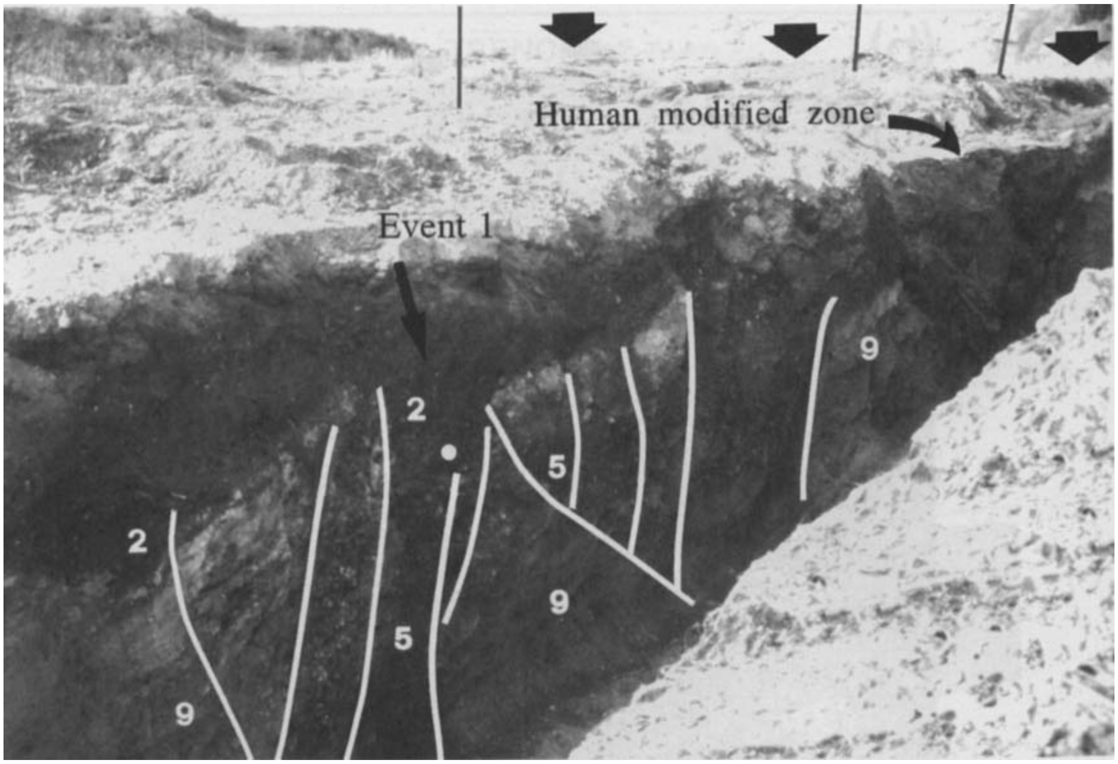

Figure 6. Photograph of the secondary fault zone on the west wall of trench 2. The major fault traces are marked by white lines, unit numbers correspond to those in trench 1 (see Fig. 5a for descriptions); the dot indicates the location of sample S4 (see Table 1 for age). Thick arrows show the main fault scarp.

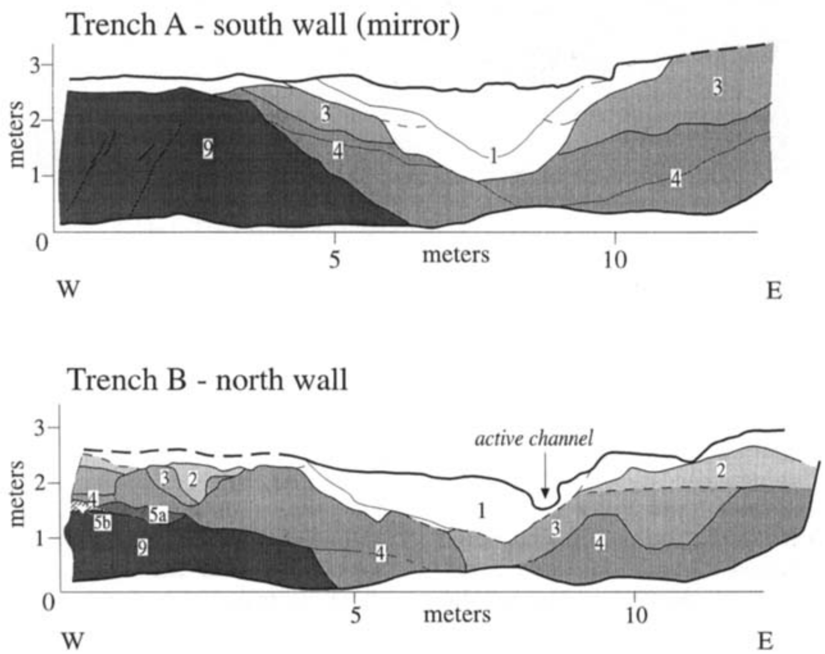

Figure 7. Schematic logs from 1:20 detailed mapping of fault-parallel trenches A and B (see Fig. 4a for location). The stratigraphic sequence in these trenches correlates with that of trench 1 (see Fig. 5a for descriptions). Unclear contacts and the modified ground surface are represented by dashed lines.

of its stratigraphic position, the age of Event 1 should be close to the age of unit 2, which is partially involved in the deformation, and definitely younger than unit 3. Three samples from unit 3 have been dated (Table 1); sample 12 (780–400 BC) and sample 103 (380–60 BC) are from charcoal fragments and are assumed to be more representative of its actual age. The maximum age for Event 1 is thus probably younger than 380 BC. It is difficult to establish a minimum age for Event 1 from our data. However, given the variability of the dating results for samples from unit 2 and the intrinsic uncertainty of

Table 1. Measured and dendrochronologically corrected ^{14}C ages of the samples collected in the trenches. The calibration is based on the calibETH calibration program (Niklaus 1994). The locations of the samples from trench 1 are reported in Fig. 5(a) (except sample 12, which is out of the log), and those from trench 2 in Fig. 6. In the text, ages are adjusted to the nearest decade.

Sample	Sample depth (m)	Material	Trench/unit	^{14}C age (yr BP)	Cal. age (2σ interval)
S1	0.4	Palaeosol	1/2	1150 ± 60	759–1006 AD
S4	1.1	Palaeosol	2/2	740 ± 60	1164–1320 AD
S5	0.6	Palaeosol	1/2	740 ± 50	1180–1307 AD
Z4	0.6	Palaeosol	1/3	2460 ± 60	771–408 BC
12	0.3	Charcoal	1/3	2430 ± 80	780–397 BC
103	0.6	Charcoal	1/3	2150 ± 60	378–63 BC

soil dates, we suggest two scenarios: (1) contamination is an important problem and the most representative age for unit 2 is sample S1 (760–1010 AD); or (2) contamination is not important so the ages of samples S4 (1160–1320 AD) and S5 (1180–1310 AD) are significant. Thus Event 1 would have occurred in case (1) shortly after 760 AD, and in case (2) shortly after 1160 AD. Because we suspect that contamination from young organic carbon is a problem, we prefer scenario (1).

As mentioned above, from the trenches we cannot estimate the youngest possible age for Event 1, which is not reported in the historical catalogue of Italian seismicity. Similar to other sites along the Apennines, this lack of historical accounts may be due to the sparse population and settlement in the mountainous regions until recent times. Historical reconstruction of the settlement distribution of some areas of the central Apennines has indicated that the beginning of the 14th century marks a general cultural and economical development; therefore, the occurrence of a large earthquake since 1300 AD would probably have been reported in the historical record, even in sparsely settled regions (D'Addezio *et al.* 1995). In the Pollino region, several small settlements already existed prior to 1300 AD, and because of the region's relatively favourable climatic and topographic conditions it is likely that cultural centres able to report large earthquakes in the area were settled at least since 1200 AD. Thus, combining the historical and palaeoseismological evidence, Event 1 probably occurred between 380 BC and 1200 AD, and probably close to 760 AD.

The age of Event 2 can be constrained only by the ages of unit 3. Because the event occurred before the deposition of this unit, we can use the oldest age available for it (sample Z4, 770–410 BC). On this basis, Event 2 is older than 410 BC. The only age constraint presently available for Events 3 and 4 is that they occurred during the last 30 000 years, which is the maximum age for the faulted alluvial sequence.

4 CHARACTERIZATION OF THE CASTROVILLARI FAULT

The structures and sedimentary relations recognized in the trenches indicate that the CF scarps are the result of catastrophic coseismic slip and not aseismic creep. On the basis of geomorphic evidence, trenching results and historical considerations, we propose preliminary estimates of the main fault parameters for the CF. These estimates are a first attempt to understand the seismic behaviour of this fault. Besides dating uncertainties, questions exist as to whether the history at the trench site is representative of the entire structure. In fact, the trench site is located at a stepover along the easternmost scarp, and no information on slip partitioning and on the hierarchy of the CF scarps is yet available. If we assume that all three scarps were active during each palaeoearthquake, then the slip per event and slip rate at the site should be minimum values. On the contrary, if each CF scarp acted separately, then the recurrence interval and elapsed time at the site are maximum values.

Fault length

The complex setting of the CF does not allow us to estimate an exact fault length. On the basis of the mapped fault scarps, the minimum length of the structure is 10 km, but it could be 13 km long if the W-trending scarps at the northern boundary are included (Fig. 2). However, at a regional scale, considering transverse structures that could define boundaries of seismogenic fault segments in the Apennines (Valensise *et al.* 1993), the CF may extend south to the next transverse fault, resulting in a total length of about 25 km (Fig. 1). The surface expression of this southern part of the CF may be buried by unconsolidated alluvial deposits in the Sibari Plain.

Slip per event

The slip per event can be estimated only in trench 1. Because this trench does not cross all of the scarps at the site, this measurement is a minimum value for this site and for the entire CF. Moreover, the possibility of a horizontal component on individual faults adds further uncertainties to this estimate. Incorporating these uncertainties, we estimate a minimum slip per event of between 0.8 and 1.6 m on the basis of the apparent vertical slip associated with the individual Events 1, 2 and 4.

Slip rate

Because of the large uncertainties in the slip per event, we estimate the slip rate of the CF on the basis of geomorphic evidence of long-term deformation. At the trench site, the minimum vertical separation across the stream bed is 5–6 m in the past 30 000 years (Fig. 4b), which yields a minimum vertical slip rate of about 0.2 mm year^{-1}. On the other hand, the 100–150 m of vertical separation across the entire structure, measured on the fan-delta top-set sequence, which is estimated to have an age of 300–600 ka (Colella 1994), yields a long-term slip rate of 0.2–0.5 mm year^{-1}. At present, these estimates are not sufficiently representative of the overall structure to make assumptions about the distribution of slip on the thr CF scarps.

Recurrence interval

Age constraints are available only for Events 1 and 2. Event 1 occurred between 380 BC and 1200 AD, with a best estimate close to 760 AD, whereas Event 2 occurred prior to 410 BC. On this basis, we estimate a general recurrence interval between 30 years (380–410 BC) and 1610 years (1200 AD–410 BC), with a best estimate of 1170 years (760 AD–410 BC). These values are considered to be minimum estimates of the recurrence interval because we have only a minimum age for Event 2. Furthermore, considering the similarity between the rates of activity estimated for the CF and those for other fault segments of the central and southern Apennines seismogenic belt (Pantosti *et al.* 1993; Michetti *et al.* 1996; Pantosti *et al.* 1996), we may also expect a comparable interval of activity, and thus we prefer the upper part of the minimum interval.

Elapsed time

The time elapsed since Event 1 ranges between 800 years (1200–1996 AD) and 2380 years (380 BC–1996 AD) and is probably close to 1240 years (760–1996 AD).

5 CONCLUSIONS

The Castrovillari fault is a NNW-trending normal fault located in the southern part of the Pollino gap. This area is considered to be a seismic gap or an area of aseismic deformation because of the lack of large-magnitude earthquakes in the historical record. However, the geomorphic evidence of the CF and the stratigraphy and structures exposed in the trenches show that the CF is an important seismogenic source. The CF has prominent scarps along 10–13 km of its length, and on the basis of structural considerations the fault could be as long as 25 km. At least four surface-faulting events have occurred on this fault in the last 30 ka: the most recent (Event 1) occurred close to 760 AD, and the penultimate event prior to 410 BC. The average minimum vertical displacement per event at the trench site is 1.2 m. The CF vertical slip rate and minimum recurrence interval are estimated to be 0.2–0.5 mm year^{-1} and 1170 years, respectively. Using the Wells & Coppersmith (1994) empirical relations between moment magnitude, surface-rupture length and average displacement, the expected magnitude for a future event on this fault is $M = 6.5$–7.

The CF at the surface deflects towards the west in its northern final portion (Fig. 2); trenching at this site (Vittori *et al.* 1995) provided evidence of a surface-faulting event of approximately the same age as that proposed for Event 1 that occurred along the NNW-trending main scarps. Despite the uncertainties related to the timing of the events, it seems possible that the NNW-trending and the W-trending scarps represent the surface expression of the same seismogenic structure. This result, along with the comparison between geomorphology and modelling of surface deformation (Cinti *et al.* 1995), supports the hypothesis that the W-trending scarp at the foothills of the Pollino Range is at present part of the CF and is not direct evidence of present activity of the Pollino fault.

A complete set of data including other sections of the Castrovillari fault is required for a more reliable evaluation of its seismogenic potential. At present, uncertainties on dating yield recurrence-interval and elapsed-time estimations with a wide variability. Depending on which part of the range represents the actual seismic parameter, the CF seismic behaviour might vary substantially. However, assuming a periodic strain release on the CF, our preliminary estimates suggest that the fault might be ready to produce a large earthquake. In fact, the time elapsed from the most recent event is comparable to the minimum recurrence time expected for surface-faulting earthquakes ($\approx$ 1200 years).

The seismic parameters of the CF from trenching and surface observations are similar to those of other seismogenic Apennine faults (Valensise *et al.* 1993). These similarities, along with the location and geometry of the CF, suggest that this fault is part of the Apennines seismogenic belt, and that fault segments in the belt have comparable seismic behaviour. This also confirms that the present NE–SW to E–W extension is the common mechanism that controls the seismogenic processes in the central and southern Apennines.

A major finding of this work derives from the fact that the most recent event on the Castrovillari fault inferred from the trench study is not found in the historical record. The absence of this event can be interpreted as a consequence of the low population and the scarcity of settlements in the epicentral area, which is similar to other parts of the Apennines (D'Addezio *et al.* 1995). This may have resulted in Event 1 not being reported in the record, or in its mislocation. Two historical earthquakes could be the 'mislocated Event 1': the 1184 AD ($I =$ IX MCS) earthquake, located about 50 km south of the Pollino region, or the 951–1004 AD ($I =$ IX MCS) event, located with great uncertainty about 40 km offshore southeast of the CF (Fig. 1). This case highlights (1) the possibility that regions with important seismogenic potential, such as Pollino, can be wrongly assigned a low seismic hazard based on the historical record alone, and (2) the contribution that palaeoseismological investigations make in determining the earthquake hazard of a region.

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