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Active compressional tectonics and Quaternary capable faults in the Western Southern Alps

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Two earthquakes struck the central Po Plain during the Middle Ages: the Jan. 3, 1117, Verona and the Dec. 25, 1222, Brescia events (e.g., Magri and Molin, 1986; Guidoboni, 1986; Serva, 1990; Galadini et al., 2001; Guidoboni, 2002; Guidoboni et al., 2005). These are the strongest known historical earthquakes in the Northern Po Plain, which is one of the most vulnerable areas in Italy in terms of high population density and industrialization.

The Jan. 3, 1117, event was centered near Verona an area that has been affected by numerous seismic induced ground effects. Despite difficulties in the interpretation of medieval descriptions, cracks in the ground (also with emission of sulphurous waters), uprooting of trees, landslides, liquefaction, muddying of springs, and overflowing of lakes has been recognized (Guidoboni et al., 2005). Also the Dec. 25, 1222, Brescia event, located SE of Lake Garda, affected numerous localities along the whole Po Plain producing effects on the environment as reported in contemporary chronicles, including stream deviations and ground cracks (CFT catalogue "Catalogo dei Forti Terremoti in Italia dal 461 a. C. al 1980"; Boschi et al., 1995). Based on type and size of ground effects and intensity distributions (macroseismic field) these earthquakes had magnitude on the order of 6.0 to 6.5, in agreement with published estimates (Serva, 1990; Guidoboni, 2002).

We conducted geological and geomorphological analyses and interpreted Po Plain seismic reflection data, made available by the Italian oil company ENI E&P, in order to characterize the tectonic environment of these earthquakes and to verify if they can be considered the “characteristic” events for this sector of the Southern Alps.

In particular, in this paper we focus on the active tectonic of the Western Southern Alps, where recent low magnitude earthquakes (M 4.2, Nov. 13, 2002, Lake Iseo eq.; and M 5.2, Nov. 24, 2004, Salò eq. on the west coast of Lake Garda, showing a compressive focal mechanism) suggest that this area is characterized by active shortening.

South-east of Lake Garda, Desio (1965) has previously documented the occurrence of some isolated areas of higher relief (Castenedolo, Ciliverghe and Capriano hills) whose presence cannot be explained by glacial or fluvioglacial morphogenic processes. Each of these hills has in fact been interpreted as the culmination of young anticlines. At Castenedolo and Capriano hills, Early Pleistocene marine deposits are uplifted more than 200 m; to the east, a Middle Pleistocene continental sequence constituting the Ciliverghe hill was faulted, uplifted and gently tilted (Baroni & Cremaschi, 1986).

Our work, aimed to a better characterization of these structures, is based on a) review of literature; b) geological and geomorphological field survey; c) morphology interpretation of digital elevation models; d) subsurface data compilation (seismic lines and exploration drillings).

We identify evidence of Quaternary compressive tectonics. In particular, the reinterpretation of ca. 18.000 km of ENI seismic profiles clearly show a belt of segmented, 10 to 20 km long, fault propagation folds, controlled by the Plio-Quaternary growth of several out-of-sequence thrusts.

Based on fault length, geometry, the thickness of seismogenic crust and slip rates, these thrusts seem capable of producing significant surface deformation and faulting during future moderately-sized earthquakes (e.g., Mw 6.0-6.5).

Moreover the coexistence in the area SE of Lake Garda of historical and instrumental earthquakes and of active tectonic structures lead us to consider a plausible seismic potential for this area at least comparable with the Dec. 25, 1222, Brescia event.

Moving westward from Lake Garda the geological and seismic reflection data show similar structural settings. In the area between Lake Iseo and Lake Maggiore (Insubria region) indications of active tectonics, among which paleoliquefaction features (Chunga et al., 2006), reverse faulting, tectonic uplift and karst phreatic conduits dislocated by flexural slip (Orombelli, 1976; Bini et al., 1992; Zanchi et al., 1997), can be found at several sites.

Despite the absence of local damaging historical earthquakes, in the Insubria region our investigations pointed out a seismic landscape (*sensu* Serva et al., 1997; Michetti and Hancock, 1997; Michetti et al., 2005) comparable with that in the Garda area, albeit at lower strain rates.

In conclusion, our preliminary results indicate that the whole W Southern Alps piedmont belt, between Lake Maggiore and Lake Garda is being actively shortened across a number of out-of-sequence north and south verging thrust and fault-related folds. As a working hypothesis, it is possible to consider the Dec. 25, 1222, Brescia event as a "characteristic" earthquake for these structures in terms of earthquake magnitude and effects, probably with increasing recurrence intervals moving from east (Garda) to west (Insubria). In other words, this event could be the reference earthquake that should be associated to Quaternary structures capable of producing surface faulting / folding. Further paleoseismological research is in progress to verify this hypothesis.

The case of the M5.2, Nov. 24, 2004, Salò earthquake suggests instead the size of the earthquake that can be considered a "floating" event for the W Southern Alps. This because these kind of earthquakes do not cause easily recognizable primary tectonic effects, nor other extensive ground effects. In other words, with the available data, in the studied tectonic setting there are no clear criteria to associate a crustal earthquake of M5 to 5.5 to a specific tectonic structure. Therefore, because of the similarity of the tectonic structure and the theological conditions in the piedmont belt of the Southern Alps between Lake Garda and Lake Maggiore, it is impossible, at this stage of knowledge, to exclude that an earthquake in that range of magnitude can occur anywhere.