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The Vallo di Diano Range-Bounding Fault-System (Southern Italy): New Evidence of Recent Activity From High-Resolution Seismic Profiling

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1 Introduction. Seismicity and extensional basins in the Southern Apennines: a case study from the Vallo di Diano

The axial portion of the Southern Apennines thrust-belt (Fig. 1) is one of the most active seismic regions in the Mediterranean area. Several earthquakes up to M7 struck the chain in the last two millennia. Present-day crustal seismicity is mainly related to a NE-directed extensional stress-regime. Extension was accomodated by dip-slip and oblique-slip faults which generated, since Lower-Middle Pleistocene, several intermountain basins.

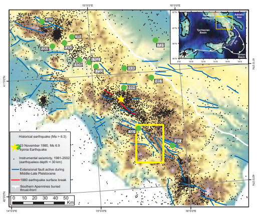

Fig. 1: Historical and instrumental seismicity of the Southern Apennines (Italy). The main inland Quaternary extensional faults are also shown. The yellow box encloses the Vallo di Diano basin (Fig. 2).

The **Vallo di Diano** (Fig. 2) is the largest extensional basin in the Southern Apennines. Its northern sector was struck by a M 6.3 earthquake in 1561. The basin is bounded to the East for more than 35 km by NW-trending, SW-dipping normal and oblique-slip faults (Vallo di Diano Fault System, ***VDFS***). Holocene surface faulting is reported for the northernmost ***VDFS*** segments (*Caggiano Fault*, in: Galli et al., 2006; Fig. 2), while recent activity along the central and southern sets is uncertain.

Commercial seismic lines image the large-scale structure of the basin documenting ***VDFS*** activity up to the Middle Pleistocene (Amicucci et al., 2008). However, shallow imaging of the ***VDFS*** is poor due unfavourable surface conditions and strong lateral heterogeneities along the eastern basin border.

We present high-resolution seismic surveys targeting the basin structure and the shallow structure of the ***VDFS***. Our results yield clues of recent activity along the central segments of the ***VDFS***, with significant implications for its seismogenetic potential.

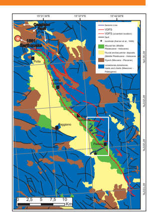

Fig. 2: Geological sketch of the Vallo di Diano basin. White box encloses the study area (Fig. 3).

2 - Purposes and Methods

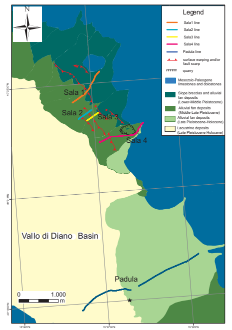

Fig. 3: Geological map of the Vallo di Diano sector targeted by the seismic surveys. Red lines with triangles indicate surface flexures (possible splays of the *VDSF*?).

We acquired 3 high-resolution (HR) and 2 very high-resolution (VHR) profiles on the central segment of the ***VDFS*** (Fig. 3; Table 1), covered by Late Pleistocene - Holocene fan and lacustrine deposits. HR profiles targeted the shallow ***VDFS***, VHR profiles crossed some intringuing flexures identified on Late Pleistocene fans (Figs. 4, 5).

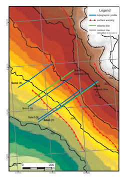

Fig. 4: Details of some flexures affecting a Late Pleistocene fan in the SALA3 survey site.

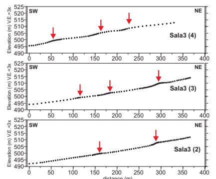

Fig. 5: High-precision topographic profiles across the flexures shown in Fig. 4. Red arrows indicate possible ***VDFS*** surface expression.

A HR Vibroseis was used to acquire all the profiles, with the exception of Sala3 (buffalo-gun). We combined reflection techniques with travel-time tomography, adapting the *dense wide aperture* crustal profiling (Ravaut et al., 2004) to shallow targets. Dense sources were recorded by a wide array of 168 geophones with a good compromise between its aperture (*i.e.* investigation depth) and the receiver interval (*i.e.* model sampling) (Fig. 6 and Table 1). We thus collected both CMP reflection data and highly redundant first P-pulses.

Table 1 - Acquisition Geometry

Seismic Line	Total Length	Shot Spacing	Number of Shots	Receiver Spacing	Receiver spred size	Overlapping spreads
SALA1	1075 m	10 m	100	5 m	168	2
SALA2	405 m	4 m	98	2 m	168	-
SALA3	352 m	4 m	90	2 m	168	-
SALA4	1315 m	10 m	101	5 m	168	2
PADULA	3400 m	10 m	280	5 m	168	5

We built reflectivity images by CDP-processing of reflection data (Fig. 7). First-arrival travel-times were input to a multi-scale, non-linear tomography (Improta et al., 2002) targeting the shallow ***VDFS*** with a gradually increasing spatial resolution. Structural interpretation benefited from the integration of the different approaches.

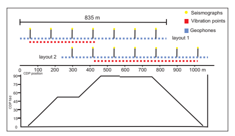

Fig. 6: Pattern of "wide aperture" acquisition geometry and relative CDP folding (SALA1, SALA4 and PADULAl lines). Two overlapping receiver spreads are illustrated. The maximum CDP fold is 90.

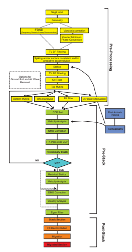

Fig. 7: Indicative processing flow used for our data.

3 - Seismic imaging of the VDFS along the eastern border of the Vallo di Diano

SALA1 HR profile

Vp and reflectivity images for SALA1 profile (Figs. 8, 9) depict at least two main stacked alluvial fan generations that sit atop the carbonate bedrock. The ***VDFS*** shows several splays in a 600 m wide deformation zone. They displace both Mesozoic bedrock and Late Pleistocene deposits, causing their noticeable back-tilting.

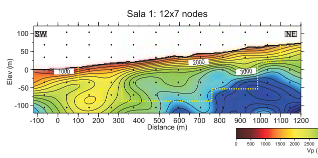

Fig. 8a: SALA1 Vp long-wavelength model. The yellow line outlines resolution depth (estimated by checkerboard tests).

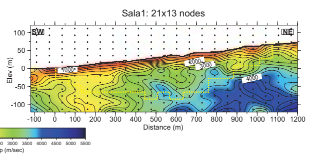

Fig. 8b: SALA1 Vp short-wavelength model. The yellow line outlines resolution depth.

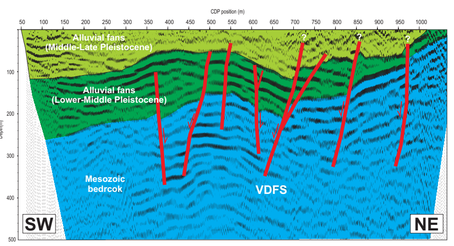

Fig. 9: SALA1 depth-converted, migrated stack-section with simplified structural and stratigraphic interpretation.

SALA4 HR profile

SALA4 profile was acquired with a crooked geometry close to a quarry exposing faulted Late Pleistocene fan deposits (Figs. 10, 11).
The resulting stack section (Fig. 12) depicts a complex array of faulted alluvial fan generations covering the Mesozoic bedrock.

Fig. 10: Aerial view of SALA4 crooked line (X and Y coordinates in m). The yellow dashed line is the acquired profile. The red line is the processed profile. The pale blue area includes real midpoints. The yellow area is CMP bin area.

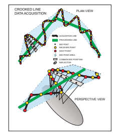

Fig. 11: Schematic 2D crooked-line profiling. (a) plan view, (b) a segment of (a) and a cross-line dipping reflector shown in a perspective view. The crooked profile is exaggerated for clarity (see Nedimovic and West, 2003).

The stack section (Fig. 12) clearly images the internal architecture of alluvial fans (progradations foresets outlined by black arrows) and their noticeable vertical displacement due to ***VDFS*** activity. Here, the ***VDFS*** fault zone is about 500 m wide.

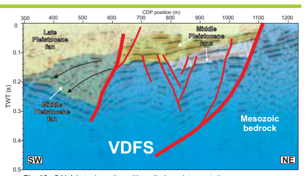

Fig. 12: SALA4 stack section with preliminary interpretation.

SALA3 VHR profile

The very-high resolution profile SALA3 was specifically designed to investigate surface flexures possibly relatable to ***VDFS*** recent activity (see also Figs. 4, 5)

Vp models show strong lateral changes (Fig. 13) around 250 and 280 m, which outline steps in the carbonate bedrock (Vp > 4000 m/s) and in the overlying alluvial fans (Vp=2000-3000 m/s). The steps suggest normal-faulting activity and well correspond upward to soft and thick bodies (Vp < 1000 m/s) resembling *colluvial packages* or entrapped sediments in the fault hangingwall.

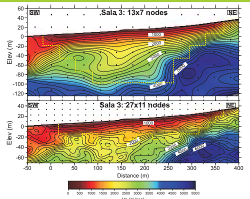

Fig. 13. (top panel) Vp long-wavelength model; (bottom panel) Vp short-wavelength model. The yellow dashed line outlines resolution depth.

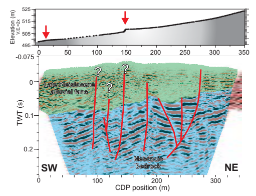

Fig. 14. (Top panel) High-precision topographic profile along SALA3 (arrows indicate surface flexures; V.E.= 2x; see Fig. 5). (Bottom panel) stack-section (datum at 490 m a.s.l.).

The stack section, together with the Vp images, strongly supports recent activity of the ***VDFS***. Several fault splays displace both the bedrock and alluvial fans. A normal-fault positioned at 280 m also cuts near-surface horizons. This fault well matches high-Vp steps and a rapid thickening of near-surface soils illuminated by tomography. Diffractions at CDP positions 100 m and 120 m indicate possible faulting of shallow layers, as suggested by surface flexures.

4 - Seismic imaging of the Vallo di Diano Basin: PADULA line

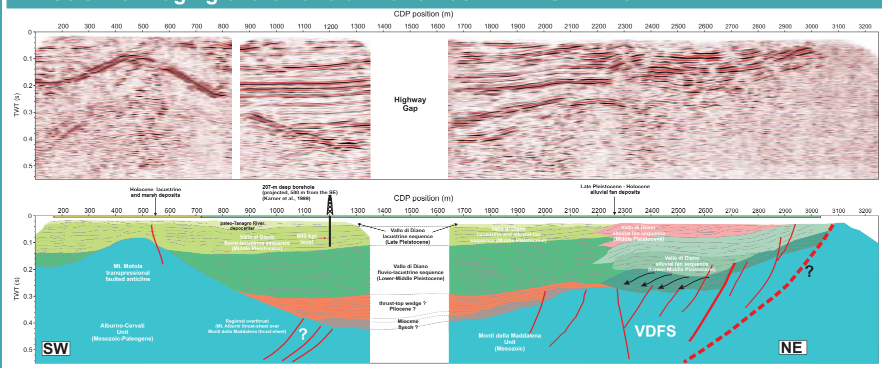

Fig. 15. (Top panel): stack-section of PADULA line; very good-quality and significant signal was recorded down to 0.5 sec TWT. A remarkable acquisition gap is due to crossing highways. (Bottom panel): preliminary structural and stratigraphic intepretation.

Our preliminary interpretation (Fig. 15) is based on field and literature data, together with few chronostratigraphic constraints (a 207 m deep well analyzed by Karner et al., 1999).
We relate the deepest sedimentary bodies to a Pliocene (?) thrust-top wedge (pre-dating ***VDFS*** generation) and possibly Miocene flysch overlying folded Mesozoic cabonates.
Clear internal architecture of Pleistocene stacked alluvial fan generations is imaged on the eastern basin border (progradation outlined by black arrows).
The ***VDFS*** shows several synthetic-antithetic splays in a about 0.8 km wide fault zone. It is moreover responsible for the syn-sedimentary thickening of the Lower-Middle Pleistocene fluvio-lacustrine and alluvial fan sequence filling the basin. Possible splays reaching very shallow structural levels are found at CDP positions 2900 m, documenting recent ***VDFS*** activity.

5 - Summary and Conclusions

High-resolution seismic surveys in the Vallo di Diano basin provide new constraints on its structure and tectonic evolution:
- The Vallo di Diano basin origin pre-dates Pleistocene extension in the Southern Apennines belt axis (*i.e.*: the ***VDFS*** is superimposed on a pre-existing thrust-top basin)
- The central segment of ***VDFS*** consists of several shallow splays defining a 0.5-0.8 km wide fault zone
- The ***VDFS*** displaces Late Pleistocene alluvial fans, but recent sediments seal most of fault splays
- The VHR profile SALA3 shows clues to very recent (Holocene) surface faulting
- This study proves the recent activity of the central segment of the ***VDFS***

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