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Constraints from Moho geometry and crustal thickness on the geodynamic origin of the Vrancea Seismogenic Zone (Romania)

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Abstract

Reprocessing of industry deep seismic reflection data (Ramnicu Sarat and Braila profiles) from the SE Carpathian foreland of Romania provides important new constraints on geodynamic models for the origin of the intermediate depth Vrancea Seismogenic Zone (VSZ). Mantle (70–200 km) earthquakes of the VSZ are characterized by high magnitudes (greater than 6.5), frequent occurrence rates (approximately 25 years), and confinement in a very narrow ($30\times70\times200\,km^3$) near vertical zone atypical for a Wadati–Benioff plane, located in front of the orogen. These two deep (20 s) seismic reflection profiles (70 km length across the foreland) reveal (1) a high-amplitude, gently east-dipping reflection across most of the section from what we interpret to be the Moho at ~15 s (40–42 km) on the Ramnicu Sarat line to ~16 s (47–48 km) on the Braila line, (2) a thick sedimentary cover increasing in thickness from east (1 s; ~800 m) to west (7.5 s; 14 km), (3) an eastward increase in crustal thickness from 38 km (near VSZ) to ~45 km, (4) seismic and topographic evidence for a newly imaged, possibly seismically active basement fault with a surface offset of 30 m observed on the Ramnicu Sarat line, (5) a lack of notable west-dipping structures in the crust and across the Moho, and (6) variable displacements on Peceneaga–Camena Fault of ~5 km at Moho and ~200 m at the basement–sedimentary cover contact.

These observations appear to argue against recent models for west-dipping subduction of oceanic lithosphere at or in the vicinity of the Vrancea Seismogenic Zone given the lack of west-dipping fabrics in the lower crust and across the crust–mantle boundary. Consequently, one possible explanation for the geodynamic origin of VSZ could be partial delamination of the continental lithosphere in an intra-plate setting along a sub-horizontal lithospheric interface in the Carpathian hinterland that likely involves remnant lithospheric coupling between the crust and uppermost mantle in the foreland.

Keywords: Focsani Basin; Crustal thickness; Moho; Vrancea; Delamination

1. Introduction

One of the most intriguing aspects of the SE Carpathians of Romania is the significant concentration of intermediate depth (down to 220 km) earthquakes in an extremely narrow volume. Two industry deep seismic reflection lines acquired in the Focsani Basin in front of the SE Carpathians bend and to the east of the Vrancea Seismogenic Zone (VSZ) of Romania were reprocessed in an attempt to elucidate the mid to lower crust and uppermost mantle structure some ~50 km eastward from the locus of mantle seismicity. These lines were recorded down to 20 s TWTT in the Focsani

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Basin as part of the Romanian petroleum exploration activities (Fig. 1).

Under the framework of plate tectonics, mantle earthquakes are understood and explained by subduction of brittle, dense oceanic lithosphere underneath oceanic or continental lithosphere (Isacks et al., 1968), with earthquake hypocenters aligning along Wadati–Benioff planes that mark the subducting slab. Bird, in 1979, proposed delamination as an alternate mechanism for generating mantle earthquakes in an intraplate setting, that do not align on a Wadati–Benioff plane. Delamination is thought to be caused by gravitational instability of over-thickened lithosphere that detaches along a horizontal interface in the lithosphere and sinks into the mantle.

Situated within the 110° bend region of the Southeastern Carpathians, the VSZ represents one of the most active seismic areas in Europe and its yet unclear nature and mechanisms for mantle earthquake generation motivate significant scientific interest. While there have been a number of comprehensive studies on the VSZ and the SE Carpathian foreland (Matenco, 1997; Tarapoanca et al., 2003), these studies have yet to examine the relationship between crustal deformation in front of the Carpathian bend and the VSZ. The foreland Focsani Basin is the site of wide spread low magnitude (<5.5) crustal seismicity and exhibits active subsidence (Radulescu et al., 1996). Documented (Oncescu and Bonjer, 1997) crustal seismicity occurring over a much broader region ($150\times200\times45\,km^3$) in the SE Carpathian foreland, has not received due attention despite the fact that it is both vertically (~25 km gap) and horizontally (50–100 km) offset eastward from mantle seismicity. The relationship between crustal structures related to basin evolution (especially neo-tectonic structures) to mantle structure and seismicity poses an important and significant geodynamic problem. Foreland deformation at the crustal scale suggests a geometric association with the Vrancea mantle source region, implying a mechanical coupling of the Vrancea seismogenic body with the overlying crust (Knapp et al., 2003).

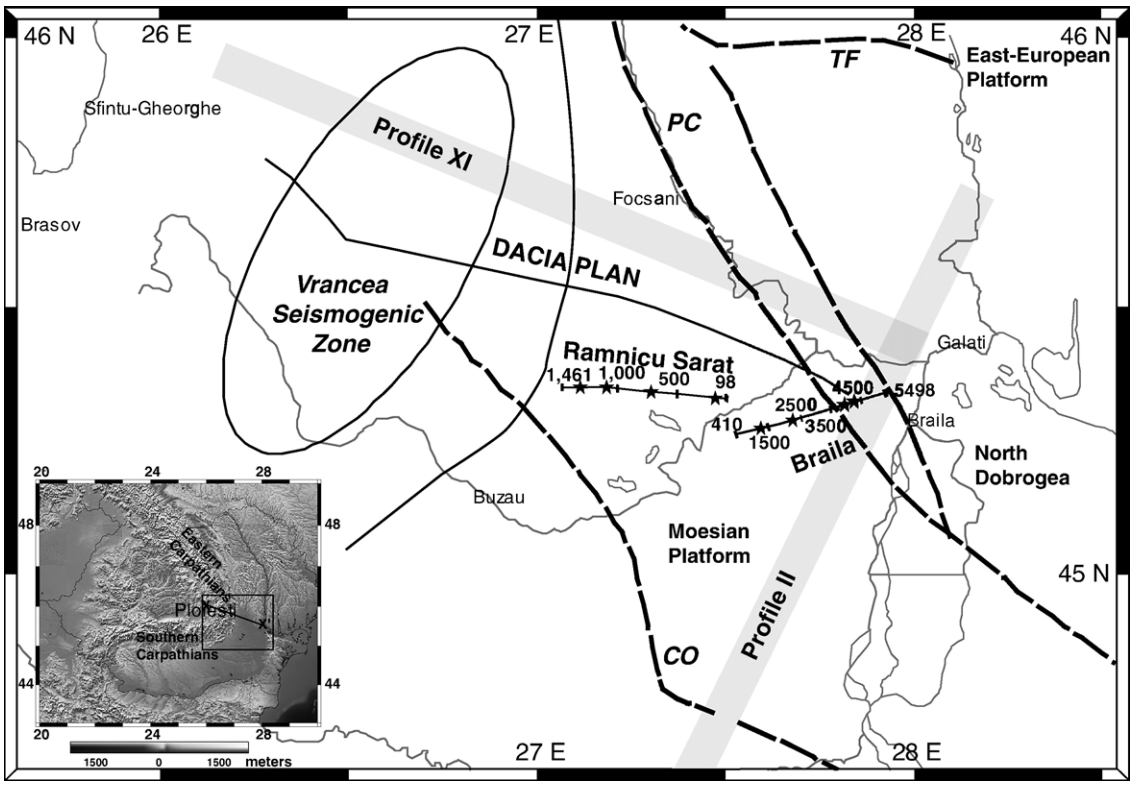

Fig. 1. Location map showing tectonic setting of the Vrancea Seismogenic Zone (VSZ) and location of (1) the Ramnicu Sarat and Braila deep reflection lines, (2) DACIA PLAN seismic reflection profile and (3) refraction profiles XI and II (after Pompilian et al., 1993). CO: Capidava–Ovidiu fault, PC: Peceneaga–Camena fault, TF: Trotus Fault. Inset shows location map of Southern and Eastern Carpathians within the territory of Romania; X–X′ line shows position of cross-section in Fig. 7; box shows location of study area; stars show position of amplitude decay analysis performed in Figs. 2b and 3b; numbers represent CDPs.