Lithosphere-scale imaging of the Romanian Carpathians: New approaches with the PASSCAL instrument pool

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The Vrancea zone of Romania constitutes one of the most active seismic zones in Europe, with high recurrence rates (~10 years) of strong (M_b>7.0), deep (70-200 km), volumetrically confined (30x70x200 km) mantle earthquakes. Two primary competing theories to explain this unusual distribution of mantle seismicity involve either (1) active subduction of a remnant oceanic slab, or (2) delamination of a thickened lithospheric root within the bend region. Constraints from existing geological and geophysical data for differentiating these mechanisms are ambiguous. While the weight of scientific opinion continues to favor an oceanic slab model for generation of Vrancea seismicity, constraints from existing geological data suggest this explanation is untenable, and favor a delamination origin. Passive-source seismological studies targeted on the mantle source region of the Vrancea zone have not successfully resolved this geodynamic conundrum, and are not likely to. Critical to substantiating or refuting the subduction model are (1) illumination of the crustal structure within the Carpathian hinterland, beneath the purported suture zone, and (2) documentation of mechanical coupling of mantle seismicity to active crustal-scale faults within the Carpathian foreland. Despite several recent active-source seismic experiments in the region, high-resolution crustal-scale data on these key targets are still lacking. It is only with such data that the Vrancea zone may prove to be a unique setting in which to establish evidence for active lithospheric delamination.

Through National Science Foundation (NSF) funds, ~260 km of deep seismic reflection data, in two orthogonal profiles will be acquired as part of a multinational collaboration to study the lithospheric structure and geodynamic setting of the Vrancea seismogenic zone of Romania. Project DRACULA (Deep Reflection Acquisition Constraining Unusual Lithospheric Activity), to be carried out with the University of Bucharest and the National Institute for Earth Physics in Romania, will employ deep seismic reflection techniques to (1) map the main structural detachment(s) of the Eastern Carpathians, and their westward continuation into the hinterland, (2) provide reliable constraints from the geometry of crustal reflectors on the postulated existence, position, and polarity of a Miocene-age subduction zone within the Transylvanian crust, (3) elucidate the geometric relationship between active faults in the Carpathian foreland and the seismogenic volume in the mantle, in order to (4) test the hypothesis of mechanical coupling of the foreland crust with Vrancea seismicity, and ultimately, (5) evaluate competing subduction/delamination geodynamic models for the origin of mantle seismicity in the Vrancea zone based on these results.

Our experimental design for *Project DRACULA* is based directly on experience from *Vrancea 2001*, a pilot deep seismic reflection profile acquired in the vicinity of the Vrancea zone as a multinational collaboration among ISES (Netherlands Center for Integrated Solid Earth Sciences), the University of Karlsruhe (Germany), the University of Bucharest (Romania), the University of South Carolina, and the University of Texas at El Paso. Central to the economy and efficiency of this experiment was the use of 600 Texan seismometers in two static-spread deployments. The acquisition of *Vrancea 2001* was based on coordination with the co-located wide-angle reflection/refraction transect (Fig. 1). A 100 m station spacing resulted in a 50 m midpoint interval, which was coarser than standard near-vertical acquisition, but still afforded sufficient resolution for imaging of shallow structures. A two-person team was able to deploy ~30 instruments in a day, so a total of 20 crews and 10 days were budgeted per deployment for setting out, recording, and picking up the instruments. The entire field experiment took a little over three weeks. Sources consisted nominally of 25 kg shots in 25 m holes at 1 km intervals, and were recorded to 90 s TWT at a 5 ms sample rate. While these shot sizes may seem small for crustal-scale imaging, results from the Vrancea 2001 experiment indicate that coherent reflections can be imaged at these travel times with 20 kg shots (Fig. 2). Significant strengths of this approach were (1) the novel use of a common set of statically positioned instruments for both the near-vertical and wide-angle recordings, and (2) the extension of the new seismic reflection transect in both the foreland and hinterland basins with the existing deep seismic profiles. This proposed experimental design translated to a substantial economy for acquisition of near-vertical reflection data, and a dramatic reduction in field time. The acquisition cost (including all field expenses) was below \$700/km, or less than 1/10th the cost of traditional land-based seismic surveys contracted through industry crews. In addition, this approach offered the possibility for both graduate and undergraduate students to fully participate in the field acquisition as a valuable learning experience in geophysical techniques.

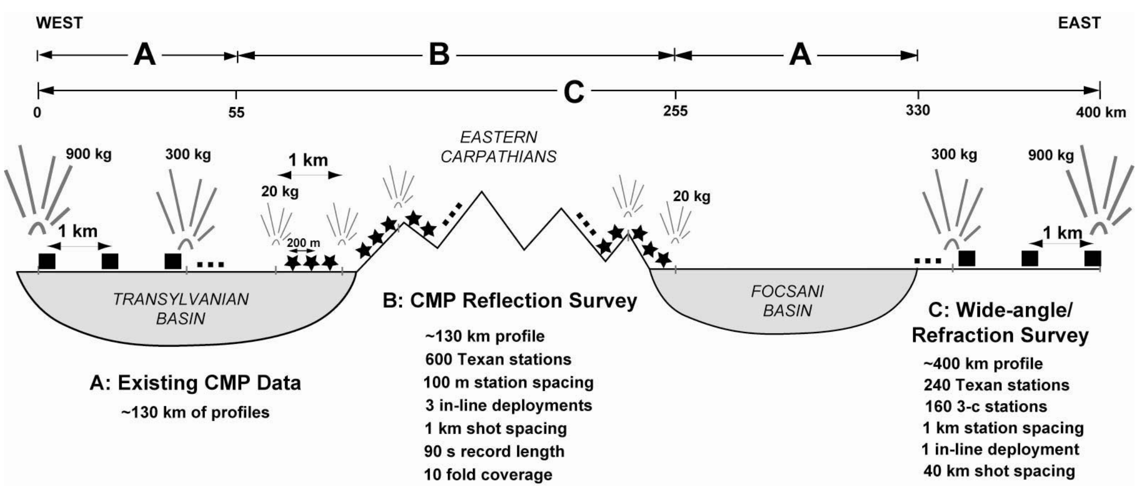

Figure 1. (top) "Texan" seismic recorders used in the "Vrancea 2001" deep seismic reflection/refraction acquisition; (bottom) Acquisition scheme for combined near-vertical Vrancea 2001, and wide-angle reflection/refraction profiles.

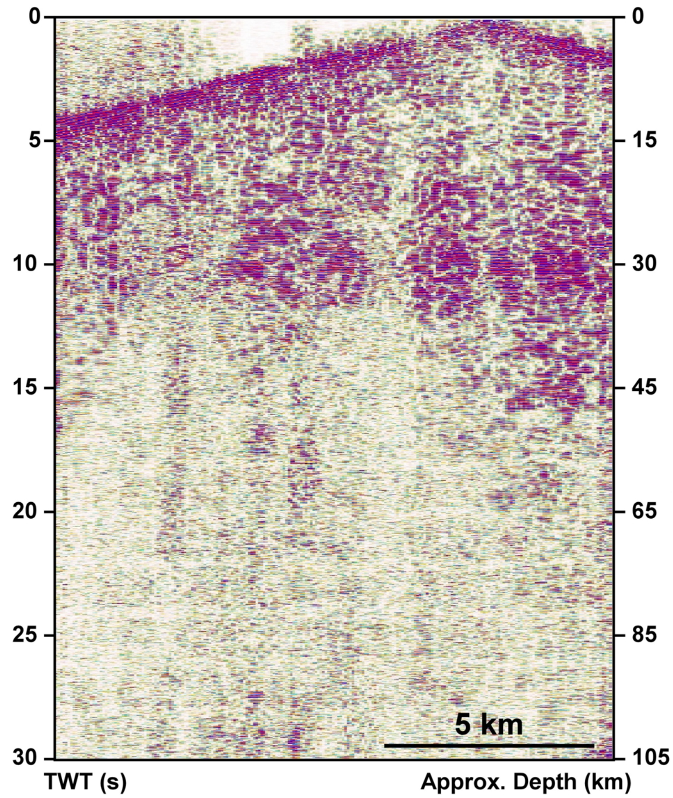

Figure 2. *Shot gather (25 kg) from western portion of Vrancea 2001 reflection profile, showing abundant sub-horizontal mid- and lower-crustal reflectivity directly above the Vrancea zone, inconsistent with foreland subduction.*

Preliminary results from the *Vrancea 2001* wide/angle reflection/refraction and near-vertical reflection transect in the vicinity of the Vrancea zone show little if any evidence for subduction related structures. More particularly, these data indicate (1) strong reflectivity throughout the crust (and perhaps some sections of the upper mantle), and (2) subhorizontal layering throughout the foreland basin, as well as the area directly above the Vrancea zone. Although not clearly defined in the near-vertical reflection data, the Moho appears to occur across a subhorizontal boundary at ~45 km depth. The lack of a clearly defined reflection Moho in these data may suggest that in fact, this boundary has been superimposed by a metamorphic phase change within the orogenic root to higher density eclogite facies rocks. While these preliminary results are still highly speculative, critical high-resolution reflection data on the crustal structure beneath the purported suture in the Transylvanian hinterland are still lacking, and these data will be collected in the Summer of 2004 as part of *Project DRACULA*. The integration of these new reflection data with results from co-located deep seismic refraction experiments (*Vrancea 2001* and existing industry lines), will provide a full ~330 km transect that will image the entire southeastern Carpathian orogen from the eastern extent of the Focsani basin to the western side of the Transylvanian basin.