MODELING OF CROOKED-2D SEISMIC ILLUMINATION - A CASE STUDY FROM ROMANIA

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Abstract. In most of the deep seismic reflection and refraction surveys, the data acquisition is performed using irregular receiver and source spacings, due to the field conditions. In this study, I analyzed a field seismic reflection dataset recorded along a crooked profile that crossed the southeastern Carpathians (the Vrancea zone). The seismic section, obtained after the data processing, is clean, without clear reflections.. The finite-difference and the ray-tracing modelings were used to explain the lack of reflections on the seismic section. Both types of modeling were performed along straight and crooked profiles. The geometry for straight line is regular, meaning geophones spaced at 100 m and sources spaced at 1000 m. The geometry for crooked lines was defined using the field receiver and source (x,y)-coordinates. The velocity model used in modeling was build using the velocities obtained after the inversion of the first-arrival travel-times picked on the field records. The finite-difference modeling showed that the irregular geometry and complex geology affect the continuity of the reflections on the seismic sections. The ray-tracing modeling showed that the non-uniform seismic illumination is due to more the complex geology of the subsurface than the irregular geometry.

Key words: deep seismic reflection, processing, finite difference, ray tracing

INTRODUCTION

Seismic reflection and refraction surveys are used to image the geological structure of the subsurface. In general, the receiver spacing is very irregular in the deep reflection and refraction surveys. The accuracy of some processing processes (frequency filtering, interactive velocity analysis, migration) is influenced by the errors introduced during the seismic data acquisition, such as irregular receiver and source spacing, generation of seismic energy at smaller depths than designed, etc (Panea *et al*., 2005).

In this study, I analyze the effect of complex geology, irregular receiver and source spacing on the continuity of the reflections. I also used ray-tracing modeling to identify which parts from the geological interfaces are well illuminated. The modeling was done using the finite-difference method (FDM), a complex velocity model and field data acquisition geometry. The velocity model is built using the velocity model obtained after the inversion of the first-arrival travel-times picked on the field records (Bocin *et al*., 2005).

DESCRIPTION OF THE ANALYZED FIELD SEISMIC DATA

The deep seismic reflection dataset used in my study, Dacia Plan (DP), was recorded as part of an international collaboration between the University of Bucharest and the Netherlands Research Centre for Integrated Solid Earth Sciences (ISES), represented by the Delft University of Technology and VU University of Amsterdam, the Romanian National Institute for Earth Physics, University of South Carolina. The DP profile crossed the southeastern Carpathians and the Focsani Basin (Fig. 1). The seismic data were recorded along a crooked profile of about 140 km length, with a WNW-ESE direction (Fig. 1).

The seismic energy was generated using 25 kg dynamite/shot point. The source spacing was about 1 km and the receiver spacing was about 100 m. The data acquisition was performed on three overlapped segments along the profile, in order to provide a minimum fold higher than zero. The number of receivers was different on each segment (334, 637 and 632). The field records used in my study were obtained

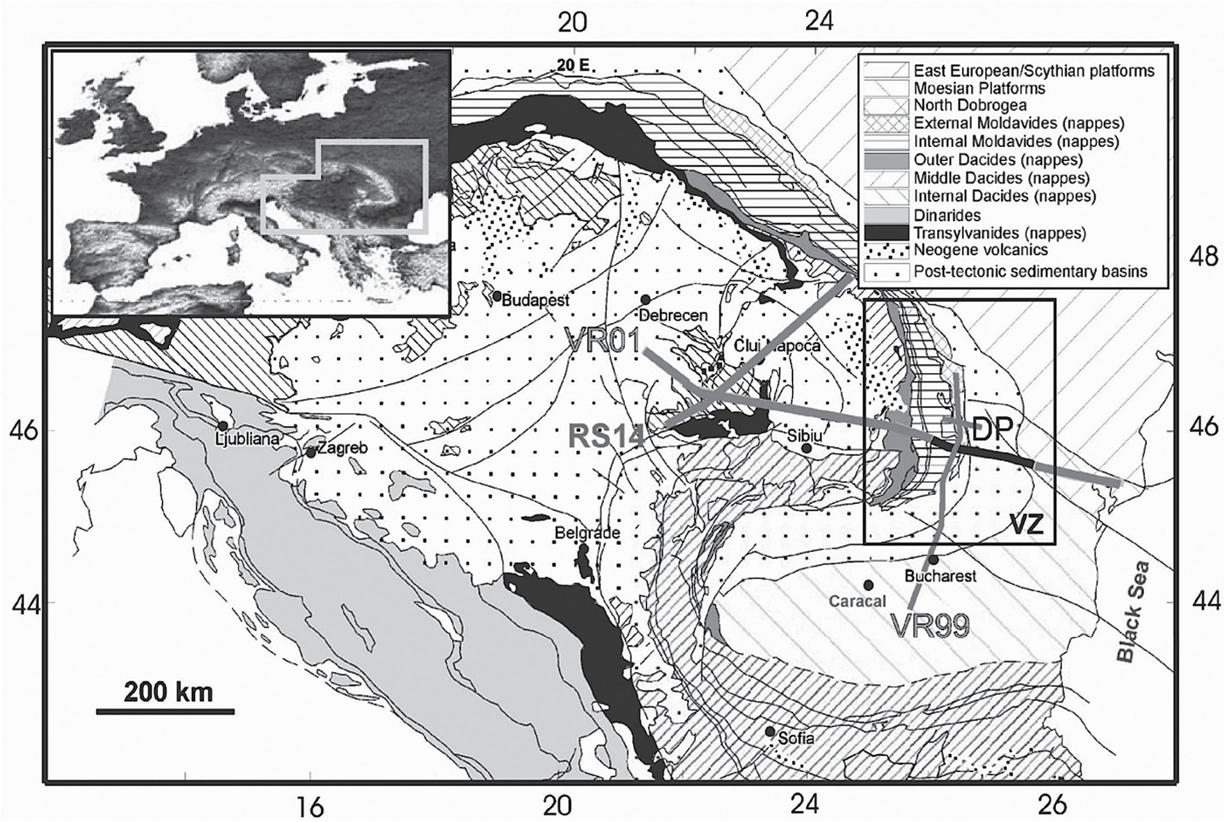


Fig. 1. Tectonic map of the Carpathians/Dinarides/Pannonian Basin system in southeastern Europe showing setting of the deep reflection (DP) and deep refraction (VR99, VR01, RS14) seismic profiles; VZ – Vrancea earthquake zone (modified after Sandulescu, 1984).

using 637 receivers/shot point, and cover the contact area between the Carpathians and the Focsani Basin (Fig. 2). The time sampling interval was 5 ms. The record length was 90 s.

The entire DP dataset was processed to obtain a migrated seismic section. Examples of raw field records are presented in Panea et al. (2016). The elevation varies from 1240, in the mountainous area, to 50 m, toward the end of the DP profile, in its ESE part. The crooked-line geometry was defined using a bin size of 50 × 4500 m. Static corrections were computed and applied to 0 m. The signal-to-noise ratio (S/N) was enhanced using band-pass frequency filter and fx deconvolution. The interactive velocity analysis was performed using the velocities obtained after the inversion of the first-arrivals travel-times picked on the field records as guidance velocities. The migrated seismic section is clean, without clear reflections, in its central part that covers the contact area between the Carpathians and the Focsani Basin. Their absence may be due to the complex geology and irregular source and receiver spacing used for data acquisition (Panea et al., 2016).

ANALYSIS OF SYNTHETIC SEISMIC DATA

Seismic modeling was used to create a synthetic image of the seismic section. The modeling was done for linear and crooked profiles, using a velocity model obtained after the inversion of the first-arrival travel-times picked on the field records and the field source and receiver coordinates. The synthetic shot gathers were obtained in three steps. First, we created shot gathers which contain a number of traces equal with that one used in the field for data acquisition. Then, we loaded the geometry defined for straight and crooked lines. After that, the gathers with geometry loaded were used as input data to FDM. I modeled 47 shot gathers with 637 traces/shot. The straight-line geometry was defined for a receiver spacing of 100 m and a source spacing of 1000 m. The modeling was done in the absence of variations in elevation, at the final datum of 0 m, because I was not interested to analyze the effect of the rough topography on the wave propagation. The crooked-line geometry was defined using the field (x,y)-coordinates for receivers and sources. The binning was done using the same trajectory of the seismic profile as the one used for the field data processing, with a bin size of 50×4500 m. The synthetic shot gathers obtained for straight and crooked lines were processed to obtain migrated synthetic sections which would show us the effect of irregular receiver spacing on the wave propagation (Fig 3a,b). Comparing the migrated seismic sections, we notice that the continuity of the reflections is interrupted on the seismic section with crooked-line geometry (Fig 3b).

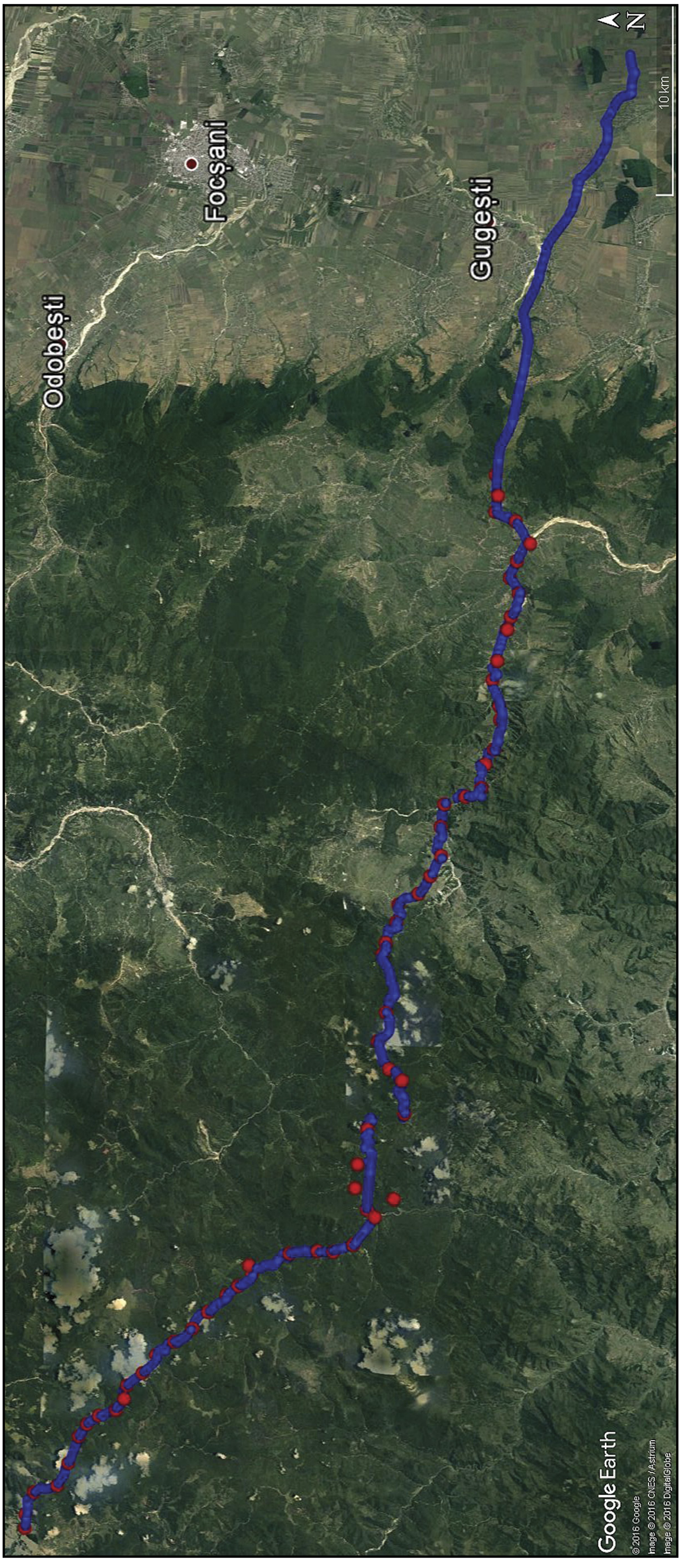


Fig. 2. Map showing the positions of the receivers and sources on the seismic profile; blue – receivers, red – sources. Source map: http://maps.google.com.

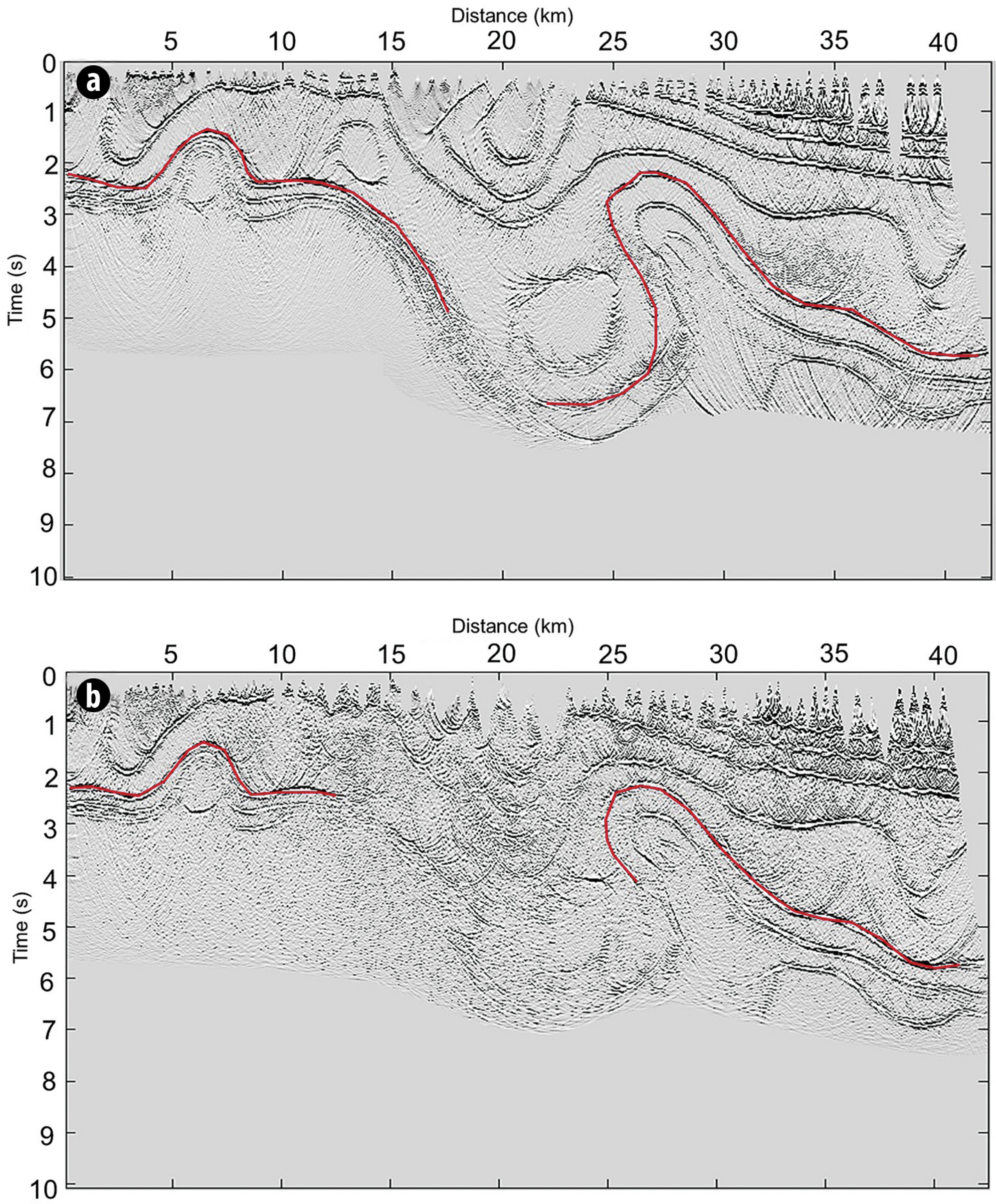


Fig. 3. Seismic sections obtained from snthetic records modeled using FDM for (a) straight and (b) crooked profile. Red line-geological interface analyzed using Ray Tracing method.

The ray-tracing modeling was used to identify which parts from the geological interfaces are well illuminated using the field data acquisition geometry. The crooked-line geometry was build using the field (x, y)-coordinates for sources and receivers. The straight-line geometry was defined for a receiver spacing of 100 m and a source spacing of 1000 m. The modeling was done for 637 receivers and 47 sources. I display in Fig 4a,b the rays that hit the analyzed interface for the same shot point, but with straight-line and crooked-line geometries .

Next, I processed the synthetic records to obtain time seismic sections (Fig 5a,b). Modeling results show that the lack of reflections on the field seismic section can be a result of complex geology in the subsurface (Fig 5a,b).

CONCLUSIONS

I used seismic modeling to analyze the lack of the reflections on the field seismic section obtained after the processing of a dataset recorded along a crooked profile in the south-eastern Carpathians (Romania). The subsurface geology is very complicated because the seismic data were recorded in the contact area between the mountainous area and the Focsani Basin. The FDM showed that the irregular geometry affects the continuity of the reflections seen on the seismic sections. The ray-tracing modeling showed that the seismic illumination is less affected by the crooked-shape of the profile and it is strongly affected by the complex geology of the subsurface.

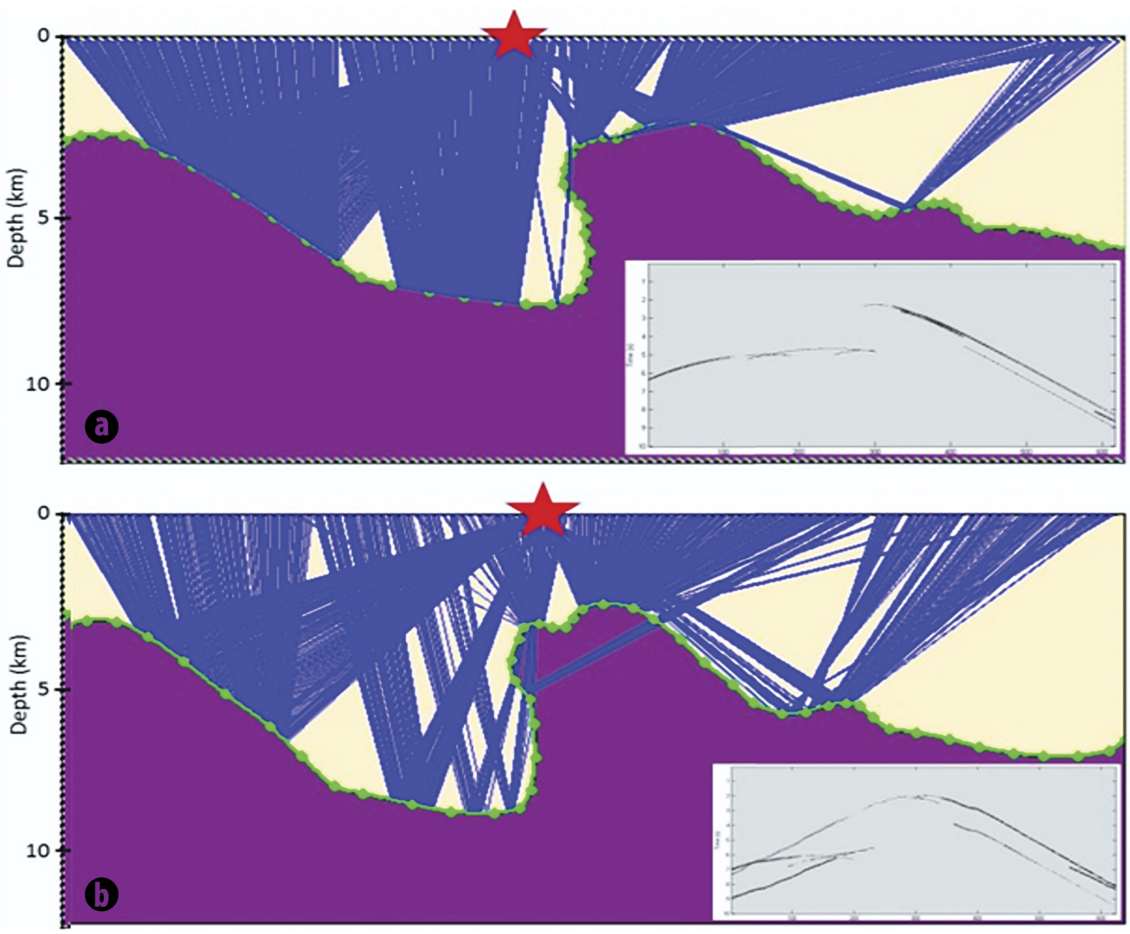
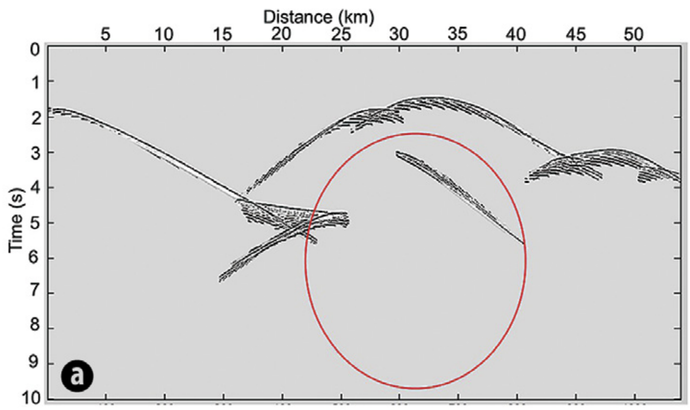


Fig. 4. Rays for (a) straight and (b) crooked profile. Rectangle – synthetic record. Star – shot point.



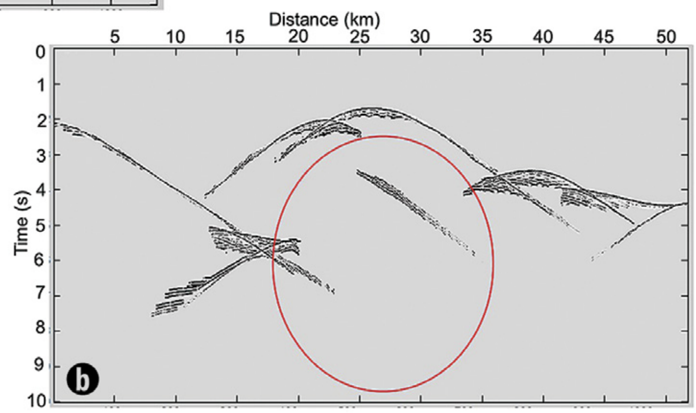


Fig. 5. Time seismic sections obtained from synthetic records modeled using ray tracing for (a) straight and (b) crooked profile. Red circle – poor seismic illumination.

ACKNOWLEDGEMENTS

The author thanks Dr. I. Panea (University of Bucharest) and Stefan Prisacari (Tesseral Technologies Inc.) for their support in the performing of this study.

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