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CRS imaging of 3-D seismic data from the active continental margin offshore Costa Rica

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Summary

The macro-model independent CRS imaging technique has proved to produce superior images in various 2-D seismic case studies. However, presently available 2-D CRS software allows imaging of 3-D marine datasets which are based on a 2-D acquisition geometry. Following this strategy, a line-by-line CRS imaging is carried out for a 3-D marine dataset from the active continental margin offshore Costa Rica. The CRS processing aims at enhancing the image of the slope sediments and deeper crustal structures.

Introduction

During the last decades, the continental margins have increasingly appeared in the focus of economic exploitation. Besides oil and natural gas, there are as well gas hydrates and mineral resources increasingly appearing in the focus of interest. The intensified exploitation of the continental margins, however, requires better estimates of the natural risks. Devastating earthquakes and volcanic activities mainly threaten the active continental margins. Unstable sediment layers on the continental slopes may slide downhill and destroy technical installations in the marine environment as well as send devastating flood wave to the coasts. A precise investigation of the subsurface risk zones is required in order to localize danger areas and to limit the risk.

The 3-D reflection seismic method plays an important role in the reconnaissance and exploration of the continental margins. This has strongly focussed the scientific and industrial efforts on the development of new processing methods that increase the resolution of 3-D seismic data. Among the recent advances in seismic imaging, the CRS stacking technique has demonstrated superior imaging in various 2-D case studies. This paper presents the advantages of CRS imaging in the case of a 3-D marine seismic data from the active continental margin offshore Costa Rica.

Increased information by the Common-Reflection-Surface technique (CRS)

Today’s efforts towards an improved evaluation of seismic data are directed at an increased resolution, realistic imaging, more exact velocity models, and possibilities to derive further subsurface parameters. These kinds of improvements were achieved for 2-D seismic data by the CRS imaging method, which has been developed by the research group Hubral et. al. (e.g. Hubral, 1999) at the University of Karlsruhe, Germany, and has successfully been applied in various projects (e.g. Trappe et. al., 2001).

The CRS or Common-Reflection-Surface technique (Jaeger et. al., 2001) follows the strategy of a macro-model independent imaging (Hubral, 1999). Unlike the horizontal-layering assumption of conventional NMO stacking, the CRS technique implies a subsurface with reflectors of arbitrary dip and curvature. In accordance with this complex model assumption, the reflections from a subsurface element are not constrained to the seismic traces of a constant CMP position, but are distributed across several CMPs. As a consequence, the CRS techniques involves stacking along reflection time surfaces that extend over several CMP locations. This again contrasts with the NMO/DMO technique, where stacking follows the hyperbolic reflection time functions at exactly one CMP location.

The different strategy of the CRS method implies the following advantages, which have previously been encountered in 2-D applications:

- High signal-to-noise ratio as a consequence of high CRS fold,

- Enhancement of faults at a general increase of reflector continuity,
- Excellent imaging of dipping and curved reflectors due to explicit incorporation in CRS assumptions,
- Good depth imaging in combination with poststack depth migration,
- Automatic derivation or improvement of a velocity depth model,
- CRS velocities and travel time curves for an improved AVO analysis,
- Additional information from CRS parameters (e.g. the spherical divergence, Fresnel zone).

The presently available 2-D CRS technique may also handle 3-D marine data, which is acquired more or less in a 2-D fashion. The processing of arbitrary 3-D acquisition geometries is a main topic of current CRS development (Hoecht, 2001).

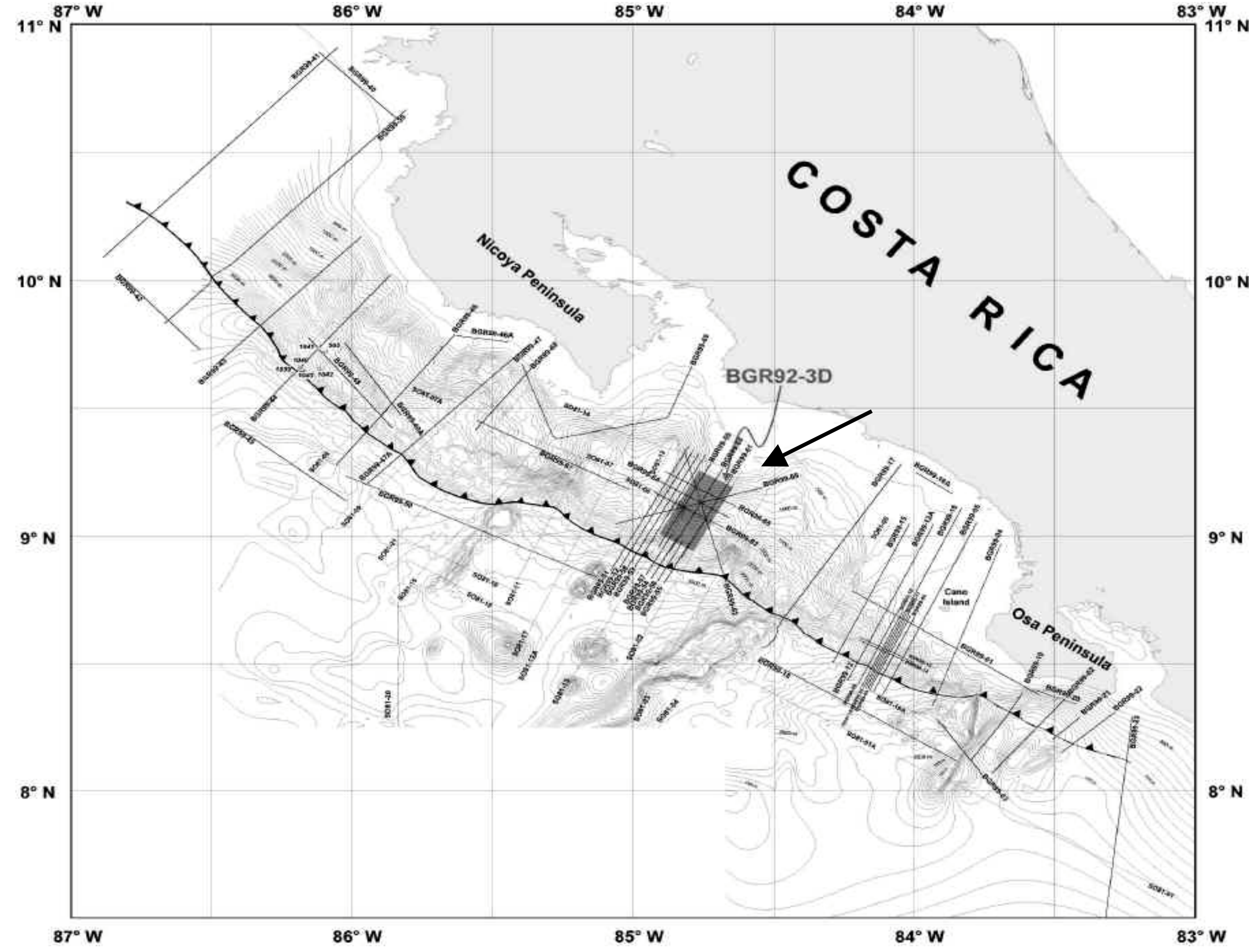

Fig. 1: Location of 3-D survey BGR92-3D (arrow), with 2-D lines by BGR (black: Cruise BGR99, grey: Cruise SO81).

CRS application to 3-D seismic data from the active continental margin of Costa Rica

The active continental margin of Central America shows high complexity. Different types of oceanic crust are subducted and both areas with accreted sediments are observed as well as completely erosive margin areas. Wide parts of the margin are characterized by a wedge-shaped structure with high seismic velocities, which probably serves as an hinge for the downgoing plate.

The active continental margin offshore Costa Rica is in the focus of scientific research since many years (Hinz et al., 1996, Barckhausen et al., 1998). The investigations aim on structure and tectonics, with emphasis on natural risks as earthquakes, and submarine slides. Gas findings at the active continental margin of Nicaragua indicate that further investigations with respect to hydrocarbon reservoirs are promising as well.

The complex structure of this target area motivated BGR (German Federal Institute for Geosciences and Natural Resources) to extend their previous grid of 2-D reflection seismic lines (Figure 1) by a 3-D seismic survey in 1992. The survey area has an extension of 15x30 km2 and covers a part of the wedge-shaped structure, starting from the seaward edge. Previous time and depth processing allowed to solve a wide range of open questions regarding the interpretation. However, several questions still need to be answered:

1. At the edges of data volumes the response of migration operators deteriorates the image. This resulted in an insufficient migration of the edges of the survey, which are partially important for interpretation. The CRS method is expected to provide a crucial decrease of edge effects.
2. The seaward edge of the wedge-shaped structure including the structures in front of it is a key to understand the subduction process. However, their structural composition is so complicated that the macro-model based depth imaging reached its limits. The CRS method promises improved images in this region, since it does not depend on a macro-model.
3. Below the wedge-shaped structure the imaging of the downgoing plate approaches the limits of available migration methods. The long wave path through a complex overburden yields an uncertain velocity model and the signal-to-noise ratio is in wide parts insufficient. Especially here, in the proto-seismogenic zone, the estimation of the quantity of subducting sediments and the determination of the roughness of the downgoing plate are key parameters for the understanding of earthquake mechanisms taking place in the further subduction. The CRS method utilizes all available signal components that illuminate the given reflector element, independent of the trace binning, which may allow a vital improvement of the imaging of the downgoing plate.

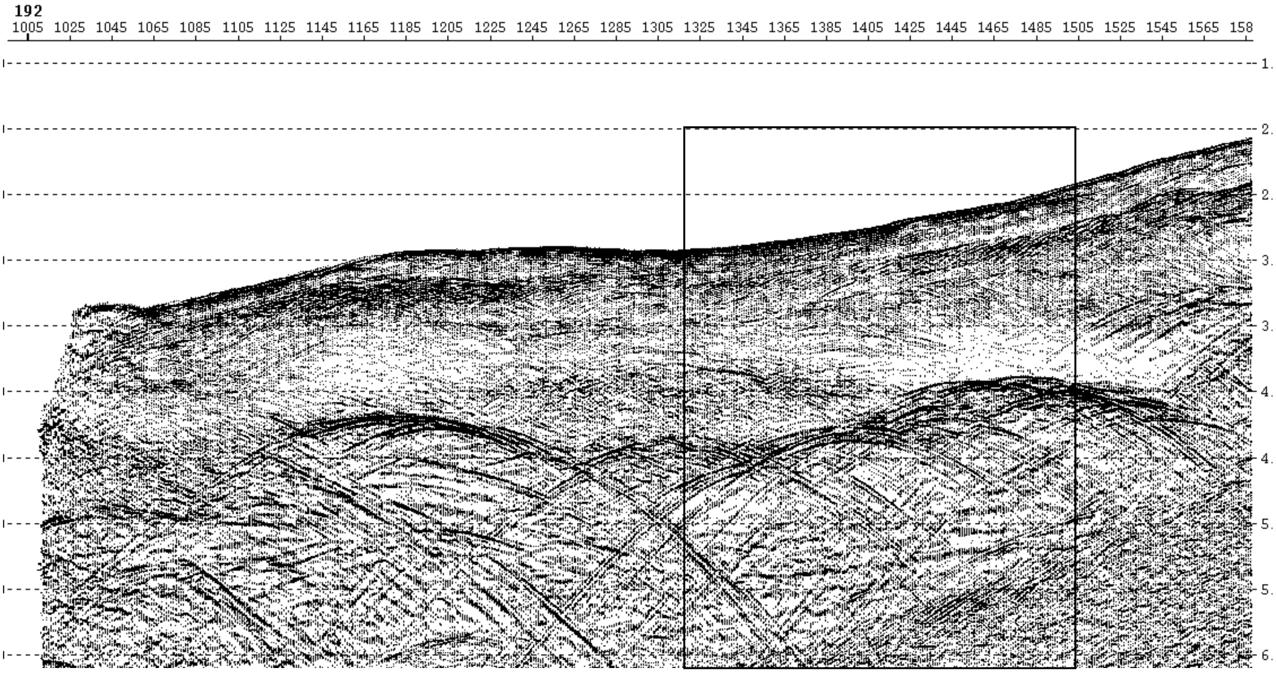

Fig. 2: CRS stack / Inline 192 (with indication of Figure 3 zoom area).

Initial CRS imaging results

Application of the CRS technique to the 3-D marine dataset from Costa Rica has been started on a line by line basis, with some distinct improvements in the data so far processed. As an example, a CRS stack is displayed in Figure 2 for inline 192. For the indicated zoom region of this inline, the NMO and CRS stacks are compared in Figure 3. Signal-to-noise ratio, and resolution of structural details are obviously increased in the CRS stack.

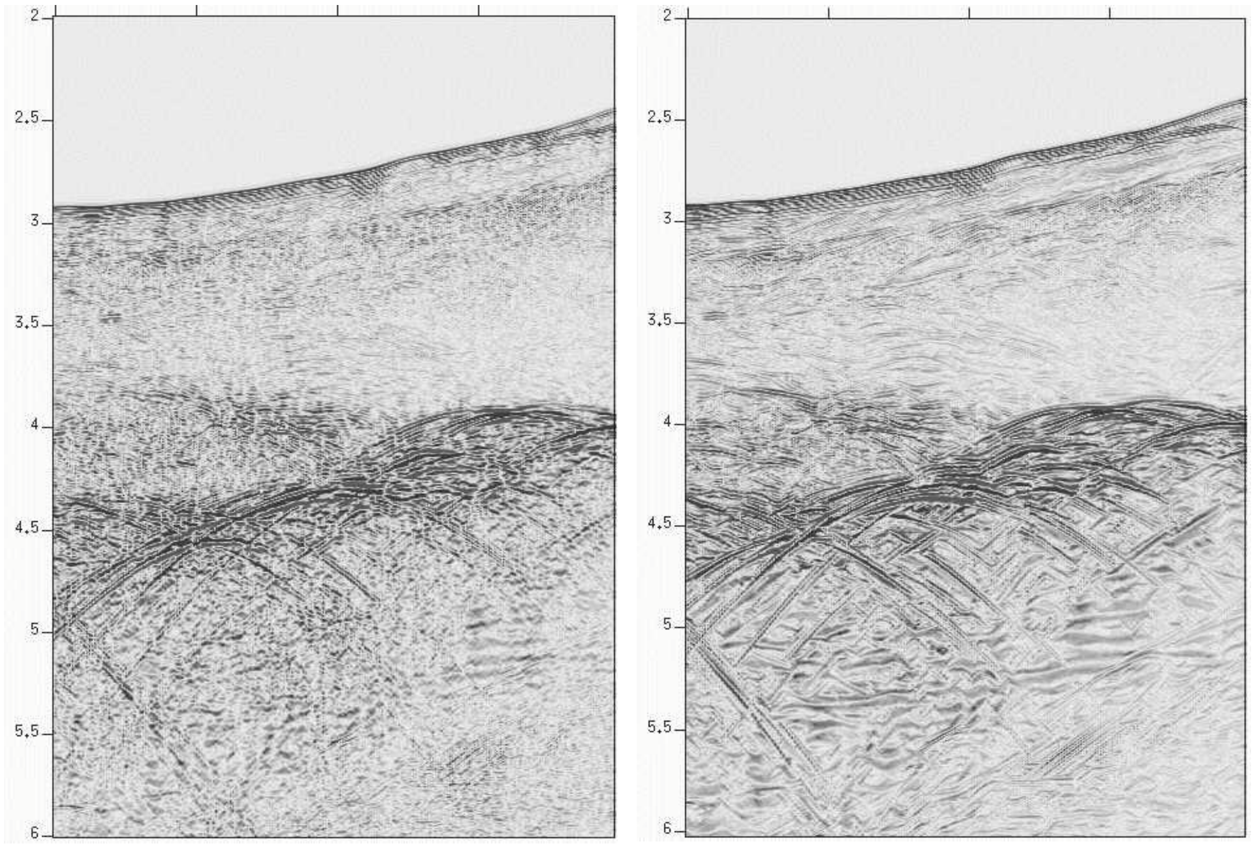

Fig. 3: NMO stack / Inline 192 (zoomed) CRS stack / Inline 192 (zoomed)

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