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Using the OBS wide-angle reflection/refraction velocities to perform a pre-stack depth migration image of the "single bubble" multichannel seismic: example of the Moroccan margin

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Abstract

The SISMAR marine seismic survey acquired over 3600 km of deep seismic reflection profiles on the Atlantic margin of Morocco, one of the oldest on earth. We present here a crustal scale cross section of the Moroccan margin off El Jadida. To penetrate below the salt layer, a nonconventional, low frequency seismic source was used in the "single bubble" mode (4805 in.^{3}), and recorded by Ocean Bottom Instruments (hydrophones and seismometers) and a 4.5-km-long streamer that recorded multichannel seismic (MCS). This profile was also reshot with a conventional reflection seismic source (2369 in.^{3}), in order to evaluate the differences with the single bubble source image. In this study, the single bubble mode source was the best source to image deep structures due to the strong energy produced in low frequency band. In the second part of this study, two velocity models were constructed in order to perform a pre-stack depth migration of the MCS section. The first velocity model was obtained by a depth-focussing error analysis of the MCS data and the second from modelling of the Ocean Botton Seismometer data located along the profile. A comparison of these two velocity models shows 10% higher mean P-wave velocities for the OBS velocity model, probably due to anisotropy. After reducing the OBS velocities by 10%, we show that there are no significant differences between the pre-stack depth migration images obtained by using MCS velocity analysis and the OBS velocity model. Using OBSs data is another way to provide a velocity model to perform pre-stack depth migration of MCS data.

Keywords: Single bubble mode; Pre-stack depth migration; Crustal seismic imaging; Velocity model; Multichannel seismic

1. Introduction

The Atlantic margin off Morocco, formed during the Triassic–lower Jurassic rifting of the central

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Atlantic (around 180–200 Ma), is one of the oldest margins on the earth (Hinz et al., 1982; Klitgord and Schouten, 1986). The SISMAR seismic cruise was carried out in April 2001 to image the deep structure of Moroccan margin, to characterise the nature of the crust in the transitional domain and define the geometry of syn-rift basins. The results obtained from a joint interpretation of MCS and wide-angle reflection/refraction seismic data are presented elsewhere (Contrucci et al., 2004).

To image the deep structure of this margin, a seismic source tuned in "single bubble" mode was used (Avedik et al., 1993). This type of source has been used since 1995 by the French scientific community to image the crustal structure of passive and active continental margins (e.g. Biscay/Amorican Margin, Thinon et al., 2003; Angola Margin, Contrucci et al., 2004). This kind of source is used to increase the energy in the frequency band of 10–15 Hz, and thus allows a deep penetration of the seismic signal. As a result, there is a low resolution of the seismic image. This source is not minimum phase.

In this study, we present two deep multichannel seismic (MCS) profiles, SISMAR 4 and SISMAR 12 recorded along the same transect, acquired, respectively using a single bubble source and a conventional reflection source and operated both at the same pressure in order to compare the seismic quality image when using the two sources. After the description of the seismic processing, the results from Pre-Stack Depth Migration of MCS profile SISMAR 4 using two velocity models are presented. The first velocity model was constructed at GEOMAR (Kiel, Germany) through depth-focussing error analysis of the MCS data and the second was derived from wide-angle reflection/refraction seismic modelling of ocean bottom seismometers data recorded along the profile (Contrucci et al., 2004).

2. Seismic data acquisition

Wide-angle seismic data recorded by Ocean Bottom Instruments along with reflection MCS data were collected during the SISMAR project. Two ships were used: R/V Nadir, for shooting and for MCS data recording; and R/V Almeida Carvalho, for deployment and recovery of Ocean Bottom Seismometers/Hydrophones (OBS/OBSH). On Profile SISMAR 4, 14 ocean bottom instruments (2 OBS/12 OBH) were deployed (Fig. 1).

This profile was shot twice using two different sources (Fig. 1). The first seismic source, for profile SISMAR 4, consisted of a 4805 in.^{3} array of 12 airguns, towed 24–27 m below the sea level, fired every 150 m (shot interval). The array was used in the "single bubble mode" (Avedik et al., 1993). The second seismic source, for profile SISMAR 12, consisted of 12 airguns of 2369 in.^{3}, towed 24–27 m below sea level, fired every 50 m. The source was used in the conventional reflection mode. We will discuss the advantage and disadvantages of using these two kinds of sources in the next paragraph.

A 4.5-km-long, 360-channel, numerical streamer was towed 225 m behind the ship at 20-m depth and recorded the signal over a 20-s window, at a 4-ms sampling interval. This acquisition geometry (6.25 m between each Common Mid Point) resulted in a 15-fold coverage (profile SISMAR 4) with 150 m shot interval and in 45-fold coverage when the shot interval was 50 m (profile SISMAR 12).

3. Conventional and single bubble mode sources

The single bubble mode source consists in synchronising the signature of the airguns on the first bubble pulse instead of on the first pulse, which is the conventional reflection seismic source (Fig. 2a–b) (Avedik et al., 1993). In this fashion, a relatively low and monofrequency (10–15 Hz) source is produced (Fig. 2e–f). Fig. 2f shows the increase of the energy in the frequency band of 0–20 Hz for the single bubble mode source compared to the first pulse mode.

Fig. 3 shows the same profile acquired with the two kinds of sources, profile 4 with the single bubble source and profile 12 with the initial pulse source. An onboard conventional processing routine was applied to the two MCS profiles 4 and 12, using the Geovecteur software. After application of a dynamic correction, an F-K multiple attenuation and an internal mute to reduce the water bottom multiple effects, velocity analyses were performed every 200 CMP. The CMP gathers were NMO