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가스 하이드레이트 자료에 대한 중합전 키르히호프 심도 구조보정

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Kirchhoff prestack depth migration for gas hydrate seismic data set

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Abstract : Korean Institute of Geosciences and Mineral Resources (KIGAM) has studied on gas hydrate in the Ulleung Basin, East sea of Korea since 1997. Most of all, a evidence for existence of gas hydrate, possible new energy resources, in seismic reflection data is bottom simulating reflection (BSR) which parallel to the sea bottom. Here we conducted the conventional data processing for gas hydrate data and Kirchhoff prestack depth migration. Kirchhoff migration is widely used for pre- and post-stack migration might be helpful to better image as well as to get the geological information. The processed stack image by GEOBIT showed some geological structures such as faults and shallow gas hydrate seeping area indicated by strong BSR. The BSR in the stack image showed at TWT 3.07s between shot gather No 3940 to No 4120. The estimated gas seeping area occurred at the shot point No 4187 to No 4203 and it seems to have some minor faults at shot point No 3735, 3791, 3947 and 4120. According to the result of depth migration, the BSR showed as 2.3km below the sea bottom.

1. Introduction

Gas hydrates compound, consisting of a complex structure of water molecules surrounding methane molecule, are solid-like substances naturally occurring beneath the ocean and in the polar regions. As the gas hydrates contain vast and potentially unstable reverse of methane and other natural gases, so they are seen as embracing three of the most important issues in the earth sciences: energy supply, climate change and natural hazards. However, the little is known about the actual resource potential of gas hydrate resource potential and environmental consequences of them, as yet, hypothetical exploitation or anthropogenic impacts (Beuchamp, 2004)1). One of very important feature in the identification of gas hydrate is bottom simulation reflector (BSR) which is defined as a sharp impedance contrast on seismic profile and marks the transition between the hydrates zone and free gas zone beneath it. The study on gas hydrate in Ulleung Basin of Korean Institute of Geosciences and Mineral Resources (KIGAM) has been performing since 1997. The numerous seismic surveys (Fig. 1) have been carried out in this area and successfully located the gas hydrate stabilization zone within the basin by the occurrences of BSR in seismic profiles (Ryu et. al., 2003)2).

The Kirchhoff migration has been proven as an appropriate method to image the subsurface with complicated geological conditions.

The objective of this paper is to introduce and apply the Kirchhoff migration for gas hydrate data set in order to locate better the BSR as well as clarify some of geological features.

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2. Wave Equation and Kirchhoff Migration

The existences of such geological features like faults and the lateral change in velocity may cause the seismic events diffracted. In the other hand, the main idea of Kirchhoff migration is to assume the reflector is built up of diffraction points. The value which is assigned to each diffraction points can be calculated independently of all the point diffractors. By the way to calculate the diffracted events, the reflectors are imaged.

Both prestack and poststack Kirchhoff migration is based on the integral solution of wave equation (Dochety, 2001)[3]. The wave equation in Helmholtz type is expressed as follows:

$$\nabla^2\psi-\frac{\omega^2}{v^2}=-q(x) \qquad (1)$$

Where ψ is total field due to the source at location x_s. ω, $q(x)$ and v are frequency, source density and velocity, respectively.

The solution of Eq. 1 can be found in Morse and Feshbach (1953)[4]; Duffy (2001)[5] in term of initial condition, boundary condition and Green 's function. According to Zhu and Lines (1998)[6], by using the WKBJ theory for the Green 's function approximation (Aki and Richard, 1980)[7], the solution of wave equation , $\psi(x,x_s)$, bounded observation surface S_0 and below by reflected surface, $\sum$ is given as follows:

$$\psi(x,x_s)=\int_{\Sigma} n\nabla\tau_r(x_r,x)A(x_r,x,x_s)u^m\left(x_r,\tau_s(x,x_s)+\tau_r(x_r,x),x_s\right)dx_r \qquad (2)$$

Where τ_s and τ_r is traveltime from shot point, x_s, to the subsurface point, x, and from the subsurface point x to the receiver point, x_r, respectively; n is outward normal vector of surface $\sum$. Hence, u^m denotes the time derivative of the recorded traces. For a 2-D case, $m=1/2$. The term $A(x_r,x,x_s)$ is geometrical spreading that functions here as an amplitude modulator recording traces. The Eq. 2 is a basic Kirchhoff migration equation. The other solution of wave equation can be found in Schneider (1978)[8] and it matches with the Eq. 2. As seen in Eq. 2 the determinations of travel time as well as the amplitude play key roles in the integral calculations. Traditionally, the ray tracing methods will give all the information of τ_r, τ_s. The finite difference solution of eikonal equation developed by Vidale (1988)[9] will be employed to calculate the travel time table. For the amplitude compensation due to the distance propagation is treated similar to Grey and May (1994)[10]. Since the travel time and amplitude calculation, based on the velocity model and by finite difference calculations, are required for Kirchhoff migration, the Kirchhoff migration is considered as the numerical approach. Thus, the accuracy of Kirchhoff migration depends on the accurately built velocity models for travel time and amplitude calculations. The procedure for Kirchhoff migration is shown in Fig. 2.

3. Application of Kirchhoff migration in the gas hydrate data set

The data set highlighted in Fig. 1 was acquired by KIGAM seismic acquisition team in 2003. The receiver interval was 12.5m with 4200 shot gathers and total length about 60km from East to West. Each shot gather consists of 80 channels. The preprocessing steps included: deconvolution, amplitude correction, muting, bandpass filter and making source gathers. The shot gather No. 3700 and all shot gathers from 3700 to 4200 which will be used for Kirchhoff migration is shown in Fig. 3 a&b. As seen in Fig. 3a, the first events of the seismic traces indicate to determine the velocity of seawater which will be used to build up the velocity model. After preprocessed the shot gathers, the CMP sorting, velocity picking and normal moveout (NMO) correction was done. All the preprocessing works were perform in Geobit developed by Suh (2005)[11]. The picked velocity values from the velocity spectrum were not unique and base on the senses of the operators. Consequently, the stacked section will be different. The interactive velocity picking tool based on X-windows developed by Suh (2005)[11] gives more accurate and unique picking velocity. The stacked section is presented in Fig. 4. From the stacked section, the high amplitude seismic events can be seen at shot point from No. 3940 to No. 4120, which indicates the occurrence of BSR. However, the stacked section still exists the diffracted events, and the geological features need to be depth migrated for interpretation. The advantages of stacked section also are to give the first idea for estimating the velocity of the study area and then building up the velocity model for Kirchhoff prestack depth migration. The linear vertically increasing velocity model (Fig. 5a) may be generally used for brute migration velocity model. The other velocity model based on the Krigging interpolation of the picking up the NMO velocity from the velocity spectrum (see Fig. 5b) is also present here. The reason is to find out the criteria for building up the reasonable velocity model. Once the velocity model is obtained, the next step is to divide the model into grid satisfying the grid node on the surface will cover all shot gather position and then to apply the travel time and maximum amplitude calculation. This data set the grid size, $N_z\times N_x=626\times1876$ and the number shot gathers of field data set is 551. The results of travel time and maximum amplitude calculation of node No. 1000 are shown in Fig. 6a and Fig. 6b, respectively. As seen in Fig. 6a, the when the incident angle is small (less than 45°) the wavelets look perfectly semi-spherical in the homogeneous layer, but when the encountered angle is higher, close to 90° the errors in travel time calculation become serious problems. The travel time calculation is correct only for the low incident angle or small offset. For the real dataset of gas hydrate the minimum offset is 50m and maximum offset is 1037.5m. So that the incident angles will be less than $\tan^{-1}(1037.5/4000)=14.54°$ (because the depth of sea bottom is about 2㎞). Consequently, the travel time calculation for these models can be use to adopt the Kirchhoff migration. The results of prestack Kirchhoff depth migration gas hydrate dataset are shown in Fig. 7a and 7b corresponding to two kinds of velocity models. The BSR locations are very well mapped and also the normal faults are clearly identified in both migrated sections. The slight difference between Fig. 7a and Fig. 7b is the occurrence of some minor fault at position of 5km and 8km in Fig. 7b.

4. Conclusion

The prestack Kirchhoff depth migration has been adopted successfully for gas hydrate dataset based on both vertical increment and interpolation picking velocity model in the complex geological structure area. The interpolation velocity model based on the picking velocity values from the spectrum give was first introduced also gave a acceptable result of migration.

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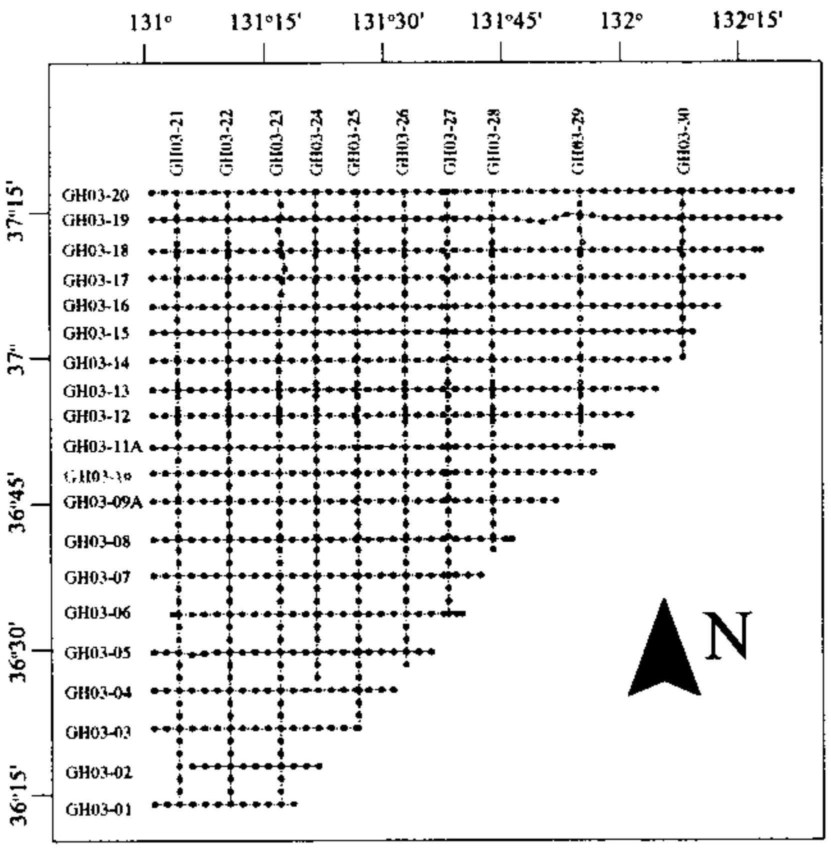

Fig. 1 Location of seismic surveys

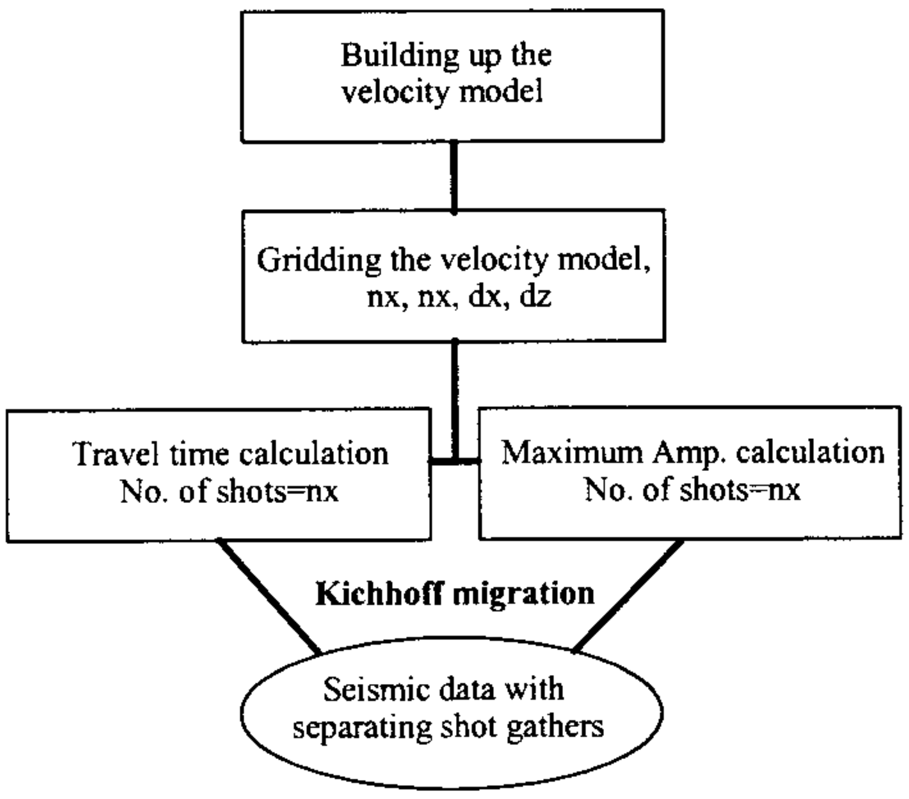

Fig. 2 Procedure of Kirchhoff migration.

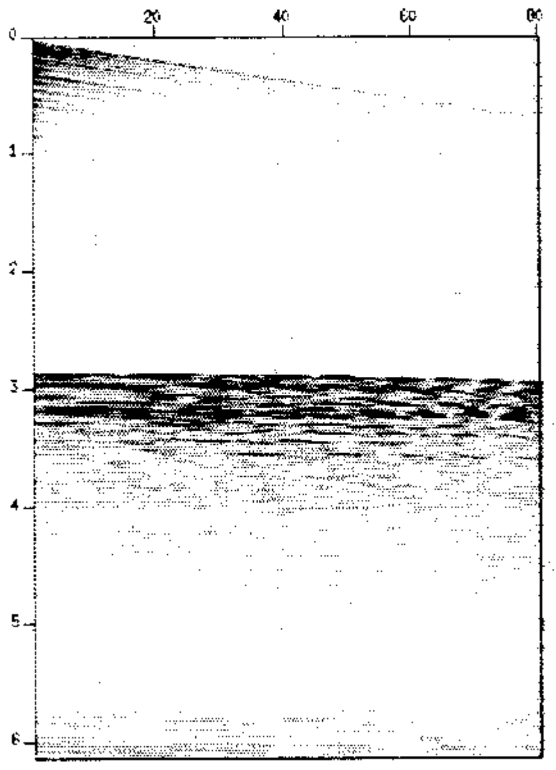

Fig. 3a The No. 3,700 shot gather.

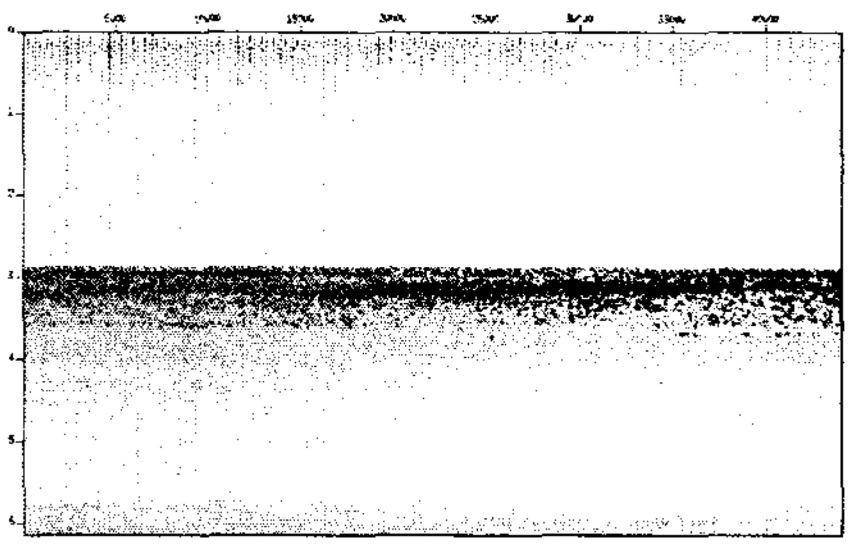

Fig. 3b Shot gathers from No. 3,700 to No. 4,200

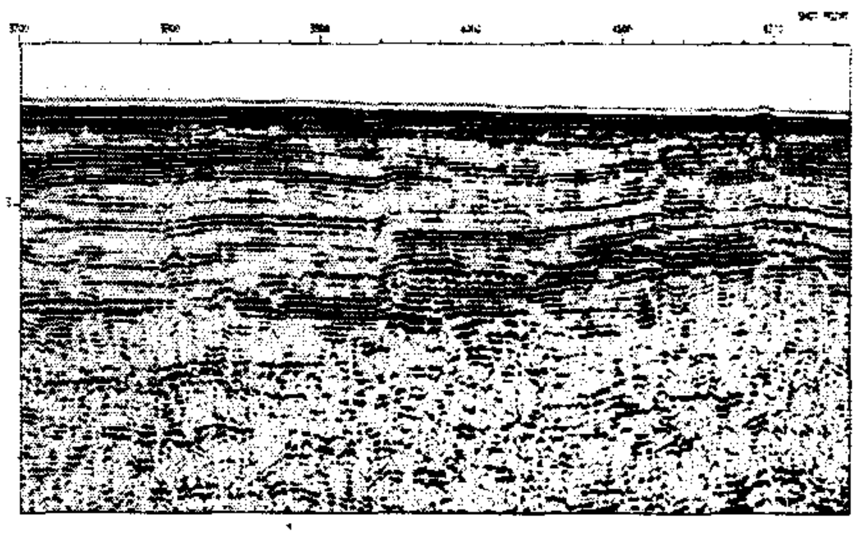

Fig. 4 Stacked section of GH03-10

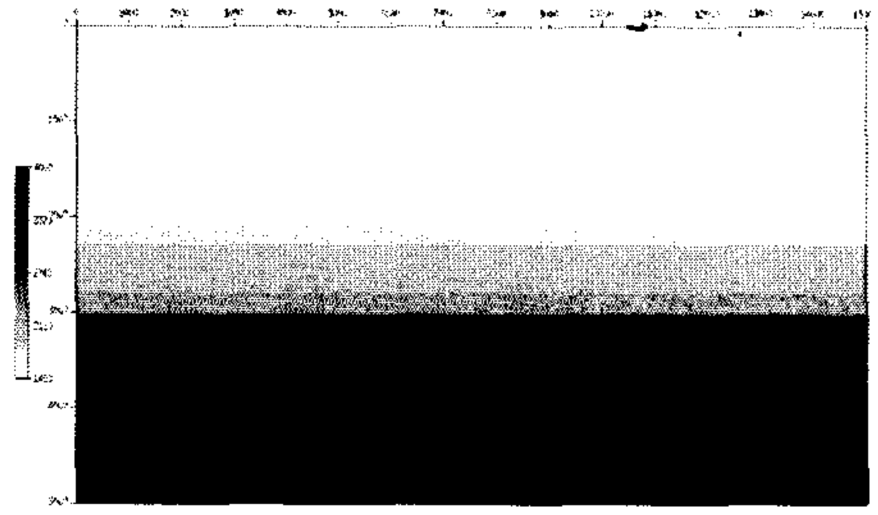

Fig. 5a Vertical linear increment velocity model

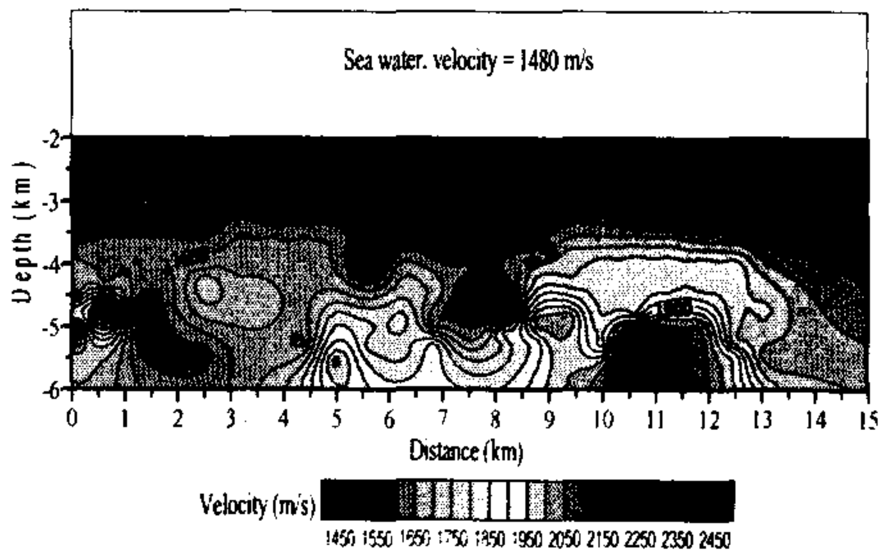

Fig. 5b Interpolation velocity model

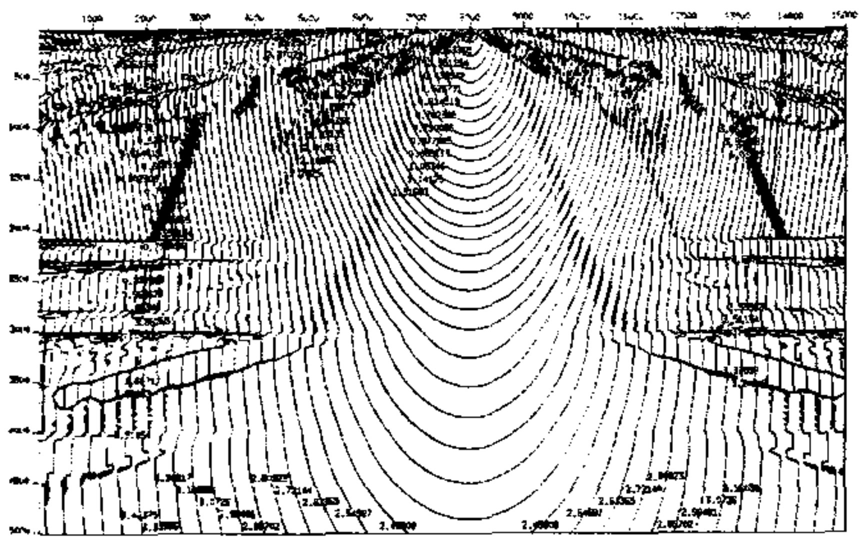

Fig. 6a Travel time table at shot point No. 1,000

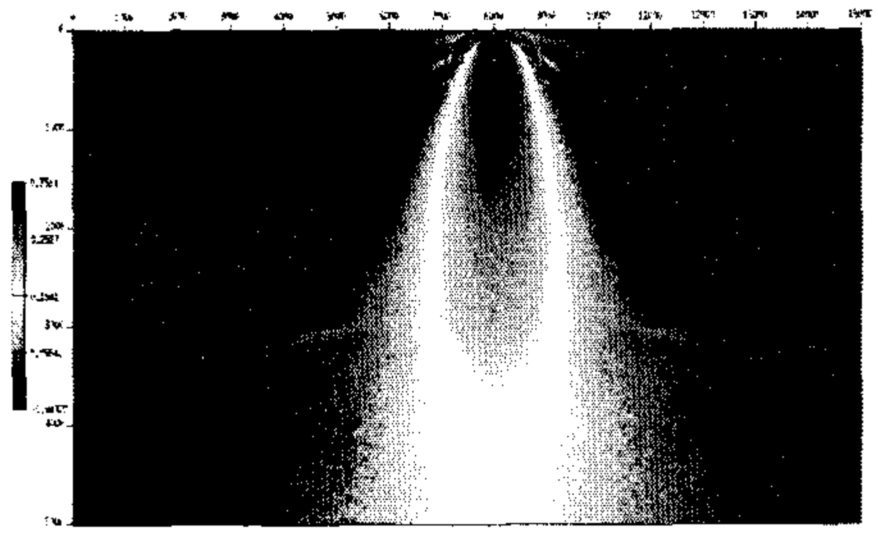

Fig. 6b Maximum amplitude at shot point No. 1,000

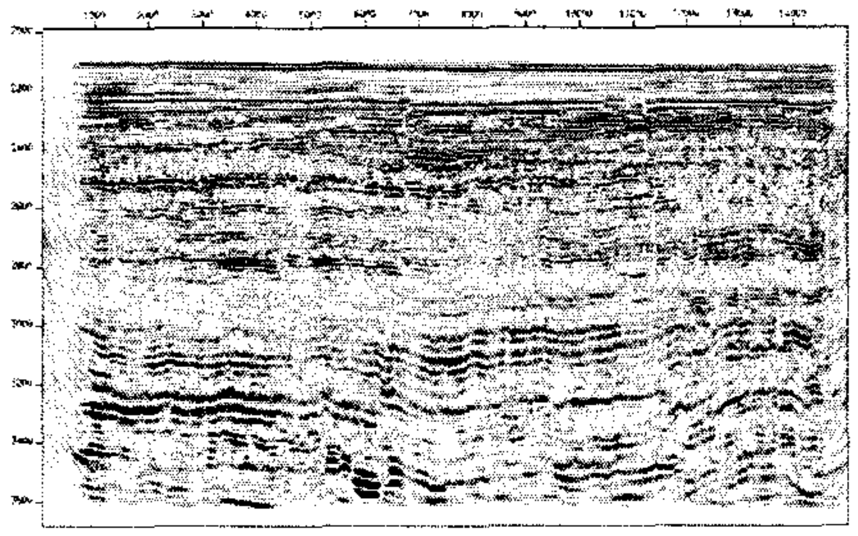

Fig. 7a Kirchhoff migration of the linear increment velocity model

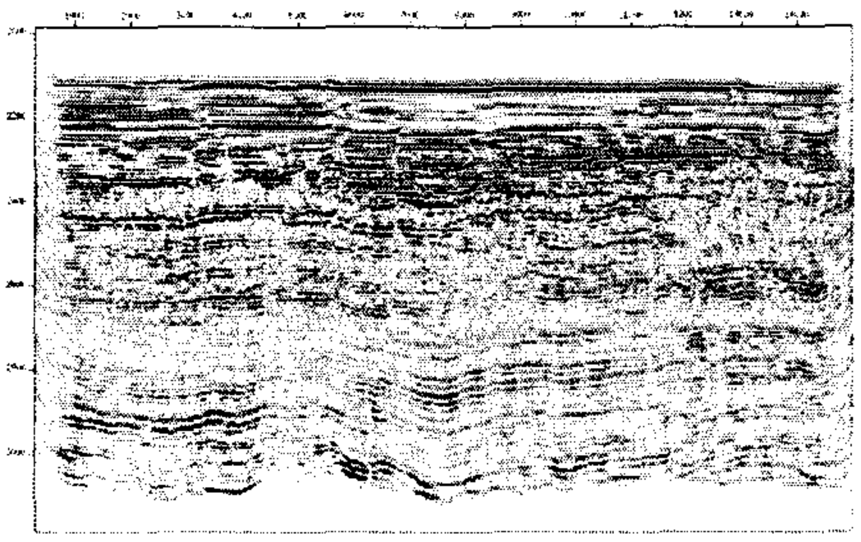

Fig. 7a Kirchhoff migration of picking velocity interpolation model