Refined CSP gathering of Scattering wave imaging method for rugged topography

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***Abstract*—Scattering wave imaging method and technique is a new kind of prestack migration. Based on the assumption that the earth subsurface consists of a large number of points (referred to as scatter points), closely located on the interfaces, scattered-waves is formed by single point scattered-wave. Other types wave, such as reflected wave, refracted wave, diffracted wave are formed by many points scattered-waves interference each other. Scattering wave imaging method is divided into two steps: the first is the mapping of prestack data into common scatter point (CSP) gather (The CSP gather construction is considered as a pre-stack partial migration), and then migration image.**

Keywords—CSP gather; rugged topography; scattering wave imaging

I. THEORY

As scattering wave imaging method does not have restrict on the exploration geometry, this method is benefit for complex structure situation seismic processing (particularly the fault zone of mountain front, the crushed zone of basin edge). The CSP gather is superior with a greater number of traces, and a larger maximum offset. That's why this technical not only enhanced the signal-to-noise ration effectively, but also can increase the imaging precision greatly. Scattering wave imaging method provides a practical and useful tool in the shallow Engineering and Environmental geophysical prospecting and the middle- deeper seismic survey including the urban active fault survey, the coal field and the metal mineral exploration.

The process of scattering wave imaging method using CSP gathers was initially based on input data converted to a horizontal datum[1-4]. In the following paper the process may be adapted for rugged topography[5-6].

The equivalent offset method of migration may also be performed from surface by computing the equivalent offset at a datum set for each CSP gather[7-8]. The equivalent offset is found by equating the travel times to the scatter point from a zero offset source and receiver on the datum with the original source-receiver travel times, as illustrated in Fig. 1 below.

The total travel times for the original ray paths are computed from equation, using the appropriate offsets h_s and

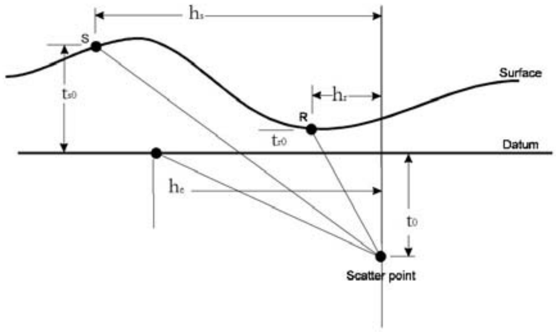


Fig.1. The schematic representation of the geometry used for rugged topography

$$t = t_s + t_r = \left[(t_0 + t_{s0})^2 + \left(\frac{h_s}{v_s(t_0 + t_{s0})}\right)^2 \right]^{\frac{1}{2}} + \left[(t_0 + t_{r0})^2 + \left(\frac{h_r}{v_r(t_0 + t_{r0})}\right)^2 \right]^{\frac{1}{2}} \quad (1)$$

h_r ,the zero offset time for the source $t_0 + t_{s0}$, the zero offset time for the receiver $t_0 + t_{r0}$ (where t_{s0} and t_{r0} are the total vertical travel times from source and receiver to the datum for the CSP gather, which are positive when the source is higher than the CSP datum or negative when the source is lower than the datum.) and appropriate velocities for the source $v_s(t_0 + t_{s0})$ and $v_r(t_0 + t_{r0})$ receiver defined from the surface.

The total travel times from the new defined source and receiver that are forced to be collocated and positioned at the equivalent offset position E to the scatter point are computed from equation below ,

$$t = 2t_e = 2\left[{t_0}^2 + \left(\frac{h_e}{v_e(t_0)}\right)^2 \right]^{\frac{1}{2}} \quad (2)$$

where the equivalent offsets h_e is defined from the CSP datum surface, $v_e(t_0)$ the RMS velocity at the scatter point and t_0 the one way zero offset time of the scatter point.

Substituting (2) and (1), the equivalent offset is giving

$$h_e = v_e(t_0)\left[(\frac{t^2}{4}) - t_0^{\ 2} \right]^{\frac{1}{2}} \tag{3}$$

v_e is known, v_s , v_r is the RMS velocity be calculate using Dix formula.

$$v_e = \left(\frac{\sum_{i=1}^{n} t_i v_i^2}{\sum_{i=1}^{n} t_i} \right)^{\frac{1}{2}} = \left(\frac{\sum_{i=1}^{n} t_i v_i^2}{t_0} \right)^{\frac{1}{2}} \tag{4}$$

and

$$\sum_{i=1}^{n} t_i v_i^2 = t_0 v_e^2 \tag{5}$$

v_s the RMS velocity from source to the scatter point：

$$v_s = \left(\frac{\sum_{i=1}^{n+m} t_i v_i^2}{\sum_{i=1}^{n+m} t_i} \right)^{\frac{1}{2}} = \left(\frac{\sum_{i=1}^{n} t_i v_i^2 + \sum_{i=1}^{m} t_i v_{S-surface-i}^2}{t_0 + t_{s0}} \right)^{\frac{1}{2}} = \left(\frac{t_0 v_e^2 + \sum_{i=1}^{m} t_i v_{S-surface-i}^2}{t_0 + t_{s0}} \right)^{\frac{1}{2}} \tag{6}$$

The same way we get v_r the RMS velocity from the scatter to the receiver :

$$v_r = \left(\frac{\sum_{i=1}^{n+m} t_i v_i^2}{\sum_{i=1}^{n+m} t_i} \right)^{\frac{1}{2}} = \left(\frac{\sum_{i=1}^{n} t_i v_i^2 + \sum_{i=1}^{m} t_i v_{R-surface-i}^2}{t_0 + t_{r0}} \right)^{\frac{1}{2}} = \left(\frac{t_0 v_e^2 + \sum_{i=1}^{m} t_i v_{R-surface-i}^2}{t_0 + t_{r0}} \right)^{\frac{1}{2}} \tag{7}$$

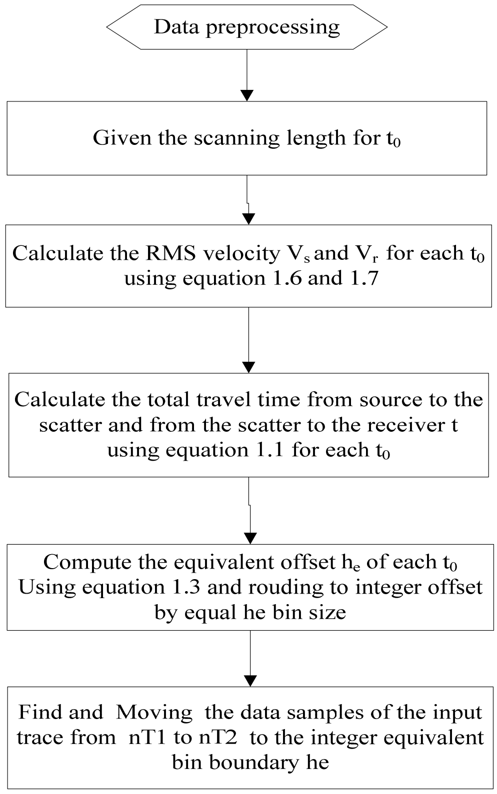


Fig2. The program flow chat of forming the CSP gather for rugged surface

Where $v_{S-surface-i}$ and $v_{R-surface-i}$ are the near surface interval velocity of the source and receiver, t_{s0} and t_{r0} is the one way total time from source to the CSP datum.

When the CSP gathers have been formed, each CSP gather may be scaled and filtered, or processed. Conventional algorithms such as noise and multiple removal, or velocity analysis, may also be used on the CSP gathers. The rugged topography is completed on the base of CSP gathers.

II. NUMERICAL MODELING EXAMPLE

To demonstrate the correctness of the rugged CSP gather, a one - point model with homogeneous velocity structure was create with 21 shot and 401 fixed receiver, the shot distance is 40m and the distance of receiver is 2m. The model is shown in Fig. 2 and the scatter point is located at (400m,200m), the velocity of scatter point is Vp=2500m/s, Vs=1380m/s; the model is 800m*800m, with Vp =2000m/s, Vs=1110 m/s. The CSP gather is forming with aperture 400m and the increment of the CSP gather is 2m.

Another Numerical Model is constructed to test my algorithm as in Fig.4 . This Incline Interface model is consisted of two Homogeneous medium, the velocity of the up space is

Vp=2500m/s, Vs=1380m/s; with down space Vp =2000m/s, Vs=1110 m/s. The geometry is created with 25 shot and 601fixed geophone, the shot interval is 50m and the distance between receivers is 2m. The CSP gather is forming with aperture 400m and the increment of CSP gather is 2m.

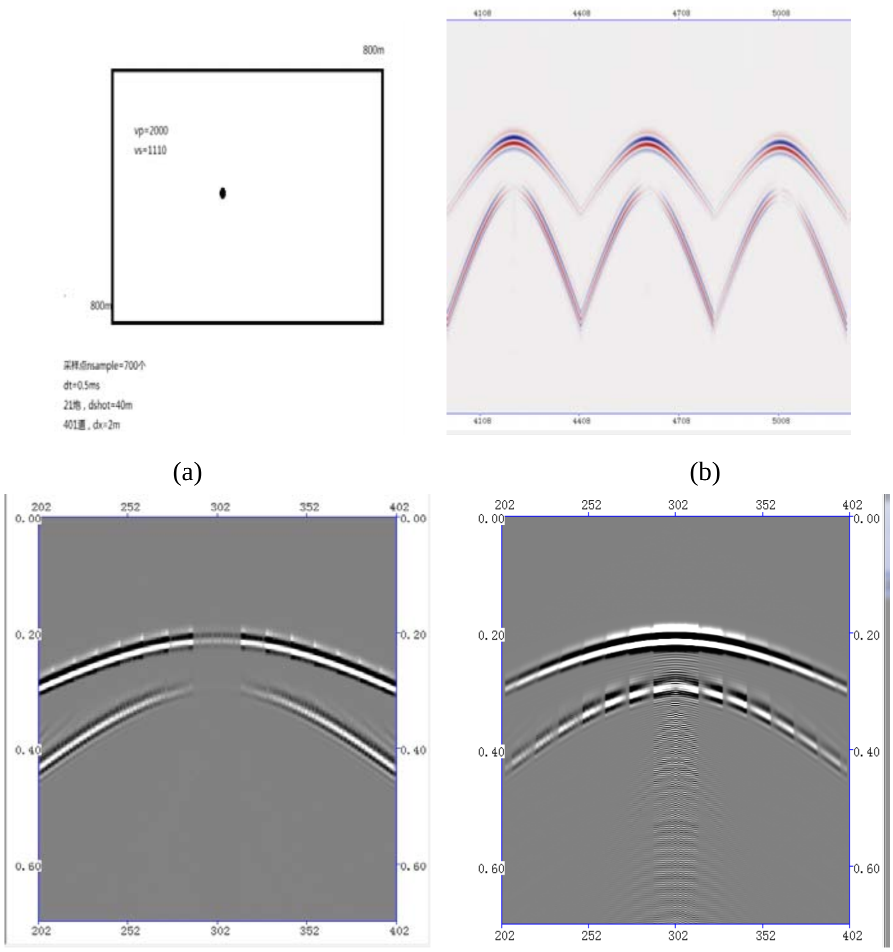
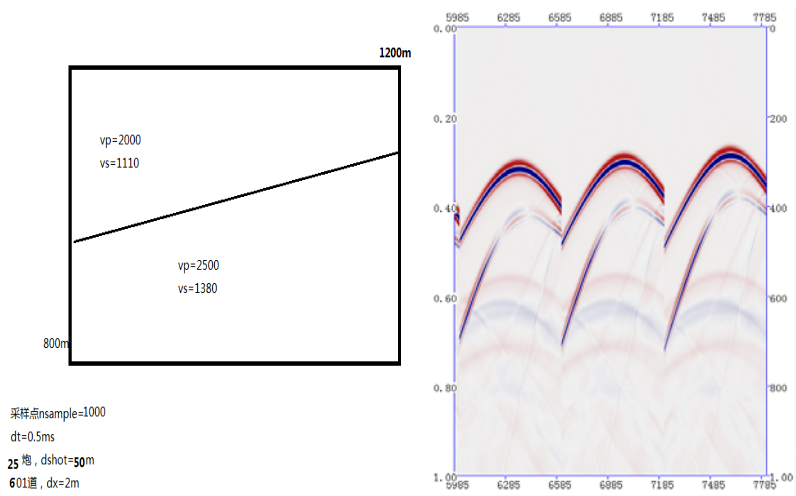
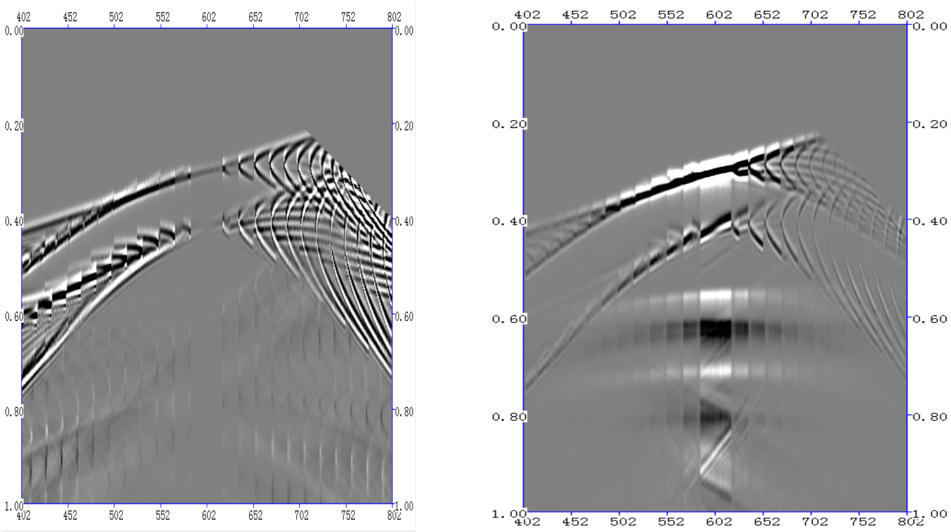


Fig3. (a)One scatter point model,(b)part of shot gather;(c) the CSP gather at the scatter point using the algorithm for horizontal surface assumption;(d) (c) the CSP gather at the same scatter point using the algorithm for rugged surface.



(a) (b)



(d) (e)

Fig4. (a) Incline Interface model,(b)part of shot gather;(c) the CSP gather at 600m using the algorithm for horizontal surface assumption;(d) (c) the CSP gather at the same point using the algorithm for rugged surface.

III. Conclusions and Future Work

The new algorithm we presented here is to complete the CSP gather for rugged surface. From the two numerical modeling example we demonstrate the corrected CSP gather for rugged surface for prestack migration is correct.

Some possible future work is related to: (1) comparing test for the CSP gather construction of rugged surface numerical model; (2) real field seismic dataset will be needed to test the feasibility; (3) final image example

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