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Short Note

DMO velocity analysis with Jacubowicz's dip-decomposition method

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INTRODUCTION

Dip-moveout (DMO) velocity analysis (VA) may be performed in several ways. Using the Fourier transform-based DMO techniques (Hale 1984, Notfors and Godfrey 1987, Liner and Bleinstein 1988), VA is done iteratively where a sequence of VA, normal moveout (NMO), DMO, inverse NMO, and a second VA yields an estimate of the DMO velocities. Using an integral method for application of a DMO process, Fore1 and Gardner (1988) proposed a way for performing VA by transforming the data into the (k, t_1) domain, where DMO velocities are obtained by any common VA technique. In another work, carried out by Chon and Gonzalez (1987) a velocity-sensitivity analysis was added to a Kirchhoff integral DMO algorithm.

An efficient DMO method, in terms of data management, has been proposed by Jacubowicz (1990). This DMO method can be used as a tool for a VA procedure, resulting in dip-independent velocities. In the following sections we present and demonstrate this VA technique.

THE METHOD

The VA procedure we introduce here generates a velocity spectrum at prespecified common-midpoint (CMP) locations. The velocity spectrum displays stack power, which is a function of DMO velocity and two-way normal ray traveltime, and is constructed by scanning a range of velocities and dips. The method searches for coherent energy on localized stack sections (10-20 CMP gathers centered around the specified CMP coordinate). We assume that at that small scale, seismic events can be approximated by arbitrarily dipping straight line segments.

The construction of the velocity spectrum starts by discretizing the velocity range. It is sampled using an equally-spaced argument AV. We mark the total number of velocity samples by N_v, and therefore a velocity V_j will be given by:

$$V_j = V_{min} + (j-1) \, l \, \Delta V, \tag{1}$$

where j = 1, l l l , N,, and V_{min} is the lowest velocity we search for.

Next, we define a dip angle θ_k, $k = 1, . \cdot l , N_\theta$, where N_θ is the number of dips we search for. For each velocity V_j and dip angle θ_k we construct a localized stack by using a constant velocity V_{stack} given by (Levin, 1971):

$$V_{stack} = \frac{V_j}{\cos \theta_k}. \tag{2}$$

Having a local stack for a given V_j and θ_k, a slant sum $S(V_j, p_k, \tau)$ is calculated Via

$$S(V_j, p_k, \tau) = \sum |U(x, \tau + p_k x)| + |U(x, \tau - p_k x)|, \tag{3}$$

where

$$p_k = \frac{2 \sin \theta_k}{V_j} \, l \tag{4}$$

U is the amplitude field of the localized stack, x is the spatial distance from the central CMP coordinate of the local stack, and τ denotes the two-way normal ray traveltime. The slant stack trace S has a high stack value at a certain time if the correct sampled dip and velocity were used in the stacking and summing process.

Finally, we construct a velocity spectrum trace $\zeta(V_j, \tau)$, by summing the slant stack traces:

$$\zeta(V_j, \tau) = \sum_{p_k} S(V_j, p_k, \tau). \tag{5}$$

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Repeating the above three-step process of calculating U, S, and ζ for the chosen range of velocities and dips, results in a velocity spectrum.

Note that the slant stack operation proposed here is simply an efficient replacement of the dip filters used in the original Jacubowicz approach.

Using this method for DMO VA results in the following data processing scheme: we first perform the proposed DMO VA. Then we use the resultant velocities for a DMO-stack operation.

SYNTHETIC DATA EXAMPLE

In this example we demonstrate the DMO VA technique. The model we use consists of an anticline crossing a flat layer at a depth of 800 m (Figure 1). The subsurface

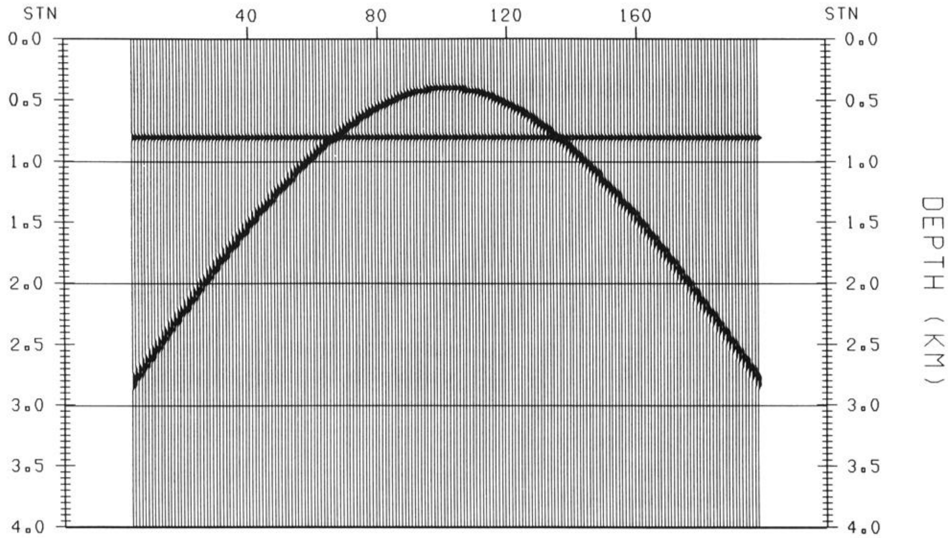

FIG. 1. Constant velocity synthetic depth model. Subsurface velocity is 3000 m/s.

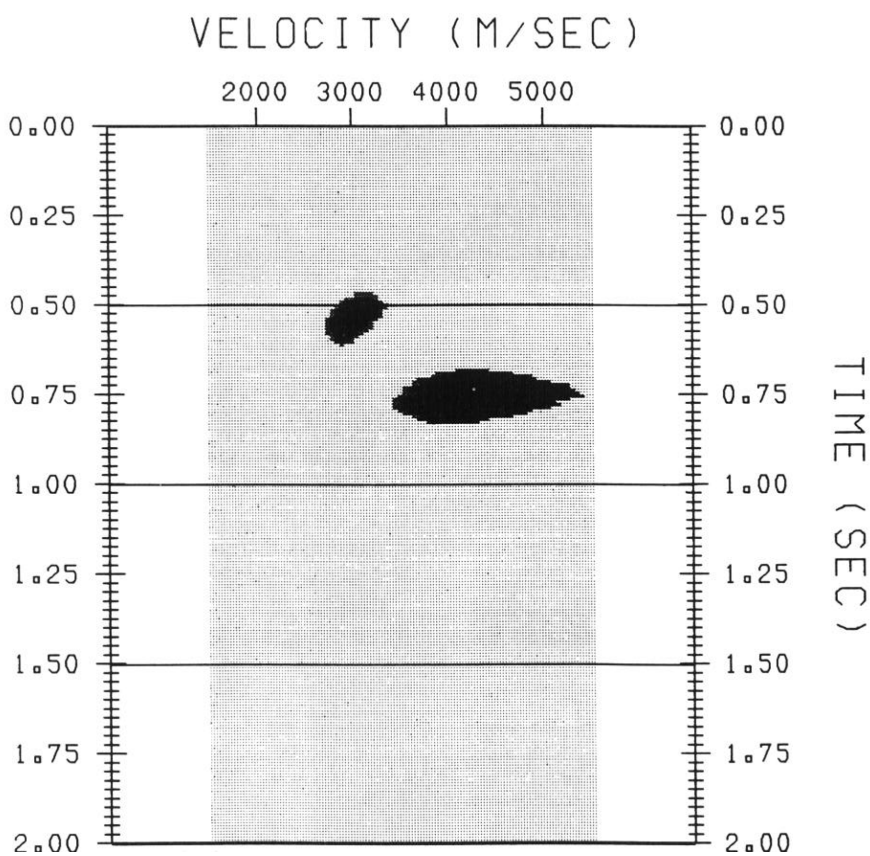

FIG. 2. Velocity spectrum resulting from a stacking velocityanalysts

velocity is constant at 3000 m/s. Using a ray-tracing technique, a seismic line of 100 shots with a group interval of 50 m and cable length of 2.5 km was simulated. A stacking VA at station 37 resulted in the velocity spectrum of Figure 2. As we expect, dipping events introduce a higher velocity than the correct one. Picking the low velocity is appropriate for the Rat event, but will fail to image the dipping event (Figure 3). Performing the DMO VA at the same station yields the velocity spectrum of Figure 4. As we can see, the proper velocity for both events is now observed. Picking this dip-independent velocity, we apply a DMO stack process (Figure 5). This operation results with a proper presentation of the zero offset section.

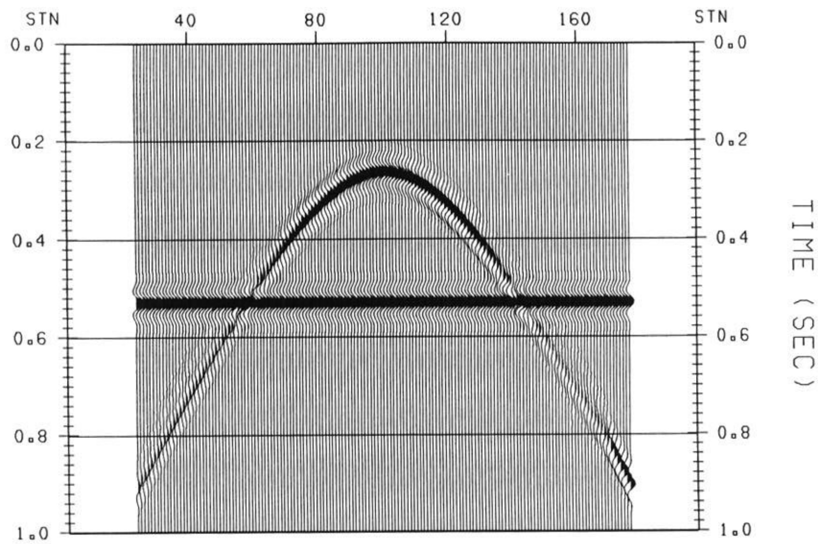

FIG. 3. Stack section obtained by using a stacking velocity of 3000 m/s. The dipping event is not imaged properly.

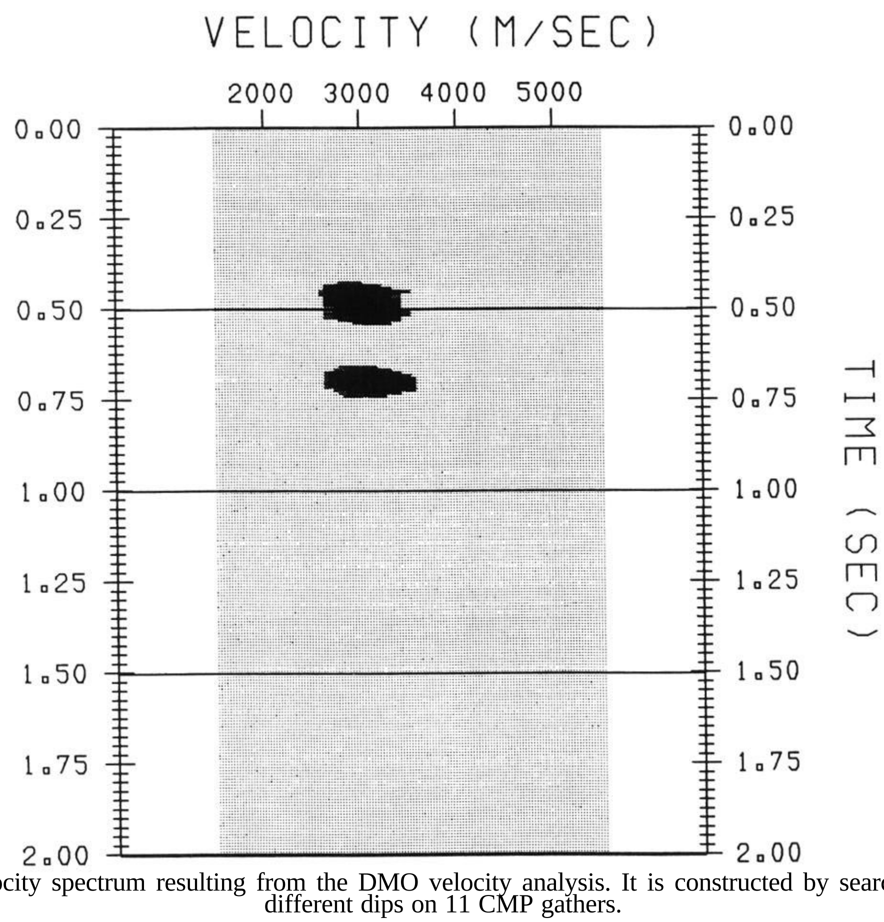

FIG. 4. Velocity spectrum resulting from the DMO velocity analysis. It is constructed by searching for 13 different dips on 11 CMP gathers.

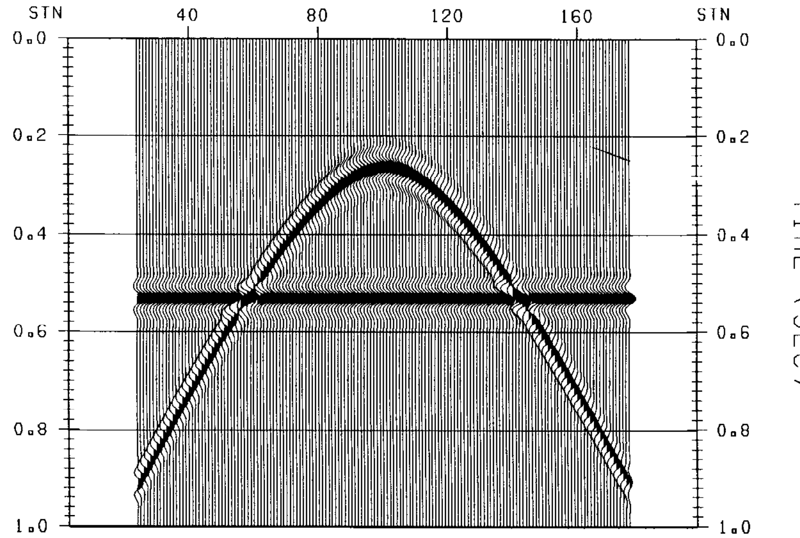

FIG. 5. DMO stack section obtained by using the DMO velocity spectrum of Figure 4. Both flat and dipping events are imaged properly.

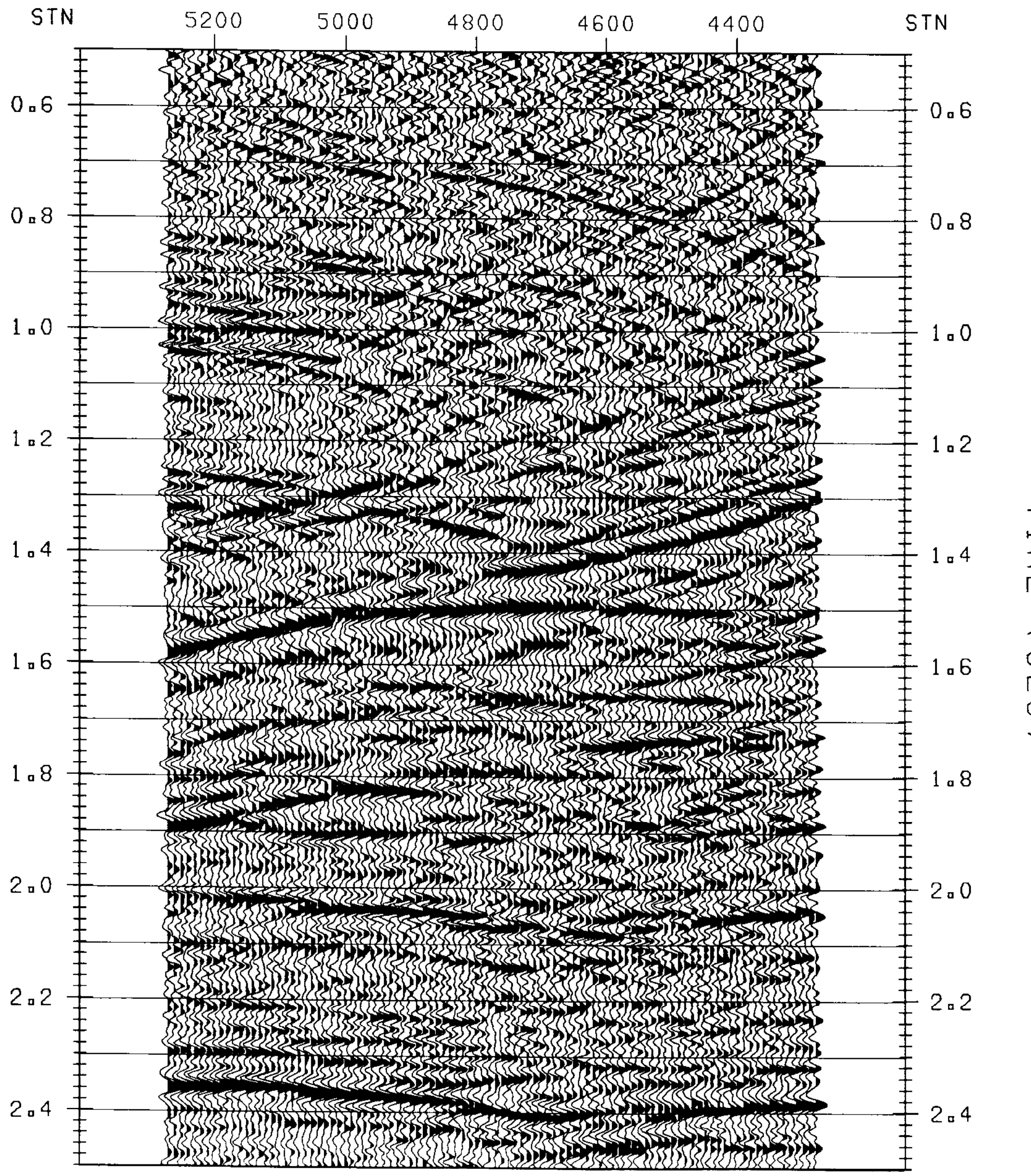

FIG. 6. Field data example: conventional stack section.

FIELD DATA EXAMPLE

A land data set consisting of 180 shots gathers, a 3040 m cable, and a 75 Hz highcut frequency was chosen for this study. A portion of the conventional stack is shown in Figure 6. Stacking VA and DMO VA were performed at station 5000 for velocities ranging from 2000 m/s to 10 000 m/s, and dips ranging from 0 to 80 degrees. The resulting stacking velocity spectrum is shown in Figure 7. This velocity function clearly indicates the conflicting dips that exist in the data. The proposed DMO VA algorithm produced the velocity spectrum presented in Figure 8. This velocity function has been greatly simplified, compared to the one of Figure 7.

To verify the accuracy of the DMO velocities, we use the velocity spectrum shown in Figure 8 to generate a DMO stack (Figure 9). As we can see (see arrow on figure 9). segments of the stack section that include conflicting dips show better amplitude and continuity on the DMO stack section than on the conventional stack section.

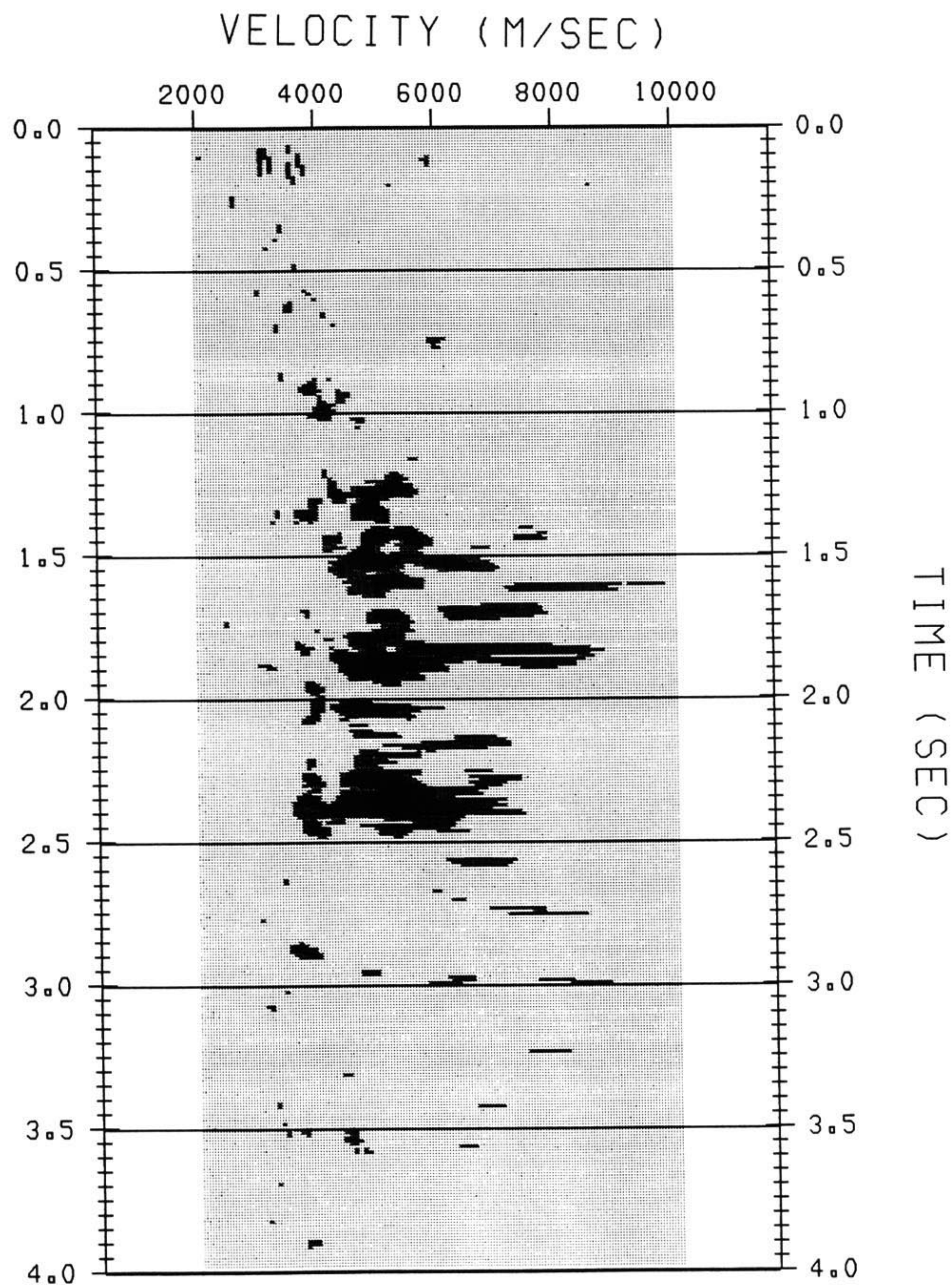

FIG. 7. Stacking velocity spectrum calculated by measuring the coherency of the NMO-corrected CMP gathers.

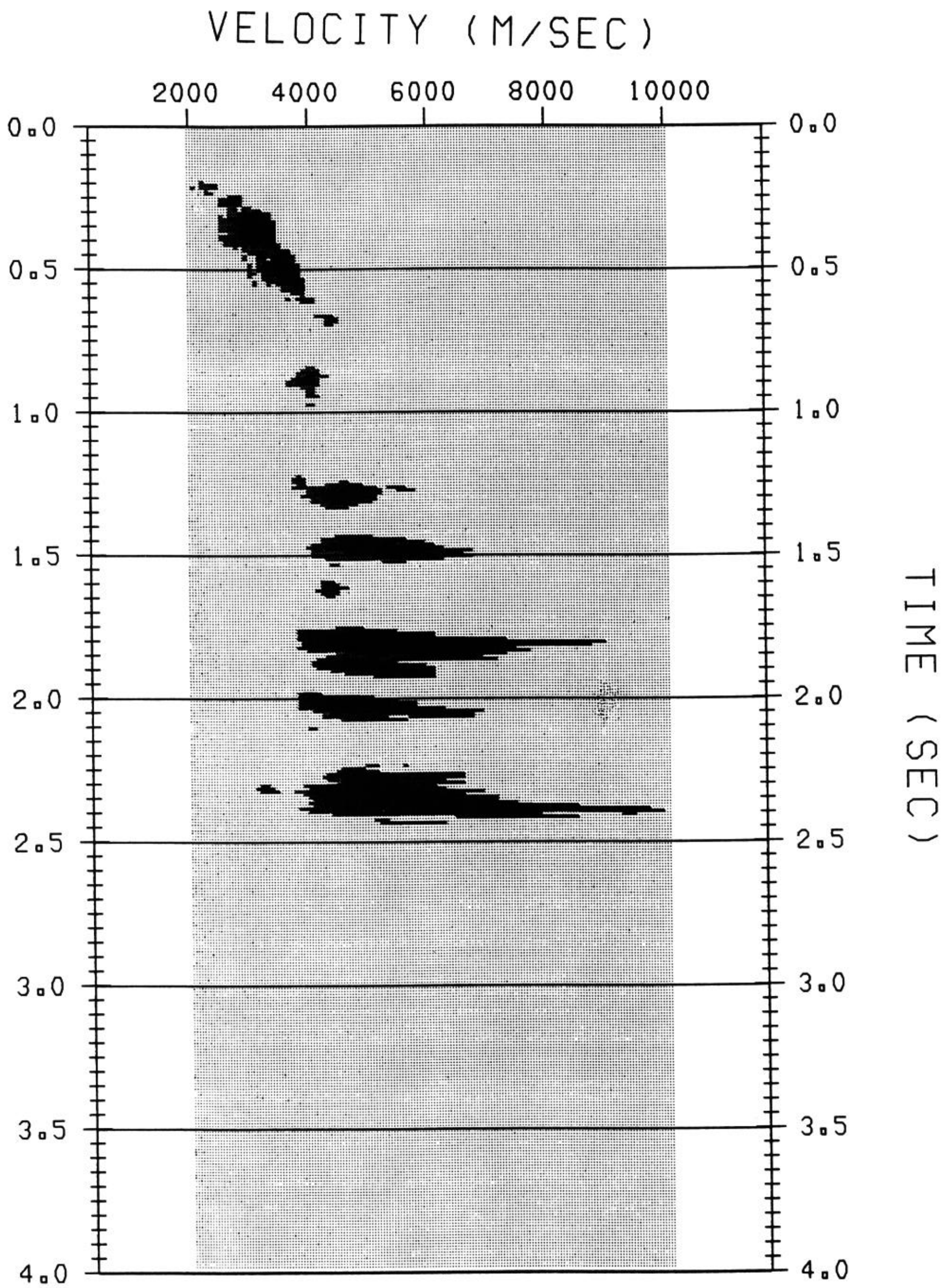

FIG. 8. Velocity spectrum resulted from the DMO velocity analysis. It is calculated using II CMP gathers located symetrically around station 5000 and by scanning over 17 different dip angles.

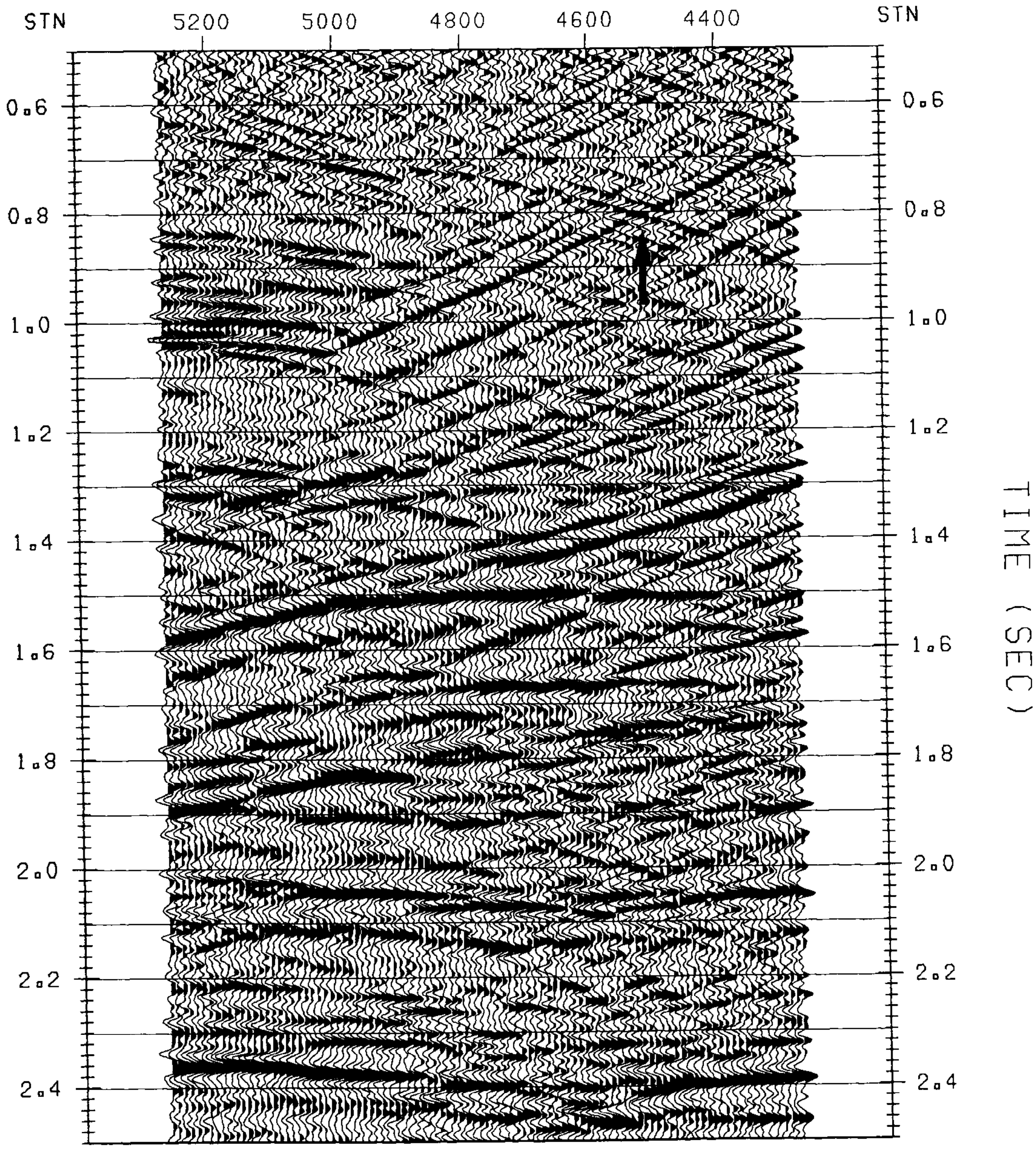

FIG. 9. DMO stack section obtained by using the velocity spectrum shown in Figure 8.

CONCLUSIONS

We have presented a method for performing DMO VA. It is a single-pass procedure and is based on scanning a range of velocities and dips.

The velocity spectrum is constructed by using a localized stack section and therefore has an improved signal-to-noise ratio over the one generated by a traditional stacking VA.

The method has the advantage of performing the DMO VA during the stacking process, and thereby allows the application of normal processing procedures, such as multiple supression, during the course of the velocity analysis process.

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