Preliminary Interpretation of the 3D-Seismic Survey at the KTB Location

P. Hluchy, M. Körbe, R. Thomas *

Summary

A preliminary interpretation has been done on an envelope stack of the three-dimensional seismic survey of the ISO 89 experiment. This kind of stack is interpretable as well as a normal stack with some restrictions, but all major elements are detectable. The major structural elements, which have been the target of the interpretation in this special case, can be divided into five groups. The three most important groups are a bundle of steeply northeast dipping reflections with outcrops in the area of the outcrop of the Franconian Line, a zone of high reflectivity with five reflections named Erbendorf body and two curved interfaces at the time range 3.5 to 4.5 s TWT. The results of this interpretation are in good correspondence to the former interpretations done on the two-dimensional seismic lines in the survey area.

1 Introduction

One, maybe the biggest, part of the experiment **I**ntegrated **S**eismics **O**berpfalz **89** (ISO 89) was the measurement of a 3D steep-angle, deep-seismic survey at the KTB location. An area of 17.85 km x 19.1 km was covered by this survey. The average coverage in the center of the survey is 15-fold. For a more detailed description of the survey and its acquisition see Rehling and Stiller (1990).

In a first step the first seven seconds of the recorded twelve seconds reflection time have been processed at the DEKORP Processing Center (DPC) at the Institute for Geophysics of the Technical University Clausthal. In the sketch of the survey area (Fig. 1) the Gauß-Krüger-coordinates related to the 12th meridian are quoted at the corners of the four subareas. The division into these subareas was necessary because of the restricted volume of disk storage at the DPC. The numbering of the inlines (I 185 – I 541) and the crosslines (C 172 - C 553) is shown at the outside of the area. The inline direction SW – NE is parallel to the geophone lines. The crossline direction NW – SE is parallel to the shotpoint lines that means they are almost parallel to the strike direction of the Franconian Line, which separates a crystalline basement area in the northeast from an smaller area covered with Mesozoic and Paleozoic sediments in the southwest.

*Authors' address : DEKORP Processing Center, Institut für Geophysik, TU Clausthal, Arnold-Sommerfeld-Str. 1, 3392 Clausthal-Zellerfeld

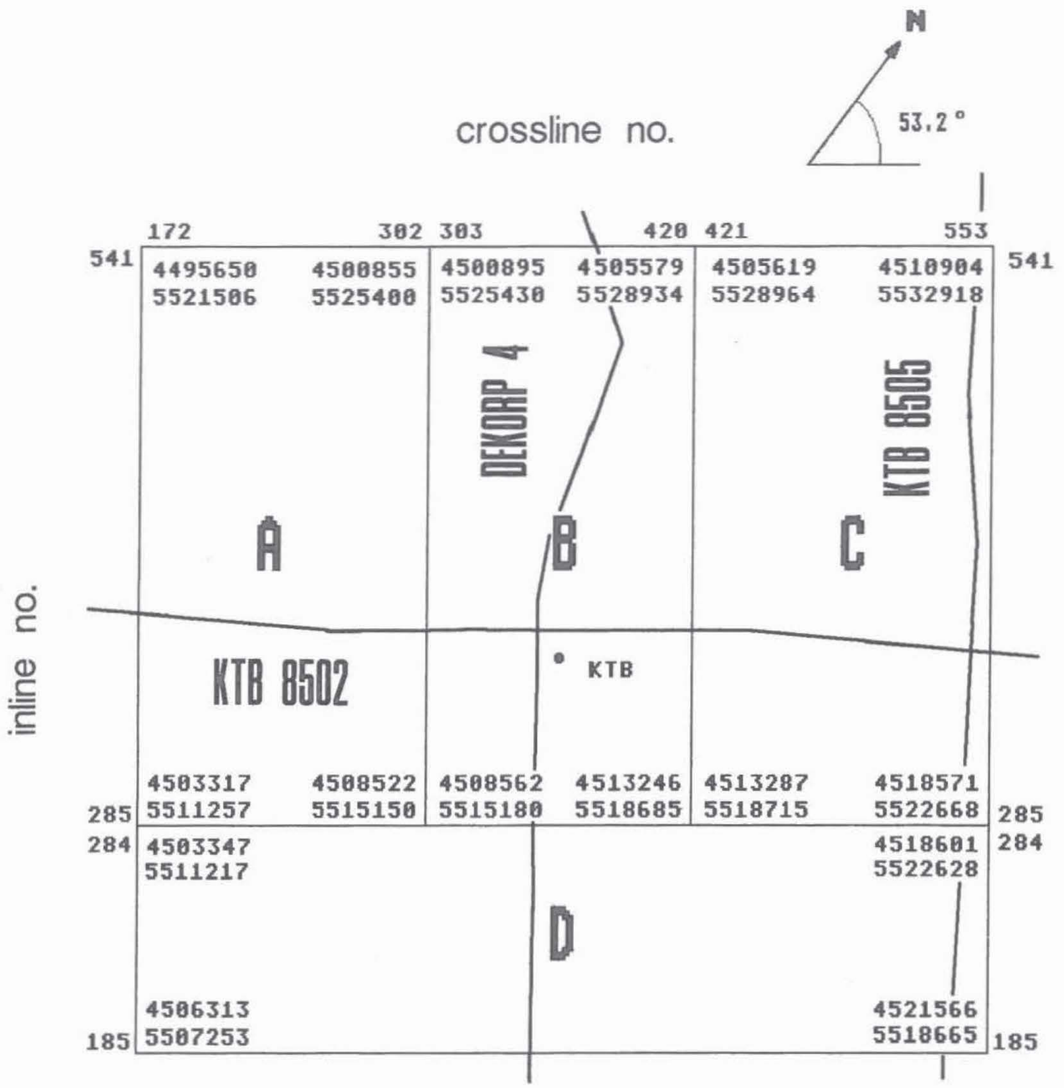

Figure 1: The 3D-survey area at the KTB location. The coordinates of the super deep borehole are 4508790/5519880. This location is almost crossed by inline 357 and crossline 363 (further details see text).

The processing of the seismic data showed that the conventional three-dimensional processing scheme based on seismics in sedimentary areas failed in such a complicated crystalline area as it was found around the KTB drill site. Therefore, the first and up to now the only stack of the whole survey has been done as an envelope stack. More details of this processing procedure can be find by Stiller (1992) in this volume.
This envelope stack of the three-dimensional survey has been interpreted with three main aims:

- Firstly, the interpretation should give support to the drilling crew at the KTB. There should be hints for zones critical for drilling as well as information about the possible casing emplacement in the deeper part of the drill hole.

- Besides the special informations about the close surrounding of the KTB the structure of the whole area covered by the survey should be evaluated. These results should be reconciled with the results of the interpretation of the two-dimensional seismic lines in this area (Schmoll, et al., 1989) or should correct the interpretations done earlier.
- Last but not least the interpretation should give support to the processing of the 3D-survey to achieve the aim of a stack with improved quality which includes informations about the phase of the signals.

2 Interpretation of an envelope stack — possibilities and problems

First of all it had to be proved that events which can be detected in a standard stack (with phase information) can be seen in a corresponding envelope stack. The necessary tests have been done with approximately 300 CMP's of the two-dimensional line KTB 8502, because there occur the same structures as they can be found in the 3D-survey.
The line KTB 8502 has an average coverage of 80-fold. The standard stack with this coverage is displayed in Figure 2. This stack has been processed with very high stacking velocities to image the steep dipping events in that area (Körbe and Reichert, this volume). A coherency filter has been used to improve the signal/noise ratio. Figure 3 shows the corresponding envelope stack. The velocities used for this stack were the same as used for the standard stack. The envelope stack was filtered with a high-cut filter with a cut-off frequency of 30 Hz to get a smoother image of the data. In this first test it can be seen that the main interpretable structures of the standard stack can be found in the envelope stack, too. Even adjacent signals can be separated satisfactorily and diffraction-like structures underneath 3 s TWT are clearly displayed.
Then the coverage was reduced to 15-fold to get a comparison with the data of the 3D-survey. At first sight there is a great loss of information in the data of the normal stack (Fig. 4). Even the coherency filtering cannot really improve the result. The reflections with steep dip are no longer continuous and it will be very difficult to interpret them. The diffraction like events underneath 3 s TWT can be hardly determined as such events, too. In contrast to this these events are still interpretable in the envelope stack with this very low coverage (Fig. 5). The steep dipping events seem to be more continuous as in the standard stack and are interpretable as well.
As results of these tests it can be summarized:

- The steeply dipping events can still be interpreted in the envelope stack, even if they are almost invisible in the normal stack. The structure of diffraction like events can be determined with some restrictions (e.g. if the hyperbola branch crosses other events this cannot be resolved).
- In general it can be said that events located separately in the data can be determined in an envelope stack even if the coverage is very poor. Events which crosses each

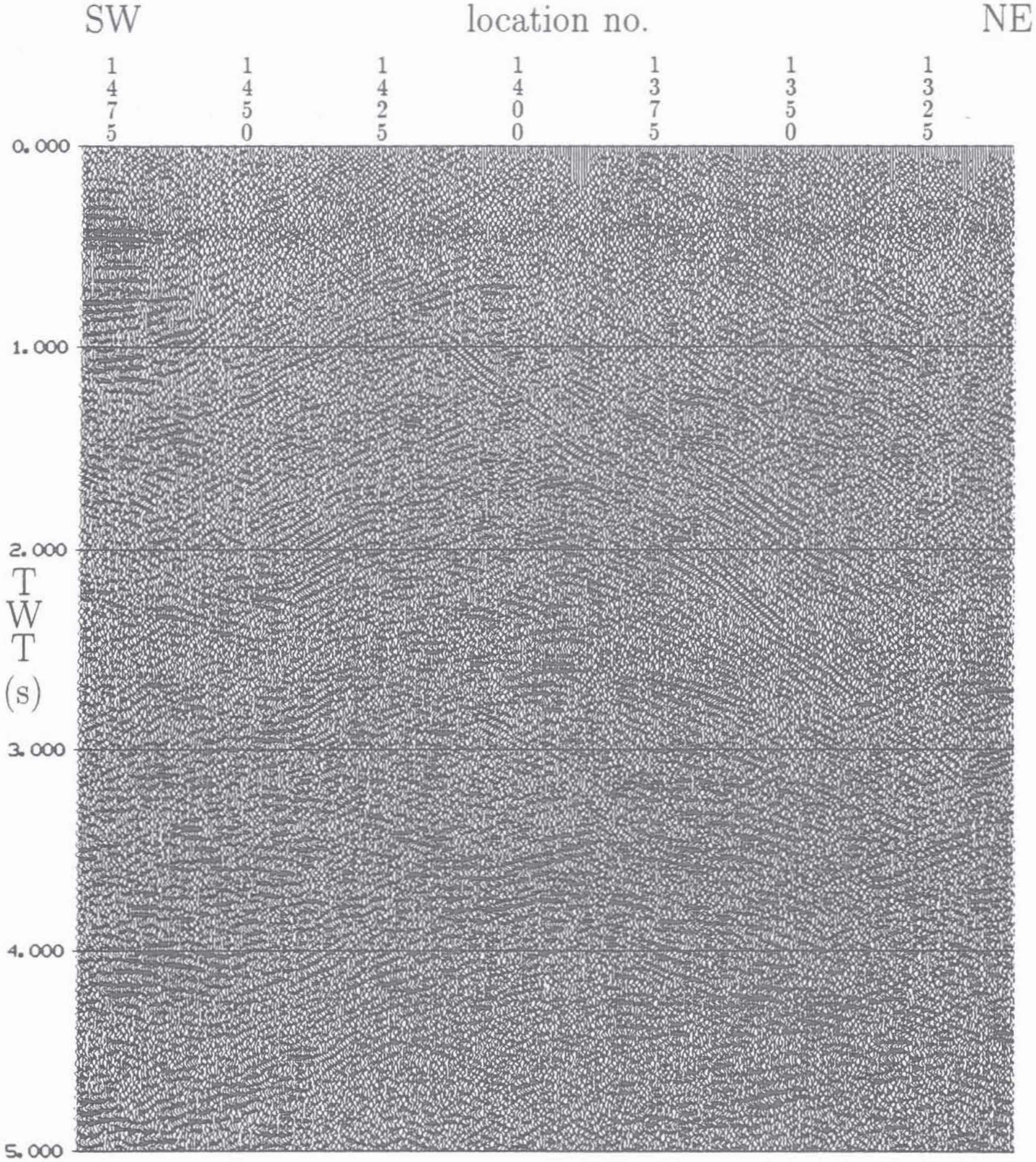

Figure 2: Part of line KTB 8502 crossing the 3D-survey. Coherency stack with 80-fold coverage. The horizontal scale is 1:100 000.

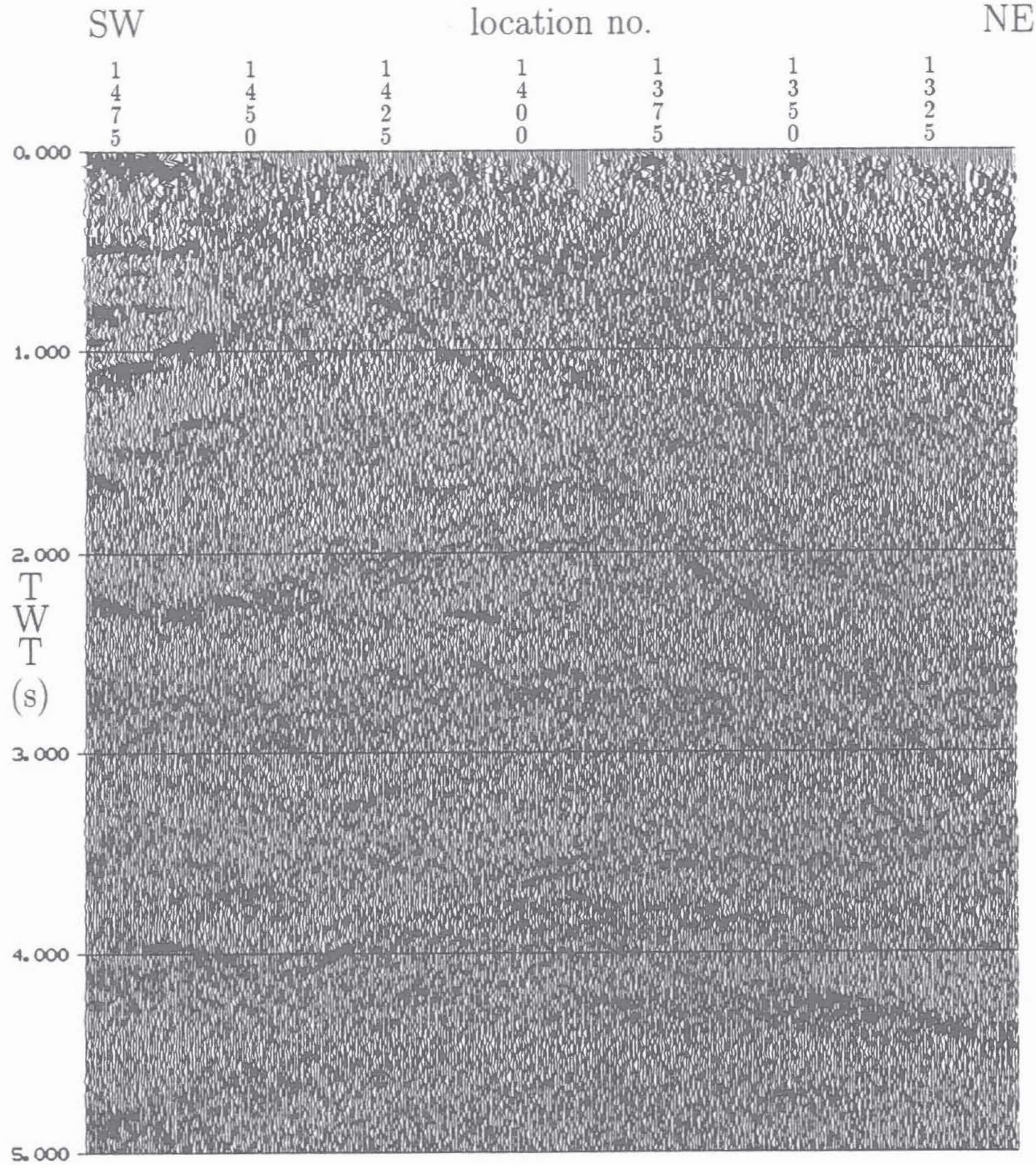

Figure 3: Part of line KTB 8502 crossing the 3D-survey. Envelope stack with 80-fold coverage. The horizontal scale is 1:100 000.

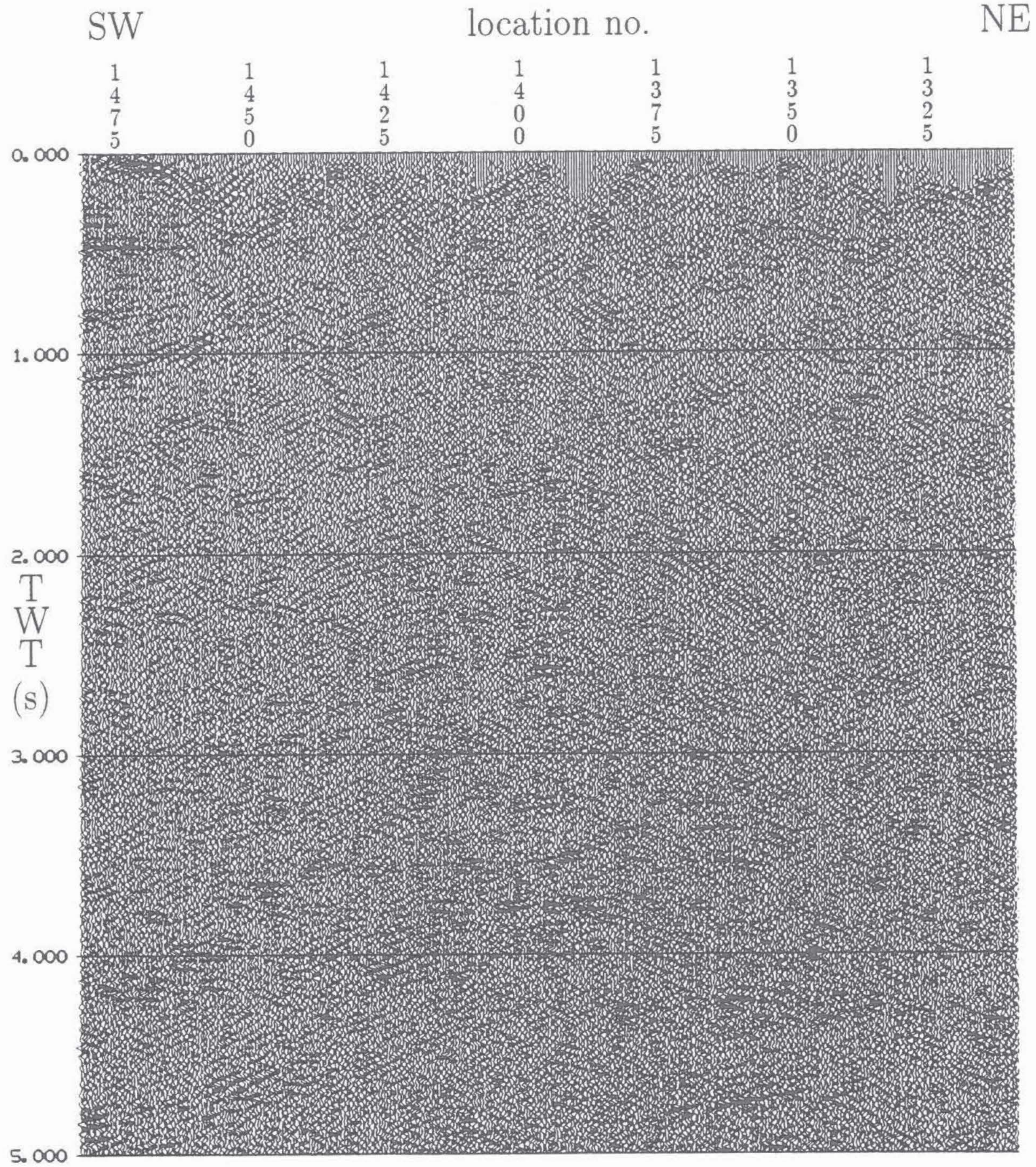

Figure 4: Part of line KTB 8502 crossing the 3D-survey. Coherency stack with 15-fold coverage. The horizontal scale is 1:100000.

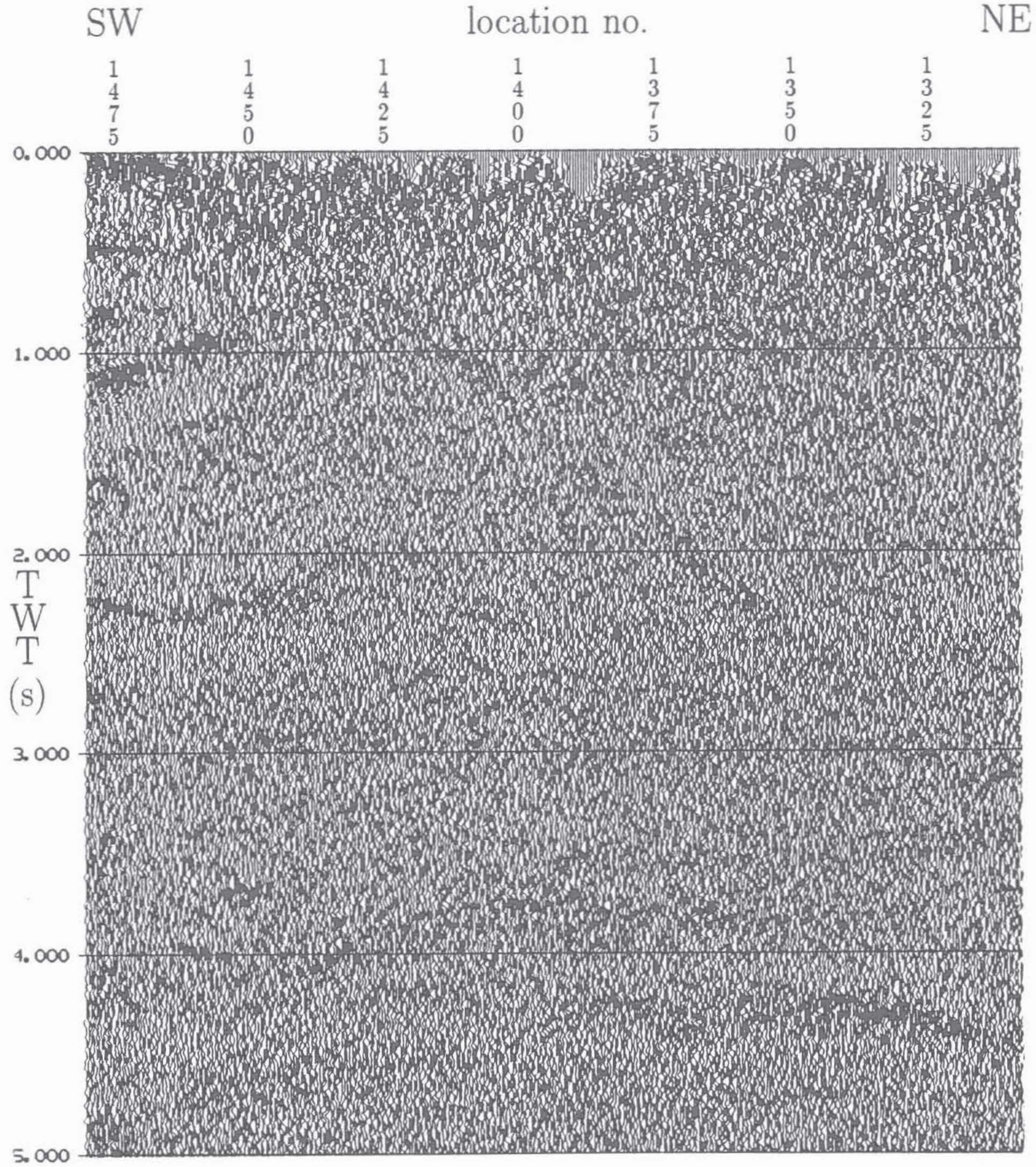

Figure 5: Part of line KTB 8502 crossing the 3D-survey. Envelope stack with 15-fold coverage. The horizontal scale is 1:100 000.

other or are adjacent in the duration of the signal cannot be resolved in such a stack, but it is possible to notice them.

- It is quite clear that such an envelope stack cannot replace a standard stack with phase information. But an interpretation made on the basis of an envelope stack will get all main structures. However the resolving of the events is not as high as in a normal stack. In this special case the reliability of the interpretation will be improved because it is a 3D-survey. Thus the interpretation must fit the data in the adjacent in- and crosslines. This will help to avoid severe misinterpretations.

After the proof of making sense to interpret such an envelope stack it is necessary to describe the considerations made for this interpretation.
The targets of this first interpretation have been the major events occuring in great parts of the area due to the nature of the envelope data. These events have been picked at the relative maximum of amplitude and not only in parts of the area where they show a very high absolute amplitude. So it has been tried to get a close interpretation of continuous events, because this has been necessary for the processing of the 3D-data. Therefore the interpretation of the inlines was transferred by its tie-points to the crosslines and reverse. So it was possible to reduce the scattering of the interpretation-picks between inlines and crosslines caused by the long duration of the signal of the envelope (30 - 70 ms). These tie-points can help to extend the interpretation to an area in which only very weak amplitudes occur, too. The interpretation has mainly been carried out in the in- and crosslines. The slices have been used to control the results of these interpretation, because a reflection of an undulating surface causes a smearing of the reflection in the slices. So the slices are not interpretable in a clear way.

3 Interpretation of the three-dimensional data

The interpretation of the survey, which has been done on a COMSEIS-system of Prakla-Seismos (now Geco-Prakla), included the results of the two-dimensional seismic lines DEKORP 4, KTB 8502 and KTB 8505, which cross the 3D-survey (for a sketch of the 3D-survey and these lines see Fig. 1). Further information on these lines can be found by Schmoll, et al. (1989).
It was necessary to do the interpretation in two blocks. The first block contains the crystalline area northeast of the Franconian Line, the second block is the area in the southwest covered with sediments. This division into two blocks is necessary because of the seismic pull-down effect caused by the sediments, which show a thickness of up to 3000 m. This effect of about 700 ms here can only be removed from the data by a depth migration, but at this time the data are still unmigrated and so the events underneath the sediments have to be considered separately.
Figures 6 to 8 show examples for the interpretation of the three-dimensional data. There are only some of the interpretations displayed to keep the clearness of the picture.
Figure 6 shows the inline 291 located almost in the center of the survey. The line is displayed in the direction SW - NE. In the sedimentary area the horizons A-1 (the lower one) and A-4 are marked. Underneath the sediments there are two horizons marked which

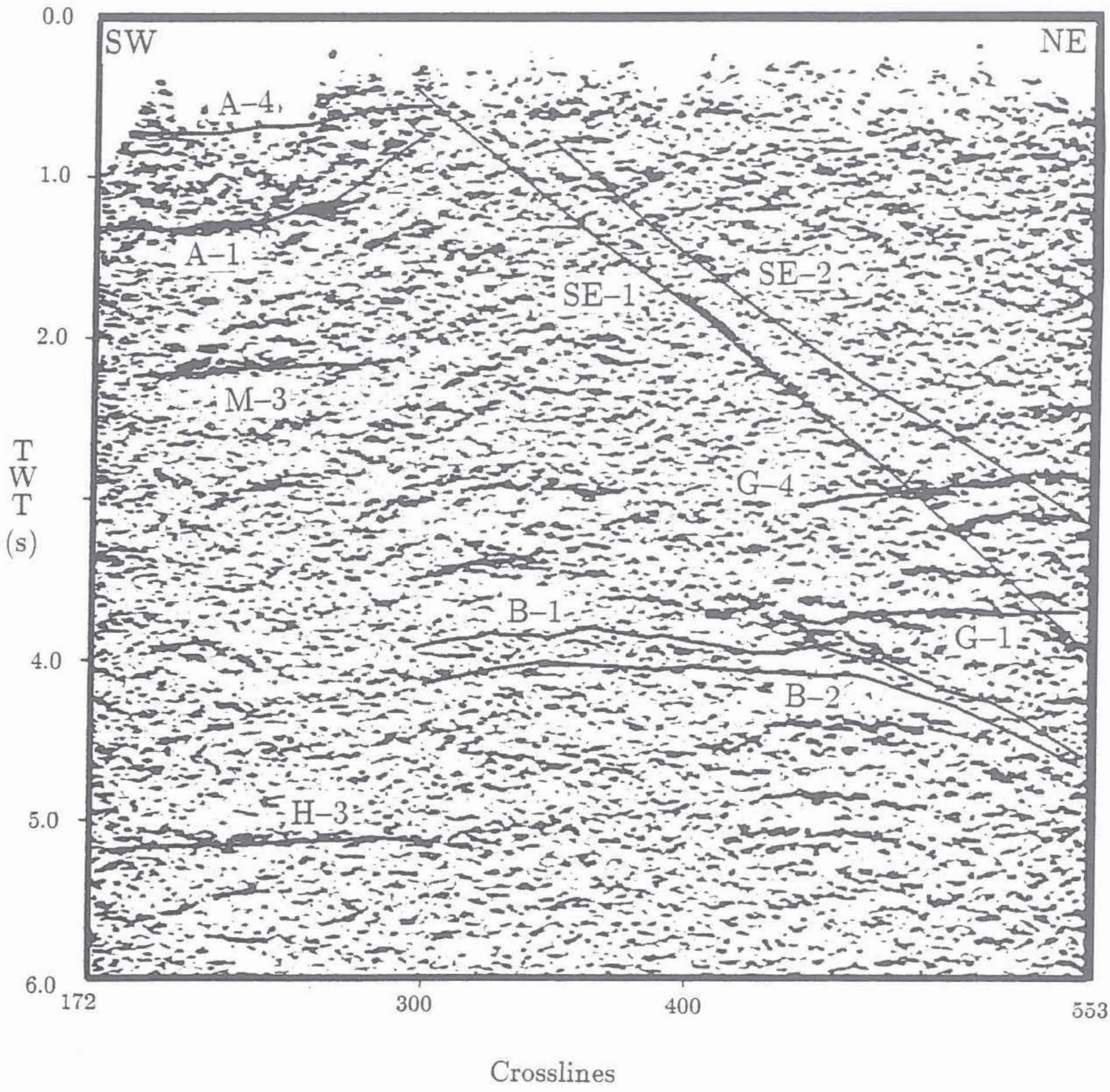

Figure 6: Inline 291 with some interpreted horizons marked (more details in the text).

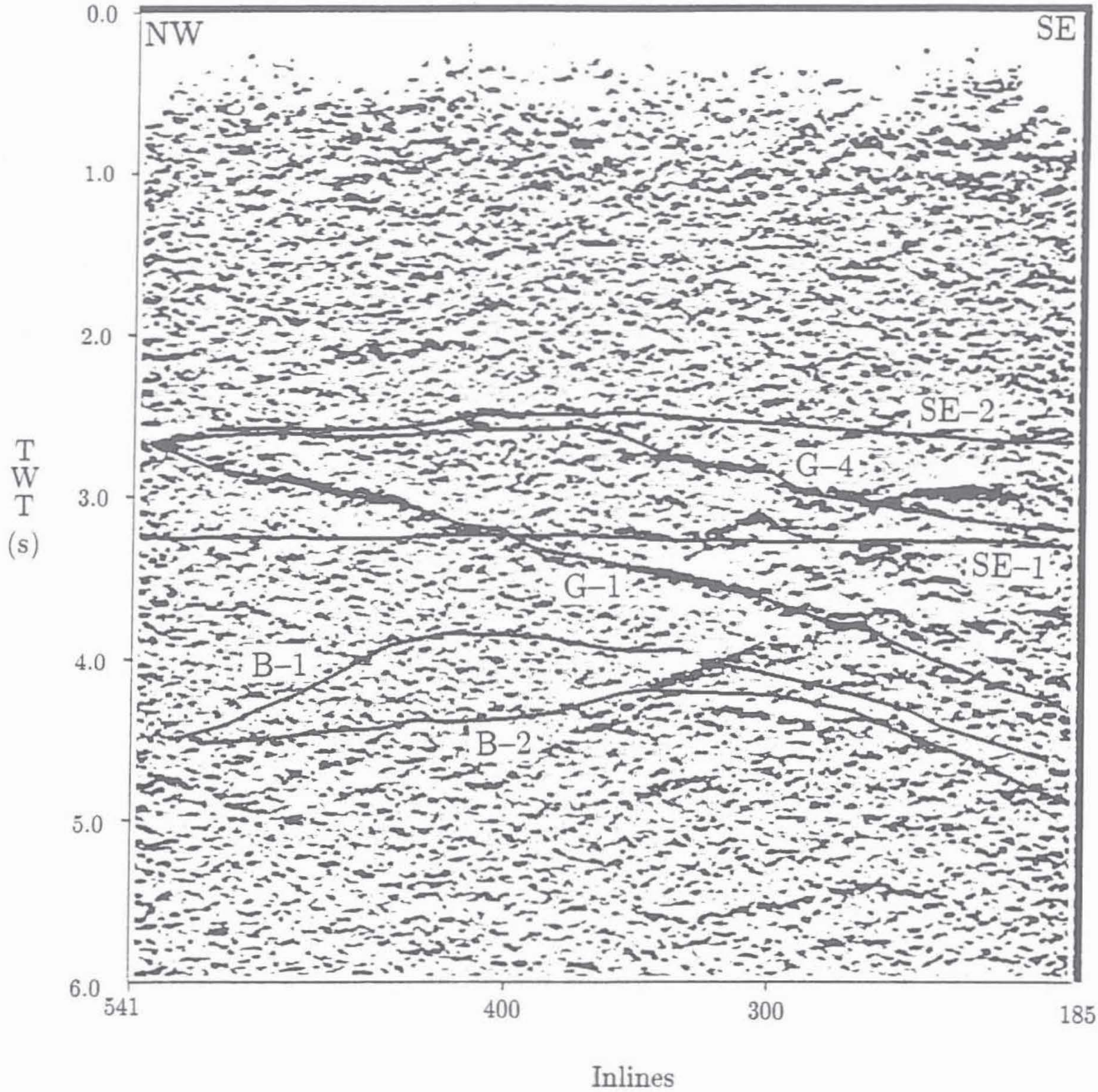

Figure 7: Crossline 494 with some interpreted horizons marked (more details in the text).

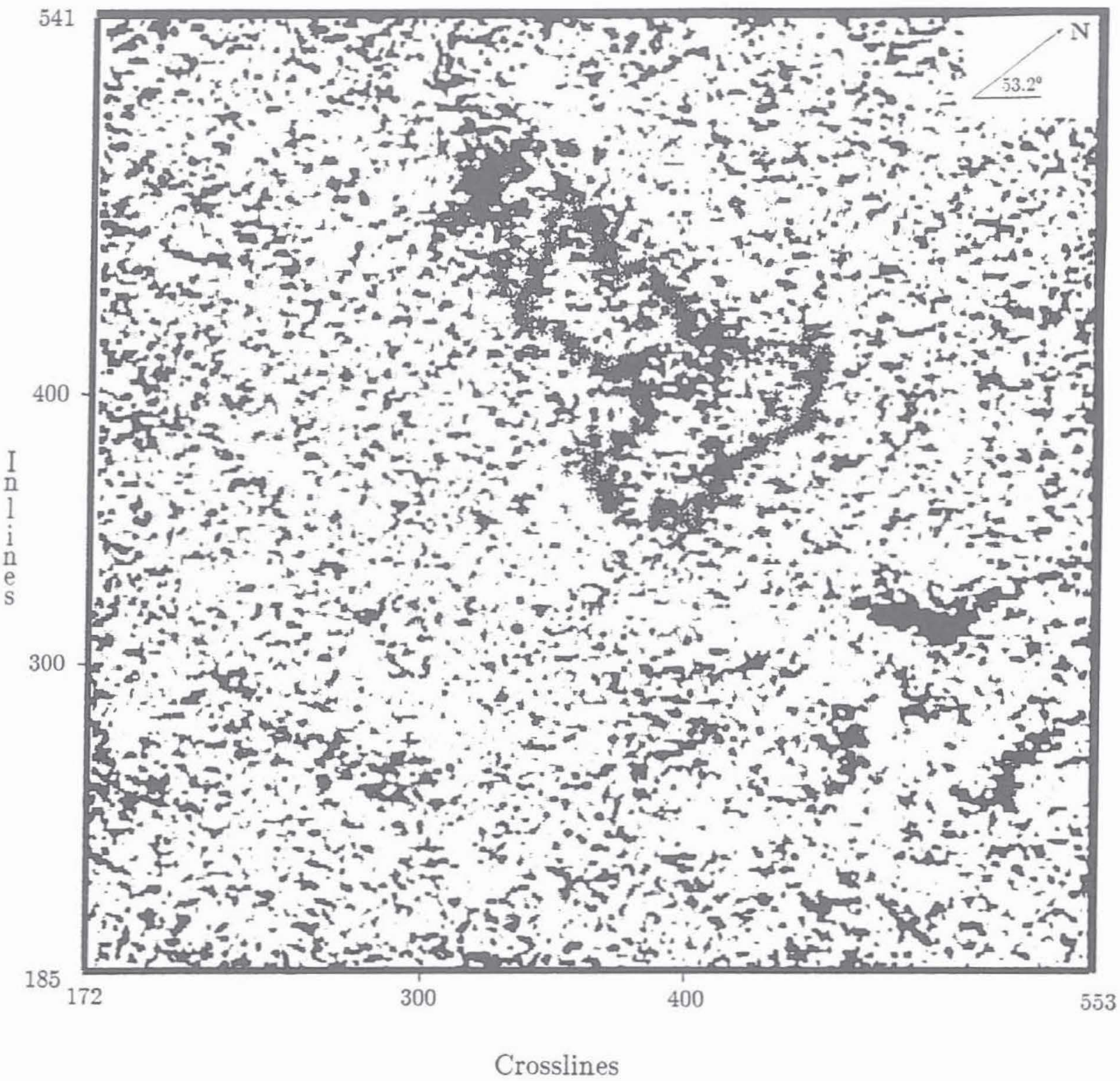

Figure 8: Time slice at 3576 ms of the 3D-survey. The tie-points of horizon B–1 are displayed.

are each an example for a number of similar horizons. The upper one (M-3) belongs to a group of southeast dipping elements which can be detected only underneath the sediments. The lower one (H-3) is one of three horizons which occur almost horizontally in the area of 5 s TWT. The connection with the horizons in the crystalline part of the survey area is not clear, yet.
In the part northeast of the Franconian Line there are two steep dipping elements (SE-1, SE-2) marked. They are the lower and upper bound of a bundle of similar elements. Besides these horizons the elements B-1, B-2, G-1 and G-4 are marked. These horizons will be described and explained below.
In Figure 7 the crossline 494 located at the northeastern edge of the survey is displayed in NW -SE direction . In this crossline the same elements are marked as in the inline as far as they can be seen here. The rhomboid structure formed by the horizons G-1 and G-4 can be seen clearly. This picture gives an impresssion of the complexity of the interpretation work which has to be done on this data. The complexity is mainly caused by a number of crossing elements especially the SE-horizons.
The 3576 ms slice displayed in Figure 8 has been used to control the interpretation done in the in- and crosslines. This controlling has been done with the tie-points which are displayed for horizon B-1 in this Figure. The horizon with the shape of a pear can be detected in the northwestern part of the survey area. But it can also be seen that there is no clear and sharp signal which can be interpreted in an unambiguous way.
The results of the preliminary interpretation can be summarized in five main groups:

- The first group consists of steeply dipping events with a true dip up to 65 degrees to northeast. These events, which have partially a parallel, partially a split structure (s. Fig. 6), are named SE (steep event)-1, SE-2, SE-3 and SE-5. The origin of those reflections may be overthrust planes, which reach the surface in the area of the Franconian Line.

- The second group contains two slightly curved, almost parallel major events and a diffraction like event in the time range 3.5 - 5.0 s TWT. These reflections seems to be continuous in the envelope stack, but there are severe hints that these events consist of a number of overlapping diffractions. This can be caused by a very rough or broken surface of a body. The elements of this group are named B-1, B-2 and R-1.

- The third group consists of five reflections interpretable in block C in the time range 2.5 - 4.0 s TWT. These reflections are well known as the rhomboid structure named Erbendorf body in the two-dimensional line KTB 8505 (Schmoll, et al., 1989). These reflections are named G-1 to G-5.

- The fourth group is composed of the reflections of the sediments in the southwest. In the envelope stack five horizons named A-1 to A-5 are interpretable.

- The events underneath the sediments form the fifth group. In the envelope stack it is quite difficult to decide which one is a multiple of the sediments and which one is a true reflection. It is quite difficult to interpret the connection of these events with the events in the crystalline block, too. So these events are not interpreted clearly, yet. There is the need for a normal stack with the informations on the phase of the signals.

Besides these five groups there are many small reflections and remarkable diffraction like events, which can be interpreted only in some parts of the area.
Some remarkable reflections shall be discribed in more detail in the following. The Figures 9 to 15 display the orientation in space of these events.

SE–1: It is a steeply northeast-dipping event with a partially split structure, which is recognizable only in the normal stack. This event shows a very poor amplitude in the northeastern part of the survey area. In contrast there are strong amplitudes in the near surrounding of the KTB well. In the area of block D (s. Fig. 1) it is quite difficult to detect this event. The extrapolated outcrops of this structure will be some ten meters west of the Franconian Line. The true dip varies between 40 and 65 degrees. The reflection SE–1 seems to be the lower boundary of a bundle of events steeply dipping to northeast. The KTB well will hit this structure as a zone of fractures. A so called "flying carpet" of horizon SE–1 is displayed in Figure 9.

SE–2: This event (Fig. 10) is a steep dipping event, too. It belongs to the above mentioned bundle of steep events and it seems to be the upper boundary of it. The reflection shows strong amplitudes mainly in the northwestern part of the survey area. The dip of this event is some degrees lower than that of SE–1. The extrapolated outcrops of this structure will be some ten meters east of the Franconian Line. The KTB well will hit this reflection as a zone of fractures, too.

SE–3: At about 900 ms TWT this event (Fig. 11) splits off from reflection SE–1. Because of this its dip is lower than that of SE–1. The reflection can be seen in the whole survey only fragmentarily. The KTB well will hit this structure, but it will be very difficult to identify this structure in the borehole beneath a number of similar zones of fractures in that depth.

B–1: It is a curved diffraction-like event between 3.5 and 4.5 s TWT. This event is interpretable in the whole survey area. The undulations, which are recognizeable in the three-dimensional display of the horizon (Fig. 12), lead to the presumption that this is not a continuous reflection. It seems that there are broken reflectors, which occur in the seismic section mainly as diffractions. Thus the interpretation of this event can be understood as an envelope of some single events located at a surface. The structure will be hit, if the KTB well can be deepened down to 11 km depth.

B–2: This event is quite similar to event B–1 (Fig. 13). It is located deeper than B–1. It seems to be possible that both events have the same origin because of their almost parallel course. Event B–1 can be the upper boundary and event B–2 can be the lower boundary of a very rough or broken body. It seems to be doubtful if the KTB well will be able to reach this lower boundary B–2 because of the greater depth.

G–1: This event is the lower boundary of a zone of high reflectivity, which occurs in the northeast of the survey area. It is quite possible that this event will continue in block B, but at the moment it can only be said for sure that it occurs in block C. Its prolongation into Block B can only be decided by the knowledge of the standard stack that means by the knowledge of the phase informations. This event dominates together with reflection G–4 in this zone.

G–4: This upper boundary of the zone with high reflectivity converges with the reflection G–1 in the northeast of the survey area. So this event intercepts the horizons G–2 and G–3 (s. Fig. 7). The rhomboid structure formed by the reflections G–1 and G–4 can be seen in Figure 14. In the two-dimensional seismic line KTB 8505 this structure is called Erbendorf body (Schmoll, et al., 1989). The seismic wide-angle measurements yielded to the result that this structure is a high velocity zone (Gebrande, et al., 1990).

A–1: The reflection A–1 (Fig. 15) is, from the actual state of the interpretation, the deepest reflection horizon of the sediments in the southwest of the survey area. The horizon shows a flat syncline, which traces in the higher horizons. The interface shows a dragging in the direction of the Franconian Line. It seems that the interface is broken because of that dragging, but this can only be decided in a standard stack, because fault zones are not recognizable in the envelope stack for sure.

The depth of the interpreted events can only be evaluated by a migration of the data or by a map migration of the interpreted horizons due to the very steep dips. Up to now the only migration which exist is a map migration of some selected reflections (Stiller and Tormann (1992) and Wiederhold (1992), this volume).

4 Conclusion

There are some major reflections in the three-dimensional survey of great importance for the structural image of the subsurface. The most problematic reflections are the steeply dipping reflections, because the true orientation in space of this events is very sensitive to the velocity model deduced for this area due to their steep dip. So there is the need for very careful investigations on the velocity model. It is also quite necessary to get a migrated data set to maintain more knowledge of the homogeneity of reflections cut by the steeply dipping overthrust planes (SE–*) (Hirschmann (1992), this volume). But it seems to be sure that some structural elements of that area cannot be reached by the KTB well. It will be difficult to integrate the interpretation into the results of the drilling, because these results show a lot of small fracture zones, which cannot be resolved by the envelope stack. A preliminary interpretation and a comparision of well data, lithology and seismic results is given by Hirschmann (this volume).
The results of the two-dimensional seismic lines could be corroborated, especially the rhomboid structure named Erbendorf body. But to achieve a resolution like the interpretations of these two-dimensional lines it is necessary to prepare a stack which shows all

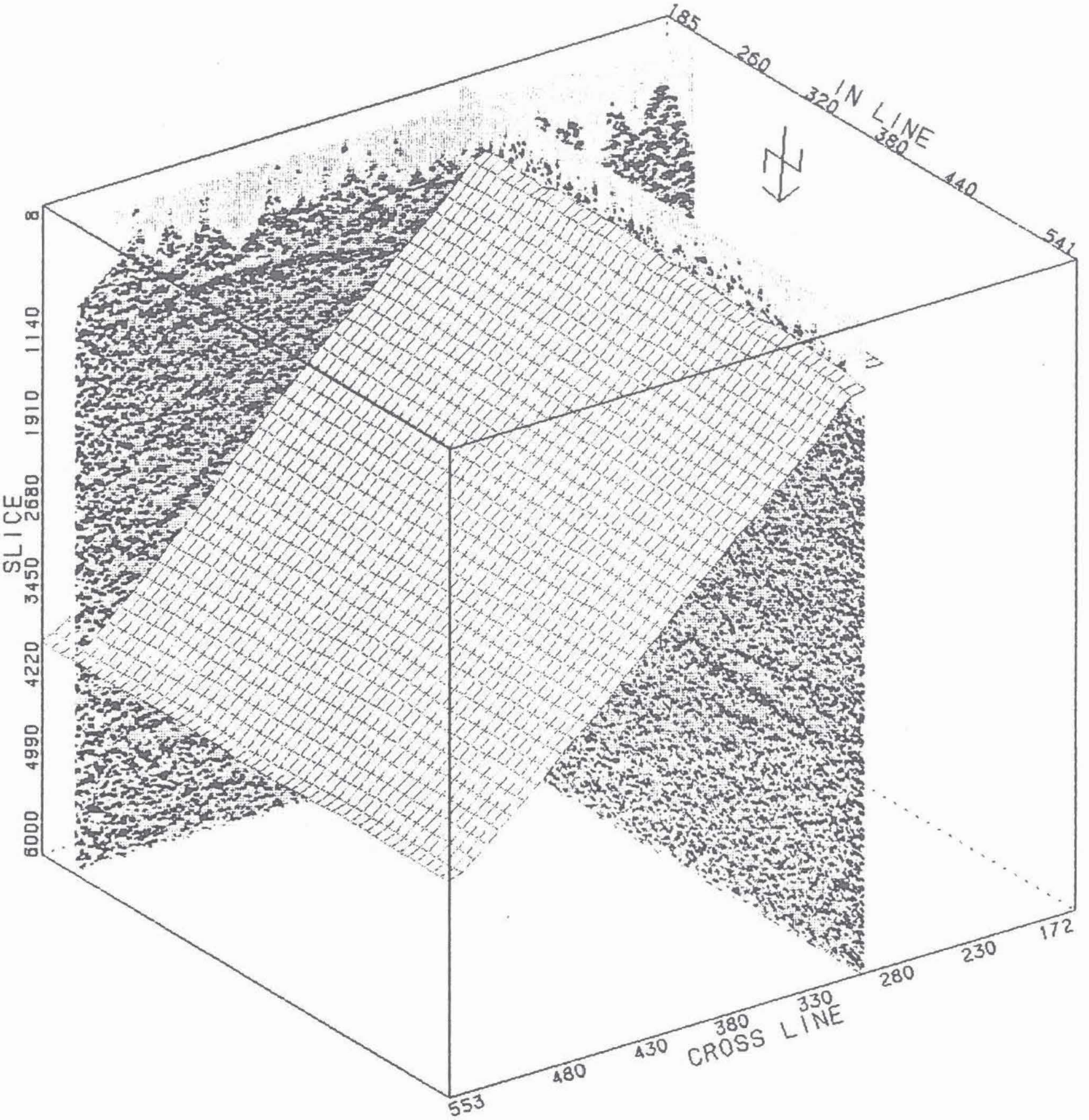

Figure 9: Horizon SE–1 displayed as a "flying carpet". The displayed data belongs to inline 210 and crossline 300. The line of sight is from the north.

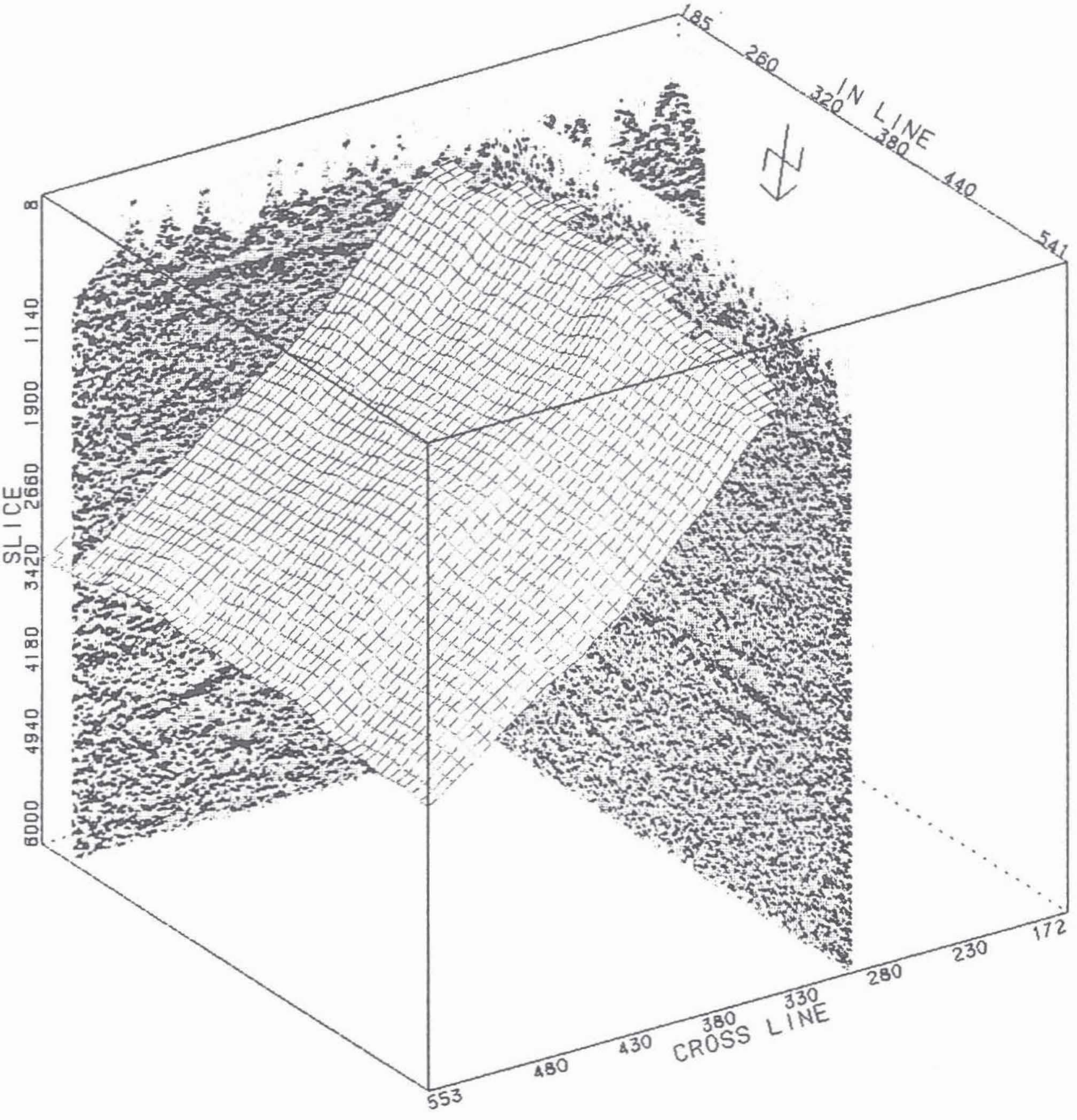

Figure 10: Horizon SE–2 displayed as a "flying carpet". The depicted data belongs to inline 210 and crossline 300. The direction of view is from the north.

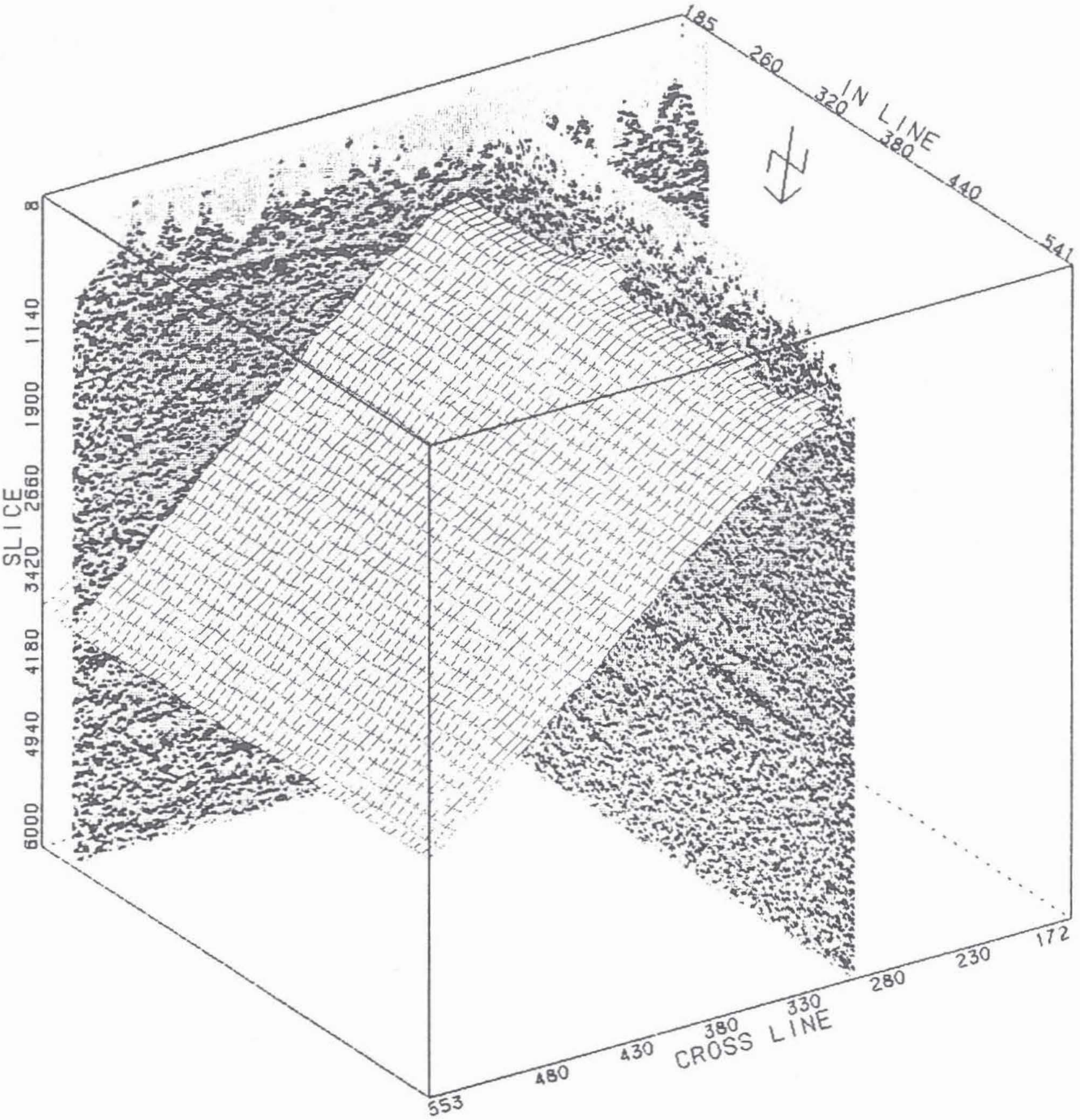

Figure 11: Horizon SE–3 displayed as a "flying carpet". The depicted data belongs to inline 210 and crossline 300. The data is viewed from the north.

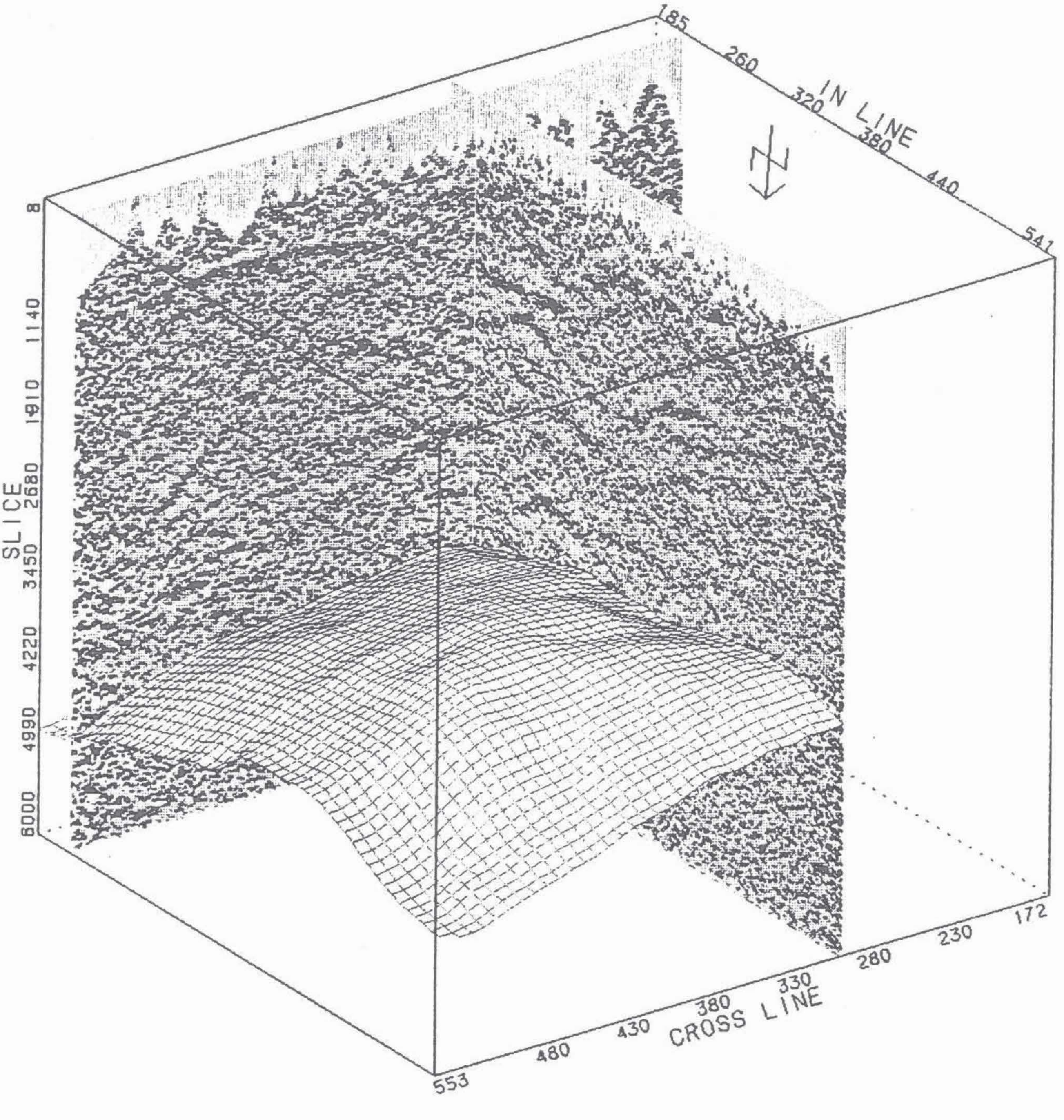

Figure 12: Horizon B–1 displayed as a "flying carpet". The depicted data belongs to inline 210 and crossline 300. The direction of view is from the north.

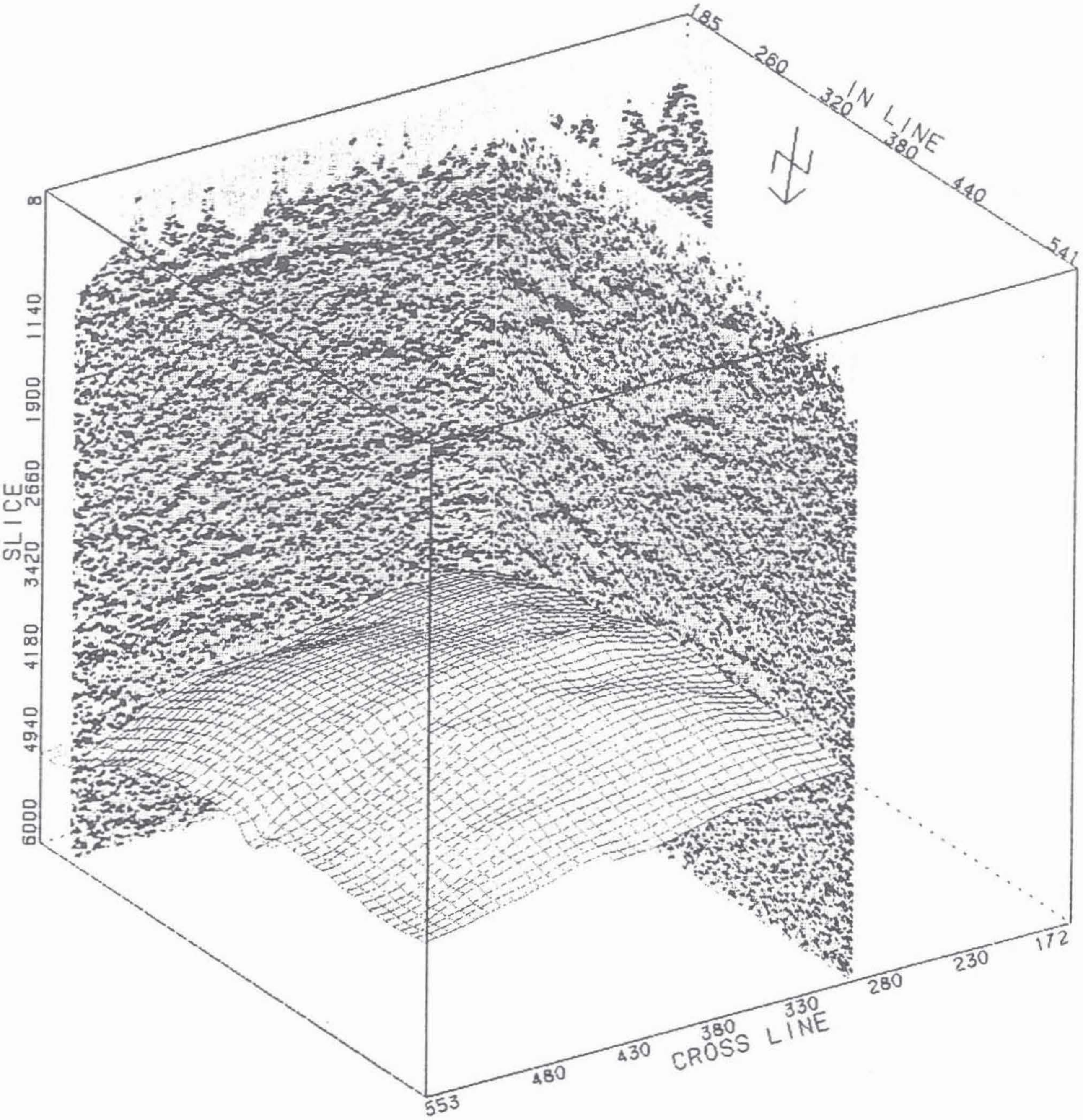

Figure 13: Horizon B–2 displayed as a "flying carpet". The depicted data belongs to inline 210 and crossline 300. The line of sight is from the north.

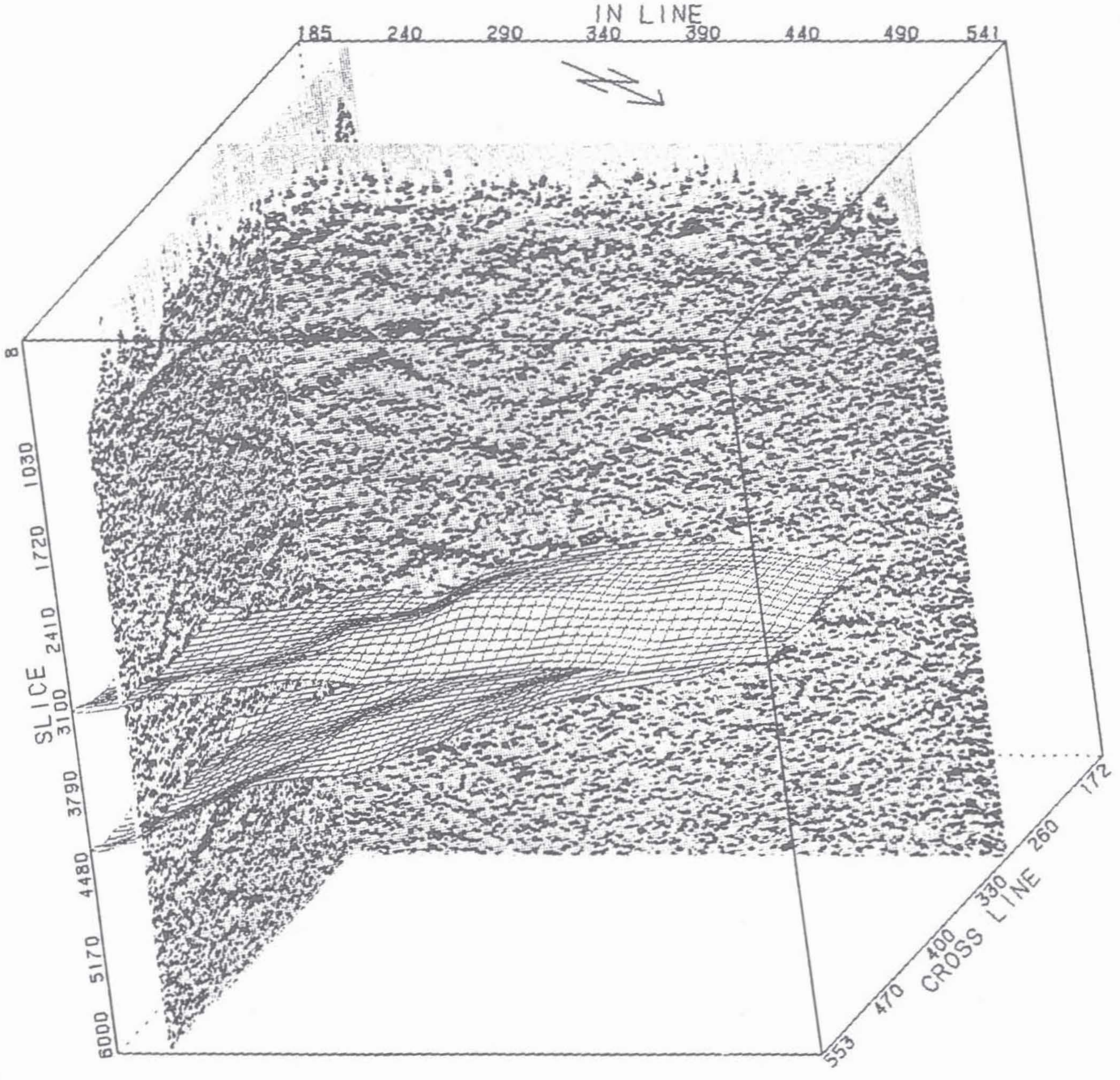

Figure 14: The horizons G–1 (the lower one) and G–4 both displayed as a "flying carpet". The depicted data belongs to inline 210 and crossline 300. The data is viewed from NNE.

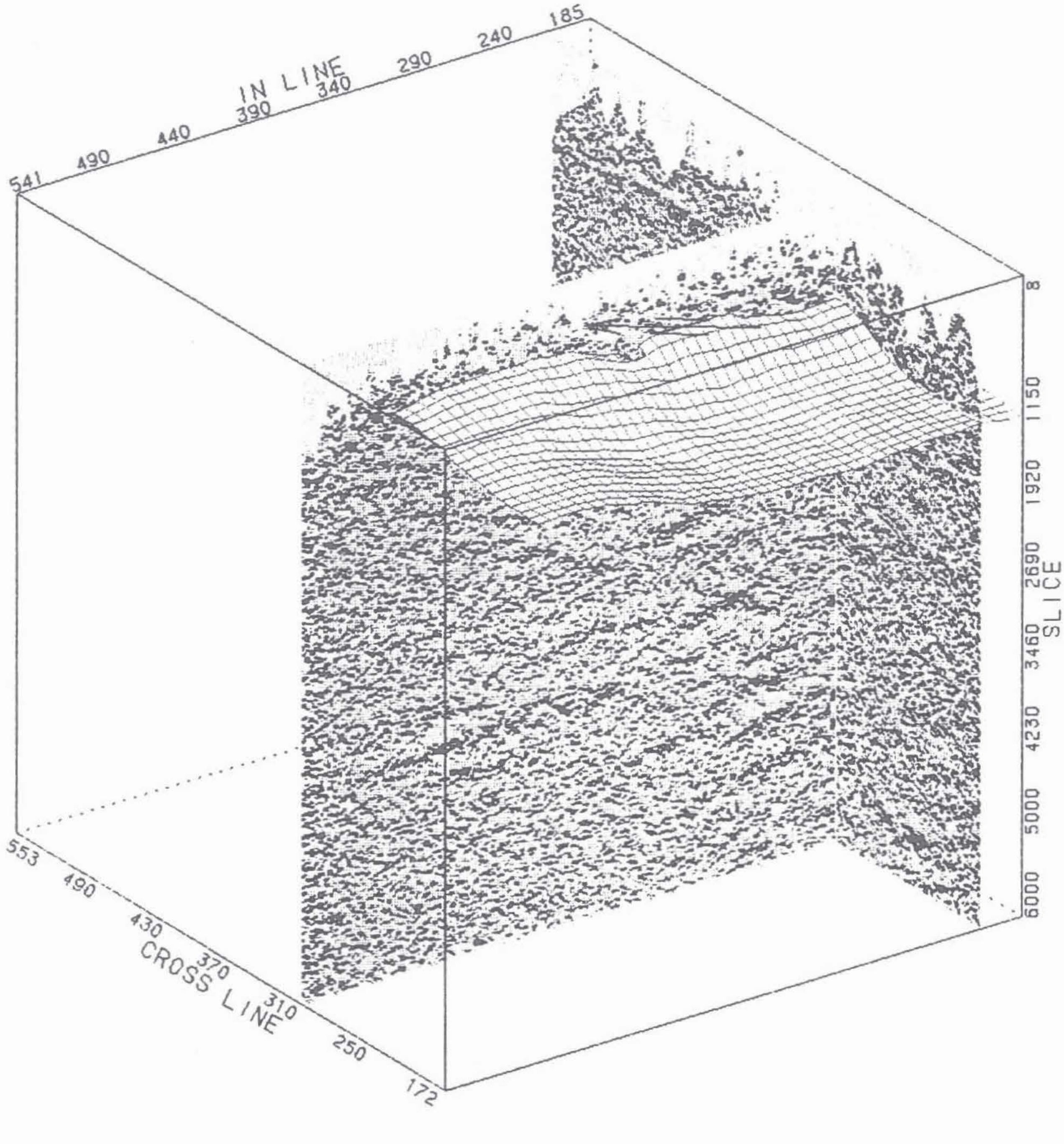

Figure 15: Horizon A–1 displayed as a "flying carpet". The depicted data belongs to inline 210 and crossline 300. The direction of view is from the west.

events and has in addition the information of phase. To reach that aim this preliminary interpretation can help in some way, because of the horizon orientated velocity discription in the three-dimensional data processing. If there will be a better stack all interpretation must be revisited and maybe changed.

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