GL00439

INTERPRETATION OF DEEP CRUSTAL REFLECTION DATA FOR STRUCTURE AND PHYSICAL PROPERTIES NEAR ACTIVE FAULTS

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INTRODUCTION

The COCORP crustal reflection profile across the San Andreas fault at Parkfield has defied interpretation. The reason for this was unclear; i.e., whether lack of coherent reflections was caused by the complex geology, by inadequate processing, or by poor data. Our goal was to reprocess the data to obtain adequate reflection quality and then to interpret this data.

THE ORIGINAL SEISMIC SECTION

The original seismic section produced by the seismic contractor (Fig. 1) does not show coherent reflections and is basically uninterpretable. Other than a shallow reflection from Tertiary sediments on the SW side and a weak diffraction at 2.0 sec in the fault zone, nothing is visible. The numerous short events are irregular, discontinuous, and lacking in character so that nothing can be correlated. Final stage processing such as migration by the contractor had also failed to produce any noticeable improvements. We, therefore, felt that we had to go back to the beginning to evaluate what the problem was.

GEOLOGY

Consideration of the geology and line location is a necessary first-step attack on a problem of poor data. Geology of the area is available from Dickinson, 1966a; Dickinson, 1966b. A crustal cross-section through the area at Cholame was obtained through the courtesy of Ben Page and appears in Figure 2. The geology is relatively simple SW of the fault where flat-lying Tertiary sediments overlie the Salinian granite block. The striking feature here is that not even the contact between Tertiary sediments and granite, a major acoustic discontinuity, appears in the reflection data. This strikingly illustrates the magnitude of the problem with the seismic data. NE of the fault zone, Franciscan rocks are present overlain by some infolded Tertiary sedimentary rocks. These rocks are highly folded thrust-faulted, and contain serpentinites. Geologic relations here might be so complex as to preclude coherent reflections, but not even the simple synclines (Fig. 2) find expression in the seismic section. The geology provides a clue to likely seismic velocities as well as possible reflection response.

REPROCESSING

Possible causes of poor data quality are as follows: 1) noisey field records, 2) static corrections, 3) incorrect stacking velocity, 4) complex raypaths that don't stack or ray kinking, 5) reverberations, 6) surface conditions, 7) complex geology. Our studies have shown that the first five of these make important contributions to degrade the data.

Surprisingly, the worst problem is poor quality of field data (Fig. 3). The correlated field records are extremely noisey. This noise problem was pointed out to the seismic contractor over one year ago by T. McEvilly and me. The contractor has investigated the problem and is still not sure of the cause except that the noise appears to be generated within the instruments instead of ground noise. This should not happen.

This instrument noise was left in the final stacked seismic section by the contractor. We have gone back to the original data and severely edited it in order to zero the traces that are noisey. Although this approach eliminated most of the noise, it also eliminated at least one-third of the data. Reflections are certainly present on the field records and do not appear in the stack, clear evidence for the poor quality of the stack.

Most of the recent reprocessing was carried out using the computer facilities of Amoco Production Company in Denver thanks to the generosity of Malcolm Knock of Amoco. The computer processing, istself, was done by Mark A. Bronston of Amoco, one of our recent geophysics graduates. Many tens of hours of computer time were contributed to the project by Amoco.

Much effort was directed toward better static corrections for the data. Static corrections were calculated by computer-based automatic static routines using special processing "tricks", and static corrections are as large as 120 ms. Clearly data quality must be seriously degraded in the CDP stack by static corrections that are this large. A computer program had been developed to determine static corrections from refraction first breaks. The next stage was to apply static corrections that were refined by hand, but support was terminated before this step could be started.

Velocities were studied by generating a large number of constant-velocity stacked seismic sections (Figs. 4 and 5). These sections showed that shallow reflections from Tertiary sediments on the SW end of the line are enhanced by stacking at a lower velocity (2.1 km/s) than had previously been used, and at higher velocities a band of diffractions along the San Andreas fault zone appears (Fig. 5). Also evident at high stacking velocities are dipping events that are probably reflected refractions crisscrossing the seismic sections.

Complex geology may be accompanied by velocity variations such that raypaths are complex and reflections don't stack in phase. This problem was attacked by using variable range stacks; *i.e.*, near-, middle-, and far-trace stacks. This approach has the effect of keeping raypaths similar and minimizing the ray-kinking problem. Variable range stacks resulted in some improvement and cleaned the data up. Some shallow reflections in the fault zone appear in a near-trace stack (Fig. 6). A far-trace stack was used for interpretation because this seemed to provide the best data quality (Figs. 7 and 8).

Autocorrelograms showed that multiple reflectons in the form of fairly short-period reverberations were also present in the data. Initial attempts to deconvolve these multiples were not very successful.

Conglomerates at the surface on the SW side of the profile and complex geology of the Franciscan on the NE side are not major factors but may contribute somewhat to decreased data quality. The reason for the poor seismic sections is the combined effect of five factors, instrument noise, bad static corrections, incorrect velocities, ray-kinking, and reverberations, of which instrument noise is the most serious cause.

INTERPRETATION

Only a minimal interpretation has been attempted because processing is far from complete. The success of any interpretation is probably limited by effects of instrument noise on the data. The far-trace stack (Figs. 7 and 8) was chosen for interpretation because it seemed to represent the best data. Individual "reflections" are not as wiggly as on the original section (Fig. 1) and show better coherence. The results of this interpretation were presented at the Fall 1979 American Geophysical Union Meeting (Bronston, et al., 1979). The seismic section suffers from prominent mute zones in the upper part and from a band of unusual character at 6 sec that may be a processing artifact. Thereis, however, a distinct change in character in the events below 7 sec. Earlier, this was interpreted in terms of a thrust so that the Salinian block was allochthonously overlying Franciscan on the SW side of the fault. Further consideration of this seismic section leads us to believe that data quality is still not adequate for such a conclusion and that the events present may be multiple reflections.

SEISMIC MODEL

A seismic model (synthetic seismogram) was generated from known geology and can be used as an estimate of the seismic response along the Parkfield line (Fig. 9). The model SW of the fault consists of Tertiary sediments overlying granite, inclusions in granite, higher velocity lower crust, and a Moho marked by a transition through lenses of peridotite. The fault zone is marked by lower velocities and heterogeneities. NE of the fault zone, a faulted syncline is underlain by folded and thrust-faulted Franciscan containing serpentinite, peridotite, and blue schist bodies; the Franciscan is underlain by oceanic lower crust in thrust slices. The seismic response of these structures is a complex series of convex upward reflection and diffraction arcs. The Moho zone is a chaotic series of arcs that would appear as composite (multicyclic) reflections. Thus events looking like diffractions would be common on both sides of the San Andreas fault zone as well as in the fault zone itself.

CONCLUSIONS

The poor data quality in the COCORP Parkfield crustal reflection line is caused by the combined effect of a number of factors, of which noisey field records probably caused by the recording instruments is the most serious problem. Reprocessing of the data was stopped at an intermediate stage because support was withdrawn. Improving seismic data in a case such as this involves a number of passes on the data with feedback in which velocity and static corrections are gradually improved on each pass. More interactions are necessary to attain the full potential of this data set, but the final result will probably never really be good because of poor quality of the original field data. Complex geology is not the major cause of poor data quality. The poor quality of this data set was pointed out to U.S. Geological Survey personnel before we started to work on the project. The inadequacies of the field recording were discussed with the seismic contractor and may result in either reshooting the line or re-correlating and editing the field data to produce a cleaner data set.

REFERENCES

*Bronston, M. A., R. L. Zawislak, R. A. Johnson, S. B. Smithson, and E. K. Shumaker, 1979, A new study of the COCORP Parkfield, California reflection seismic line across the San Andreas fault (abs.), EOS, Trans. Amer. Geophys. Union, v. 60, p. 875.

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*Publication resulting from this research

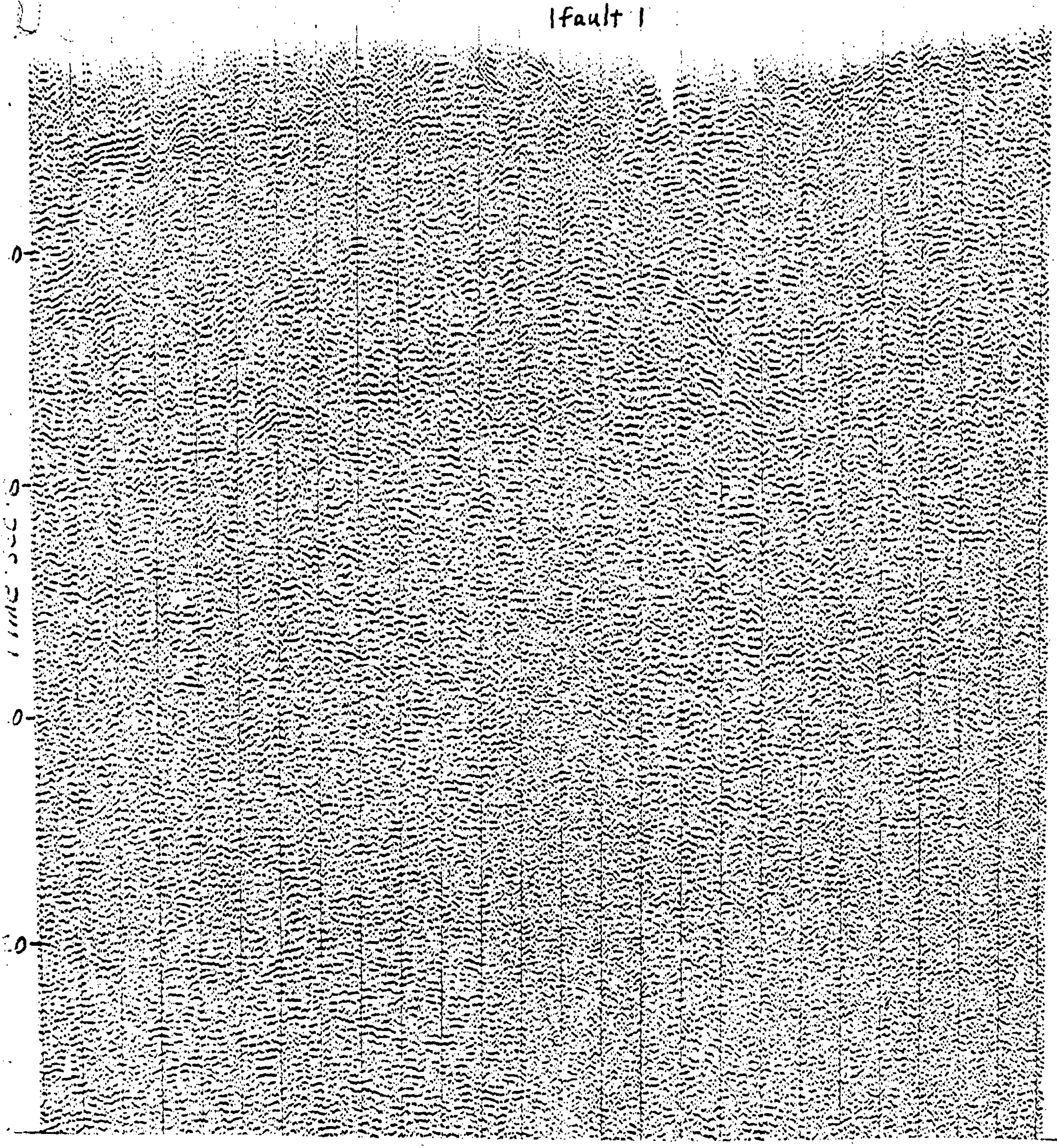

Figure 1. COCORP Parkfield "final section" released by Cornell. This seismic section is unusable. Only some poor reflections from Tertiary sediments are visible in the upper left.

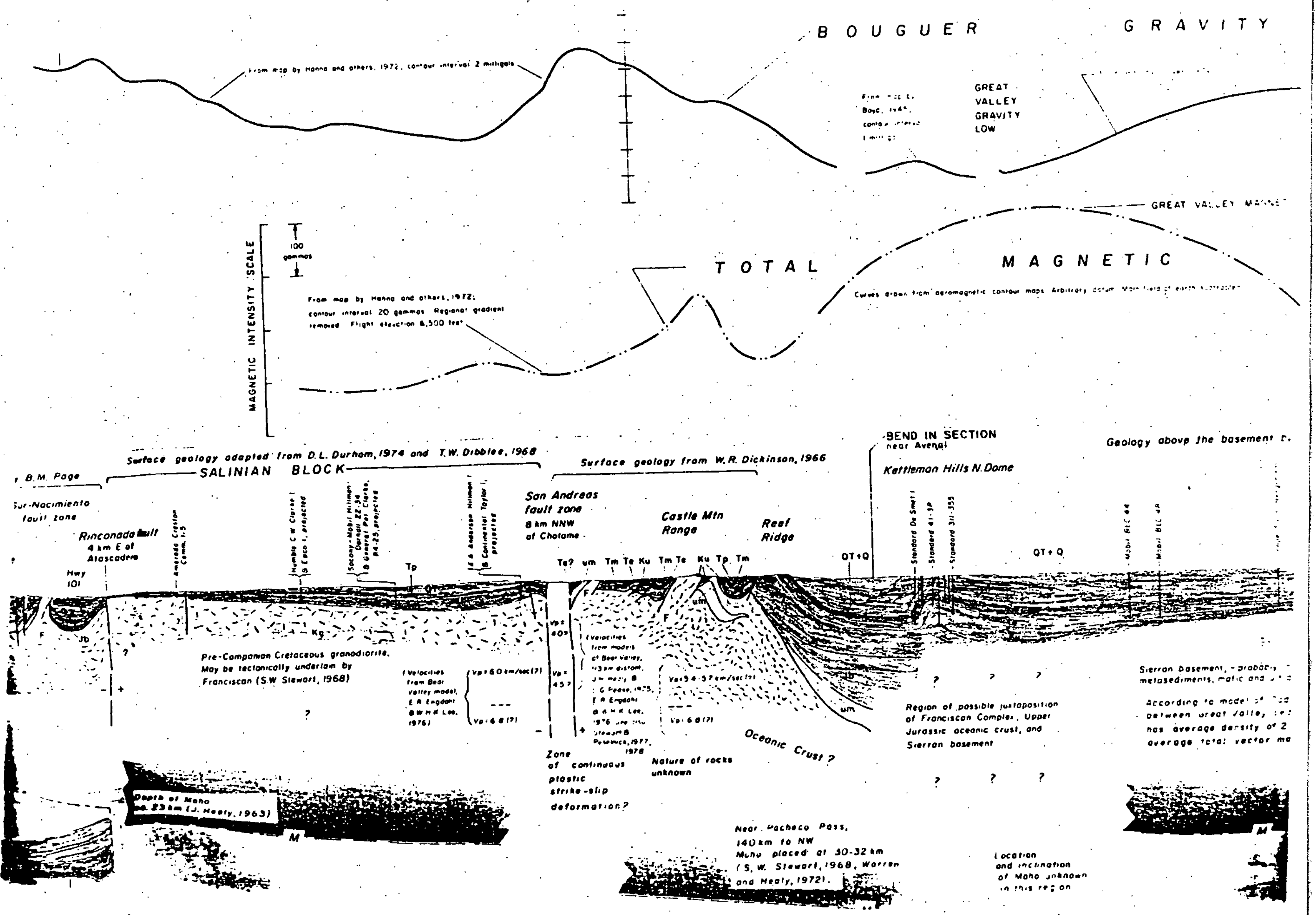

Figure 2. Geologic cross-section of the Parkfield area constructed by Ben Page. Note twin splays of San Andreas fault and complex geology of the area. On SW side of fault at last the Tertiary sediment-Salinian granite contact should appear as a good reflection.

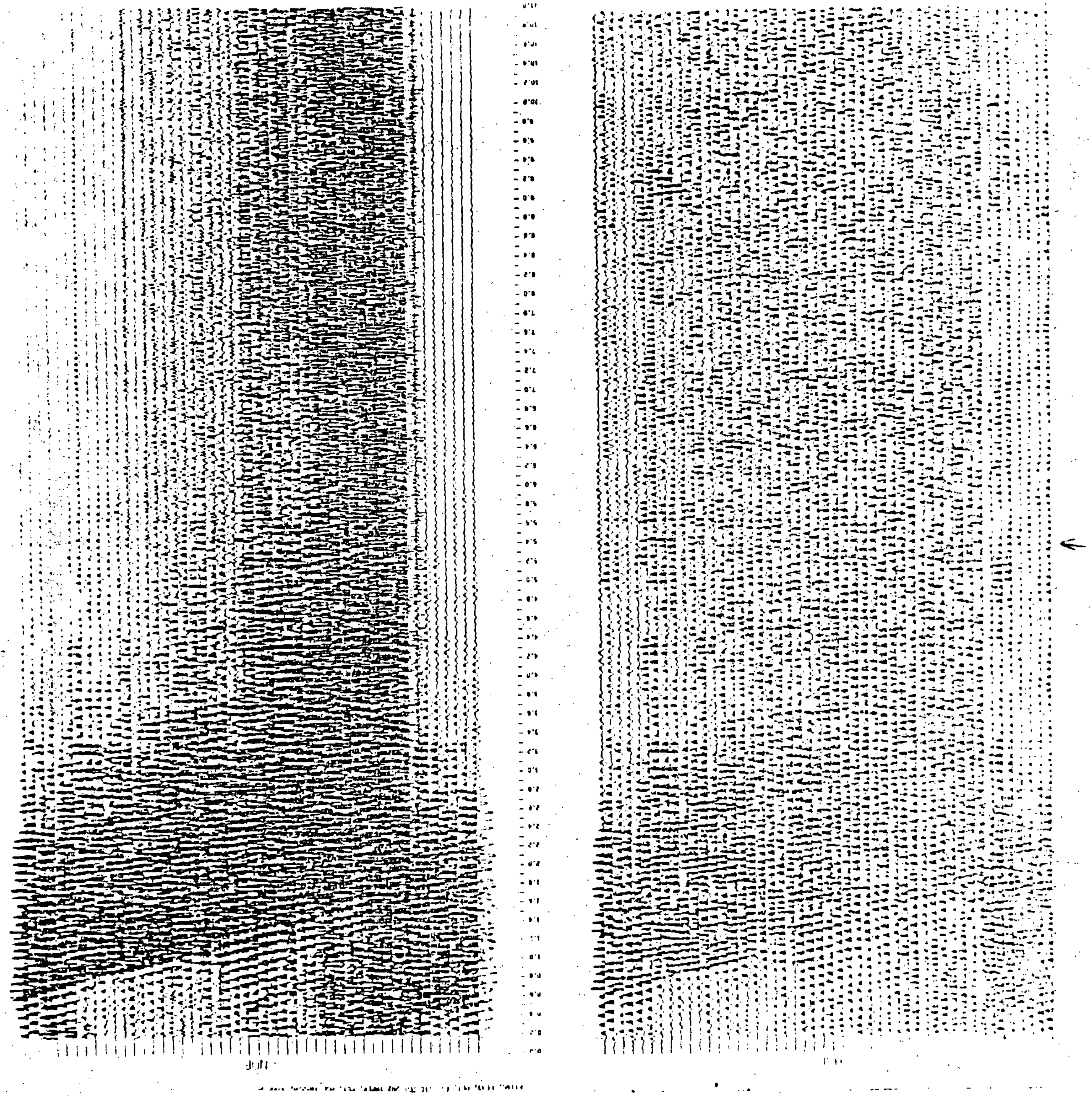

Figure 3. Unprocessed individual record (top) and same record bandpass filtered (10-20 hz) and gained (bottom). Top record is extremely noisey. Filtering has removed most of this noise and continuous event appears at 5.3 sec. Readers should note that crustal reflection data seldom shows events as clearly as even fair sedimentary reflection data.

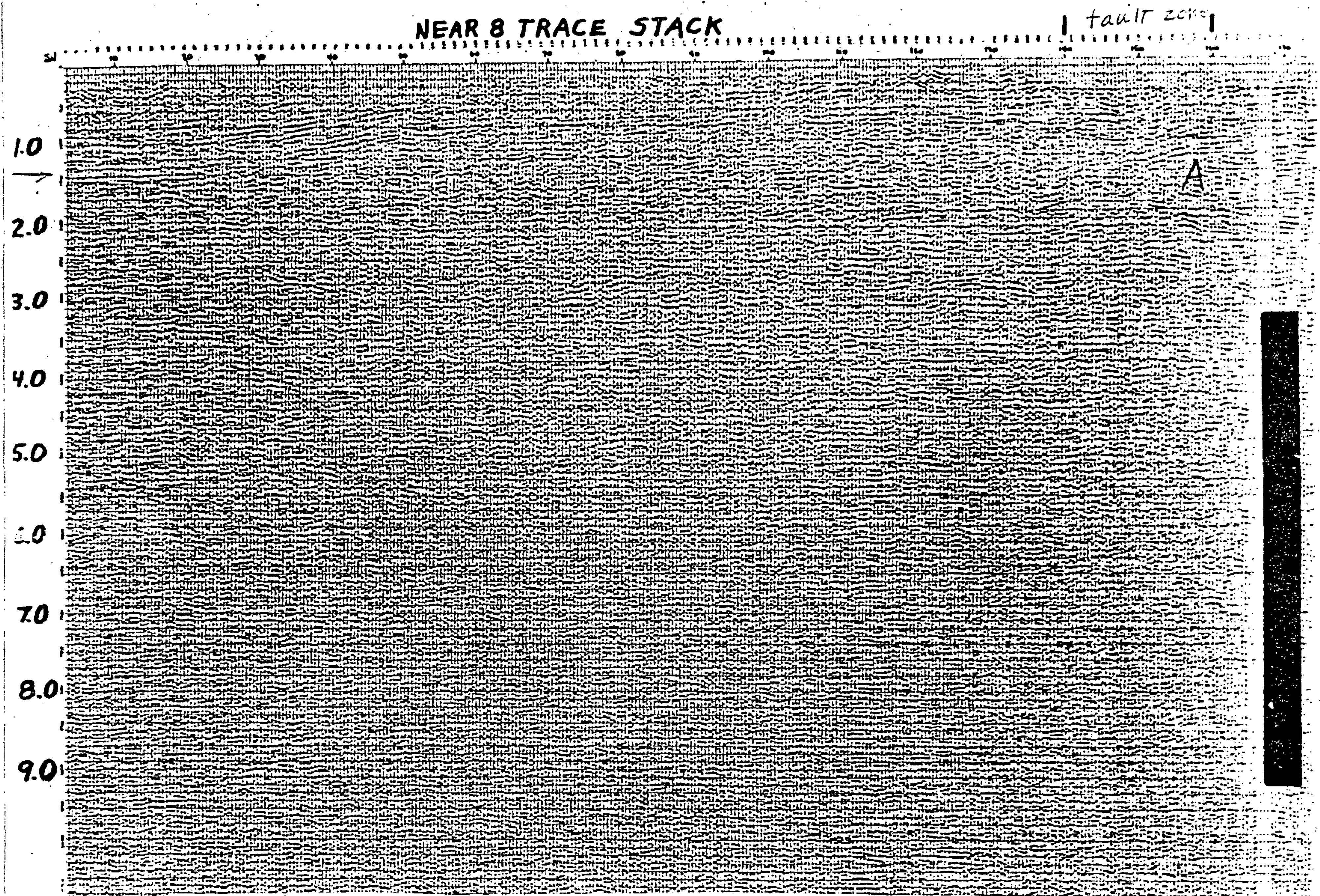

Figure 4. Near-8-trace stack with new velocity function showing improved definition of reflections from Tertiary sediments overlying Salinian basement SW of the San Andreas fault. Reflection and diffraction (A).

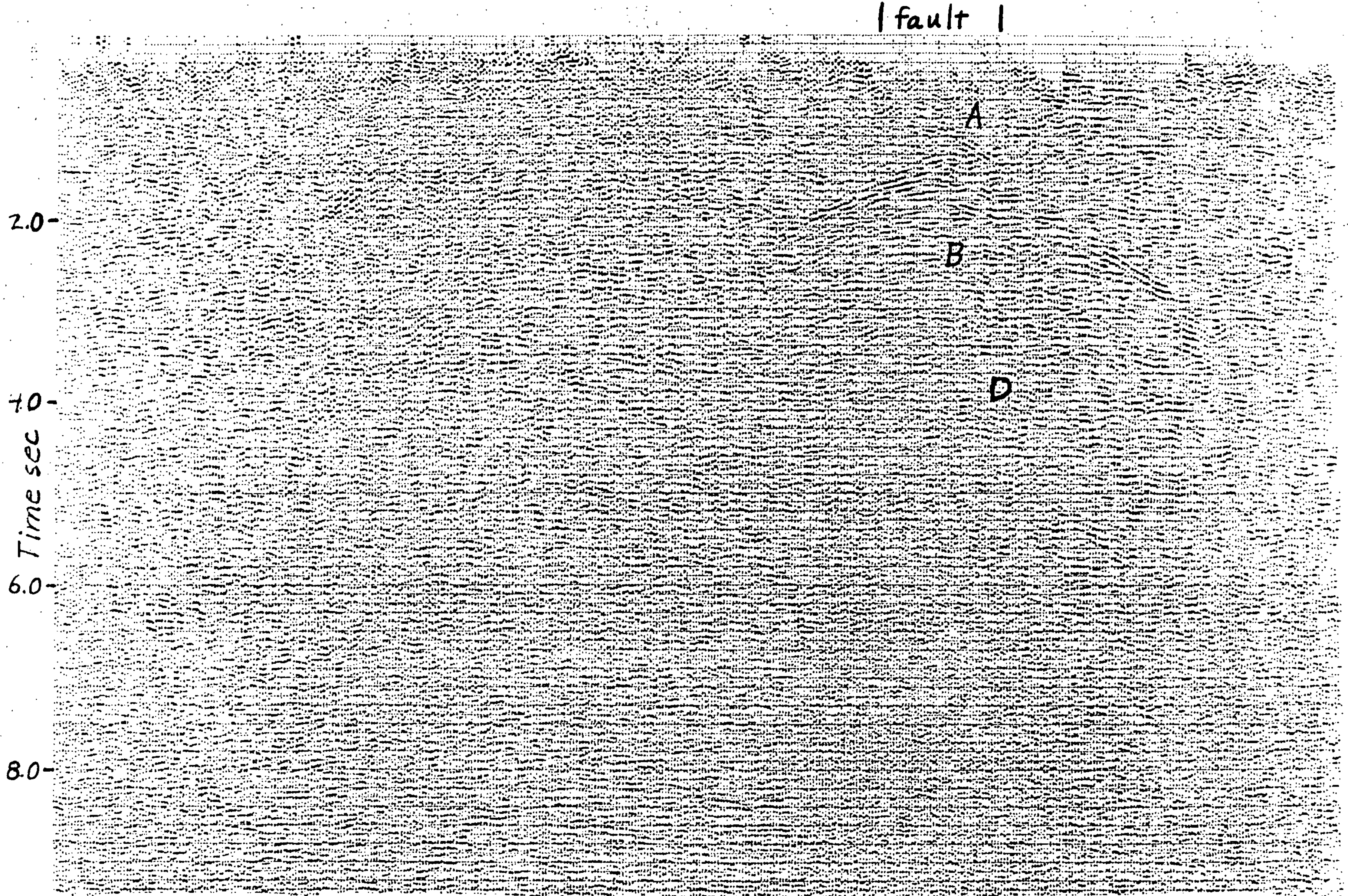

Figure 5. COCORP Parkfield initial stage of reprocessing. Constant velocity section at 7km/sec. Note strong diffractions from San Andreas fault block between 1 and 2.5 sec. (A to B) and weak deep possible diffraction at 4.5 sec (D) that allow the fault position to be traced to about 10 km depth. Possible reflections near Moho depth at 8 to 9 sec. Note dead zone continuing to depth below fault position.

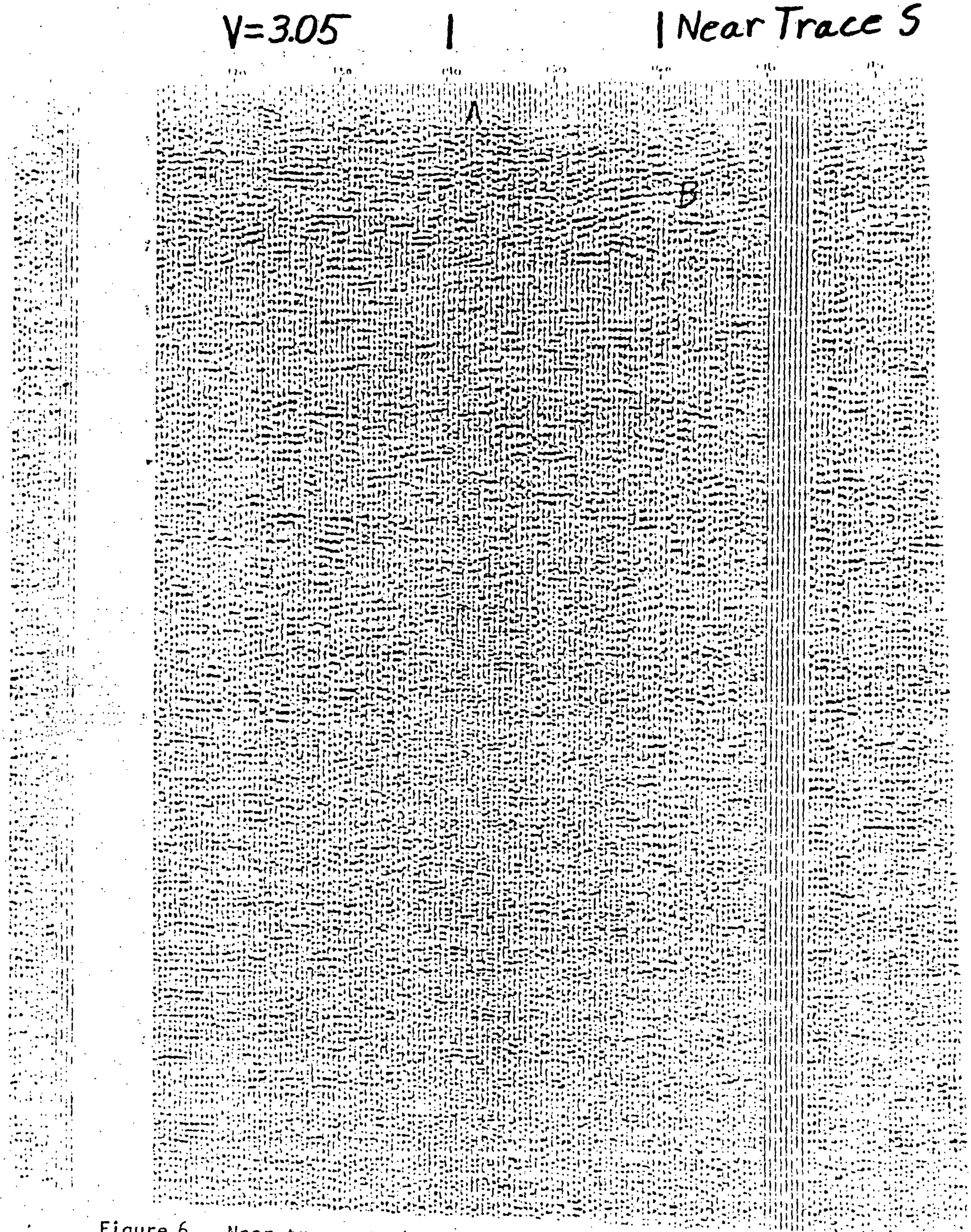

Figure 6. Near-trace stack across fault zone processed at constant velocit Possible reflection in the fault zone at 0.4 sec stack in at 3 Reflection at 0.7 sec. NW of fault zone terminates against faul passes into a diffraction. (B).

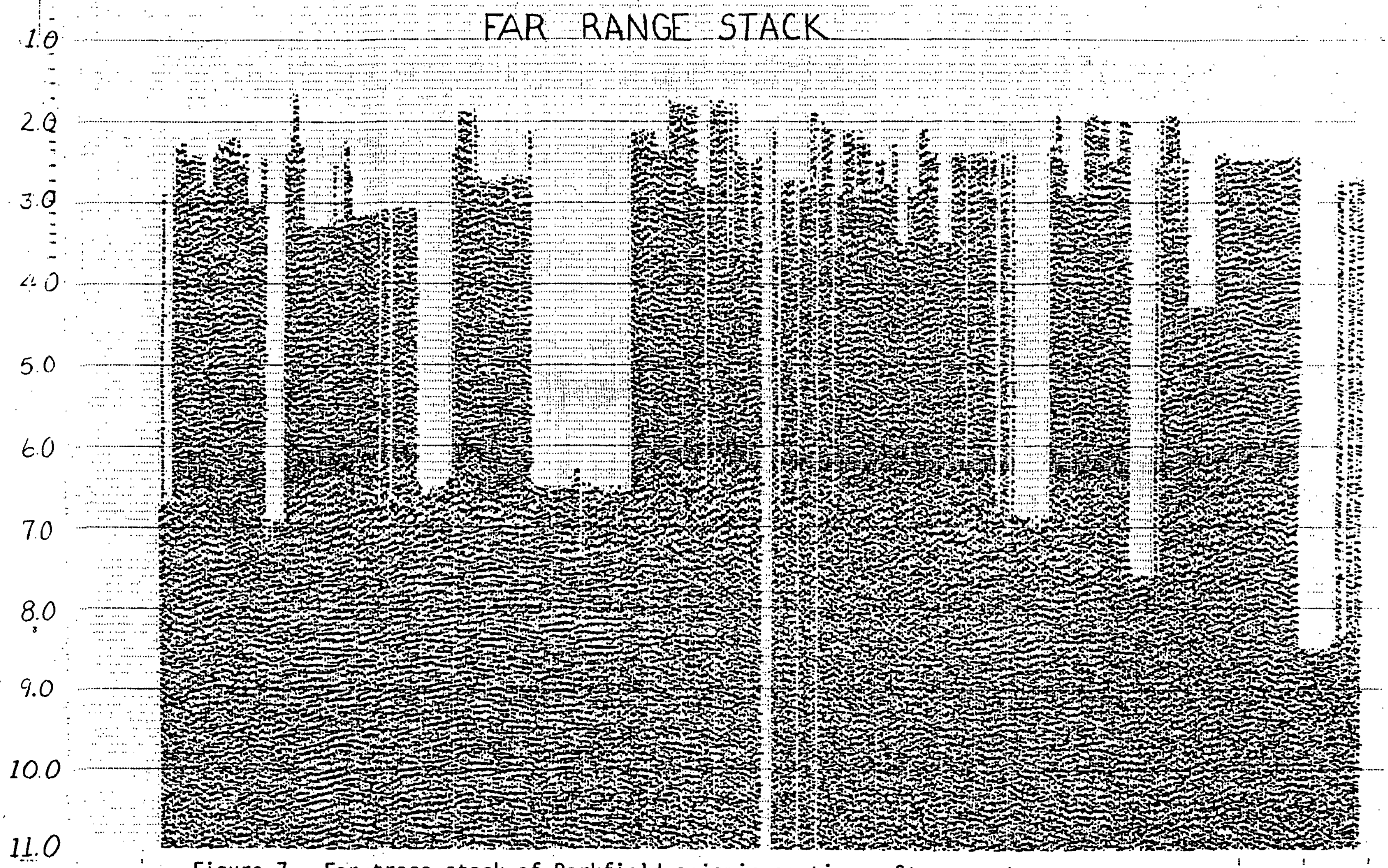

Figure 7. Far-trace stack of Parkfield seismic section. Strong mute zones along top are caused by removing noisey traces. Zone of high-frequency reflections at 6 sec may be processing artifact. Change in character below 7 sec could indicate change in crustal structure such as an allochthonous block. These deep events may, however, be multiple reflections.

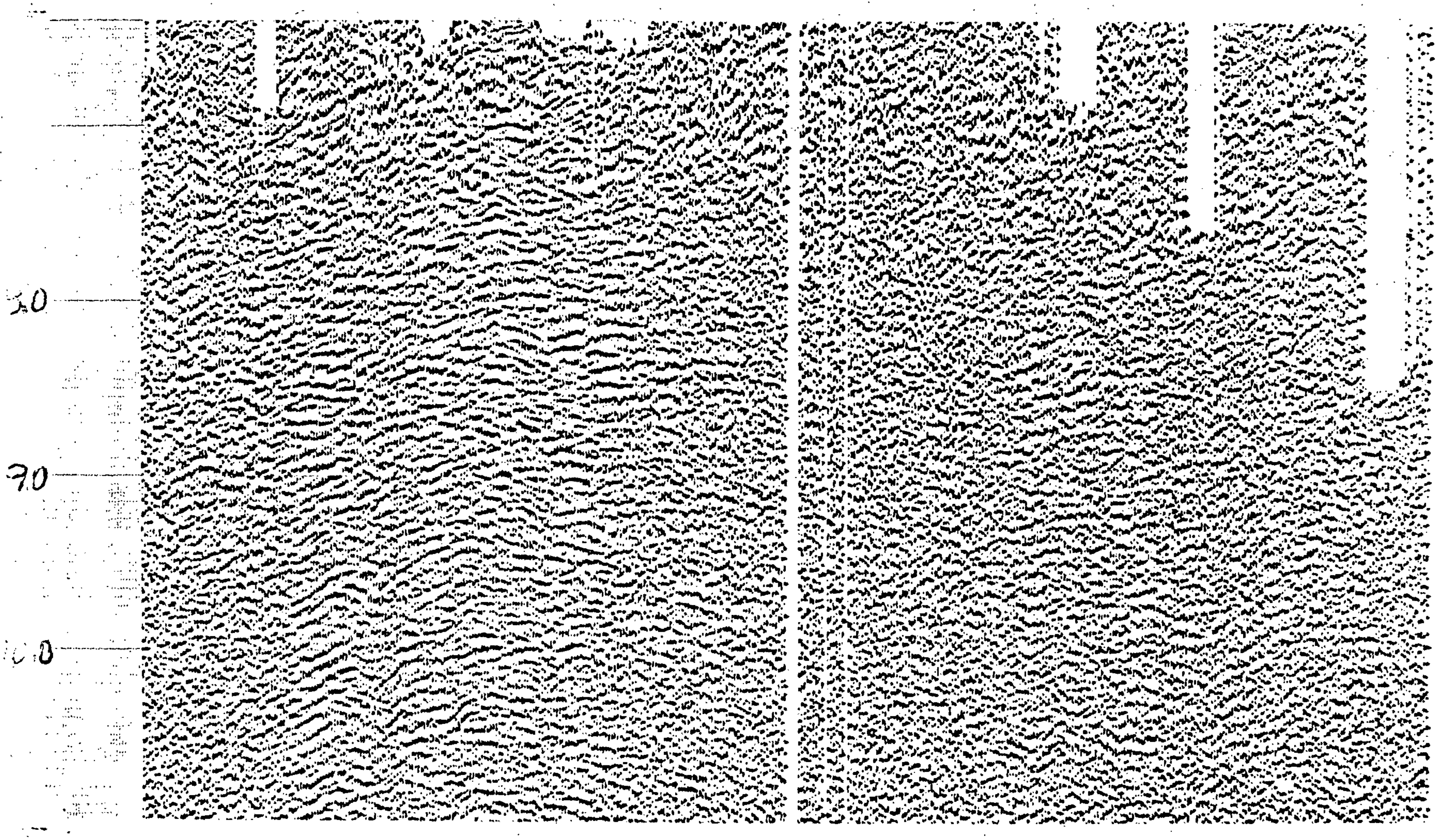

Figure 8. Enlargement of the lower part of the far-trace stack shown in Fig. 7.

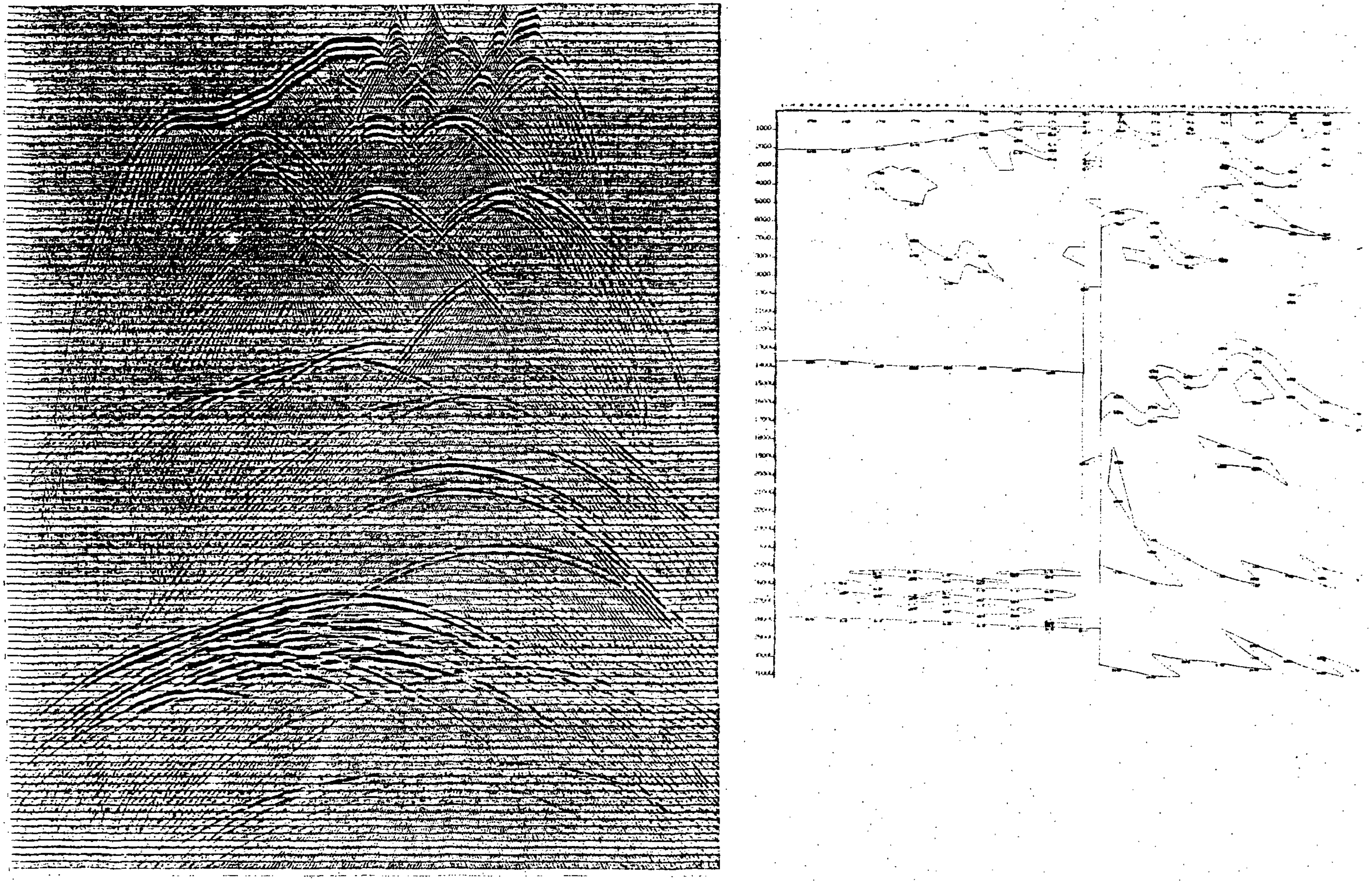

Figure 9. Synthetic seismogram generated to approximate the seismic response of the crust at Parkfield. The seismic response is a complex series of arcs.