EXAMPLES OF DIGITAL PROCESSING OF TRANSCORDED TAPES

by

J. D. BOYD*

ABSTRACT

This paper presents two case histories of digital processing of transcorded data. Deconvolution filtering was applied in both cases. The input data is studied, and empirical conclusions are made about the limits of usefulness of the frequency spectrum.

INTRODUCTION

A magnetic tape representing a paper record may be produced by transcording. The resulting tape is a faithful reproduction of the paper record except for slight timing errors and slight distortion of waveforms by the operator manually tracing the record.

This paper is a study of pre-tape data from two areas in Western Canada, one in West Central Alberta, and the other in Western Saskatchewan. The records, of relatively good quality, were shot in 1950 and 1953. None of the records are mixed. The goal in each area was to improve the resolution of the reflected wavelets by inverse filtering and to accept a reasonable increase in noise level as the price to be paid for an increase in resolution. It has also been attempted by studying these two areas to get an empirical idea of the limits to which transcorded data can be pushed through processing.

DISCUSSION

Before making too many assumptions about the quality of the data it was necessary to find out something about the signal on these transcorded tapes. The frequency content was examined by deriving amplitude spectra from the data. Figures (1) (shaded portion) and (8) are two examples of amplitude spectra of transcorded traces. Two observations can be made about them: Firstly, the spectra are reasonably broad and continuous, secondly, the low amplitude at the high end of the spectra (above 60 cps) suggests that random background noise is not a serious problem. This is important since the records have been subjected to the extra process of transcording, as well as field recording through instruments of low dynamic range by today's standards. If the frequency spectrum is fairly broad and if the field filters are reasonably linear in phase and if the reflected signal is not buried in instrument noise then processes such as inverse filtering can certainly be used with validity on the data.

Another characteristic of most pre-tape data is the band limiting of the frequency spectrum by narrow recording filters. Because we want a broad "box-car" spectrum if we are to optimize the resolution of the

*Seismotech 64 Ltd.

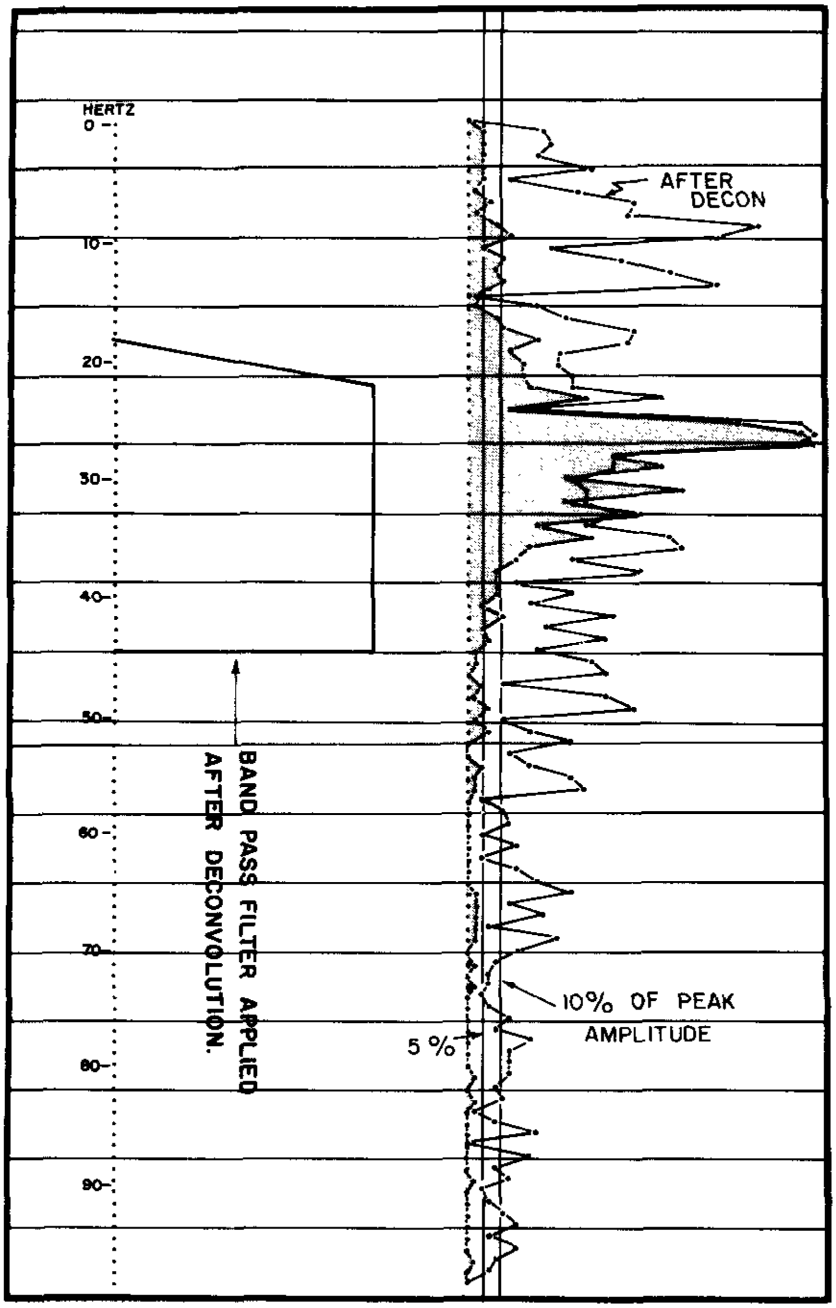

FIG. 1.—Typical amplitude spectrum, before and after deconvolution, West Central Alberta area.

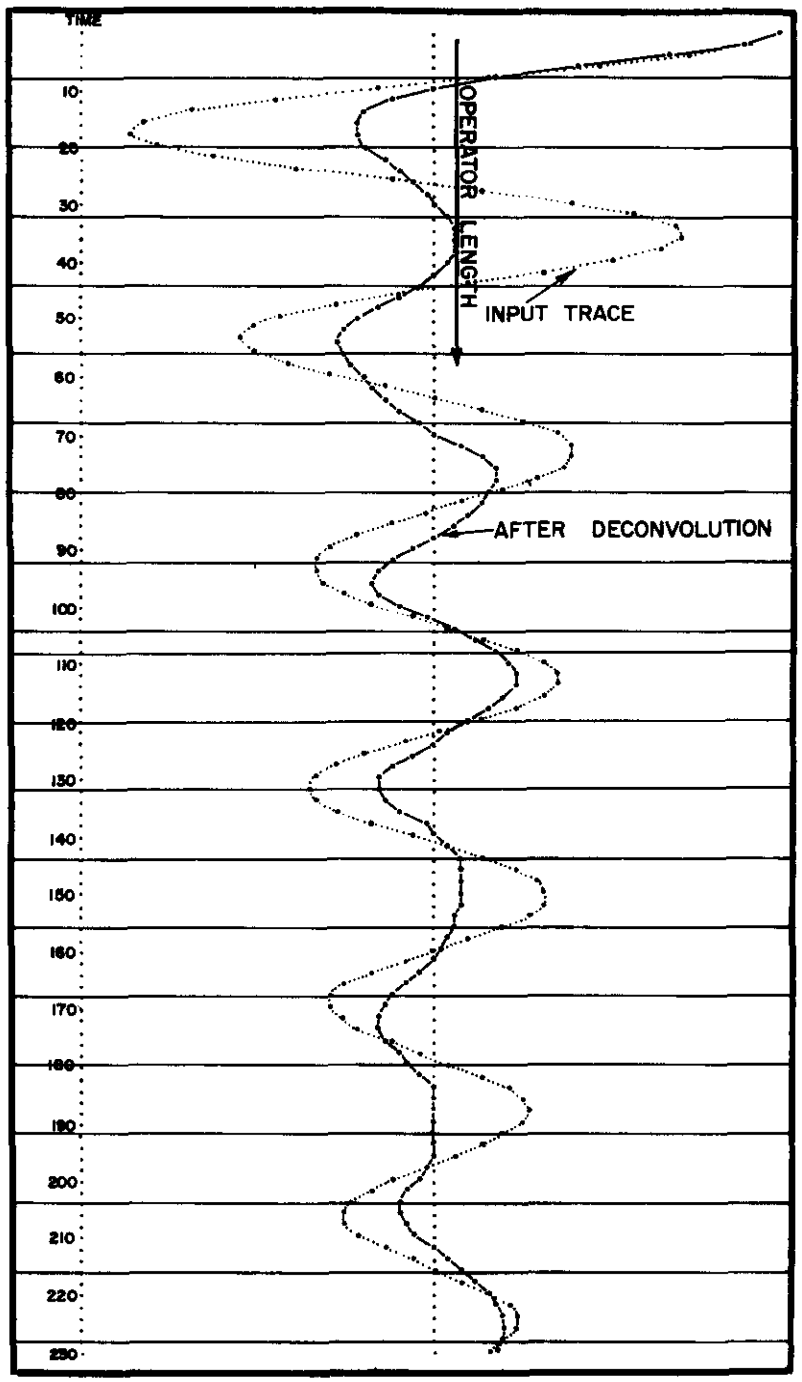

FIG. 2.—Autocorrelations, before and after deconvolution, West Central Alberta.

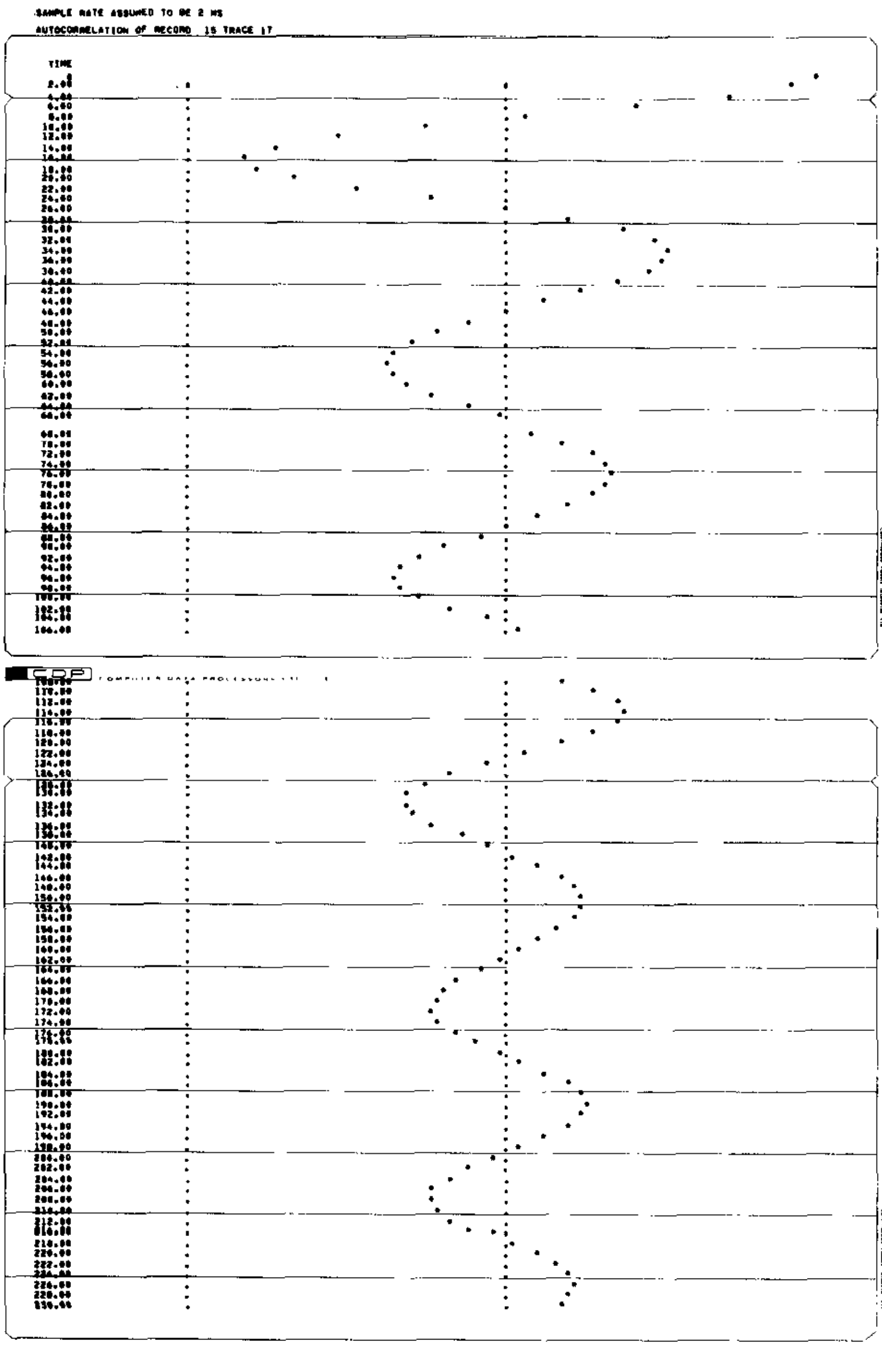

FIG. 3.—Autocorrelation of deconvolved trace after band pass filtering, West Central Alberta.

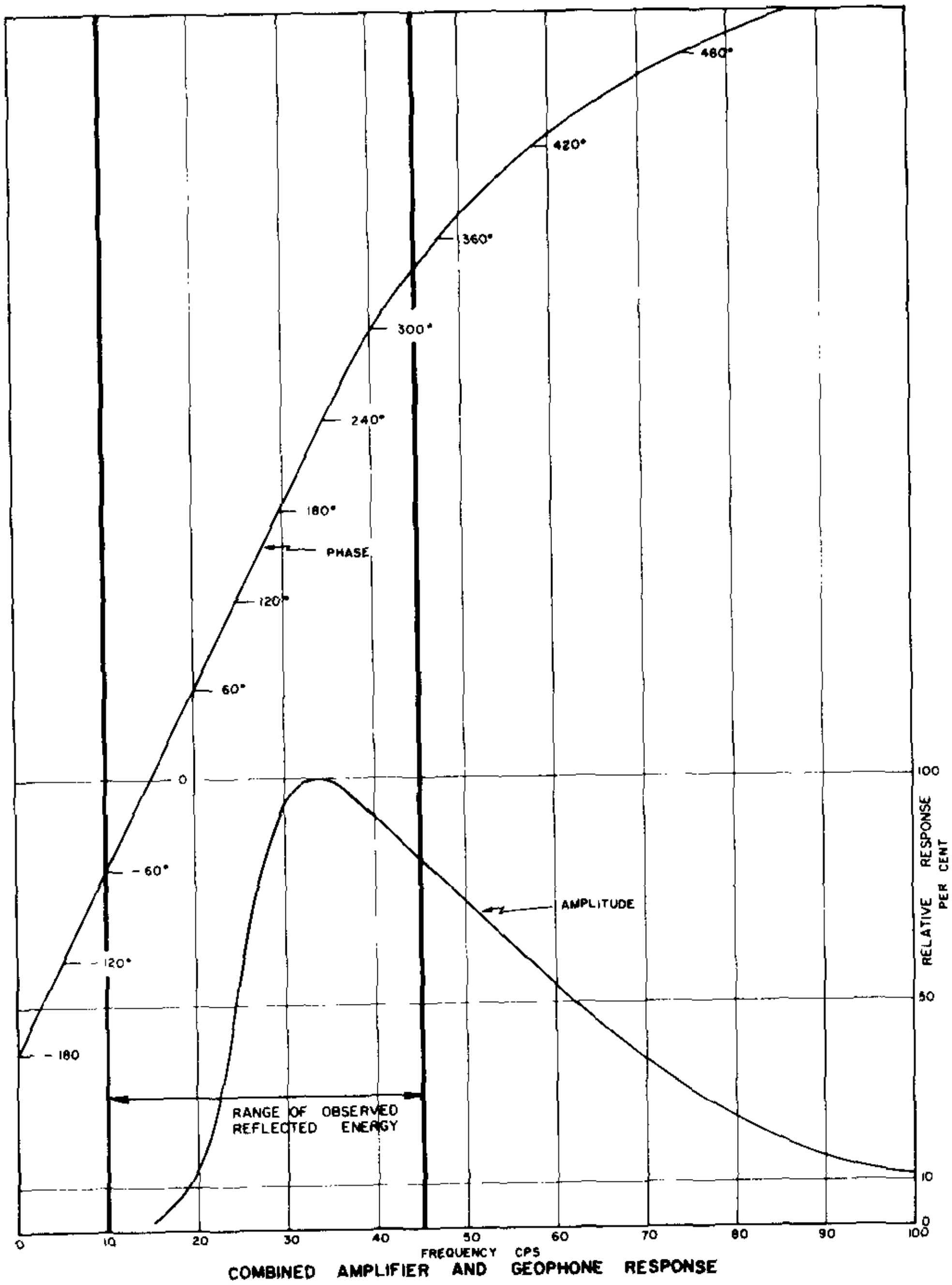

FIG. 4.—Amplitude and phase response of field recording filter, West Central Alberta.

data we will want to know to what extent the input filters limit the usable band width. Figure (4) shows the amplitude and phase characteristics of the recording filter used on the data from West Central Alberta. Comparison to the amplitude spectrum in Figure (1) shows that much more low frequency has been passed than the filter characteristics suggest and that high frequencies have been limited by earth filtering rather than the recording filter. It is noted that the phase shift is linear up to 40 cps, which will take in nearly all of the recorded energy.

As stated previously, the goal is, through inverse filtering, to whiten the spectrum and thereby increase resolution of the reflected wavelet, up to bearable limits of noise level. The records from West Central Alberta were deconvolved, using a 29 point 2 millisecond operator, designed over a window of from 1.0 to 2.0 sec., with some prewhitening. The 29 point operator was judged to be long enough to handle the ringing frequency of about 27 cps. Figure (2) shows the autocorrelation of a trace before and after deconvolution. Superimposed on the amplitude spectrum of Figure (1) is the spectrum after deconvolution. The autocorrelation is quite well spiked except for the long period reverberation of about 110 ms which was not influenced by the short operator. The 27 cps component still dominates the frequency spectrum, but other frequencies have been raised relative to it.

Figure (5) shows a record deconvolved in this manner, and then passed through a series of narrow band pass filters. The limits of coherent reflected signal seem to be from about 10 to 45 cps. The 10 cps value indicates that there is usable reflected data below the low-cut of the recording filter. The high noise level below 20 cps and above 40 cps indicates, as would be expected, that much of the spiking shown on the autocorrelation after deconvolution is due to the presence of random noise in the signal.

The limits of 10 and 45 cps correspond roughly to the 10% amplitude line on the amplitude spectrum (Figure 1). This suggests the desirability of using amplitude spectra, rather than filter curves, to predict the usable limits of frequency on data of this sort.

We therefore will band limit the output signal to something no wider than 10 to 45 cps. Actually the signal was limited still more by a low cut of 18-22 cps in order to remove low frequency surface waves observable on Figure (5) in the 5 to 20 cps. range. This step would normally not be taken, for we are obviously losing a great deal of our attempted high resolution by chopping off 10 cycles of reflected signal from an already narrow range of frequencies. The resultant autocorrelation of our trace is shown in Figure (3). Band pass filtering causes the autocorrelation to ring again, although it is still spiked somewhat in relation to the input trace. It must be realized that we cannot take advantage of stacking or spread layout to remove systematic noise such as surface waves and that it may often be necessary to apply extra filtering to transcorded data.

Figures (6-7) show some comparisons between the deconvolved and band pass filtered data and records which are band pass filtered only.

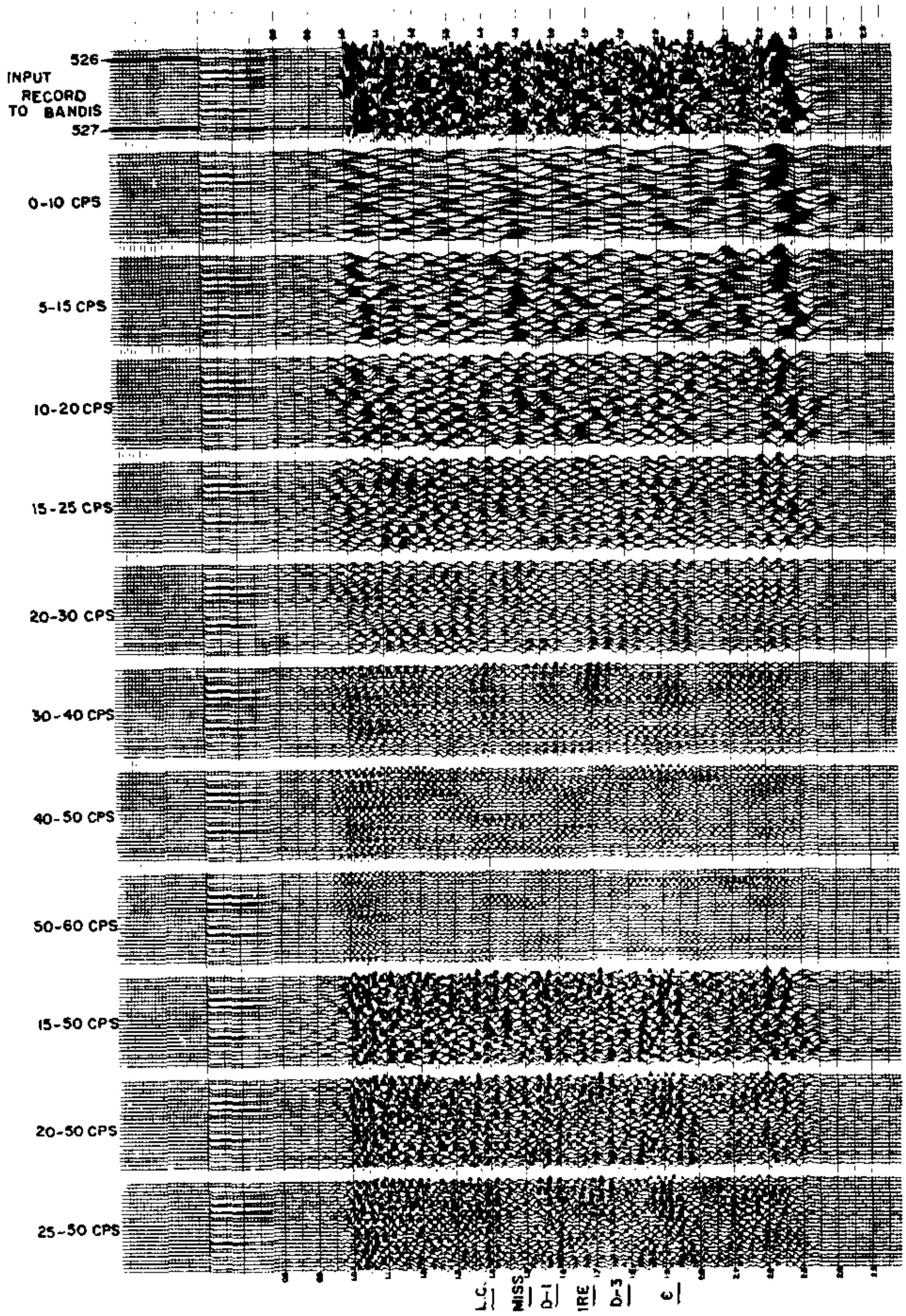

FIG. 5.—Unfiltered deconvolved record (top), West Central Alberta, and same record passed through a series of band pass filters.

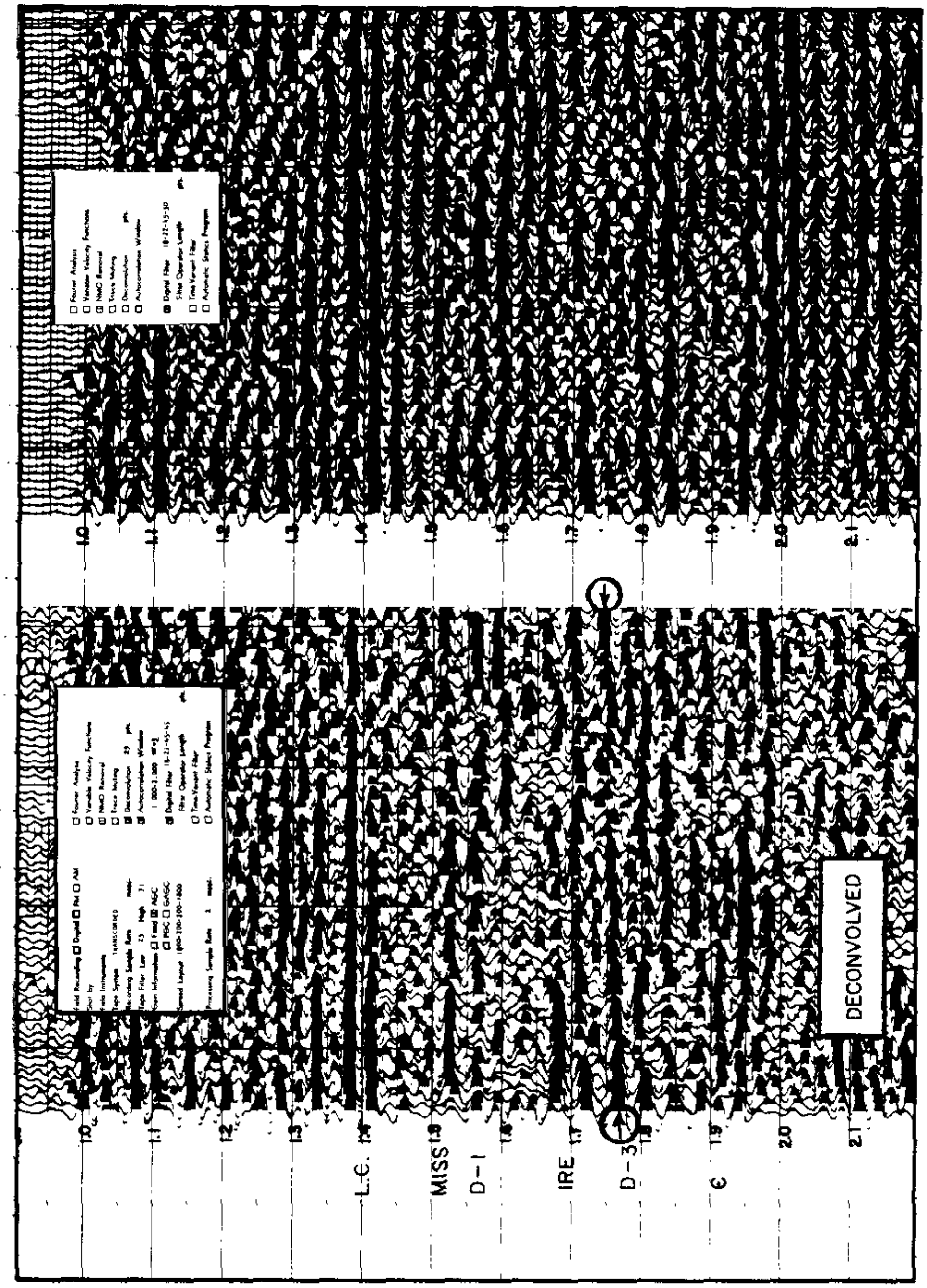

FIG. 6.—Comparison of deconvolved and filtered section (bottom) and band pass filtered section (top), West Central Alberta.

In spite of our severe filtering after deconvolution, there is a definite improvement in resolution, and the ability to make character correlations. There is also, of course, more "noise" on the deconvolved records. There is a dip indicated by arrows on the deconvolved section (Figure 6) which is difficult to see on the corresponding filtered section in the same diagram. The Ireton and D-3 reflections are much better resolved on the deconvolved section in Figure (6). The same comparison in Figure (7) shows a very great difference in the resolution of the reflections, particularly the Ireton. It is not suggested that extremely good record sections have been produced, but it is suggested that the results of the deconvolution filtering are encouraging and that this process yielded sections which are of more value to the interpreter than the sections made by only band pass filtering the data.

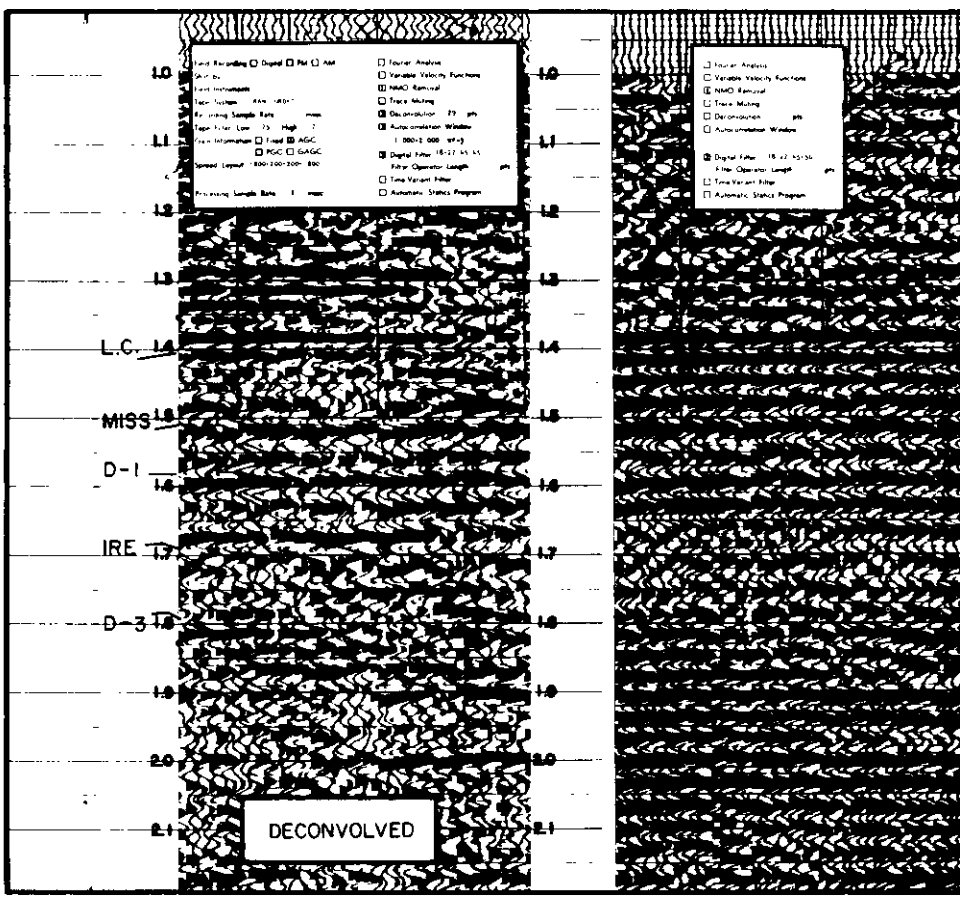

FIG. 7.—Comparison of deconvolved and filtered section (left) and band pass filtered section (right) West Central Alberta.

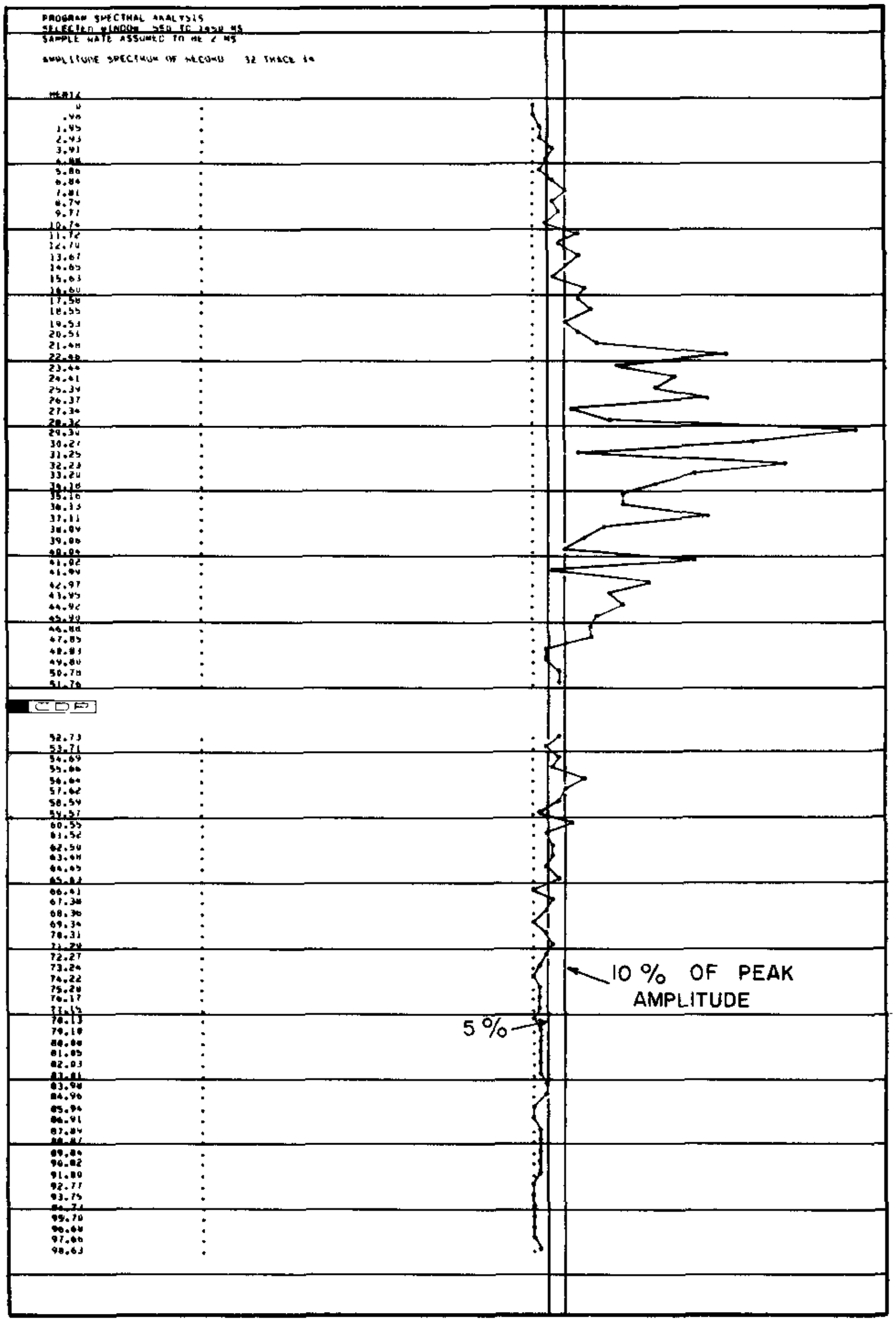

FIG. 8.—Typical amplitude spectrum, Western Saskatchewan area.

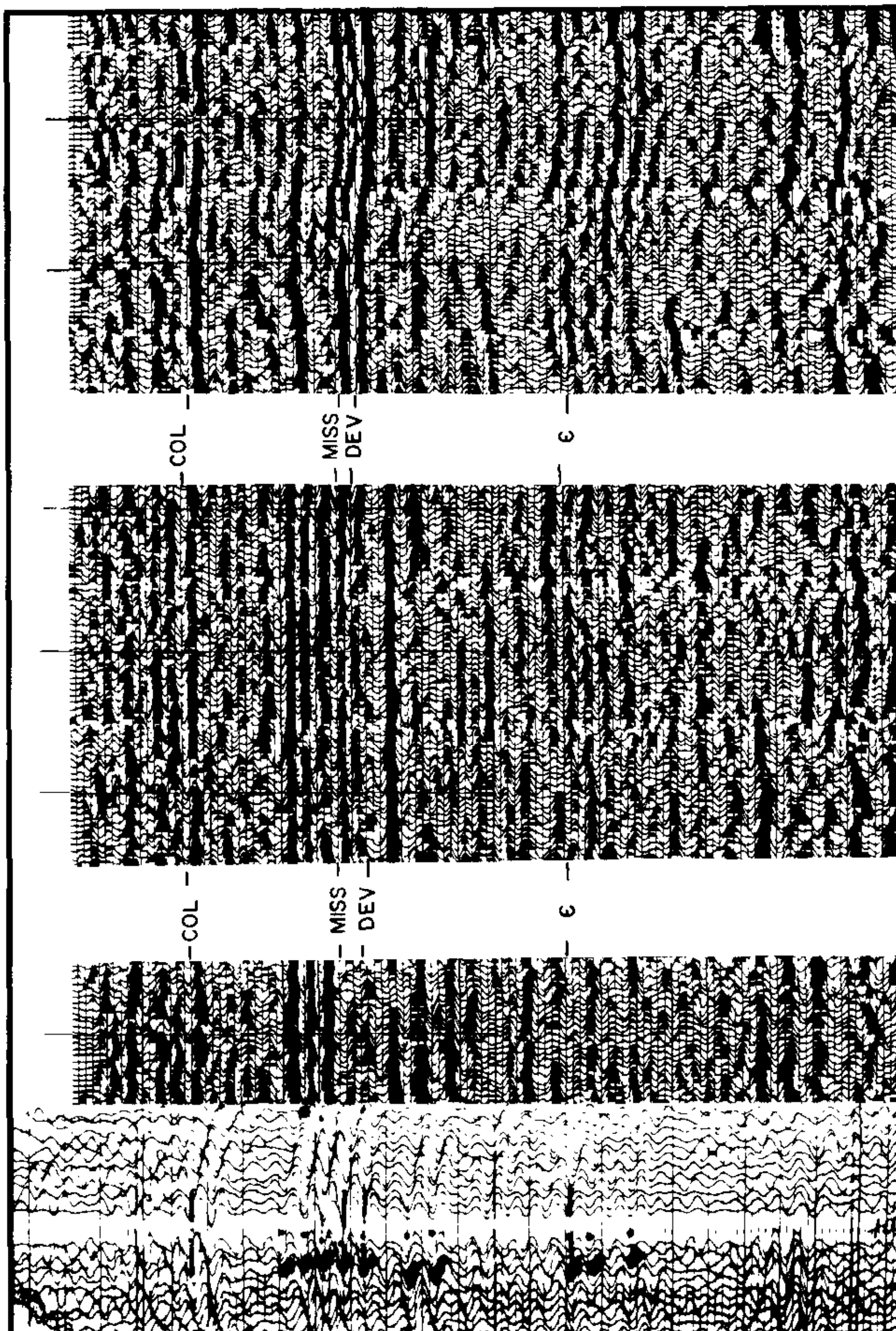

FIG. 9.—Deconvolved and filtered section with field record, Western Saskatchewan.

The second area, in Western Saskatchewan, was handled in the same way. It is discussed more briefly in order to avoid repetition. A typical amplitude spectrum is shown in Figure (8) showing quite a broad range of frequencies. The records were deconvolved, again using a short operator, and then filtered through a 15-15-55-65 band . The filter points, which were established by testing, again roughly correspond to the 10% amplitude line on the frequency spectrum. Part of the final section is shown in Figure (9). One problem here is to resolve the Mississippian and Devonian reflections. Figure (9) also shows a field record compared to the same record after transcording and processing.

The section indicates that very strong reflected energy may originate from within the Lower Cretaceous (about 80 milliseconds above the Mississippian). On the field record there is no evidence of newly initiated reflected energy at either the Mississippian or the Devonian. The same record after processing still shows a very strong Lower Cretaceous reflection but there is obviously a reflection at the Devonian which on the record looks like "back leg" energy from the Lower Cretaceous. It was virtually impossible to map the unconformity from the field records but the transcorded and deconvolved section seemed to be much more successful in delineating the unconformity.

CONCLUSIONS

The improvement in resolution of the data studied here is very encouraging. The technique is worth trying on any pre-tape data of reasonable quality, particularly in areas where a highly resolved wavelet is a necessity for interpretation.

The frequency spectra which these records produced are very significant. Both areas were recorded on narrow field filters, yet the spectra recorded were, in fact, considerably broader than the filters would indicate. It appears that deconvolution filtering can whiten the spectra within limits approximately set by a cut-off of 10 per cent of peak amplitude without introducing unworkable noise levels to the records. It would, therefore, be unwise to assume that recorded frequencies on pre-filtered records are in too narrow a range for high resolution techniques to be applied.

It appears that digital processing techniques, carefully applied, may yield a great deal of information from records which are presently of marginal use. This paper has just studied the effect of deconvolution filters on transcorded data, while it is probable that noise suppression techniques would be useful on other data, and should be investigated.

ACKNOWLEDGEMENTS

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