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Short Note

Map displays from an interactive interpretation

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INTRODUCTION

Map displays built during interactive seismic interpretation provide information not obtainable with traditional mapping techniques. Several map displays derived from the 1983 interactive interpretation of a Gippsland Basin three-dimensional (3-D) seismic survey are presented below. Similar map display results have since been obtained with the interactive interpretation of two-dimensional (2-D) seismic surveys. These types of mapping results are among the most important contributions of interactive interpretation procedures.

The topics presented here include a brief description of the interactive interpretational procedures, a generalized description of the geology of the Gippsland Basin area, and the map display results. A short discussion of the hardware used is included in the Appendix. The map examples are of four basic types: raw picks displayed in map views as a function of time; a spatially square smoothing of the raw picks; the residual map derived from differencing the raw and smoothed maps; and extracted amplitude maps. Other related map displays are also described.

INTERACTIVE INTERPRETATION PROCEDURES

Interactive seismic interpretation procedures are similar to traditional methods of working with paper sections (Denham and Holmes, 1984). Those portions of the interpretation process that can be aided by the computer are built into software applications. Of major importance is the ability to test, change, and retest different geologic concepts (Nelson and Hildebrand, 1985). A few of the interactive capabilities that affect creation of an accurate geologic model include a computer data base, high bandwidth of data access for easy and rapid section retrieval (Ottolini et al., 1984), display parameters to enhance geologic information in the softcopy seismic section displays (Verm and Nelson, 1982), horizon picking and automatic posting, horizon computations, and map displays.

THE DATA

The map displays were generated from interactive interpretation of a 3-D seismic survey in the Gippsland Basin, offshore southeast Australia. This survey was shot and processed by Geophysical Service Inc. for Esso Australia Pty. Ltd. as operator for Esso and BHP Petroleum Pty. Ltd. in one of the Gippsland Basin production license areas.

There are several major unconformities in this area, as shown by the seismic data in Figure 1. To enhance different seismic amplitude information, the sample values can be scaled dynamically from 32-bit floating point numbers to the 6-bit integers required for graphics display as data are read from an SEG-Y type file on disk. Figure 1 shows the rich detail available in variable density displays (Feagin, 1981). A stroke of the cursor changes the appearance of a section from AGC to relative amplitude. This option is particularly dramatic in displaying bright spots (Cole and Nelson, 1984).

GENERALIZED DESCRIPTION OF THE GEOLOGY

A generalized geologic cross-section that can be compared to the section in Figure 1 is shown in Figure 2. Color, as seen in Figures 3 through 6, adds a new dimension (Brown, 1983). Unique colors can easily be established to emphasize particular stratigraphic sequences (Simson and Nelson, 1984). For example, the Latrobe group is highlighted with strong blues and reds on the time-slice portion of the color display in Figure 3. The key area of interest is beneath the Eocene unconformity, labeled Top Latrobe on Figure 2. This figure also illustrates the producing Latrobe group, a sequence of interbedded sands, shales, and coals. Note that there is some post-unconformity faulting, as shown by the displacement of the unconformity. The Latrobe group grades to a siltstone, the Turrum formation in Figure 2, which was made of detrital material from the time of the Eocene unconformity. The entire Latrobe group is overlain by the Lakes Entrance Formation shale throughout the area of interest.

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MAP DISPLAY RESULTS

The map display results are from the interpretation of a portion of the 3-D survey. The area interpreted is a little larger than the time-slice section in the center of Figure 3. Horizons can be displayed in a variety of separate or combination map displays. Since each trace of a 3-D seismic grid can have horizon values, the display of all of these values in map view represents a surface. No data values will occur where horizons have yet to be picked, or have not been picked due to faulting or missing seismic. Coloring these raster horizon values as a function of time creates contour displays with subtle detail that is not possible to show with a traditional contour map. Displaying the contour map in gray scale, and dynamically moving a colored marker in time, highlights subtle highs and lows allowing detailed evaluation of spill points, etc. Contours from the same or other horizons can be overlain on the surface map display, as is illustrated in Figures 4 and 5. Overlaying contours from an upper horizon on the colored surface of a lower horizon allows evaluation of thinning and thickening from a single display. Overlaying isochron contours on a seismic amplitude raster horizon permits evaluation of the relationship of amplitude anomalies and thinnings. The results of this paper show how several types of useful map displays can be built from the interpretation of a single horizon display.

As a first step the Top Latrobe, an Eocene unconformity, was picked on each live trace of the 3-D survey. This picking was done in great detail on zoomed seismic displays. As picks were completed on one section, they were copied to the next parallel section and accurately adjusted to the correct time. Figure 4 shows the raw picks for this horizon displayed in map view as a function of time. Blues are the shallowest portion of the Latrobe group, at about 1 100 ms. The reds are at about 1 400 ms. The raster horizon is overlain by contours at an interval of 40 ms.

Note the apparent high-frequency content of the contours. This is due to the detailed picking, with time variations from trace to trace. Also notice the yellow canyon-like contours on the western, steeply dipping flank of the structure; these are unconformity drainage valleys. The solid yellow areas are areas with no horizon picks. On the right side of the map the horizon was not picked. The block at the top is due to a platform, and the yellow strip is a line that was not loaded. The yellow areas remain blank on the maps generated from the Top Latrobe horizon file.

Using horizon computational operations, the raw Top Latrobe horizon was filtered with a spatially square smoothing operator. The smoothed Top Latrobe horizon (Figure 5) illustrates how this operation enhances the gradient by removing high spatial frequencies. The results appear more like a traditional contour map. The color assignment is the same as in Figure 4. In smoothing the horizon, sharp fault breaks were smeared, once the faults are located (seen by comparing Figures 4 and 5). This smearing results from lifting the horizon on the downthrown side and pushing down the horizon on the upthrown side of faults on the few traces adjoining the fault. The amount of smearing is defined by the length of the filter operator.

A residual map, created by subtracting the raw and smoothed horizons, acts like an edge-detection algorithm to locate where the unconformity surface is broken by fault cuts. Figure 6 is a color version of this residual map. The linear trends at traces 160 and 220 are fault locations. Red is the downthrown side of the fault and blue is the upthrown side. Figure 7 is the same residual map as Figure 6, but it is displayed in black (downthrown) and white (upthrown). Note the horizontal linear noise, which is picking noise in the direction the sections were picked. Figure 8 is included to illustrate how the interactive interpretation environment allows evaluation of details by instant zooming on areas of interest. Note the crescent-shaped linear trends between traces 250 and 280; these trends are from vertical shifts in the unconformity horizon caused by the resistant subcropping beds.

The next step in the evaluation was to extract amplitude from the SEG-Y type seismic data file at the exact time of the Top Latrobe horizon. Figure 9 is a one-step pixel zoom of the resulting map. The faults still show up, because of horizon picks cutting zero crossings across the faults. An important map result is shown by the subtle amplitude variations as the unconformity cuts the Latrobe group. These variations are probably controlled by variations in the acoustic impedance, but they could also be affected by tuning effects. The most obvious example is the boundary of the Turrum siltstone (see Figure 2) on the right-hand side of the map (Figure 9). The more subtle variations from the subcropping interbedded sands, shales, and coals show up better on the screen than on the reproduction in the figure.

Adding a constant of 25 ms to the Top Latrobe and extracting seismic amplitudes show the subcropping events much more clearly. Figure 10 is a black-and-white example, where black can generally be correlated to subcropping coal layers. Note that the major fault at the south end of trace 160 is not only obvious, but it shows lateral offset. Also note the texture of the Turrum formation. The amplitude map is almost like a photograph, showing detail such as the unconformity drainage valleys. This map and the general geologic description in Figure 2 describe the geology of the entire survey area.

Other maps that are typically created from interactive techniques include water-bottom maps, isochrons, isopachs, velocity maps, fault-plane maps, closure maps, attribute-extraction maps, and different combinations of cascaded maps similar to the Top Latrobe map set described here. It is not uncommon to develop a set of 50 to 80 maps from the interpretation of a small 3-D survey over the period of a few weeks. Transferring horizon files to a host computer by tape or over a local area network allows generation of maps at scale using traditional company computer mapping methods. In general, interpreters like to do detail interpretational work and changes based on the softcopy map displays.

CONCLUSIONS

The importance of map displays is increasing with the introduction of interactive interpretation procedures. The ability to see variations in a 3-D horizon map on a trace-by-trace basis opens a new understanding of geologic surfaces. This is particularly important in producing geologic interpretations. As illustrated, a cascaded sequence of maps can be generated by smoothing, creating residual maps, extracting amplitudes, etc. The number of possible useful options is really only limited by the imagination of the interpreter. These types of map displays and associated interactive interpretation techniques seem to be creating the same type of change in the interpreta-

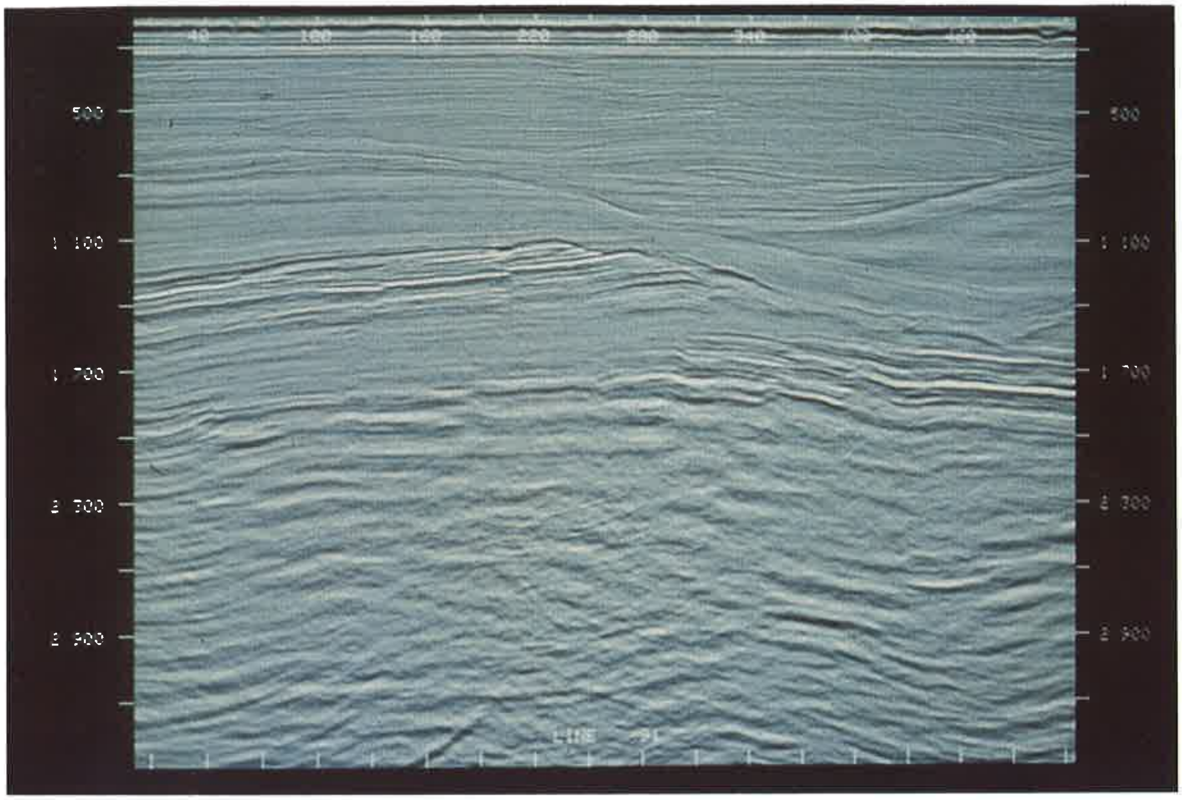
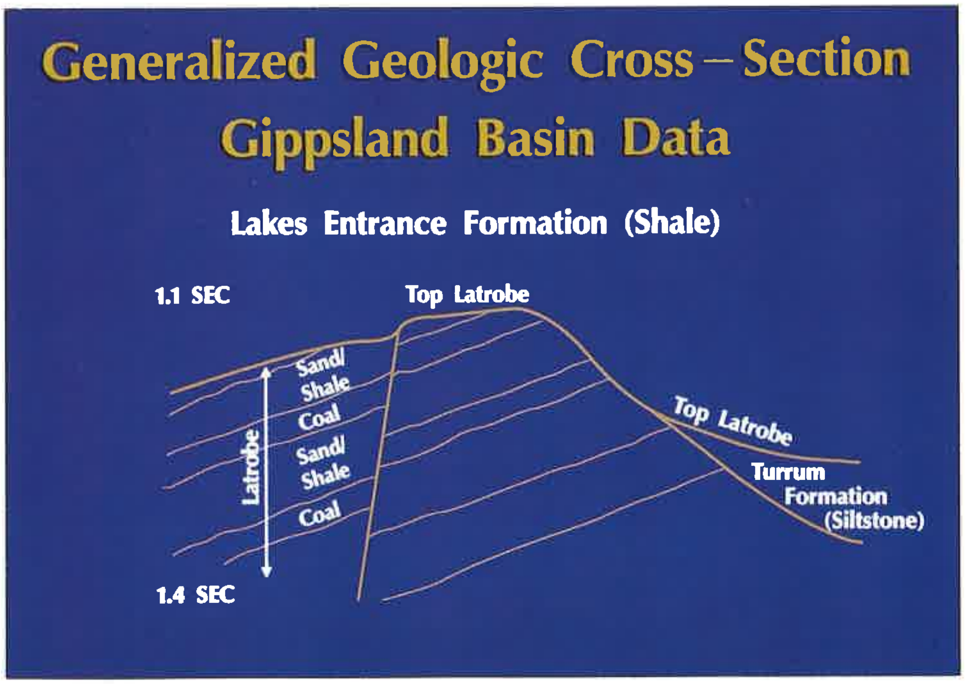


FIG. 1. Typical seismic section from the interpreted Gippsland Basin 3-D survey.



Generalized Geologic Cross – Section Gippsland Basin Data

FIG. 2. Generalized geologic cross-section for the Gippsland Basin 3-D survey area.

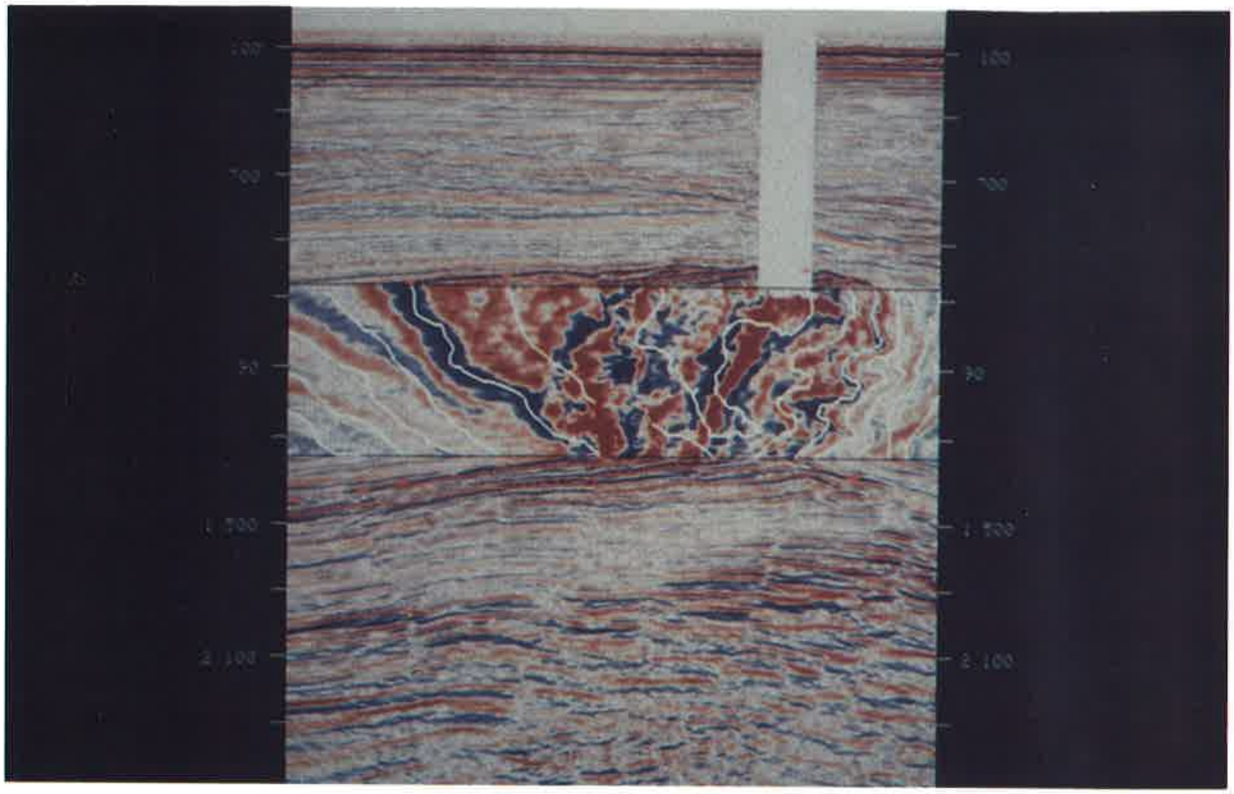


FIG. 3. Seismic chair display, where the chair back (top section) shows a white strip due to the platform, the time picks show the areal extent of the Top Latrobe structure on the time slice, and the structure of the Latrobe group is shown on the front foot of the chair (bottom).

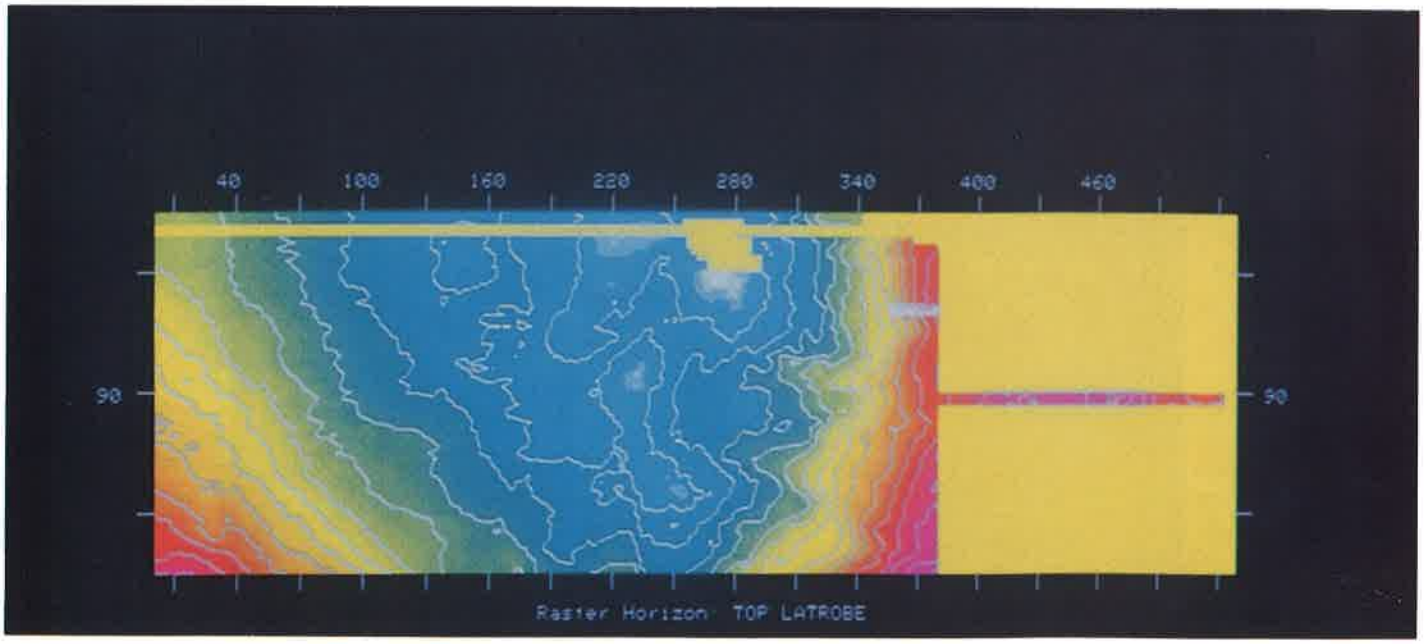


FIG. 4. Raw Top Latrobe horizon times as picked on each live trace of the 3-D survey, overlain with contours at 40 ms intervals. Whites and light blues are at about 1 100 ms, and the reds and violets are at about 1 400 ms.

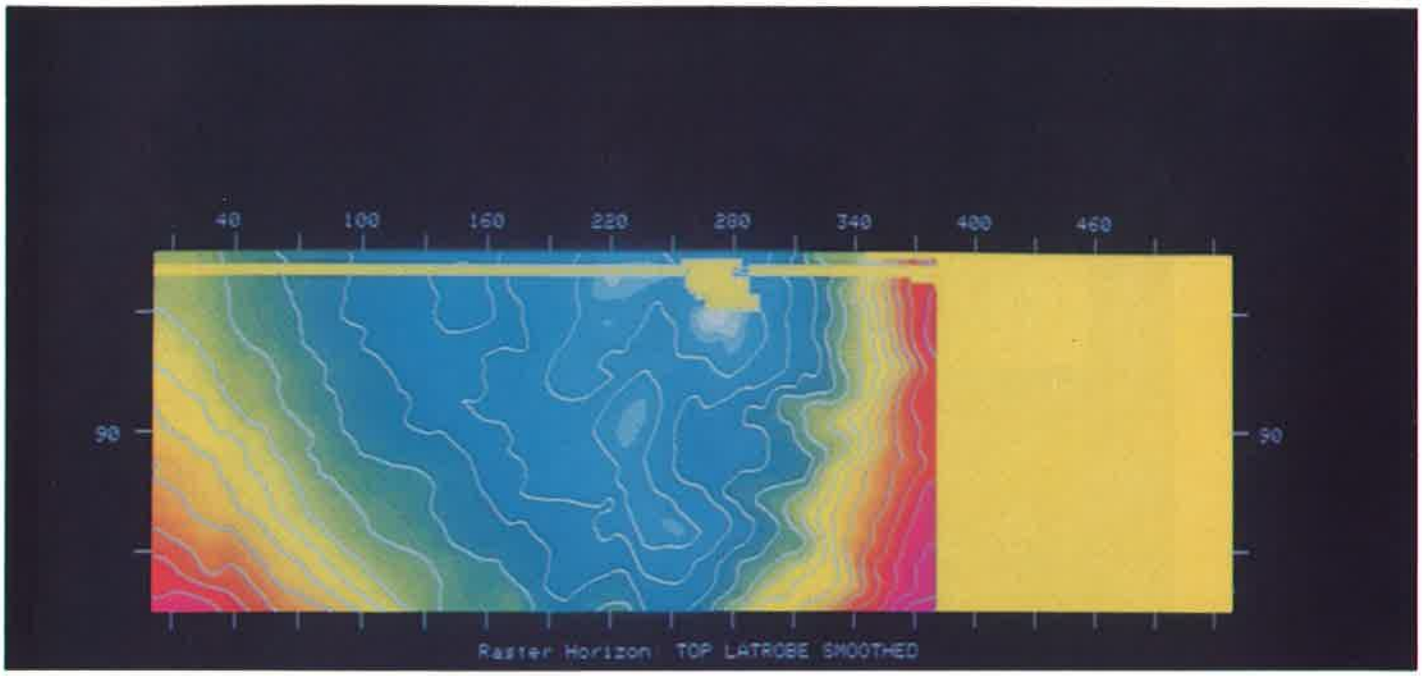


FIG. 5. The Top Latrobe horizon time map after applying a spatially square smoothing operator. The yellow blocks at the top of the map are where the horizon was not picked due to missing seismic data.

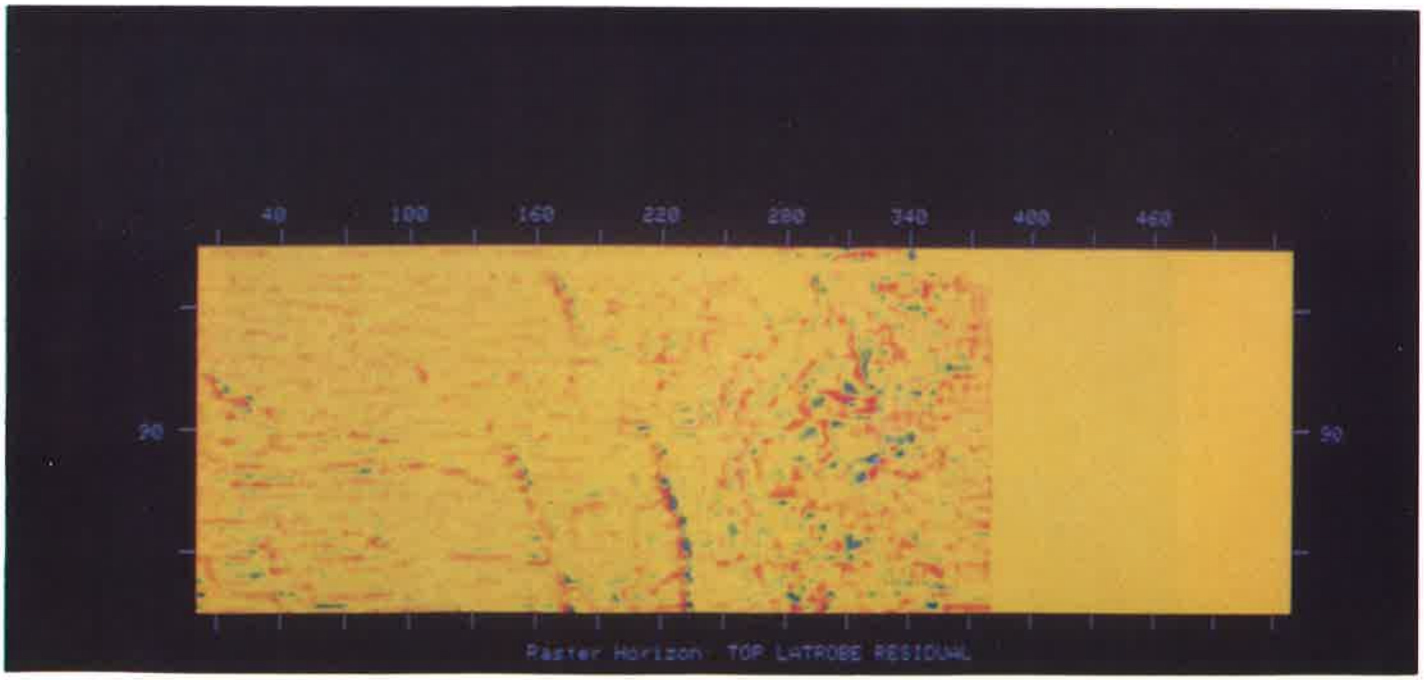
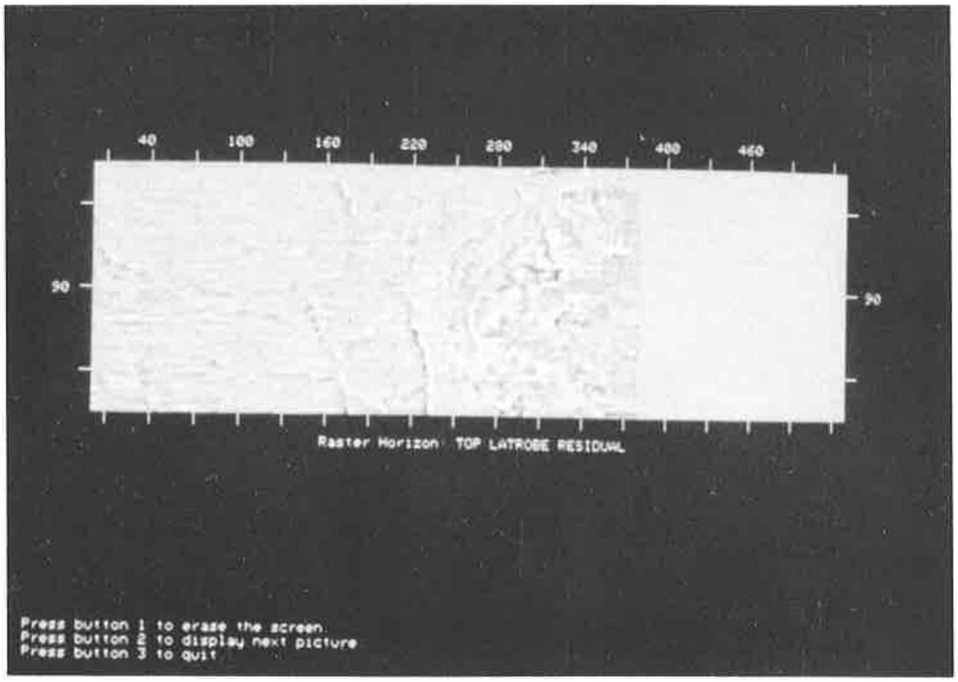
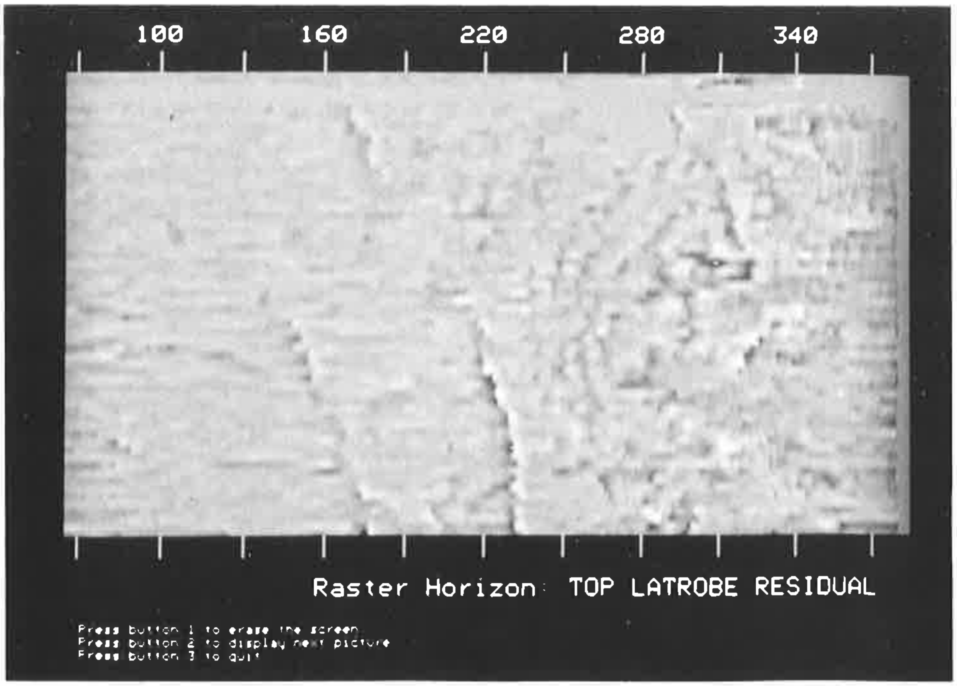


FIG. 6. A residual map created by subtracting the raw and filtered horizon files. The linear trends at traces 160 and 220 are fault cuts through the unconformity. Red is the downthrown side of the fault and blue is the upthrown side.



Press button 1 to erase the screen.
Press button 2 to display next picture
Press button 3 to quit

FIG. 7. The residual map from Figure 6 displayed black and white. Note the horizontal linear noise, which is picking direction noise.

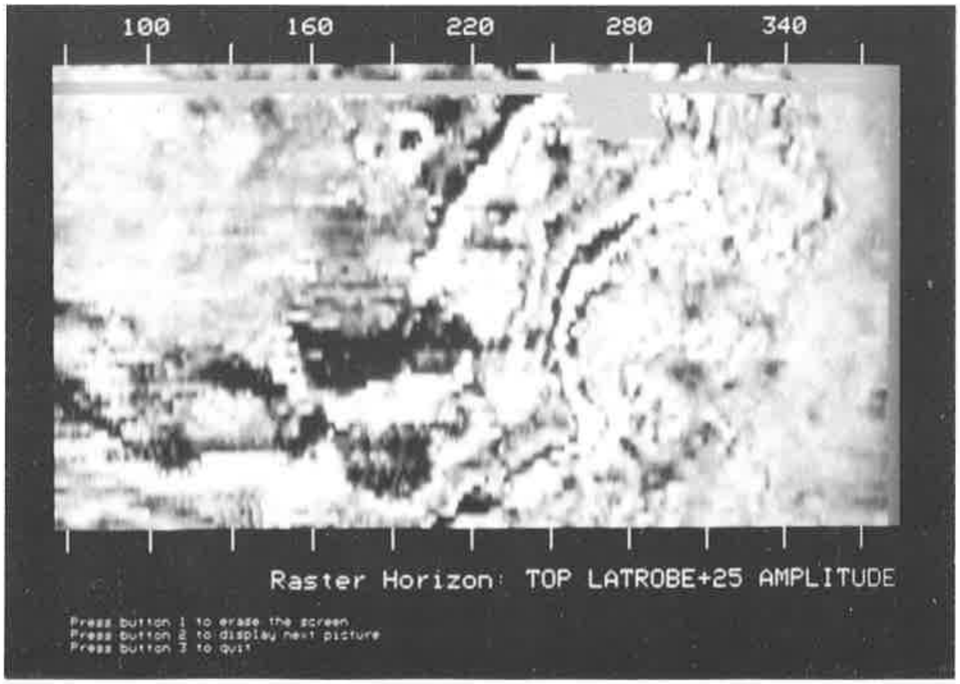


Press button 1 to erase the screen
Press button 2 to display next picture
Press button 3 to quit

FIG. 8. The residual map from Figure 7 was instantly expanded by a factor of two in x and y to create this image. Note the curved linear trends between traces 250 and 280, which is due to vertical shifts in the unconformity because of resistant subcropping beds.

Push Button 1 to Restore
Push Button 2 to Z O O M
Push Button 3 to Quit

FIG. 9. A seismic amplitude extraction at the Top Latrobe horizon. The faults show up due to picks crossing the zero crossing across faults. A notable result is subtle amplitude variations due to variations in the acoustic impedance as the unconformity crosses the Latrobe group.



Press button 1 to erase the screen
Press button 2 to display next picture
Press button 3 to quit

FIG. 10. A seismic amplitude extraction 25 ms below the Eocene unconformity. Compare this to Figure 2, and notice how well the geology is defined by the subcropping events.

tion of exploration seismic results that occurred with the conversion from analog to digital acquisition techniques.

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APPENDIX

SYSTEM HARDWARE AND SOFTWARE

The interpretation system used was a "stand alone" Landmark II+ (Nelson et al., 1983). The CPU is the industry standard Intel 80286 microprocessor with an 80287 coprocessor. Both processors are in a 21-slot Multibus$^{\text{TM}}$ with 1 MB of main memory. Main memory is shared by a 1.0 Mflop array processor. The key peripherals are a 1 600/6 250 bpi tape drive, an 880 MB (formatted) Winchester disk, the graphics processor, and an associated 1 280 × 1 024 pixel monitor. With two high-resolution monitors (1 280 × 1 024 pixels) the interpreter can work with seismic data and map data simultaneously.

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