INTERPRETATION OF GEOPHYSICAL DATA

BWIP SITE

HANFORD, WASHINGTON STATE

NRC Contract No. NRC-02-84-001

Task Order No. 0011 [A]

Prepared by

Glyn M. Jones

Weston Geophysical Corporation

Summary

Seismic reflection data along Lines 3, 5, and 8, BWIP Site, Hanford, Washington State, were interpreted to infer structural features along the top-of-basalt horizon. The results are presented in the form of two-way reflection time and depth sections and as interpreted seismic sections. Gravity and borehole data were used to supplement the seismic data. The interpretation was made using the reprocessed cross-sections prepared by Emerald Exploration Consultants, Inc., [EMEX] for Rockwell Hanford Operations. Interval velocities derived by EMEX from constant velocity stacks were used to convert borehole depths to two-way reflection times, with the aim of using the seismic data to interpolate the depths of prominent markers between boreholes. Because of loss of shallow resolution within the 220 ms mute zone, only the top-of-basalt marker was found to be generally useful for this purpose. Along major portions of Lines 3 and 5, however, even this marker lies within the mute zone. Loss of continuity in these areas made interpretation difficult.

As a result of the borehole/velocity approach, some areas of minor disagreement with the EMEX interpretation are found, but often these occur in areas of poor resolution, where interpretation is ambiguous. Two significant results of the present study that differ from the EMEX interpretation are as follows:

1. Identification of a possible reverse fault near Station 640 on Line 5, and
2. Placement of the top-of-basalt reflection considerably later in the seismic record near Borehole RRL-2 on Line 3.

Background of Interpretation Method

The data available for interpretation included seismic reflection cross-sections, interpreted depth sections, and other data along Lines 3, 5, and 8 supplied by EMEX as part of their final report to Rockwell [SD-BWI-TI-177]. The depth sections were used primarily to pick off depths to prominent markers derived from boreholes along or near to the lines. Supplementary borehole information was obtained from Deep Borehole Stratigraphic Correlation Charts [SD-BWI-DP-035] supplied by NRC.

From initial examination of the seismic cross-sections, I decided that the seismic data alone were insufficient to provide a clear interpretation. Along large sections of Lines 3 and 5, reflecting horizons fade in and out and there are areas of little or no continuity, across which interpretation is hazardous. These problems are apparently related to loss of fold in the 220 ms mute zone [EMEX] and potential statics problems related to changing elevation and near-surface structure. EMEX relied in their interpretation on correlation of reflection character for the top-of-basalt [t.o.b.] horizon, as inferred from vertical-incidence synthetic seismograms. However, I felt that this approach was not totally reliable, because of varying fold along the line related to changes in elevation in the range of travel times of interest [generally less than 220 ms]. Along Line 5, for example, the surface elevation changes by more than 150 feet between Stations 670 and 610. In this station range, there is a significant change in the appearance of the reflection record.

I therefore decided on a different approach, involving use of seismic velocities determined for the suprabasalt sediments, to convert borehole marker depths to two-way travel time. The idea was to use the travel times to the markers as tie points on the seismic cross-sections, thereby guiding the interpolation of reflecting horizons across regions of poor continuity. Ideally, one would like to have direct velocity information derived from the boreholes, either in the form of sonic logs or checkshot and offset VSPs, to perform the depth to time conversion. However, as reported by EMEX, the only direct velocity information available is for Borehole RRL-2 on Line 5. Therefore, the interval velocities used were smoothed values derived from the stacking velocities given on the seismic cross-sections.

Details of Interpretation Method

The root-mean-square [RMS] or stacking velocities given at the top of each seismic cross-section represent the velocities that were determined by the processor to give the best normal moveout correction at different stations along the line. [See, for example, EMEX - Plate 6.] With the assumption of horizontal or near-horizontal layering, which is reasonably satisfied along most of Lines 3, 5, and 8, these stacking velocities can be converted to interval velocities using Dix's formula. These interval velocities represent average velocities over varying depth ranges and in isolation are subject to large uncertainties. For these lines, however, velocity estimates were made at close intervals [every 20 stations or so] so that it was possible to reduce the uncertainty by lateral smoothing. It was found that taking a running mean over 100 stations satisfactorily reduced the interval velocity fluctuations from one estimate to the next without removing what were apparently real lateral variations in velocity along the lines.

For each line, the smoothed interval velocity values were then contoured at 500 ft/sec. intervals and used to compute from the time section an equivalent depth section. Plates 1, 2, and 3 display the time and depth sections plotted at the same horizontal and vertical scales as the corresponding seismic and depths sections from the EMEX report [Plates 7A, 8A, 9A, 26, 27, and 28] with the inferred iso-velocity contours shown in red. The sections have been corrected to a common datum of 550 feet above sea level, in order to compare the results directly with the seismic cross-sections, which are referred to the same datum. From the borehole data along each line, the measured depths relative to datum to the base of the Middle Ringold suprabasalt unit, the base of the Lower Ringold unit, and the top of basalt were plotted on the depth sections and transferred to the time sections by visual interpolation between corresponding velocity contours. These markers are shown on the figures with yellow, red, and green dots respectively.

This was done first for Line 5 and the results at Borehole RRL-2 compared with the computed reflection time to the top-of-basalt marker derived from the measured borehole depth at this location. Figure 21 of the EMEX report shows that the reflection time to the t.o.b. [measured at 605 feet depth from the surface] should be at about 260 ms. Relative to datum this value becomes 193 ms [260 - 2 x 84/2500]. The travel time to this marker as inferred from the interval velocity data, however, was about 130 ms. Examination of Figure 21 of the EMEX report suggests a reason for the discrepancy. Within the suprabasalt sediments, large velocity inversions are present which are not resolved in the interval velocity data derived from the stacking velocities. The depth sections computed using the stacking velocity data will therefore be stretched compared with the borehole logs. In order to make the borehole and interval velocity results agree, it was found necessary to compress the depth section for Line 5 [Plate 1] by 33%. This compression factor was then also applied to the depth sections obtained for Lines 8 and 3 [Plates 2 and 3].

The next step in the interpretation process was to superimpose the time sections on the seismic cross-sections and to use the seismic data to interpolate markers between the boreholes. Continuous reflectors were sought which coincided closely with the inferred marker times. Only the t.o.b. marker proved to be continuous enough for this purpose. In the interpretation, migrated and coherency stacks were examined along with the basic stack. In some cases, such as near the center of Line 5, t.o.b. markers from several boreholes fell on or near a continuous reflecting horizon. In these cases, interpolation was fairly straightforward. In other cases, only segments of reflectors could be confidently followed away from the boreholes, and the interpolation is therefore more uncertain. Details of the interpretation for the different lines are given below.

Finally, interpolated horizons and structure from the time sections were transferred to the depth sections. The inferred top-of-basalt marker is colored green on the sections, with suspected faults shown in pink.

Interpretation of Line 5

A continuous t.o.b. horizon is inferred extending from Station 870 to Station 650 on the basis of markers from Boreholes DH-21, RRL-2, DH-25, and DH-24. The interpreted horizon agrees with the EMEX interpretation. EMEX interpret a break in reflection continuity from Stations 715 to 755 as representing a possible fault structure. On the basis of the borehole/velocity data, however, a continuous top-of-basalt horizon can apparently be drawn through this region.

From Station 870 south, the coherency of reflections degrades considerably. A continuous t.o.b. reflector extending from Stations 920 to 890 has been drawn on the basis of the marker from Borehole DC-16. How this horizon joins up with the one at Station 870 is uncertain. Faulting or monoclinal folding are both possibilities.

A small fault is tentatively interpreted at Station 998 on the basis of an apparent offset of the reflecting horizon extending from the t.o.b. marker in Borehole DH-26. This horizon is then drawn flat on the basis of the coherency stack for this line [EMEX - Plate 14] to pass slightly above the marker in Borehole DH-20 and continuing to a mismatch with the existing horizon near Station 925, where another fault is drawn. Reflections in this region are, however, very discontinuous and this interpretation is uncertain.

At the other end of the line, between Stations 410 and 610, reflection continuity is also poor. Because of the large change in elevation along this part of the line, I suspect that statics problems are a major cause of the degradation in reflection quality. Two small segments of the t.o.b. horizon are inferred: one extends from Stations 548 to 525 and joins the top-of-basalt markers from Boreholes DC-4/5 and 50-85; the other extends from Station 440 to the beginning of the line and lines up with the marker in Borehole 57-83, off the end of the line. I see little evidence in the seismic data in this region for the interpretation drawn by EMEX.

The most striking anomaly along Line 5 occurs around Station 640, where an offset of 70 ms occurs between the t.o.b. markers extrapolated from Boreholes

DH-24 and RRL-7. If correct, a reverse fault with considerable throw is implied at this point. This interpretation is considered speculative because it relies upon the data from a single borehole, RRL-7. This interpretation also differs significantly from the EMEX interpretation, which shows a continuous horizon drawn through this region. EMEX did not address the reason for the breakup of the seismic reflection at Station 640. The anomalous seismic behavior, which shows up even more clearly on the migrated and coherency stacks [EMEX - Plates 11 and 14], could be a processing artifact associated with the rapid change in elevation which occurs in this area. However, some support for the interpretation of faulting is provided by the existence of a 1 mgal negative gravity anomaly [EMEX-Plate 24] extending from about Station 650 to Station 605. This anomaly is drawn above the depth section on Plate 1. Using the gravity modelling results of Holmes and Mitchell [RHO-BWI-ST-14, Appendix B], the amplitude and width of this anomaly is consistent with a fault at about the indicated depth. The new data recently shot for Rockwell about 1,000 feet west of Line 5 should be examined carefully to determine if any indications of faulting exist at a similar location on that line.

Interpretation of Line 8

This line was the most straightforward to interpret, since reflection continuity is good and a nearly continuous horizon can be drawn connecting the t.o.b. marker from Boreholes DH-22, DH-21, and 37-82B. [See Plates 2 and 7A]. This horizon agrees with the top-of-basalt reflection interpreted by EMEX. The one region of poor t.o.b. reflection continuity, extending from Stations 155 to 135, was interpreted by EMEX as due to a possible washout or faulting. An alternative explanation is that the loss of reflection strength below 210 ms in this area is caused by a high-velocity sediment lens in the sediments over the basalt. The increase of reflection strength in the suprabasalt sediments cincides with the loss of reflection energy from the top of basalt. A local .2-.3 mgal gravity anomaly [EMEX-Plate 23] in this area is also consistent with the results for a sediment lens [Holmes and Mitchell, RHO-BWI-ST-14, Appendix B].

One aspect of interpreting this line which differed from Lines 3 and 5 is that the stacking velocities for this line were apparently computed after correcting the data to a 550-foot datum, according to the processing panel on Plate 7A. On the other lines, the data were only corrected to a floating datum before velocity analysis, which is the correct procedure. The effect of adjusting the data to a flat datum first, which in the case of Line 8 would have amounted to applying about a 70 ms positive shift to the travel times, is that the stacking velocities so obtained will be larger than if the velocity analysis had been performed with respect to a floating datum near the surface. A program was written to recompute the stacking velocities with respect to the surface before converting the stacking velocities to interval velocities. It was found that this procedure resulted in interval velocities near the crossing point of this line with Line 5 which were about 500 ft/sec. lower than at equivalent depths on Line 5 and there was a 30 ms mistie in the depths to the t.o.b. marker on Lines 5 and 8. The reasons for these differences are not known, but may be related to accumulated errors in the velocity determination process described above.

Interpretation of Line 3

At the eastern end of the line, from Station 1360 to 1323, the top of basalt has been drawn to agree with the EMEX interpretation on the basis of a projection to Borehole 51-75, off the end of the line. At Station 1360, EMEX interpret a small fault. On the basis of the coherency stack [EMEX - Plate 15], however, an alternative interpretation is that the basalt horizon is continuous, but undulating, and this is the interpretation drawn.

Projecting backwards from Boreholes 50-85 and DC-4/5, again using the coherency stack, there appears to be a small offset of 10 ms in the t.o.b. horizon near Station 400, although the data quality is not good enough to interpret a fault here.

At Station 1625, a large disagreement exists between the EMEX interpretation and the interpretation based on the velocity data and measured t.o.b. in Borehole RRL-8 in the inferred reflection time to the top of basalt. EMEX interpret the t.o.b. at this point at 110 ms, whereas the borehole/velocity data indicate that the top-of-basalt horizon is here much deeper, at approximately 200 ms reflection time. Part of the discrepancy could be attributed to the fact that

Borehole RRL-8 lies 750 meters south of Line 3 and the depth values have been projected onto the line. According to the top-of-basalt structure map [EMEX - Plate 22], the t.o.b. does shallow northwards from RRL-8 to Line 3. However, projecting the shallowing trend to Line 3 results in a depth difference of only 42 feet, which, according to Plate 3 of this study, would result in a reflection time for the t.o.b. horizon of 180 ms, still much deeper than the EMEX interpretation. Without more detailed velocity information, such as a check-shot survey or offset VSP using Borehole RRL-8, the correct interpretation remains ambiguous. The EMEX interpretation is presumably based on putting the t.o.b. horizon above the first strong, continuous reflector, but as discussed above there is some evidence for occasional strong reflections from within the suprabasalt sediments as well. In the following, I examine the implications of taking the t.o.b. reflection at 180-200 ms at Station 1625.

From this point, the t.o.b. horizon may be projected forwards with westward dip to Station 1690 and backwards to about Station 1560. A 10 ms offset at Station 1610 appears to be supported by the migrated section [EMEX - Plate 12]. In the region of Station 1548 a low-angle reverse fault with a throw of 20-30 ms is inferred on the basis of a mismatch in the projected t.o.b. markers on each side of this point. Support for the interpretation of faulting here is indicated most clearly on the migrated section.

West of Station 1690, interpretation of the seismic section is difficult. According to the interpreted depth section [EMEX - Plate 28] and the t.o.b. structure map [EMEX - Plate 22], cores from holes 53-103 and DB-11 indicate that in this region, the t.o.b. horizon shallows rapidly and consists of the Pomona member of the Saddle Mountains Basalt group in contact with Middle Ringold sedimentary unit. The iso-velocity contours on the time and depth plots [Plate 3 of this study] are consistent with these results, showing a similar shallowing of the high velocity material. Isolated portions of the inferred top-of-basalt horizon have been drawn on Plate 9A using the borehole/velocity results, from Stations 1878 to 1820 and from Stations 1790 to 1720. A monoclinal structure dipping to the west has been tentatively drawn joining these horizons between Stations 1820 and 1790, following the hint of such a structure in the coherency stack [EMEX - Plate 15]. It should be noted, however, that gravity data [EMEX -

Plate 25] suggest a different interpretation, consisting of a syncline centered about Station 1792, and an anticline further east at Station 1762.

Between Stations 1720 and 1690, faulting is strongly suspected, because of the significant offset in the top-of-basalt horizon between these points and because of the generally flat-lying attitude of the reflectors. Seismic events in the shallow part of the section are disjointed and poorly focussed. However, no clear evidence of the attitude of a fault plane, if such exists, is visible in the data. It might be worthwhile to restack this part of the line with much higher velocities in an attempt to image any steeply-dipping structure present in the data.

Conclusions

Several factors contribute to the poor imaging of reflections from the suprabasalt sediments and top-of-basalt horizon on this line: the major factors are the relatively coarse receiver and shot spacing used [50 feet and 100 feet, respectively], leading to reduced fold in the mute zone, and the probable existence of severe statics problems related to changing near-surface structure. Although some further reprocessing such as stacking with higher velocities in an attempt to image any steeply-dipping fault planes, may be beneficial, I believe that the current processing has just about exhausted the possibilities of this particular data set. In a separate report, I outline some recommendations for future acquisition and processing parameters in this area. In particular, the existence of a possible major fault near Station 640 on Line 5 needs to be looked at more closely.

References

Landon, R.D., 1985, Deep Borehole Stratigraphic Correlation Charts, SD-BWI-DP-035 Rev. 3, Rockwell Hanford Operations, Richland, Washington.

Berkman, E., 1984, Reprocessing and Interpretation, Seismic Reflection Data, Hanford Site, Pasco Basin, South-Central Washington, SD-BWI-TI-177, Emerald Exploration Consultants, Inc., for Rockwell Hanford Operations, Richland, Washington.

Holmes, G.E. and Mitchell, T.H., 1981, Seismic-Reflection and Multilevel Aeromagnetic Surveys in the Cold Creek Syncline Area, in Subsurface Geology of the Cold Creek Syncline, C.W. Myers and S.M. Price [Eds.], Appendix B, RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

0098J1