Correlation of shallow 2-D seismic reflection data with lithologic well logs and cross-section, Rocker Operable Unit, Montana

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INTRODUCTION

The Rocker Timber Framing and Treating Plant Operable Unit exists within the Silver Bow Creek/Butte Area Superfund site, which is centered around the town of Butte, Montana. The site is very flat and consists of a railway switching yard and several buildings and piles of debris. The soil and debris contain high concentrations of arsenic, which has created a pollution plume in the local shallow aquifer. Remedial actions have been decided upon by the Environmental Protection Agency (EPA) based on subsurface cross sections created from lithologic well logs. Shallow two dimensional (2-D) seismic reflection can offer a subsurface image depicting lithologic boundaries, which can be checked by well log data to provide a more accurate picture of the geometry beneath the Rocker site.

Geology. The uppermost deposits of the Rocker site have been entirely disturbed by human activity. Originally, the construction of the rail yard and timber treating plant required "a large fill" (ARCO, 1995). More recently, approximately 1,000 cubic yards of arsenic-bearing wood chips and soil were removed from two areas of the site, and approximately 8,800 cubic yards of soil cover were placed to a depth of at least 12 inches in some areas (ARCO, 1995). One local contractor estimated that the upper 5 to 6 feet of the subsurface consists of at least 25 percent debris.

Underlying the fill is undisturbed Quaternary alluvium, consisting of poorly compacted sands, gravels, and silts representing meandering channel and overbank deposits. In the Butte area these deposits range up to several hundred feet thick, although the maximum thickness reported in lithologic well logs from the Rocker site is about 80 to 90 feet (ARCO, 1995).

Below the Quaternary deposits are undivided Tertiary sediments, which are believed to underlie the entire site. These consist of dense, partially cemented silt and fine to medium sand-size particles, which are irregularly bedded to massive. Occasional thin layers of highly fragmented, well-cemented silt and sand grains occur, as well as hard, well-cemented, angular, fine grained to aphanitic gravels.

Cretaceous age granitic rocks regionally identified as the Butte Quartz Monzonite underlie the Tertiary deposits at the site and in the surrounding area. Unconformably overlying and intruding these granitic rocks, and underlying the Tertiary fluvial deposits, is a highly variable suite of Tertiary volcanic rocks referred to as the Lowland Creek Volcanics. The units of the suite range from extrusive dacites and tuffs to intrusive rhyolites. The geometry of the volcanic and granitic rocks under the Rocker site remains unresolved, as all of the wells on site finish within the Tertiary fluvial sediments. Based on surface mapping, however, it appears that these Tertiary sediments are in direct contact with Cretaceous granitics just to the east of the Rocker site.

History of the Rocker Site. The Rocker Timber Framing and Treating Plant was operated by the Anaconda Company from approximately 1907 to 1957. During its years of operation, the plant milled and treated timbers for use as supports in the mines in and around Butte, as well as poles for Montana power. Both dipping and pressure treating were used to apply arsenic to the timbers, and creosote to the poles. When the plant was closed in 1957, the equipment and buildings were dismantled, and the debris disposed of on site.

In the 1970's, the Atlantic Richfield Company (ARCO) purchased the Anaconda Company and all of its inholdings. On September 8, 1983, the Silver Bow Creek Superfund site was listed on the National Priorities List (NPL), including the Rocker Operable Unit. This listing was revised on July 22, 1987 to include large areas around the town of Butte, Montana. In all cases, the Anaconda Company, and therefore ARCO, was found to be the liable party. While all decisions for the ensuing cleanup are made by the EPA, the research and cleanup of each site is being funded by ARCO and carried out by local environmental contractors.

Previous Investigations. The initial site evaluation was conducted in 1987 and 1988 for ARCO by Hydrometrics, Inc. In response to a 1989 Phase II investigation, ARCO was ordered to perform soil tests for arsenic, and remove soils which had an arsenic content of higher than 10,000 mg/kg (ARCO, 1995).

Observation wells were dug on site, and lithologic logs were obtained from the drilling, as well as samples and core samples (ARCO, 1995). From these logs, several subsurface cross sections along well lines were drawn (ARCO, 1995). In addition, geophysical logs were made of five wells by Century Geophysics. These logs consist

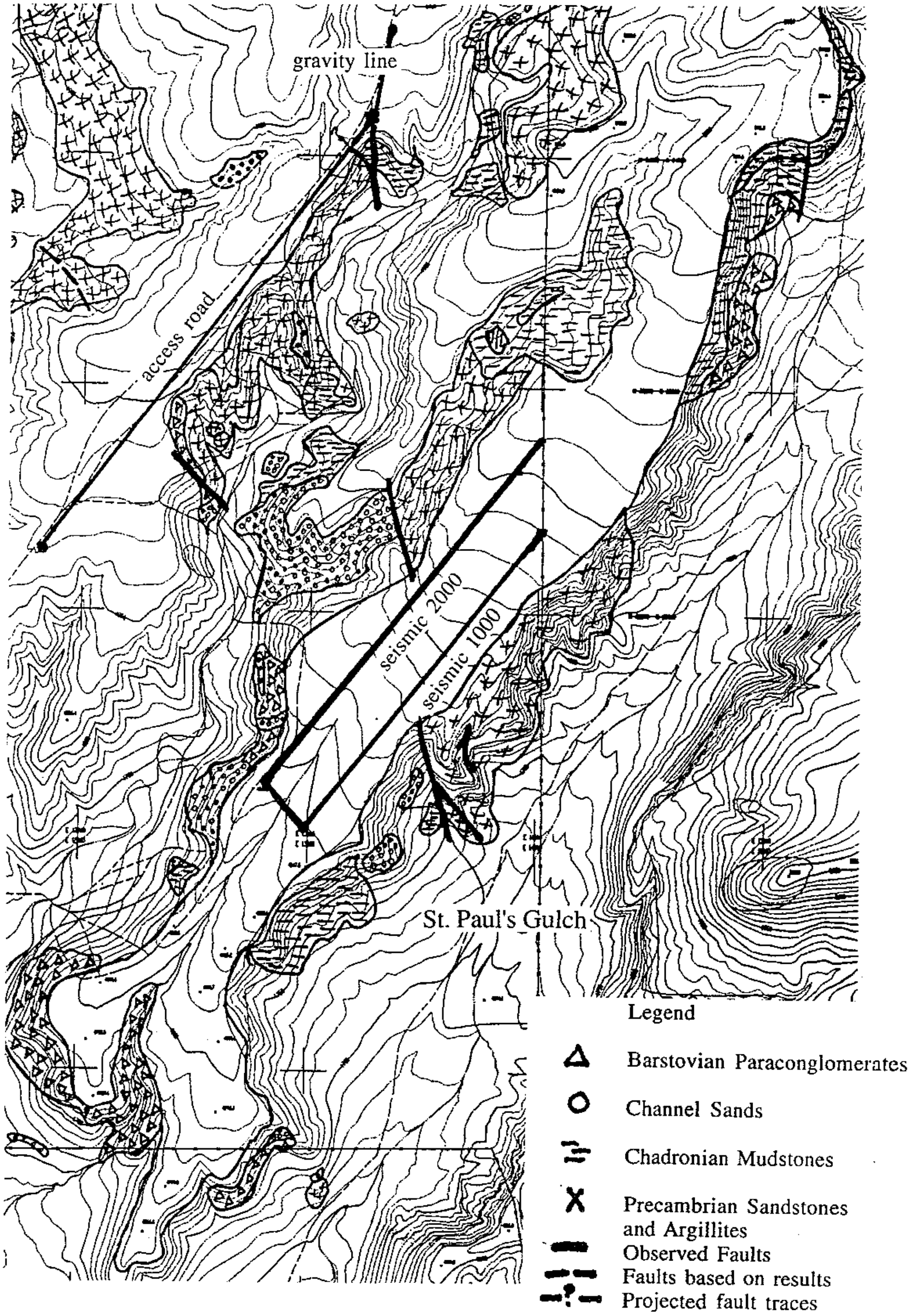
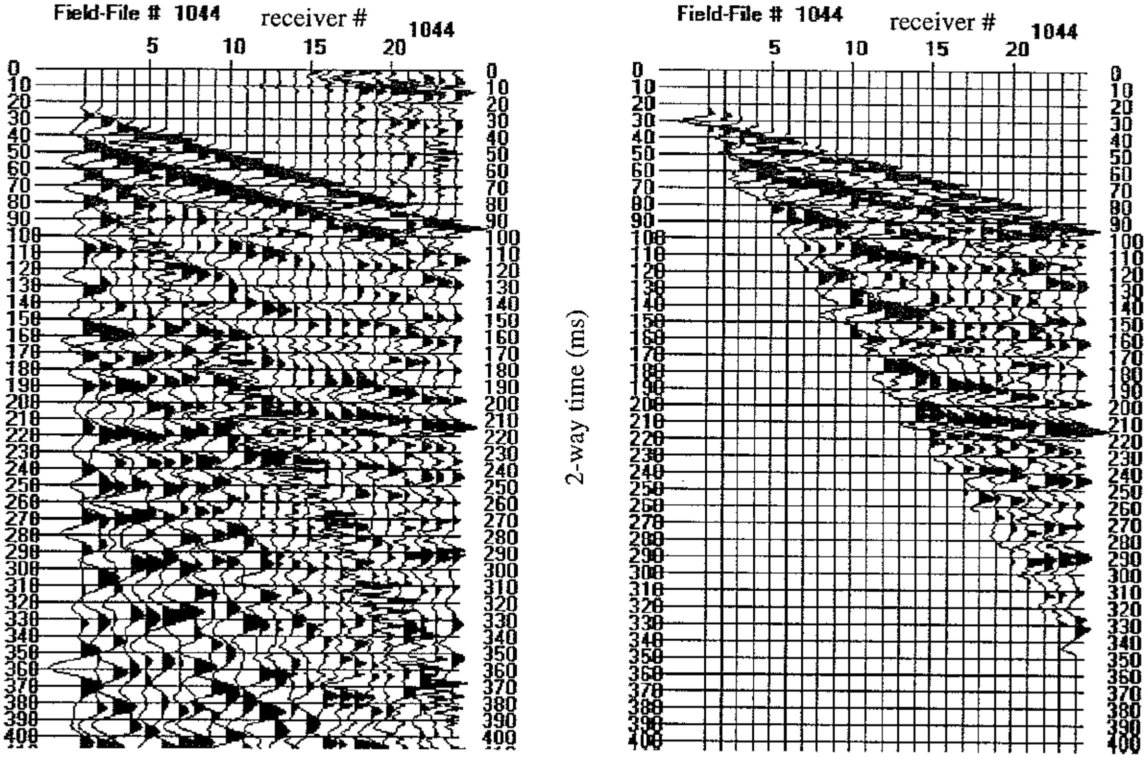


Figure 1 Location of seismic and gravity lines relative to location of the faults. Distances are measured SW to NE along each line. Contour interval=10m



(a) (b)

Figure 1: a) A standard seismic survey record, unmuted;
b) the same record muted to eliminate noise above the first arrivals,
and ground roll and air blast noise below the reflectors.

of natural gamma radiation, dual induction resistivity and conductivity, and gamma-gamma density, all recorded within the existing cased boreholes (ARCO, 1995).

METHODS

Local geologic maps (Smedes, 1959, 1964) were field checked in the immediate Rocker area, and the results plotted on 7.5 minute USGS topographic maps. Well cores and samples from the Rocker site were sparse and very poorly stored; in many cases all that remained of a core was pile of gravel in a rotting cardboard box. Most samples which were found, however, were contained in sealed glass jars. These and the few intact cores were used to check the well lithologic logs and cross sections contained in the EPA Remedial Investigation Report (ARCO, 1995).

The seismic surveys were conducted using a Bison 9000 24 channel seismograph, with arrays of three 40 Hz geophones. The geophone arrays were laid parallel to the takeout cables, with two phones at each takeout, and one between. This pattern provided a very continuous record, as well as being quick to set up and easily repeatable. Four cables were laid out at once, providing 48 takeouts per setup. A roll-along box allowed about 24 shot records per setup; as the shot point advanced to each new station along the cables, the 24 takeouts in front of it were activated in turn. Striking a metal plate with a 16 pound sledge hammer provided the seismic energy, with nine swings per shot point. The swings for each point were stacked, or added together. True reflection signals add constructively, producing a distinct peak on the record, while wind or other noise does not. In addition to stacking, extraneous noise was also limited by setting the seismograph frequency cut-offs to 32 and 250 Hz.

The elevation of each station was surveyed using a level sight and stadia rod, with wells as reference elevations. This data was calculated and correlated in a Microsoft Excel spreadsheet, and used in elevation corrections while processing. The seismic records were processed using the program WinSeis, from the Kansas Geological Survey, running on a Pentium computer.

PROCESSING

Although this seismographic data is of relatively high quality for shallow continental sediments, it is still very noisy, possibly due in part to the large amounts of debris in the ground. Identifying and analyzing the reflection traces requires manipulation, and the removal, or muting, of more than half the collected data from each record. Muting the record eliminates the large amplitude traces caused by ground roll and air blast energy (Figure 1), which can mask true reflections during processing. Unfortunately, this eliminates all data above and below certain points; in Figure 2 there are no data above 30 ms, and below 340 ms.

The data can be further refined through filtering. The data in Figure 2 have been filtered with respect to both frequency and linear slope. Linear first arrival traces were f-k filtered prior to stacking to reveal any shallow reflection traces they may have been masking. In additon, the last step in the production of the section in Figure 2 was the application of a frequency band-pass filter which eliminated peaks with frequencies below 30 Hz and above 500 Hz.

Before this filter, however, the data was aligned with a normal moveout (NMO), and then stacked. Reflector traces are hyperbolic on the shot record, and an analysis of each reflector's trace geometry yields the seismic velocity for that particular reflection path. The same equations which produce the velocities allow the traces to be shifted vertically and aligned, or normally moved out, so that they can be stacked to selectively amplify reflectors. Because velocities can vary widely both vertically and laterally in an area, WinSeis is capable of assigning velocities to distinct subsets of data, according to both occurence in time and space.

Depth conversion is the final step in fully processing a seismic section such as this. The section in Figure 2 has increments of two-way time along the vertical axis, and common depth point (CDP) numbers along the horizontal axis. Conversion of the CDP numbers to distance consists of multiplying the CDPs by their spacing, in meters. Conversion of the vertical scale into distance requires the use of the velocities produced by the NMO. Each distinct area has a velocity, by which its times must be multiplied to arrive at depths. The result of the lateral variation of velocities is that the geometry shown on distance- time plots is often different from that on a distance-distance, depth converted plot. WinSeis does not contain a depth conversion module. The simple distance-distance plot in Figure 3 was made with Microsoft Excel, and demonstrates how the geometry of the highest and lowest distinct reflectors changes when depth conversion is applied.

CONCLUSIONS

The point along the upper edge of Figure 4 labeled "Sta. 6" represents the approximate position of CDP 13 in relation to the well line cross section (AA). The Tertiary/Quaternary contact is mapped here as approximately 40 feet below the surface. The upper-most data in Figure 2 occurs at a depth of at least 35 m, on the depth-converted cross section in Figure 3; the contact is therefore not represented by a reflection trace at this point, and it is unlikely that it is represented at all on the section in Figure 2, as lithologic well logs to the west indicate a thinning Quaternary bed. Additional processing of seismic data to the east may image the contact. The thickness of Quaternary deposits is mapped as increasing to the east (ARCO, 1995), although the review of lithologic well samples disputes this to some extent.

In addition, it is unlikely, due to the velocities calculated during NMO, that reflections in solid Cretaceous granitic rocks appear in the section in Figure 2. However, the NMO velocities present are appropriate for the gravel, or gruss, which results from weathering of the granitics, and may grade from lower Tertiary gravel to upper Cretaceous solid granitic rocks. This would have the added effect of tempering any sharp density changes between Cretaceous granitics and Tertiary sediments, and therefore muffling reflections. The NMO velocities are also appropriate for lightly welded tuffs, and so may indicate the presence of the Lowland Creek unit.

Of the five lines of seismic reflection data which were gathered, the line presented here contained the cleanest data, and therefore the clearest reflectors. However, it is not very well suited to correlation for several reasons: a) it extends well beyond the last set of wells for which there are lithologic well logs; b) it was shot in the direction of thinning Quaternary deposits, where the Tertiary/Quaternary boundary is too high in the section to be imaged; and c) wells which do fall on or near the line do so near the beginning, where there are fewer traces per CDP to stack in. Future attempts at correlation should focus on the more easterly lines of data.

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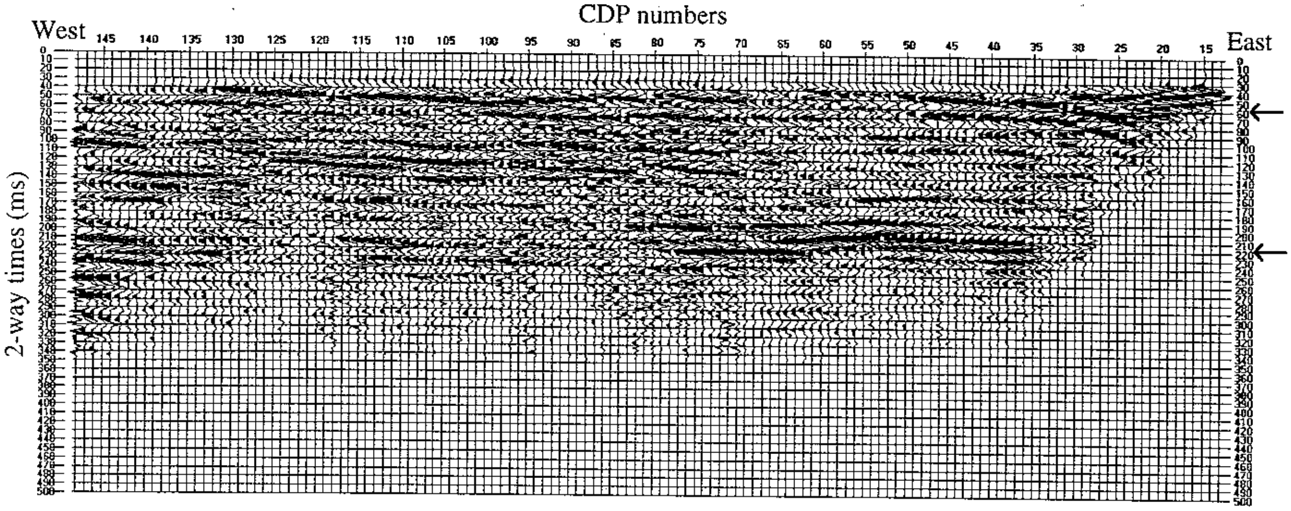

Figure 2: Seismic section. The survey line was oriented east-west. Arrows point to the time signatures of reflectors depth-converted below.

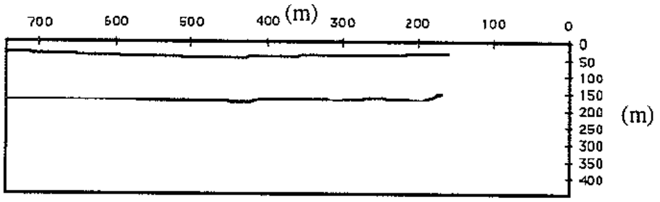

Figure 3: Depth conversion line drawing

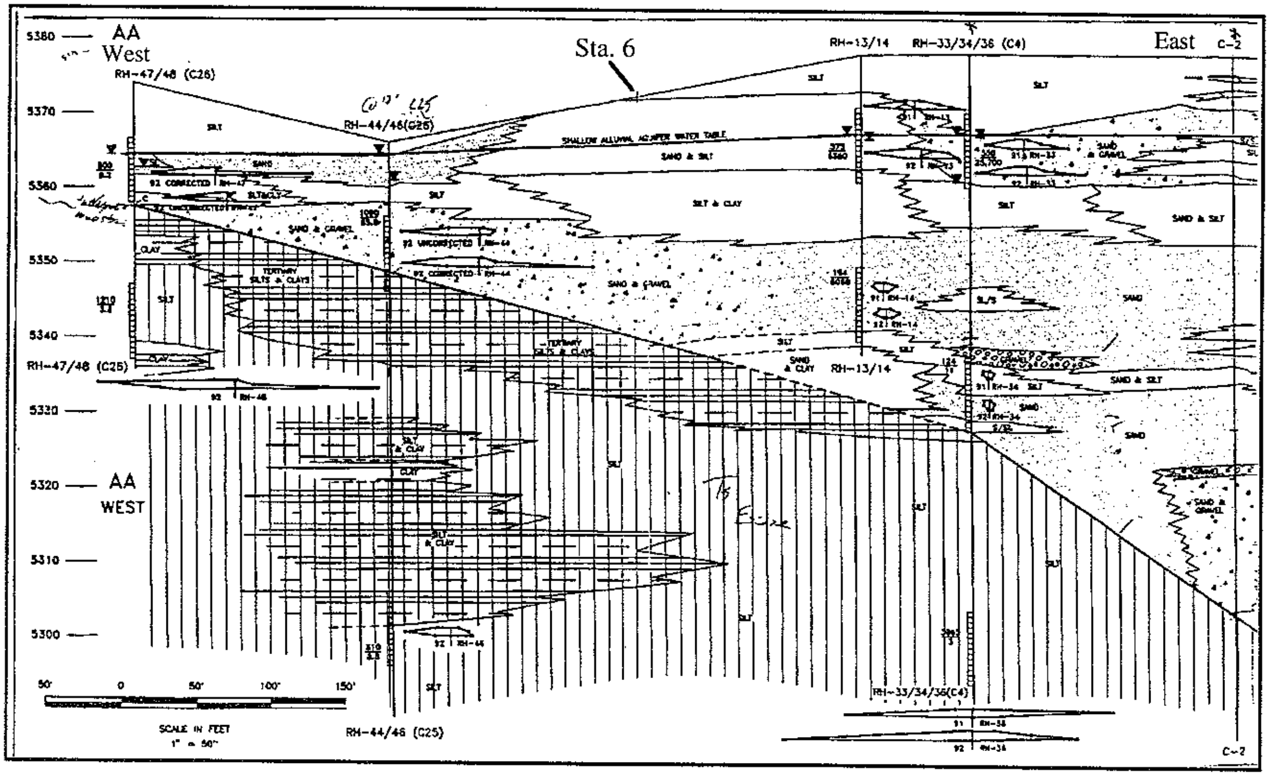

Figure 4: Lithologic cross section. The point labeled as Sta. 6 represents CDP 13; the seismic line extended to the west from this point.
(modified from ARCO, 1995)

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