5.0 CALIBRATION OF SEISMIC AMPLITUDES

Even if the seismic traces have been ideally processed, preserving all the pertinent amplitudes, the acoustic impedance of a particular layer still cannot be computed directly from the excursion of the seismic trace. Too much information has been lost from the seismic trace, so that we need supportive information, such as:

- Peak/Avg ratio on well logs
- Low frequency impedance record from Vint
- Seismic amplitude of known multiple
- Seismic amplitude of reflector with known impedance

5.1 AMPLITUDE CALIBRATION WITH RUNSUM AND ROVER4

For the past fifteen years, seismic amplitude analysis has been an important part of the evaluation of seismic data. Areas such as the the Gulf Coast Tertiary, California offshore, and Cameroon have enjoyed success with amplitude analysis. The method commonly used involves deconvolution of the data for removal of source wavelet, geophone response, etc, to produce a trace similar to a reflection coefficient series. A simple integration of the deconvolved trace makes it possible to interpret the output as a bandlimited log of the earth's acoustic impedance.

The program RUNSUM performs an 'integration' by calculating a running summation of the data samples on the trace, with subsequent removal of any resulting ramp and DC. Measurement of event amplitudes and calibration to the petrophysical data are accomplished with ROVER4 or ADEM. A thorough discussion of amplitude analysis is given in Scaife et al. (1974).

5.1.1 RUNSUM

Reflection occurs when a seismic wave encounters a difference in acoustic impedance (ρV) in the earth. The difference may be associated with changes in lithology, fluid content, cementation, porosity, or other rock properties. The reflection coefficient (RFC) of an interface may be defined as the ratio of the amplitudes of the reflected and incident waves.

$$RFC = A_r/A_i$$

For normally incident plane waves, the wavelet amplitudes can be related to the velocity and density changes across an interface by the expression:

$$\frac{Ar}{Ai} = \frac{\rho 1\ V1 - \rho 2\ V2}{\rho 1\ V1 + \rho 2\ V2} = RFC$$

If changes in acoustic impedance ($\Delta\rho V$) across subsurface boundaries tend to be small compared with the average impedance of buried layers, then we can write an approximate expression for the reflection coefficient as:

$$RFC = \frac{\Delta \rho V}{2 \rho V}$$

Peterson (1955) has pointed out that this approximation leads to a useful simplification, namely;

$$\int Rc = \int \frac{\Delta \rho V}{2 \rho V} = 1/2 \ \ln(\rho V)$$

Taking the derivative

$$Rc = 1/2 \ \Delta \ln(\rho V) \qquad \text{Eq. 6-1}$$

Reflection coefficients in most sedimentary sequences fall within the range of plus or minus 0.3. The reflection coefficients within this range can be approximated to an accuracy of 97% or better by eq 6-1 as shown in Figure 1.

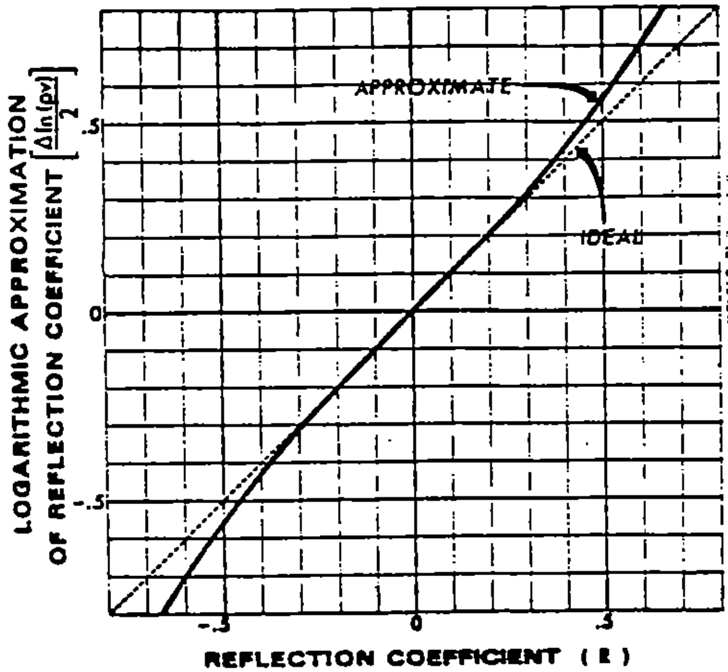


Figure 1. Accuracy of approximation to RFC: (from Peterson (1955).

The display below in Figure 2 shows velocity (1) and density (2) logs which have been multiplied and then had the natural logarithm (ln) taken. - (3). Reflection coefficients computed from the ρV values (4) correspond to deconvolved seismic traces. Deconvolved traces contain information about the relative hardness of the geologic layers but are relatively difficult to interpret. This is illustrated by integrating the reflection coefficients to obtain the RUNSUM trace (5). The RUNSUM trace is easier to interpret in terms of the physical properties, 'hardness' or 'softness', of successive layers and is a useful display for interpreters who make quantitative uses of seismic reflection amplitudes.

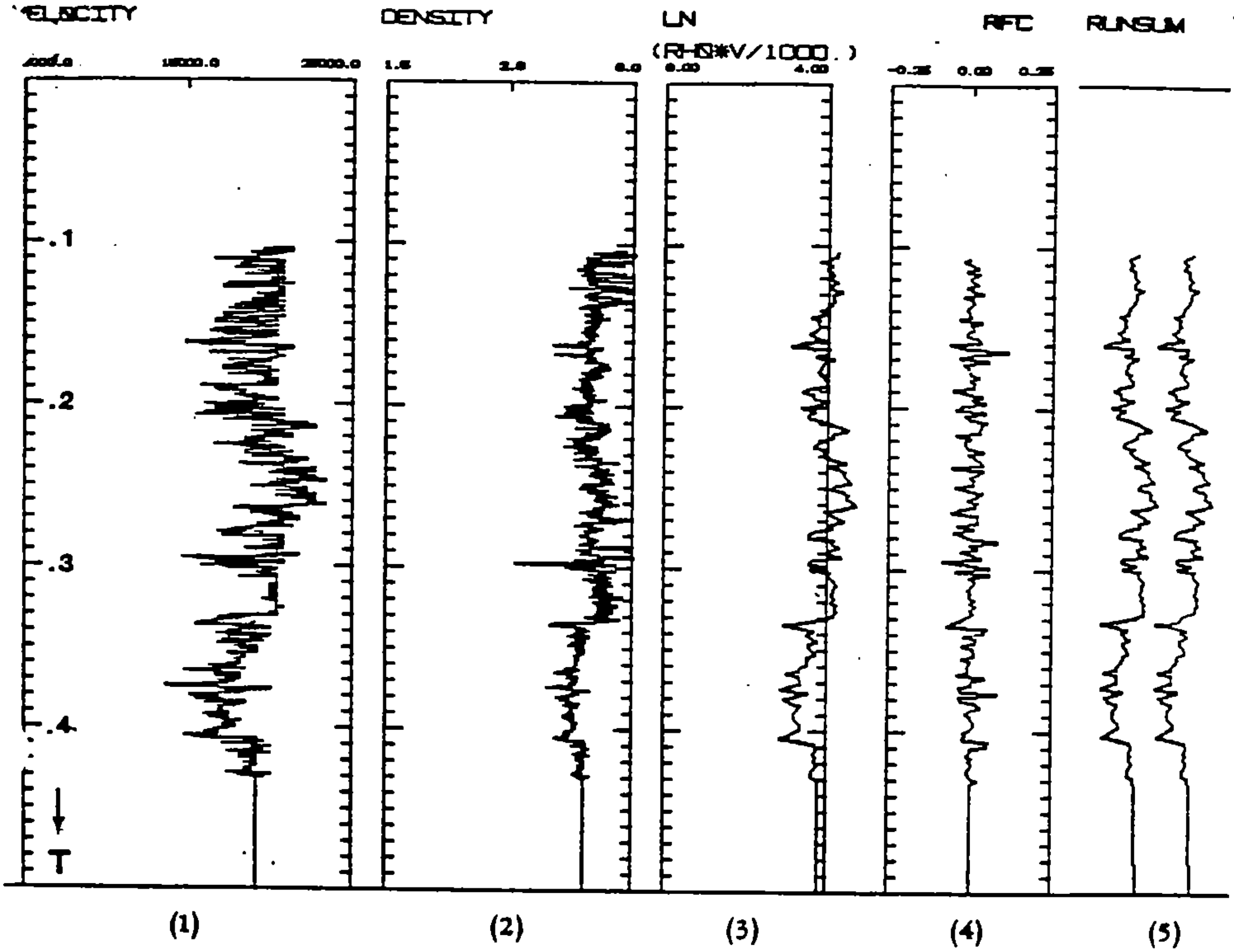
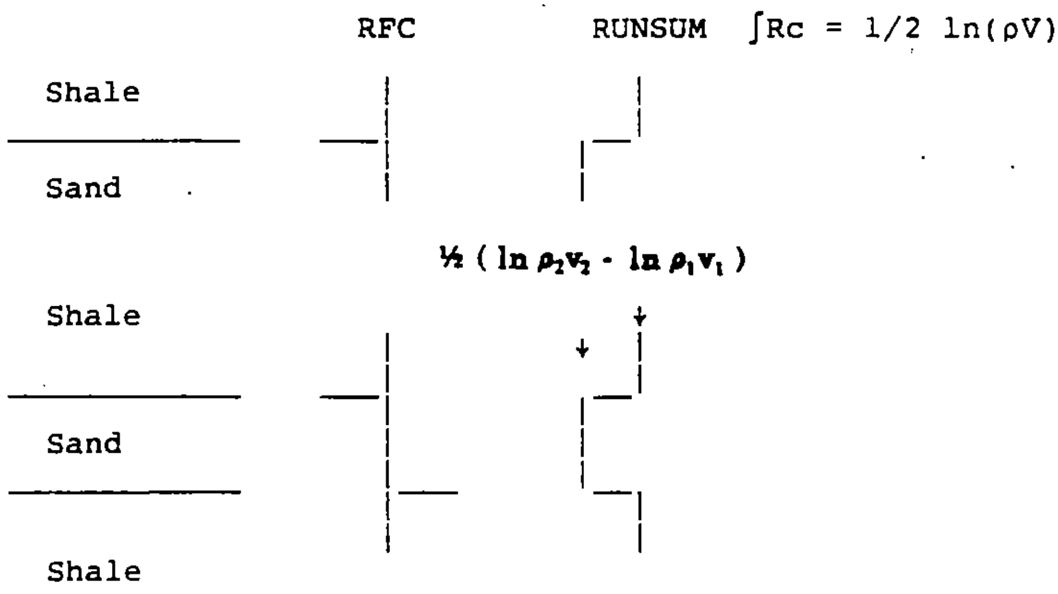


Figure 2. RUNSUMed trace constructed from logs.

We often think of our processing goal as the generation of a trace that represents, as closely as possible, the reflection coefficients of the earth. This enables us to find the contrast in acoustic impedance between two layers. We might think of RUNSUM as allowing us to make a measurement of the acoustic impedance of a 'single' lithological unit.



5.1.2 ROVER4

ROVER4 makes an amplitude measurement called 'A', on designated events (e.g., bright spots). The 'A' measurement is assumed to be equal to 1/2 $\Delta \ln(\rho V)$ from the well log. Event amplitude measurements can be made on the basis of the greatest excursion the trace makes from the zero crossing or, since the seismic response is bandlimited and a event on a RUNSUM section will be preceded by pre- and post-cursers, we can make amplitude measurements referenced to these cursers. Our choices are 1) a single cursor measurement as shown on the right in Figure 3, or a double curser measurement which is the maximum excursion from a line drawn tangent to pre- and post-cursers as shown on the left below. Experience has shown the double curser measurement to give the best results as this curser measurement method minimizes the increase in amplitudes, or enhancement, due to the overlapping waveforms from the top and bottom of thin beds.

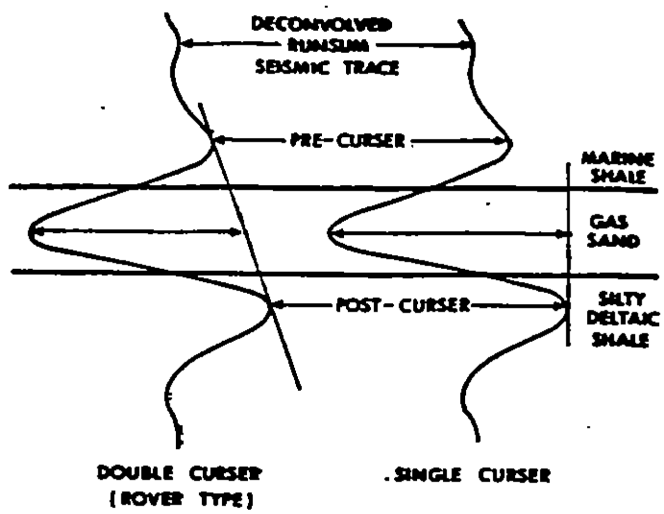


Figure 3. Various types of amplitude measurements.

Amplitude level variations from trace to trace and line to line may not necessarily be lithology related and so normalization is required to compare amplitude measurements. For normalization purposes then, in addition to an 'A', ROVER4 also calculates a 'B' which is an average background amplitude measurement determined within a gate specified by the user. A value for 'A/B' could be considered as a normalized measurement which should be roughly independent of the non-lithology differences between traces and other vintages of seismic lines. The $\Delta \ln(\rho V)$ of the normal brine saturated geologic section, (Bzl), is assumed to be proportional to 'B', (and therefore hydrocarbon bearing events are not included in the background). As one might surmise the tailoring of the 'B' gate can be critical to the ultimate measurement. The problem becomes complicated in the presence of multiple bright spots, high level noise, etc.

$$\frac{A}{B} = \frac{\Delta \ln(\rho V)}{Bzl} \qquad \text{EQ. 6-2}$$

The term Bzl corresponds to the event background B. Where control is available, Bzl values are obtained by running ROVER4's on $\ln(\rho V)$ logs filtered to the seismic bandwidth. The average amplitude value, B, measured over some time gate depends on the number of reflecting interfaces within the time gate. Consequently, Bzl values will change according to stratigraphic setting. In the offshore Gulf Coast Tertiary such grouping might pertain to (1) primarily alluvial-deltaic inner-fringe, (2) primarily deltaic outer-fringe, and (3) primarily pro-deltaic. In the exploration setting lacking subsurface control the type of stratigraphy in the B gate can be used to help estimate a Bzl value.

Following the previous discussion it is not surprising to find that Bzl values may not always be firmly established. Consequently eq. 6-2 is often written:

$$\ln(\rho V) = \ln(\overline{\rho V}) - \frac{A}{B} \text{ Bzl K}$$

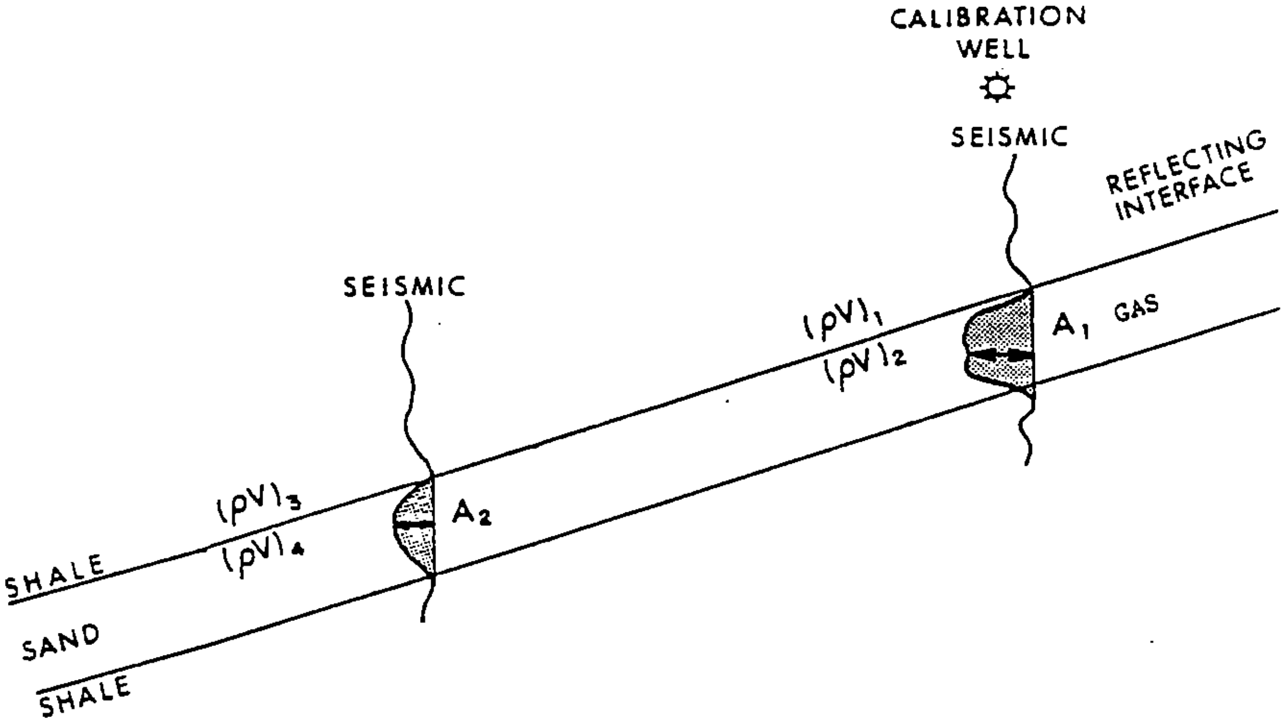
Where The K value is purely empirical and depends on local experience in the area.

$\ln(\overline{\rho V})$ = the line bisecting the Bzl band or the average $\ln(\rho v)$

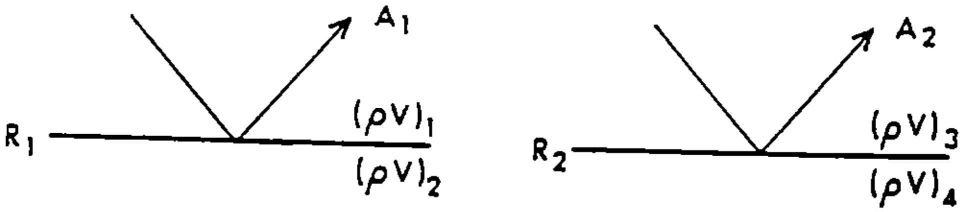
A/B values must be interpreted carefully as they can be rather ambiguous and a given value may be appropriate for: (1) Water in a very good sand, (2) Oil in a mediocre sand, or (3) Gas in a poor sand. We attempt to remove some of this ambiguity by looking at the amplitude difference between on structure and off-structure locations. This difference can be described as Δ A/B or $\Delta\ \Delta \ln(\rho v)$.

A point to watch for is that CHAMP gain functions are derived with ROVER gates in mind. If the gain function changes within the ROVER gate, due to TIMCUT or successive CHAMPS with different apply zones then the background and the event 'A' may have substantially different gains applied.

Examples of ROVER4 parameter cards and output are shown in the following illustrations:



$$\frac{A_1}{A_2} = \frac{\ln(\rho V)_1 - \ln(\rho V)_2}{\ln(\rho V)_3 - \ln(\rho V)_4}$$



$$\ln(\rho V)_4 = \ln(\rho V)_3 - \frac{A_2}{A_1}\left[\ln(\rho V)_1 - \ln(\rho V)_2\right]$$

<u>WHERE</u>

A - Is Seismic Amplitude Value

(ρV) - Is Acoustic Impedence (Density X Velocity)

$(\rho V)_3$ - Is Assumed to be Equal to $(\rho V)_1$