Basic well Logging Analysis –

Sonic Log

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Sonic Log

- The sonic log is a porosity log that measures interval transit time (Δt) of a compressional sound wave traveling through one foot of formation.

- Interval transit time (Δt) in microseconds per foot is the reciprocal of the velocity of a compressional sound wave in feet per second.

Sonic Log (Cont.)

- The sonic log device consists of one or more sound transmitters, and two or more receivers.

- Modern sonic logs are borehole compensated devices (BHC). These devices greatly reduce the spurious effects (假性效應) of borehole size variations (Kobesh and Blizard, 1959), as well as errors due to tilt (傾斜) of the sonic tool (Schlumberger, 1972).

Sonic Log

- 聲波井測為量測聲波(通常為壓縮聲波)通過 1英呎厚的地層所需的間隔傳遞時間。
- 利用聲波井測所記錄的間隔傳遞時間、配合已知(或假設)的地層岩基以及地層流體的間隔傳遞時間，可估算出地層孔隙率 (聲波孔隙率)。

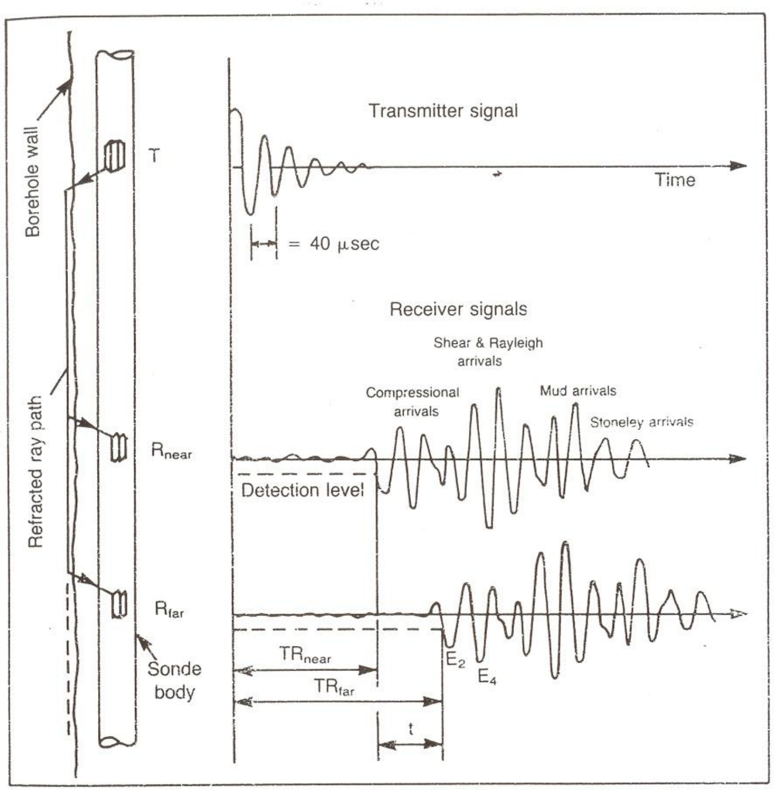
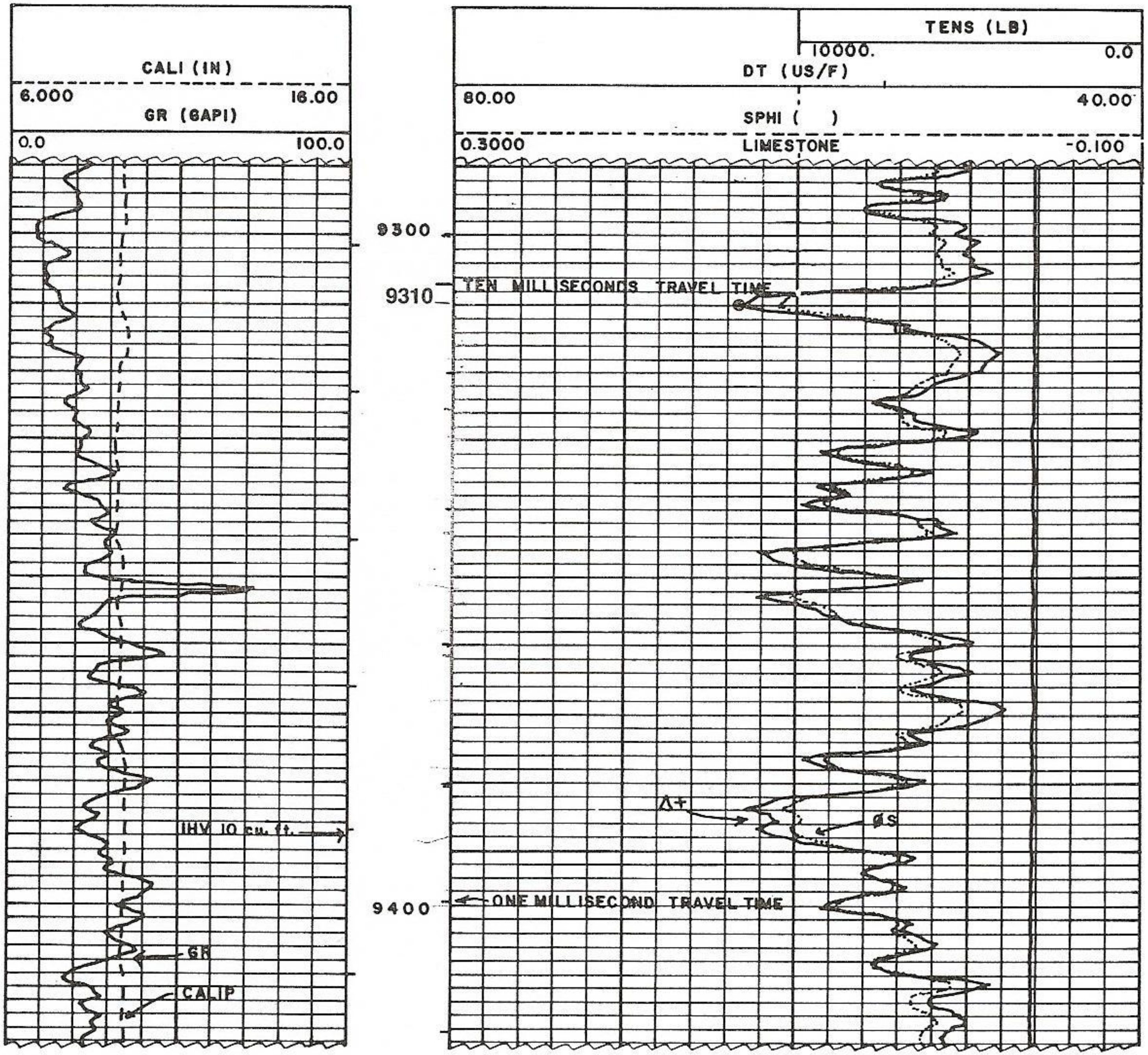


圖 A-8 聲波井測原理(Dewan,1983)


CALI (IN)
6.000
16.00
GR (GAPI)
0.0
100.0
TENS (LB)
10000.
0.0
DT (US/F)
80.00
40.00
SPHI ( )
0.3000
LIMESTONE
-0.100
9300
9310
TEN MILLISECONDS TRAVEL TIME
IHV 10 cu. ft.
Δt
ØS
9400
ONE MILLISECOND TRAVEL TIME
GR
CALIP

Sonic Log (Cont.)

- Interval transit time (Δt) is record in tracks #2 and #3 (in your example Figure).

- A sonic derived porosity curve is sometimes recorded in tracks #2 and #3, along with the Δt curve.

- Track #1 normally contains a caliper log and a gamma ray log or an SP log.

SONIC POROSITY

Sonic Log (Cont.)

- The interval transit time (Δt) is dependent upon both lithology and porosity.

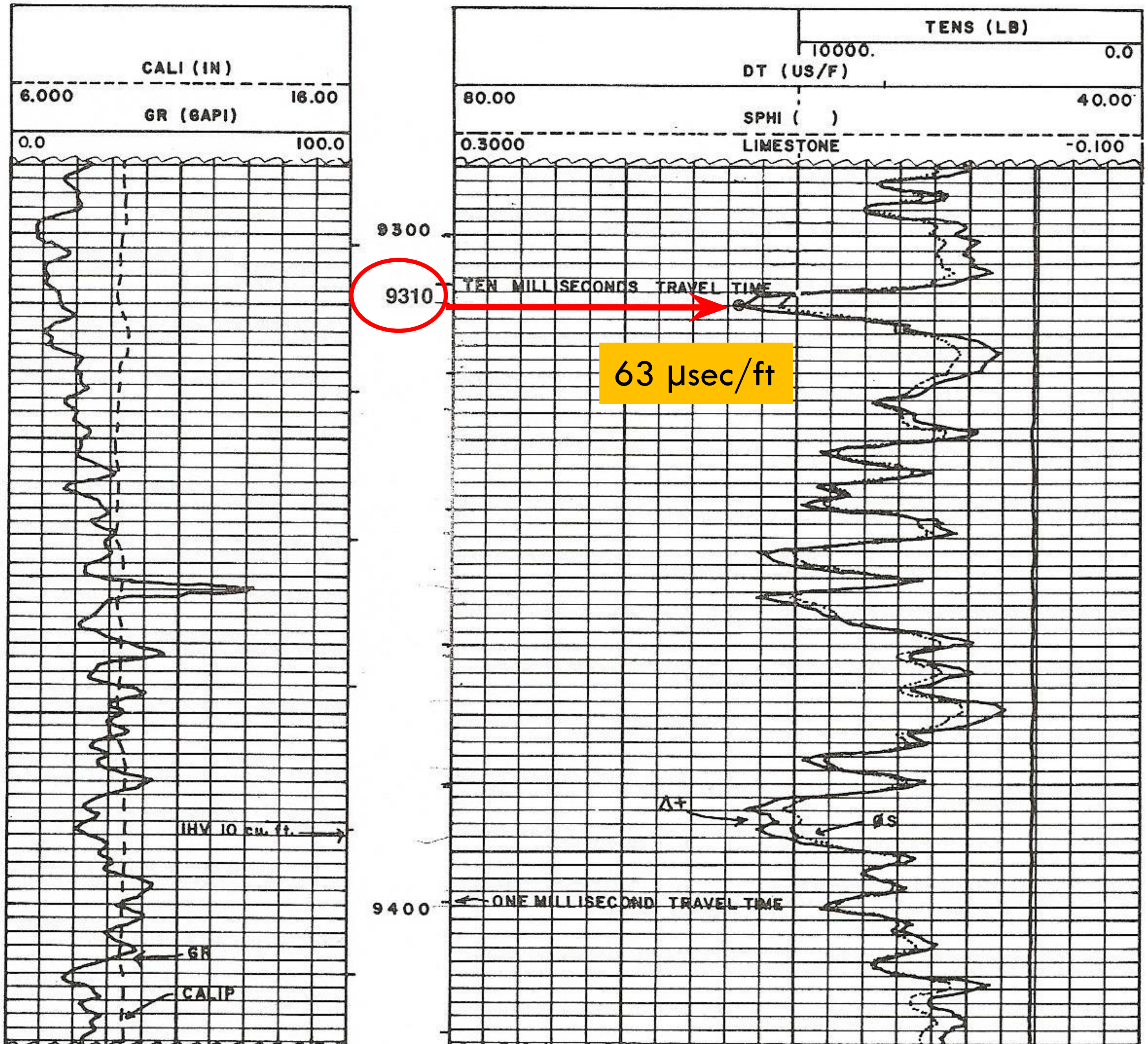
- Therefore, a formation's matrix velocity (Table 1) must be known to derive sonic porosity either by chart (Fig. 27) or by formula (Wyllie et al, 1958).

(Table-1)

MATRIX VELOCITY

	V_{ma} (ft/sec)	Δt_{ma} (µsec/ft)	Δt_{ma} (µsec/ft) commonly used
Sandstone	18,000 to 19,500	55.5 to 51.0	55.5 to 51.0
Limestone	21,000 to 23,000	47.6 to 43.5	47.6
Dolomite	23,000 to 26,000	43.5 to 38.5	43.5
Anhydrite	20,000	50.0	50.0
Salt	15,000	66.7	67.0
Casing (Iron)	17,500	57.0	57.0

(1) DERIVE SONIC POROSITY BY CHART



CALI (IN)
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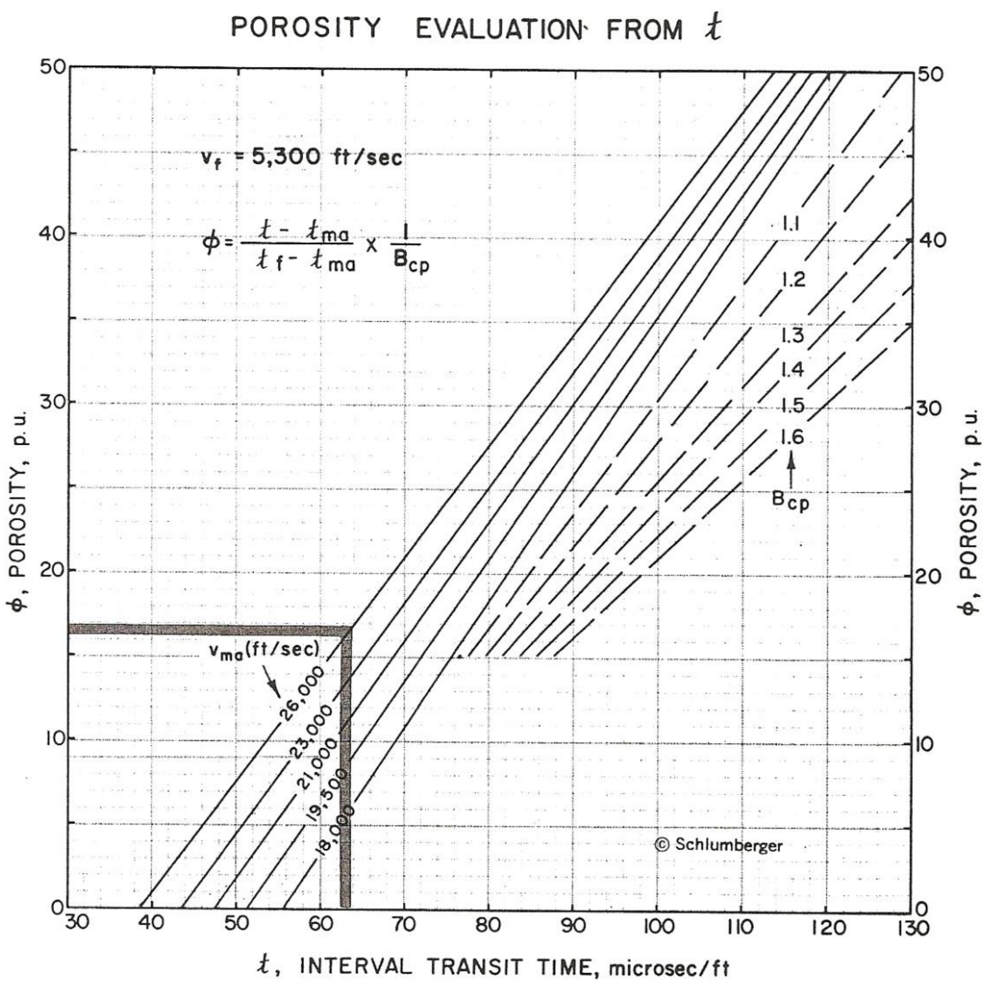
Derive sonic porosity by chart

POROSITY EVALUATION FROM SONIC



	v_{ma} (ft/sec)	t_{ma} (microsec/ft)
Sandstones	18,000-19,500	55.5 - 51.3
Limestones	21,000-23,000	47.6 - 43.5
Dolomites	23,000-26,000	43.5 - 38.5

Given:
Vma=26000 ft/sec (Dolomite)
Δt=63 μsec/ft @ 9310 ft

Note:
The formation's matrix velocity must be known

Exercise – find sonic porosity by chart

- (1)
- Depth = 9310 ft
- Lithology [=] Dolomite (Vma=26000 ft/sec)
- Sonic porosity = ?

- (2)
- Depth = 9320 ft
- Lithology [=] Limestone (Vma=21000 ft/sec)
- Sonic porosity = ?

(2) DERIVE SONIC POROSITY BY FORMULA

Derive sonic porosity by Wyllie formula

- $$\phi_{sonic} = \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}$$

- Where :
- Φ_{sonic} = sonic derived porosity
- Δt_{ma} = interval transit time of the matrix
- Δt_{log} = interval transit time of formation
- Δt_f = interval transit time of the fluid in the well bore
- (fresh mud = 189 ; salt mud = 185)

Exercise – find sonic porosity by formula

- (1)
- Depth = 9310 ft
- Lithology [=] Dolomite
- Mud [=] fresh mud
- Sonic porosity = ?

$$\phi_{sonic} = \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_{f} - \Delta t_{ma}}$$

- (2)
- Depth = 9320 ft
- Lithology [=] Limestone
- Mud [=] fresh mud
- Sonic porosity = ?

Sonic porosity for unconsolidated sands

Sonic porosity for unconsolidated sands

- The Wyllie et al. (1958) formula for calculating sonic porosity can be used to determine porosity in consolidated sandstones and carbonates.

- Where a sonic log is used to determine porosity in unconsolidated sands, an empirical compaction factor or Cp should be added to the Wyllie et al. (1958) equation:

$$\phi_{sonic} = \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_{f} - \Delta t_{ma}} * \frac{1}{C_p}$$

- Where Cp = compaction factor

Sonic porosity for unconsolidated sands (Cont.)

- For unconsolidated sands,

$$\phi_{sonic} = \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} * \frac{1}{C_p}$$

- The compaction factor is obtained from:

$$C_p = \frac{\Delta t_{sh} * C}{100} [=] \frac{\Delta t_{sh}}{100}$$

- Where Cp = compaction factor
- Δt_{sh} = interval transit time for adjacent shale
- C = a constant which is normally 1.0 (Hilchie,1978)

EMPIRICAL CORRECTIONS FOR HYDROCARBON EFFECT

EMPIRICAL CORRECTIONS FOR HYDROCARBON EFFECT

- The interval transit tie (Δt) of a formation is increased due to the presence of hydrocarbons (i.e. *hydrocarbon effect*).
- If the effect of hydrocarbons is not corrected, the sonic derived porosity will be too high.
- Hilchie (1978) suggests the following empirical corrections for hydrocarbon effect :
- $\Phi = \Phi_{sonic} \times 0.7$ (gas)
- $\Phi = \Phi_{sonic} \times 0.9$ (oil)

Sonic porosity for shaly sands

Sonic porosity for shaly sands

- After the volume of shale (Vsh) is determined, it can be used to correct the porosity log for shale effect. The formula for correcting the sonic log for volume of shale is (Dresser Atlas, 1979):

$$\phi_{S-Sh} = \left(\frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} * \frac{100}{\Delta t_{sh}}\right) - V_{sh}\left(\frac{\Delta t_{sh} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}\right)$$

- Where Δt_{sh} = interval transit time for adjacent shale

Homework #3 -- sonic log

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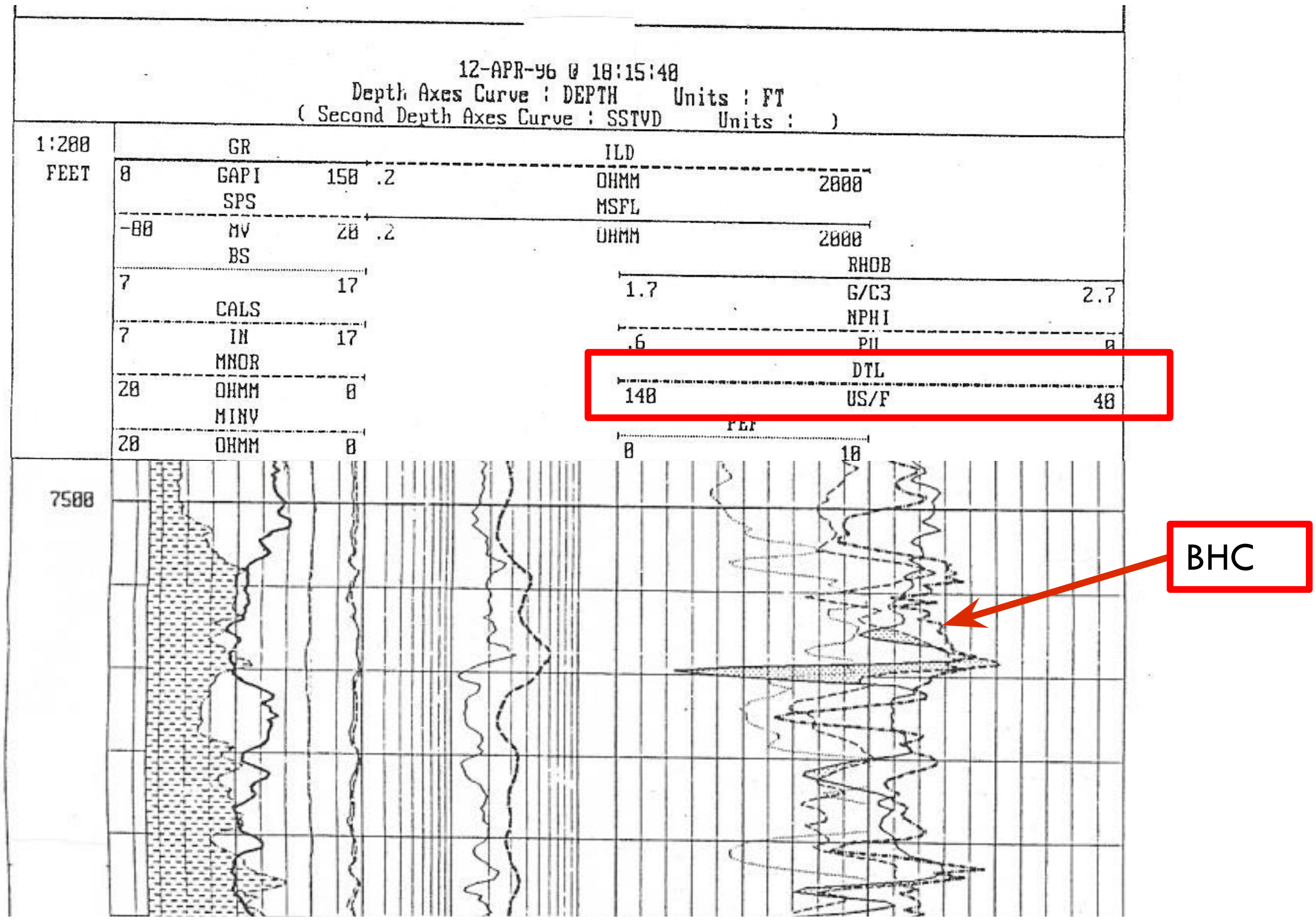

HOMEWORK #3 – SONIC LOG

Depth	BHC	Φ_s	Vsh	$\Phi_{s\text{-}sh}$
7600				
7610				
7620				
….				
….				
….				
….				
….				
….				
….				
7840				
7850				

$$\phi_S = \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} * \frac{1}{C_p}$$

$$= \frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} * \frac{100}{\Delta t_{sh}}$$

$$\phi_{S-Sh} = \left(\frac{\Delta t_{\log} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}} * \frac{100}{\Delta t_{sh}}\right) - V_{sh}\left(\frac{\Delta t_{sh} - \Delta t_{ma}}{\Delta t_f - \Delta t_{ma}}\right)$$

Information:

Δt_{ma} = 55.5 µsec/ft (Sandstone)

Δt_f = 189 µsec/ft (Fresh mud)
Δt_f = 185 µsec/ft (Salt mud)

Δt_{sh} = ? µsec/ft