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O. PR. 15/9-1	
E.ORD. PE RES	

FORMATION FACTOR TESTS
STATOIL PETROPHYSICS LAB.

STATOIL WELL [redacted]
REPORT DATE: 30/5-77.

OBJECT

To find a relationship of the kind. $F = a\phi^{-m}$ from physical measurements of plug samples of varying ϕ.

INTRODUCTION

From plugs with a wide range of porosity, Formation Factor (F) tests were done while the plugs were saturated in brine, equivalent to well 15/9-1 formation water concentration.

By using certain useful cross-plot techniques to eliminate spurious effects, a line of the equation

$$F = \phi^{-1.75} \text{ (LAB.CONDITIONS)}$$

was curve - fitted to the points.

A discussion on various cross-plots follows, and a comparison of independent (STATEX) ϕ and Grain Density measurements is made.

EXPERIMENTAL PROCEDURE

After cleaning and extraction of 53 plugs, permeabilities in air, and porosities according to Boyle's Law method ($\phi_{B.L.}$) were found.

From these, 23 plugs with a wide range in $\phi_{B.L.}$ were selected for Formation Factor tests, measured with a brine solution of 90,000 ppm. RaCl, approximately equivalent to formation water concentration, which had been permeating the plugs after vacuum extraction, and held for 24 hours under 1000 psi. pressure.

$\phi_{saturation}$ was measured as a confirmation of $\phi_{B.L}$, and the Formation Factor tests were checked successfully for repeatability.

RESULTS

$\phi_{B.L.}$ vs. F was plotted for all 23 plugs (fig 1). Much scatter was observed, but, on further investigation with $\phi_{B.L}$ vs. $\rho_{B\ LAB}$ cross-plot (fig 2), could be attributed to points which contain amounts of Dolomite.

If these points are eliminated from fig 1, we obtain the resultant plot, fig 3, which, using curve - fitting technique, gives an equation

$$F = \phi^{-1.75}$$

with coefficient of determination $r^2 = 0.99$

The F reading is affected by the dolomite content of the sand-stone plug, and gives an irrational reading for highly dolomitic sandstones.

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Grain Density ($= \rho_{ma}$ LAB) and Equivalent Bulk Density in situ ($= \rho_B$ LAB) calculations.

$$\rho ma \text{ LAB} = W/_{Vg}$$

$$\rho B \text{ LAB} = \frac{(VB - Vg)\,\rho mf + W}{VB}$$

where W = Dry weight of plug (g)
Vg = Grain volume from $\emptyset_{B.L.}$ (cc)
VB = Bulk Volume (cc)
ρmf = density of mud filtrate, (g/cc) assumed to be the predominant fluid in the invaded zone, where the log value of ρ_B is measured.

These values were calculated, and (fig 4) ρ_B Log vs $\rho_{B\ LAB}$ was plotted with $\emptyset_{B.L.}$ vs $\rho_{B\ LAB}$ (Fig 2)

Fig 2. illustrates that most of the points fall near the sand-stone line, and the limestone and Dolomite points plot to the north-east (N-E) in increasing dolomite content; shale tends to pull the points slightly to the N-E direction off the clean sand-stone line, most of the shale points having heavier minerals than basic shale which has a density of 2.52 - 2.55 g/cc. for 15/9-1.

Fig. 4 is useful in identifying the hydrocarbon effect on the ρ_B LOG values. The higher density dolomite points show deviation from the 45° line, due to the depth-shifting process limits of accuracy. This plot is also illustrated in figs 5,6, & 7.

NB Matching of logs and cores was done by relating a 1/200 core description log with the neutron-density log, and finding obvious shale and coal correlation points - good correlation was found throughout, considering that the log was from a sidetracked hole about 10 m. away horizontally from the original cored hole.

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$\emptyset_{B.L}$ vs $\emptyset_{SAT}$ (Fig 8) on 24 points was drawn using formula

$$\emptyset_{SAT} = \frac{Wwet - Wdry \times 100}{SAT\ FLUID \times VB}$$

The cleanest points plotted on the 45^{o} line, and we obtain an idea of clay-swelling properties refering to the points to the N-W of the clean line.

FIG. 9 is a plot of DRY CORE Ø (ie, $\emptyset_{B.L.}$) against Ø EFFECTIVE LOG (ie, the Ø value from the GOLOG program with the shale and hydrocarbon effect taken off.
Generally the trend is for the more shaley cores to plot to the N.W. of the 45^{o} LINE.
This suggests that there is a tendency for the drying process involed in the core porosity analysis to increase the Ø value due to the drying out of the water absorbed to the surface of the clays.
FIG. 8, $\emptyset_{DRY\ CORE}$ vs $\emptyset_{SAT}$, shows a similar effect.
This exageration of the Dry Core Ø should be taken into account in Formation Factor versus porosity tests, and also in Capillary Pressure experiments.
The need for humidity - controlled Ø measurements, and exact correlation between log and lab. work is emphasised here.

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Ø's from STATOIL and STATEX measured on the same 13 plugs, were plotted beside each other (Fig 10), and fair agreement was observed.

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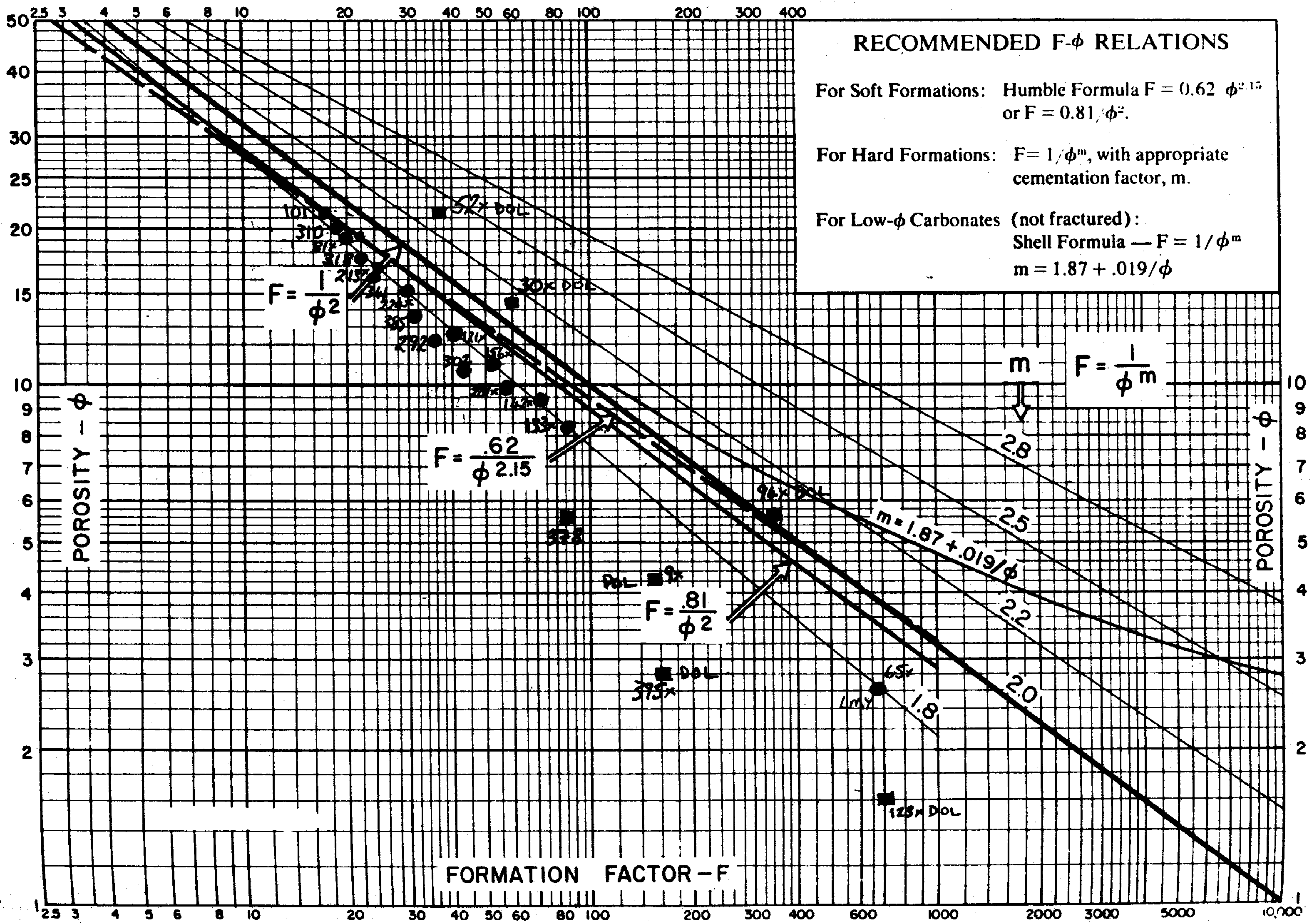
For zones of obvious hydrocarbon content, as selected by CNL/FDC log, the average ρ_{MA} equals 2.65 g/cc with range of points between 2.64 and 2.67 g/cc, apart from one shaley points of 2.69 g/cc (22 plugs).

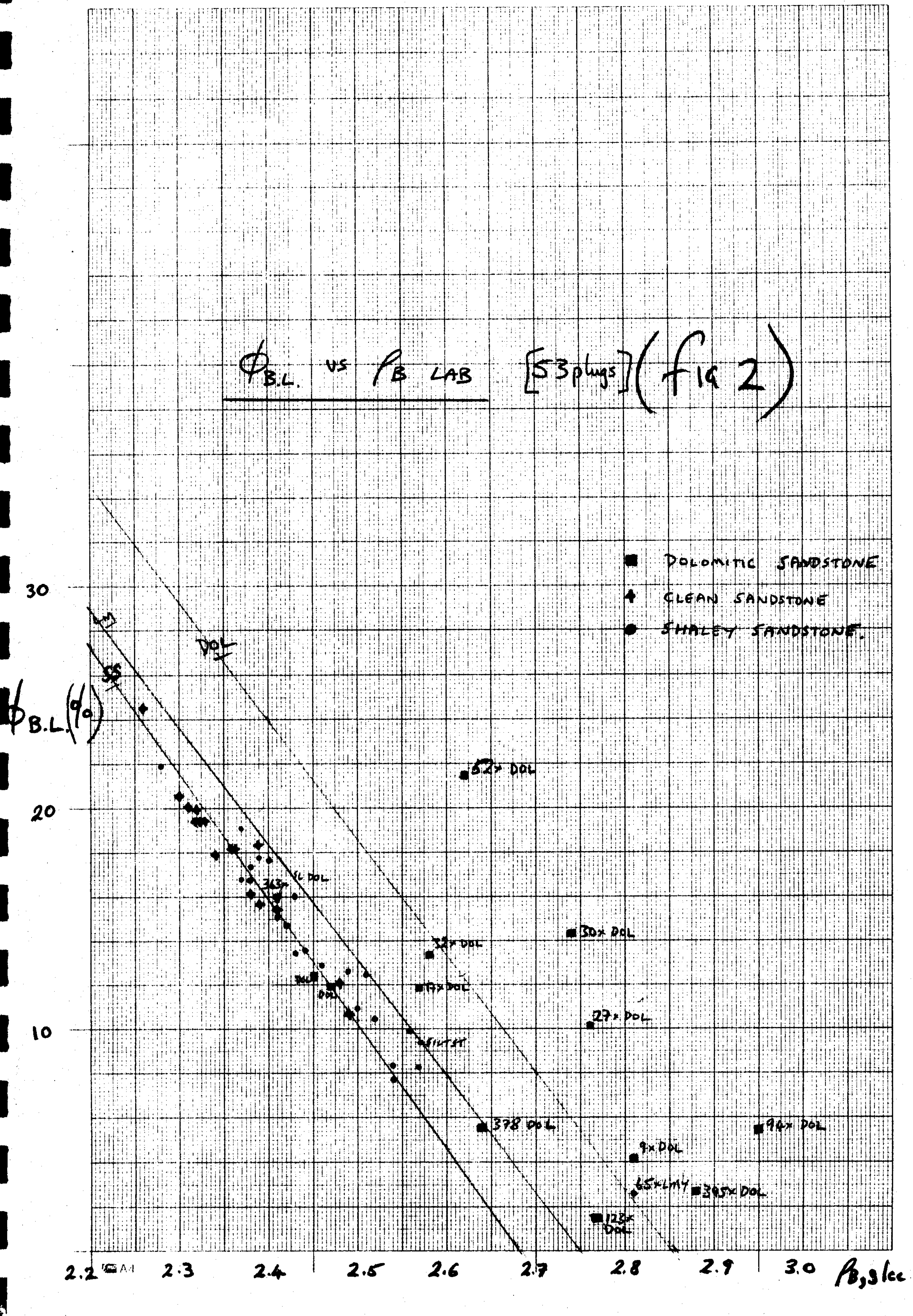
For the 13 plugs analysed by STATEX and STATOIL, the variation of ρ_{MA} from equality (fig 11) was a function of the slight differences in measured Ø.

■ Dolomitic Points
● Sandstone Points

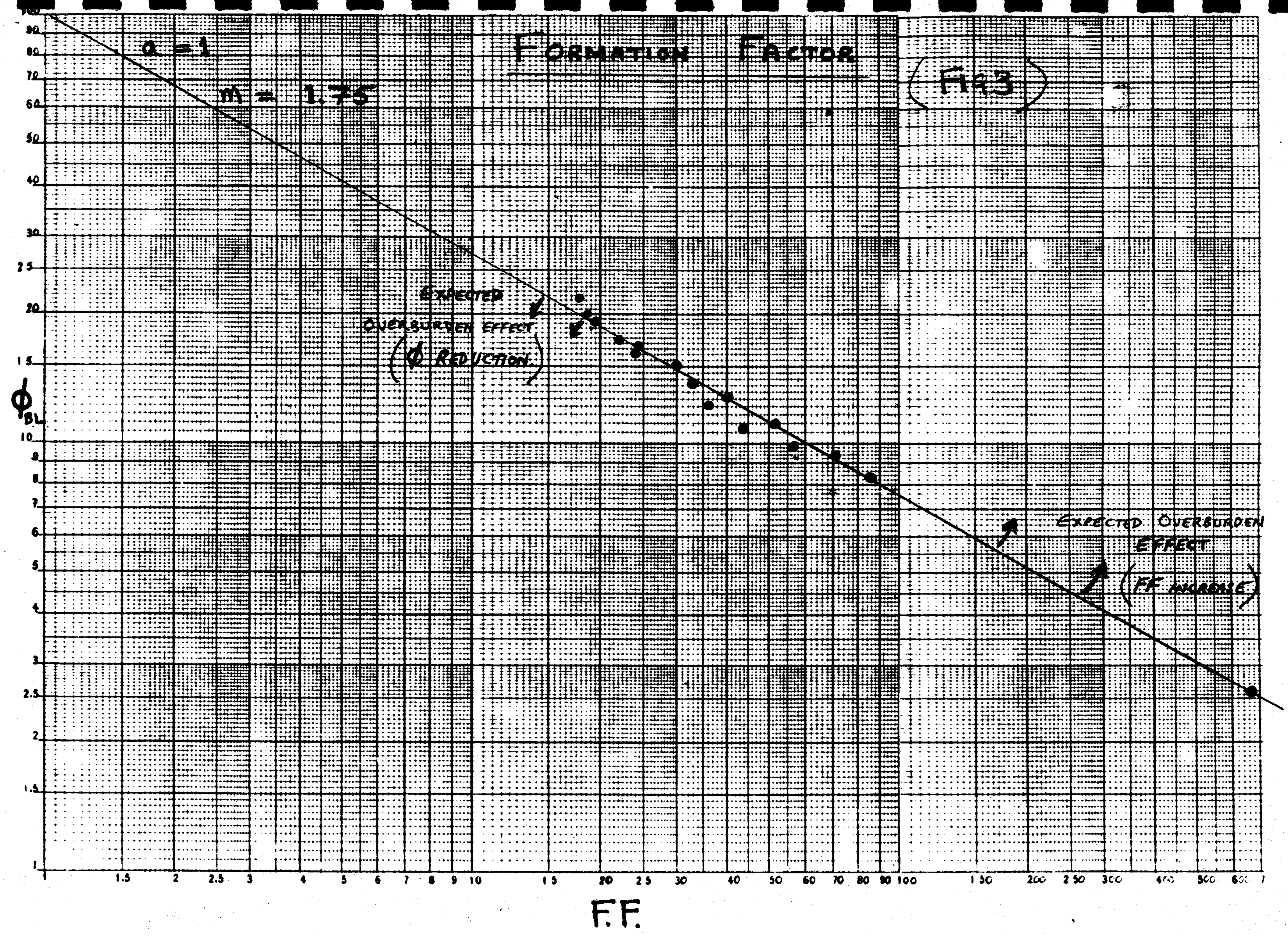
FORMATION FACTOR VERSUS POROSITY

[Fig 1] [23 plugs]





ΦB.L. vs ρB LAB [53 plugs] (fig 2)
DOLOMITIC SANDSTONE
CLEAN SANDSTONE
SHALEY SANDSTONE
ΦB.L.(%)
30
20
10
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
ρB, g/cc
DOL
SS
52× DOL
30× DOL
27× DOL
378 DOL
94× DOL
9× DOL
395× DOL
SILTST


FORMATION FACTOR
(FIG 3)
a = 1
m = 1.75
EXPECTED OVERBURDEN EFFECT (Φ REDUCTION)
EXPECTED OVERBURDEN EFFECT (FF INCREASE)
ϕ_{BL}
F.F.

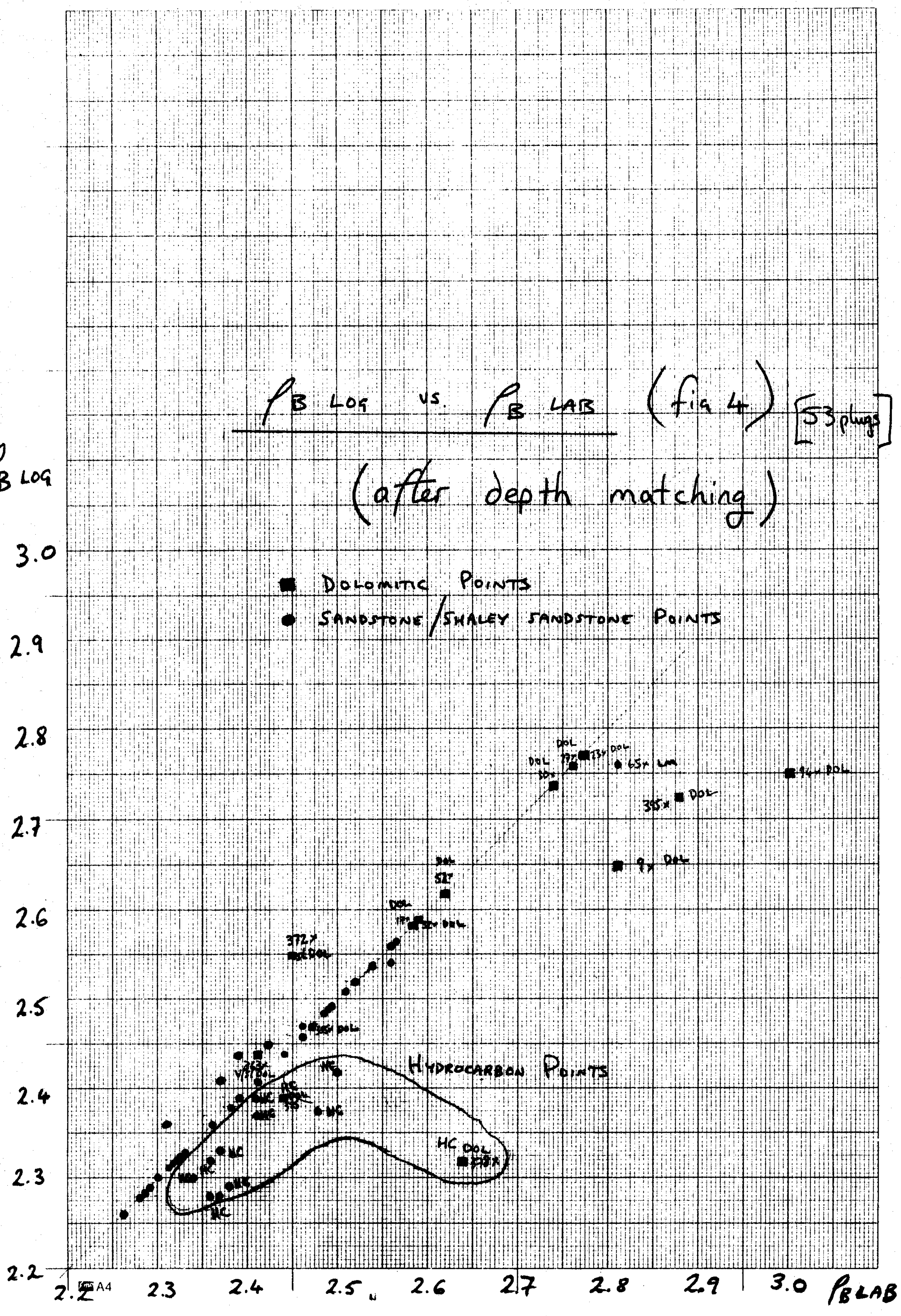

ρB LOG vs. ρB LAB (fig 4)
[53 plugs]
(after depth matching)
ρB LOG
ρB LAB
Dolomitic Points
Sandstone/Shaley Sandstone Points
Hydrocarbon Points
HC DOL
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0

FIG 5

T = 215°F R_{mf} = 0.228 @ 55°F , R_m = 0.352 @ 53°F.

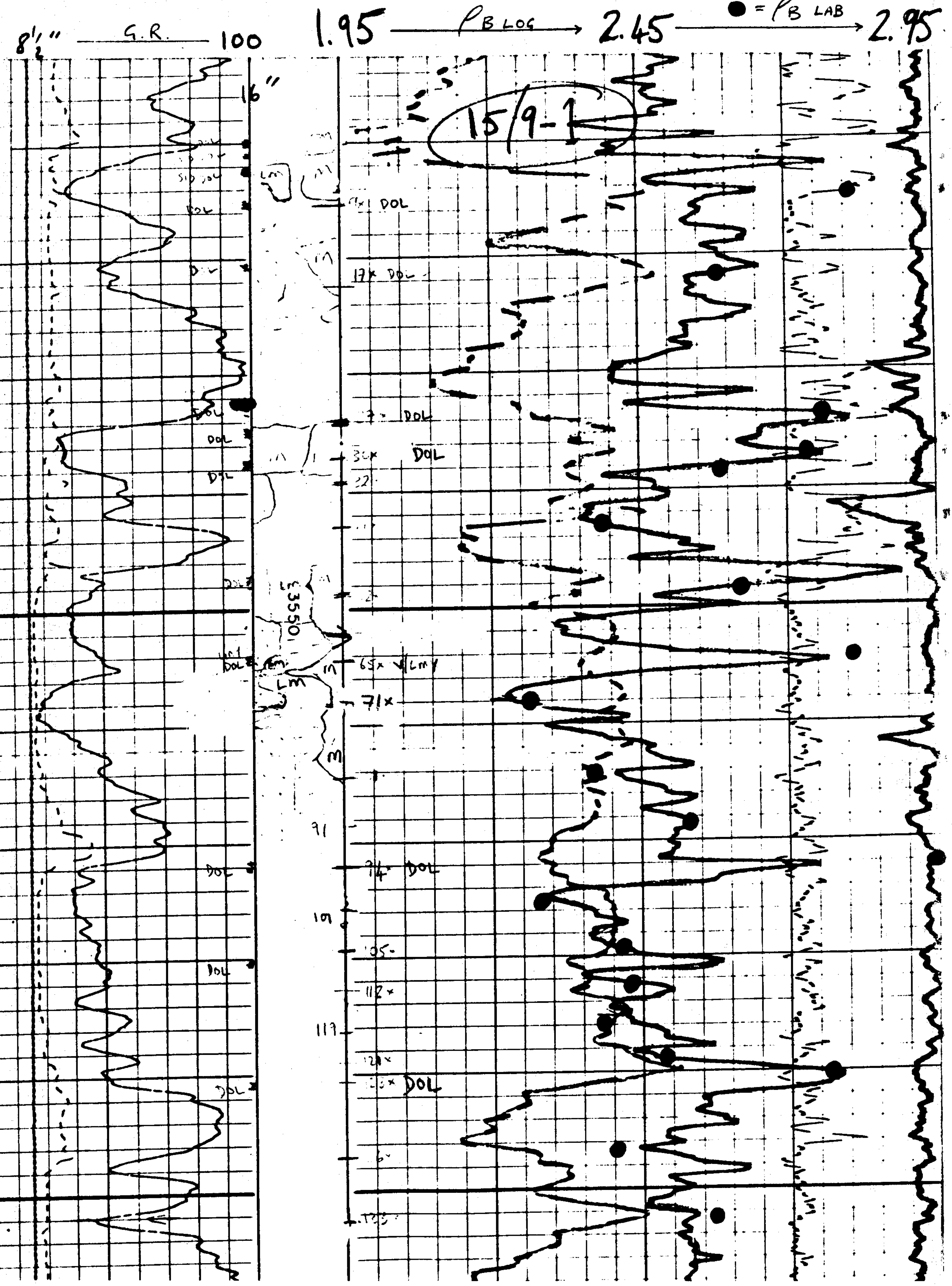
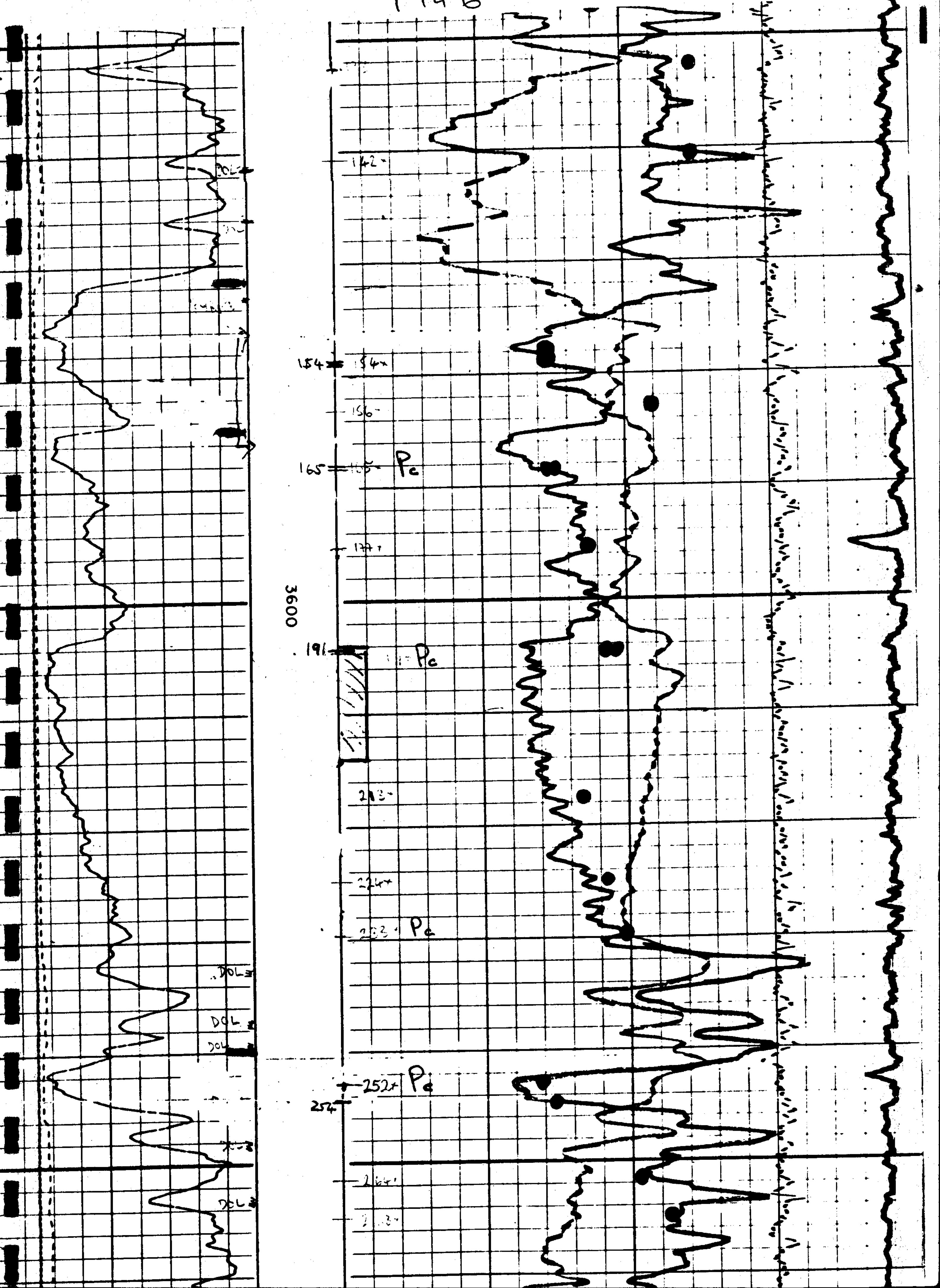
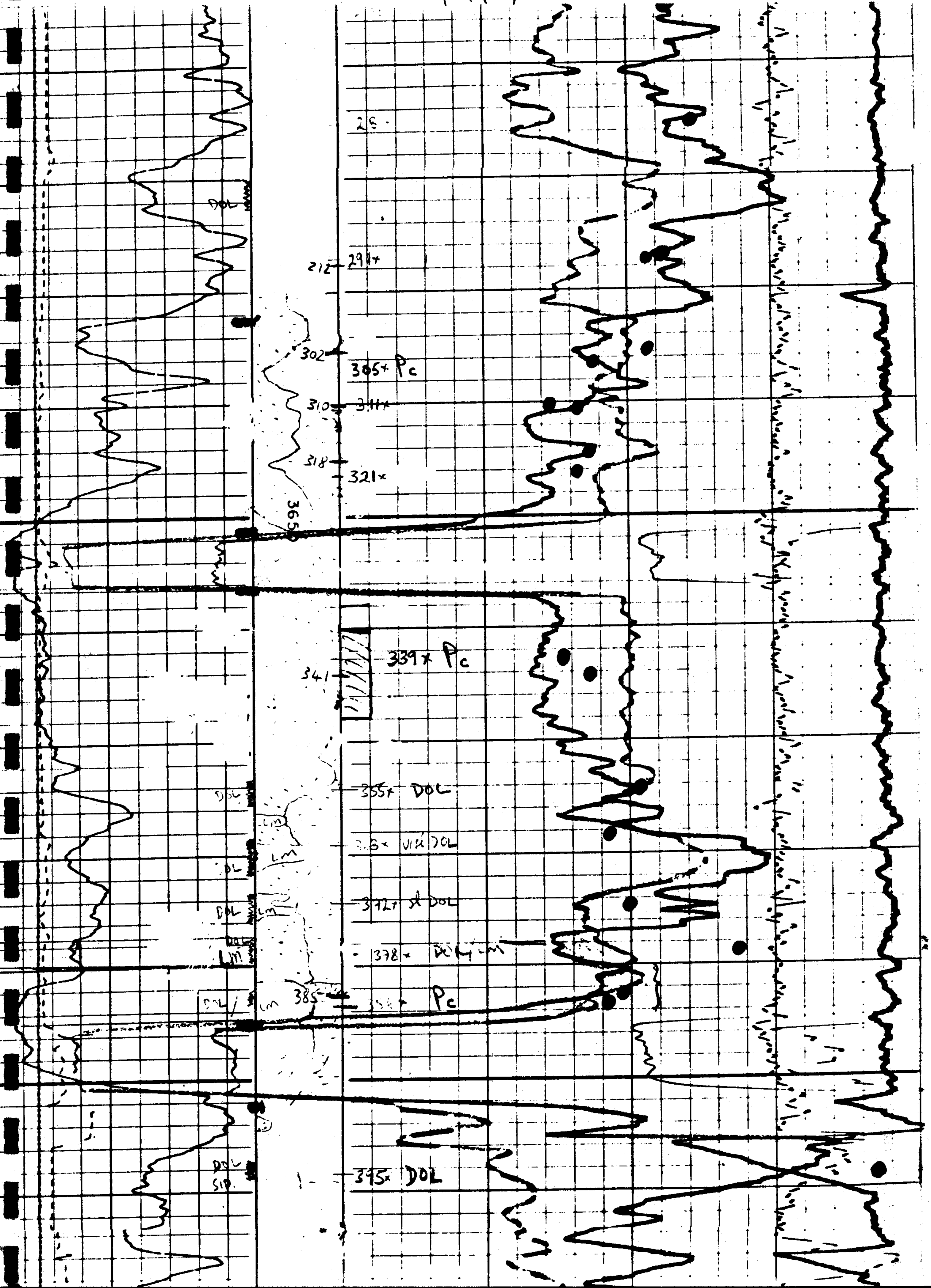


Fig 6



DOL
142
154
156
165
Pc
177
3600
191
Pc
213
224
233
Pd
DOL
DOL
DOL
252
Pd
254
DOL

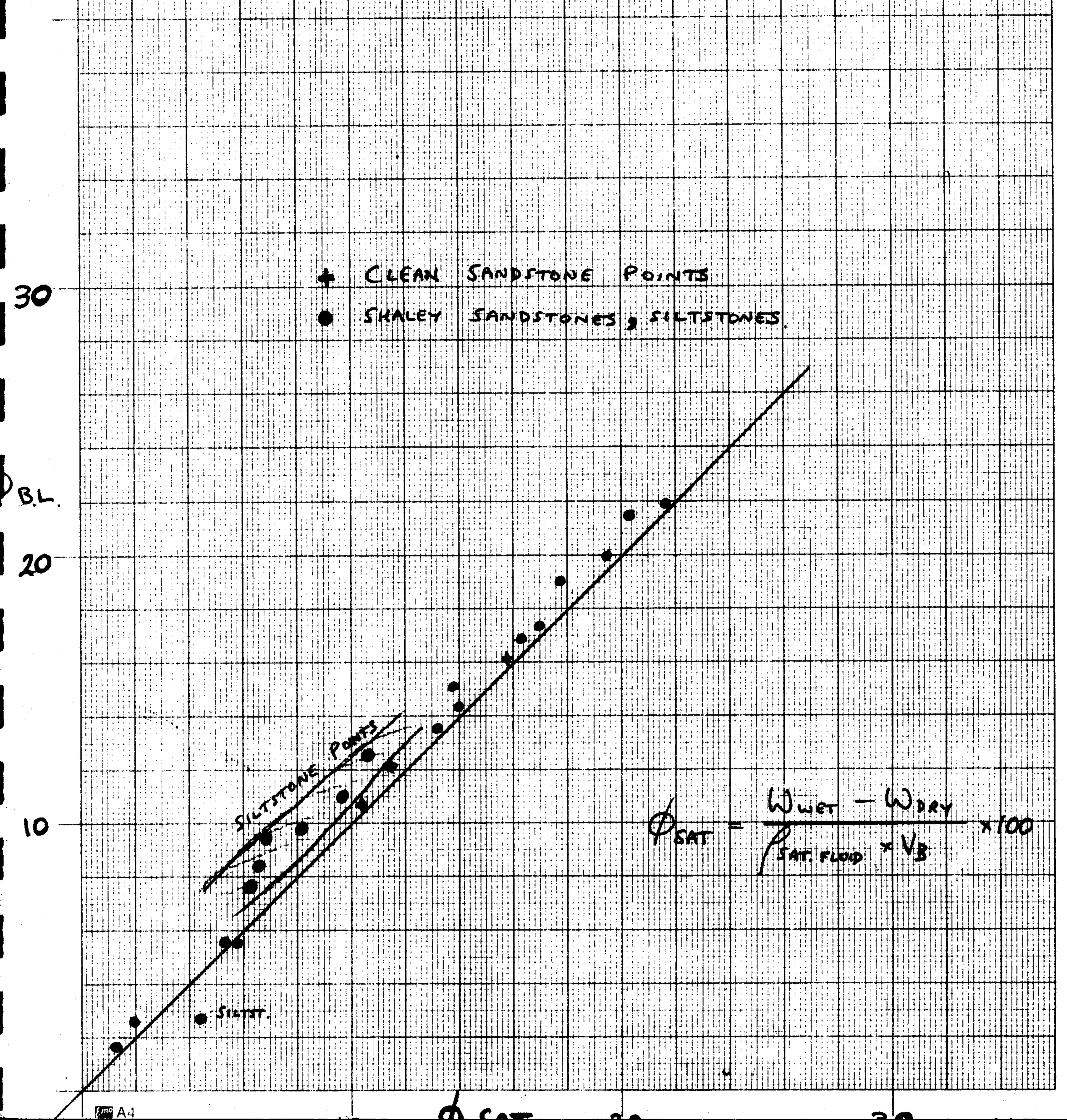
FIG 4

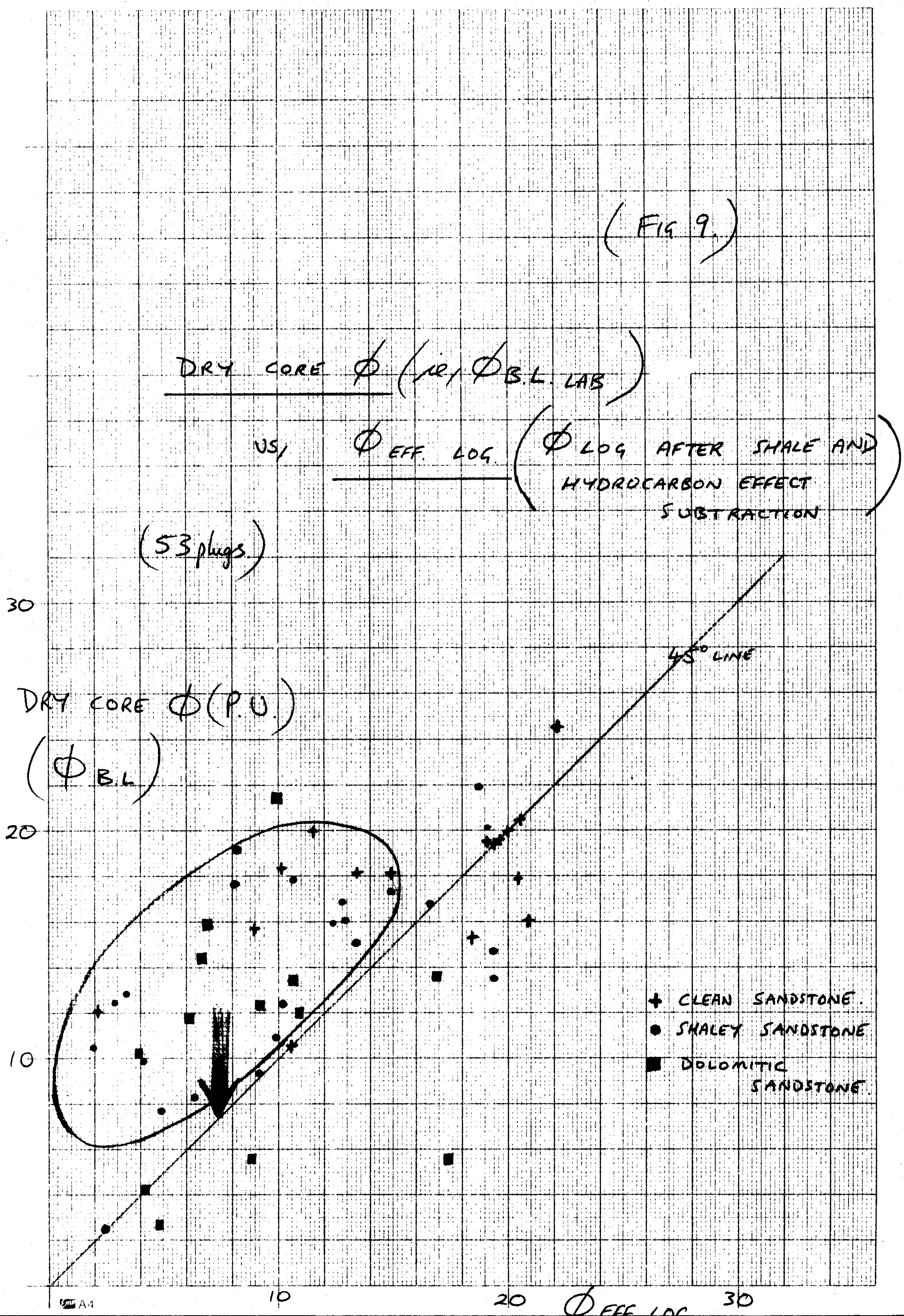


DOL
212
291×
302
305× Pc
310
311×
318
321×
365
339× Pc
341
355× DOL
LM
DOL
372× DOL
378×
LM
385
Pc
DOL
395× DOL

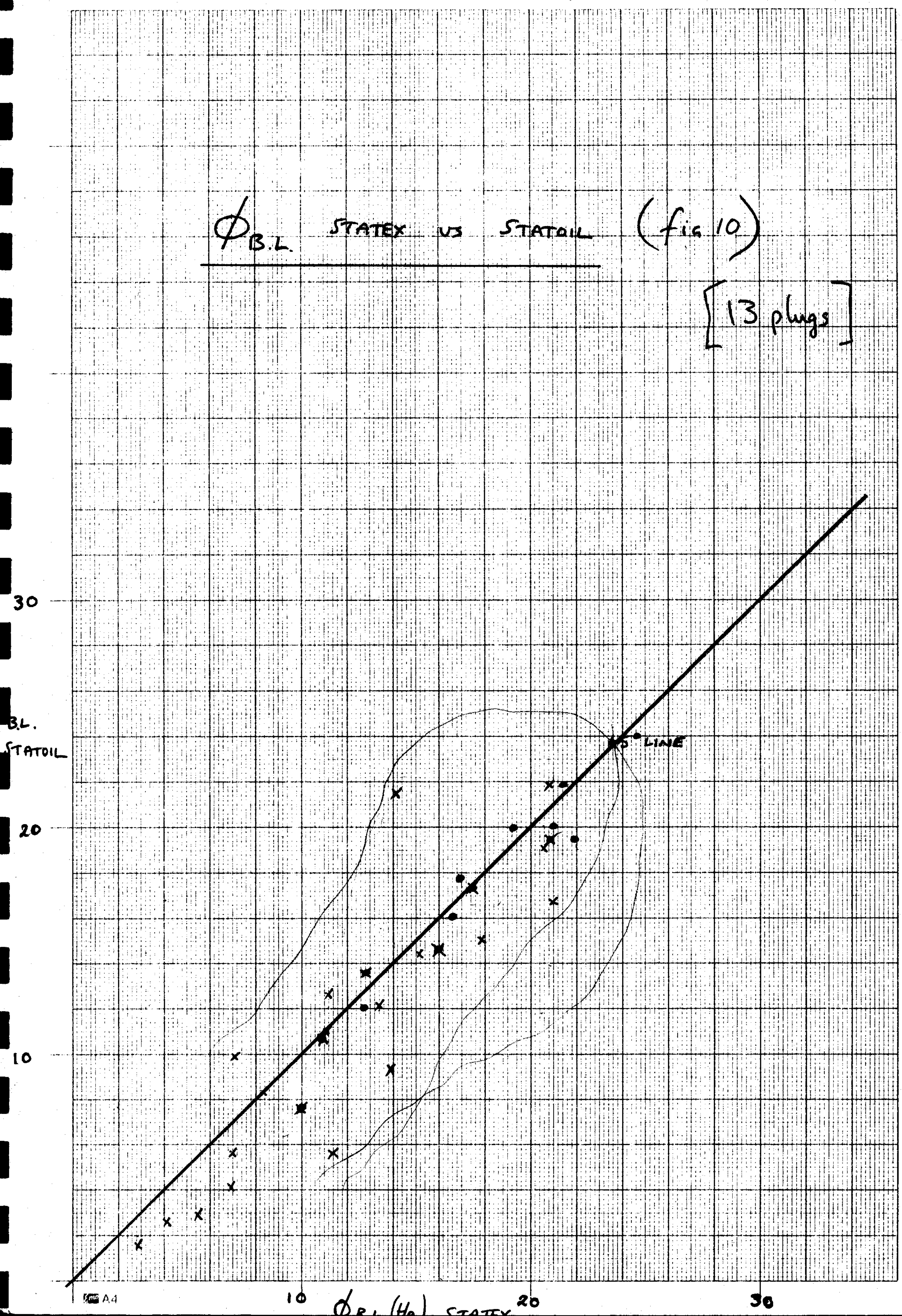
SENSITIVITY CHECK ON φ (FIG 8)

[24 plugs]





(Fig 9.)
DRY CORE Φ (ie, Φ B.L. LAB)
VS/ Φ EFF. LOG (Φ LOG AFTER SHALE AND HYDROCARBON EFFECT SUBTRACTION)
(53 plugs.)
30
45° LINE
DRY CORE Φ (P.U.)
(Φ B.L)
20
10
CLEAN SANDSTONE.
SHALEY SANDSTONE
DOLOMITIC SANDSTONE.
10
20
30
Φ EFF LOG



ØB.L. STATEX vs STATOIL (fig 10)
[13 plugs]
30
20
10
ØB.L.
STATOIL
LINE
10
20
30

ρ_{MA} LAB STATOIL vs. ρ_{MA} LAB. STATEX (FIG 11)

[13 plugs]