ABNORMAL PRESSURE PREDICTION

BY USE OF WELL LOGS.

WELL: 15/9-1

EVALUATION DONE BY PETROPHYSICAL SECTION

MAY 1977

ENGINEER: JOHN KÅRE SMISTAD

C O N T E N T

ABSTRACT

Well 15/9-1 was spudded in the last week of February 1977 and reached TD at 3734 m in the last days of April. After testing of the well, it was plugged and abandoned late in May.

Before the well has reached TD, some problems were encountered. After nine core barrels have been taken in the Dogger Sand, the bottom hole assembly was stuck during a clean-up operation and it was necessary to side track the well from 3450m and down to TD.

The plots shown behind in this report will try to explain the presence of abnormal pressure in the well and how the pressure is detected and calculated.

1. HYDROSTATIC GRADIENT

Attached behind in this report is a formation water salinity- and temperature profile for the well 15/9-1. In the top layers the formation water salinity is practically equal to that of the sea water (i.e 30 000 ppm NaCl). In the Eocenc, Paleocene, Cretaceous and Jurassic the salinity is increascing to 80 000 ppm NaCl. The Jurrassic formation has a salinity in excess of 90 000ppm NaCl with a formation temperature of 210 - 220^{o} F.

The specific gravity of the formation water should be in the range of 1.05 (0.440 - 0.445 psi/ft), when correcting for pressure and temperature.

In the calculations of the pressure profile a normal hydrostatic gradient of 0.445 psi/ft or 8.5 ppg. has been used.

2. OVERBURDEN GRADIENT

The overburden gradient as shown behind has been determined by integrating the FDC-log over depth intervals of 10 m. (Weighted average bulk density over 10 m.)

The overburden gradient is very low in the top sediments, but is increasing when passing through the thick Cretaceous limestone. In the Dogger sand (Jurassic) the overburden gradient is about 0.91 - 0.92 psi/ft. As the pore pressure in the Dogger Sand is 0.530 psi/ft (gas/oil zone) the net overburden pressure gradient will be 0.38 - 0.39 psi/ft. (Rather high net overburden gradient).

3. PORE PRESSURE

The pore pressure is calculated from the sonic plot and the shale density plot in combination. As shown by the pore pressure plot some underbalanced drilling have occured in the shale sections in Oligocene, Eocene, Paleocene and in the Kimmeridgian shale in Jurassic.

SONIC PLOT:

The plot shows that the pressure transition zone starts at 1200m. The high sonic readings in Eocene may partly be caused by high bentonite content in the shale and this cause swelling of the shale. But other things confirm the presence of abnormal pressure in this interval. Prior to logging and setting of the 9 5/8" casing, large amounts of splintery shales (slaughing shales) were washed out over the shaker during the circulation period. Difficulties to get down with the logging tools also confirm the pressure in this section of the well.

A look at the Caliper log (see behind) shows that the hole size is considerably smaller then the bit size over intervals in the Lower Eocene.

SHALE DENSITY PLOT:-

The shale density shows that the top of the pressure zone starts at 1100m. This plot is the best for this area, since it gives a good trend with no scattering of the shale points.

The pore pressure is calculated using this plot together with equivalent depth method:

$$PP = OB - (OB - Pn) \frac{De}{Di}$$

where:

PP = Pore pressure gradient (arbitrary units)
OB = Overburden gradient (arbitrary units)
Pn = Normal hydrostatic gradient (arbitrary units)
De = Equivalent depth (M)
Di = Depth of interest (M)

The pore pressure calculated in 15/9-1 was calculated after the above method using the shale density plot together with the sonic plot using the compaction equation:

$$PP = OB - (OB - Pn) \left(\frac{\Delta tn}{\Delta to}\right) Exp.$$

Δtn = Normal shale transit time (μsec/ft)
Δto = Observed shale transit time (μsec/ft)
Exp = Compaction exponent, i.e 3.0

The pore pressure calculated from the sonic plot tends to give some higher values than from the shale density plot, specially in the Eocene area. The reason is mainly that the sonic log is affected by the bentonite content in the formation.

CONDUCTIVITY PLOT The conductivity plot marks the top of the transition zone at 1100 m. The bentonite streaks in the Eocene is apparent from this plot. The scattering of the plotted points does not make this plot good for pressure estimation.

SHALE FACTOR PLOT The shale factor is defined as Fsh. = Rsh/Rw.

where: Fsh = Shale factor (dimensionless)
Rsh = Shale resistivity above and below the water sand (ohm.m)
Rw = Resistivity of formation water (ohm.m)

The shale factor plot picks up the pressure top at 1440 m, but the few points at this depth and the scattering of the data further below makes this plot not good for pressure estimates. On the other hand, it should be pointed out that all the plots showed behind have the same trend, and these trends give the conclusion that the well is abnormal pressured.

The reason why the sand bodies could be drilled with relative low mud weights compared with the calculated pore pressures in the adjacent shales is the high porosity and infinite high permeability in the sand bodies.

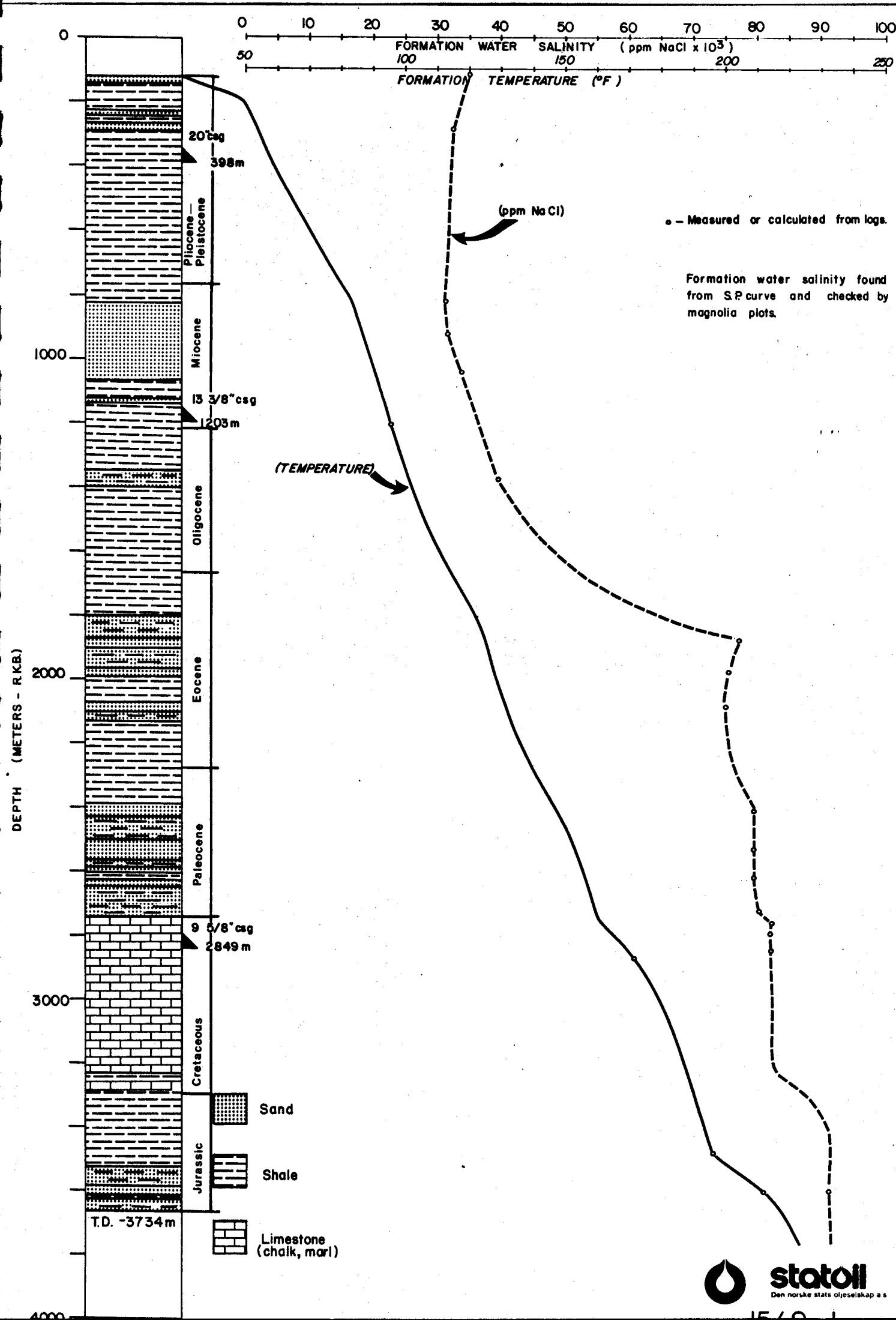
These sands may therefore bleed off the pressure from the shales laying above or below.

People with experience in pressure prediction state the fact that in sediments with a high sand/shale ratio, the sands can be able to bleed off the pressures in the shales.

The sand shale ratio in well 15/9-1 is approximately 0.35 down to a depth of 2800 m, which in fact is very high.

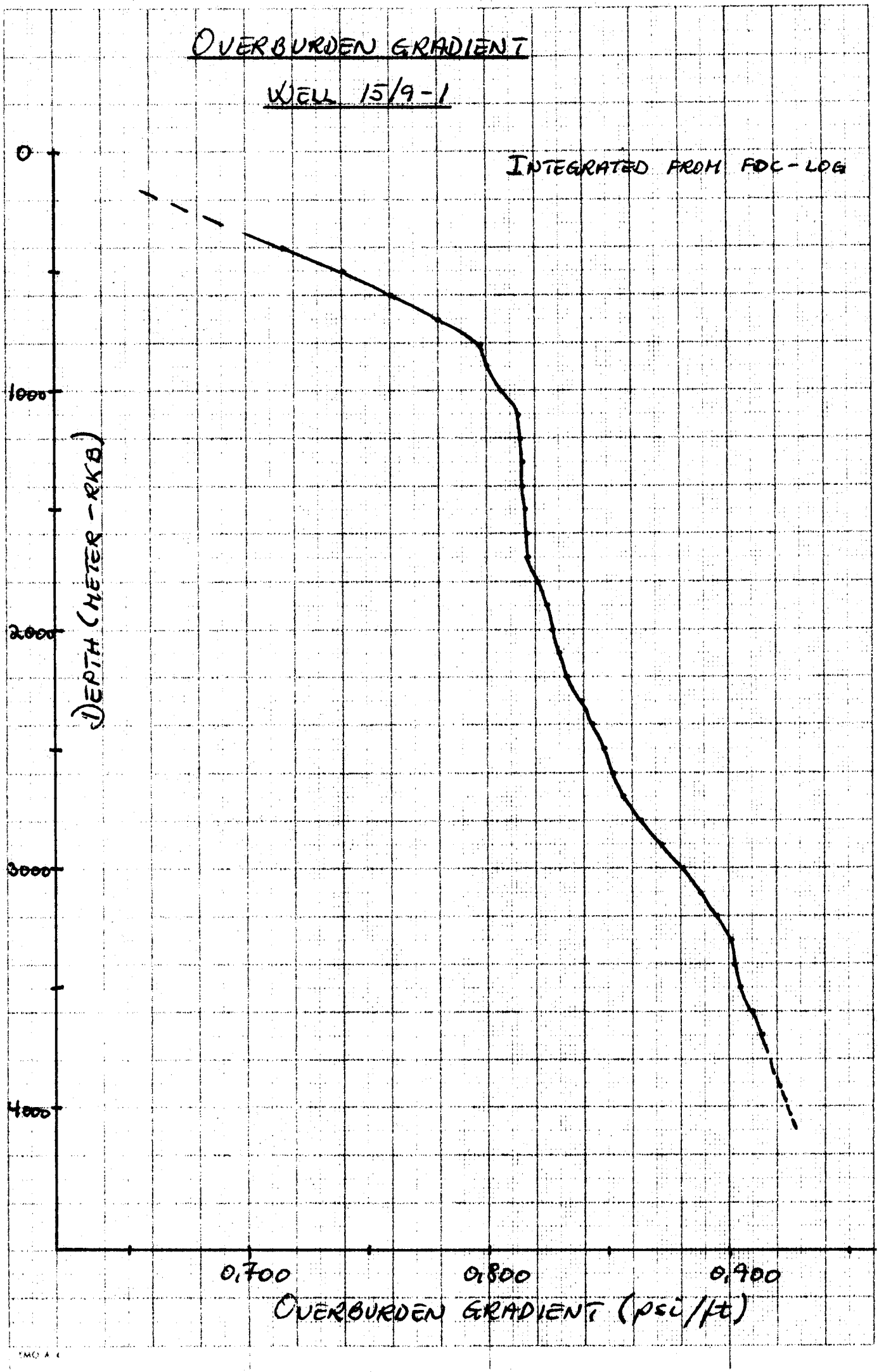
The pore pressure gradient chart behind summarize the events and the calculated data mentioned earlier.

On the estimated fracture gradient chart for the well some leak off test data have been added.


0
10
20
30
40
50
60
70
80
90
100
FORMATION WATER SALINITY (ppm NaCl x 10^3)
50
100
150
200
250
FORMATION TEMPERATURE (°F)
20"csg
398m
Pliocene—Pleistocene
Miocene
1000
13 3/8"csg
1203m
Oligocene
(TEMPERATURE)
2000
Eocene
Paleocene
9 5/8"csg
2849m
3000
Cretaceous
Jurassic
T.D. -3734m
4000
DEPTH (METERS - R.K.B.)
(ppm NaCl)
o — Measured or calculated from logs.
Formation water salinity found from S.P. curve and checked by magnolia plots.
Sand
Shale
Limestone (chalk, marl)
statoil
Den norske stats oljeselskap a.s

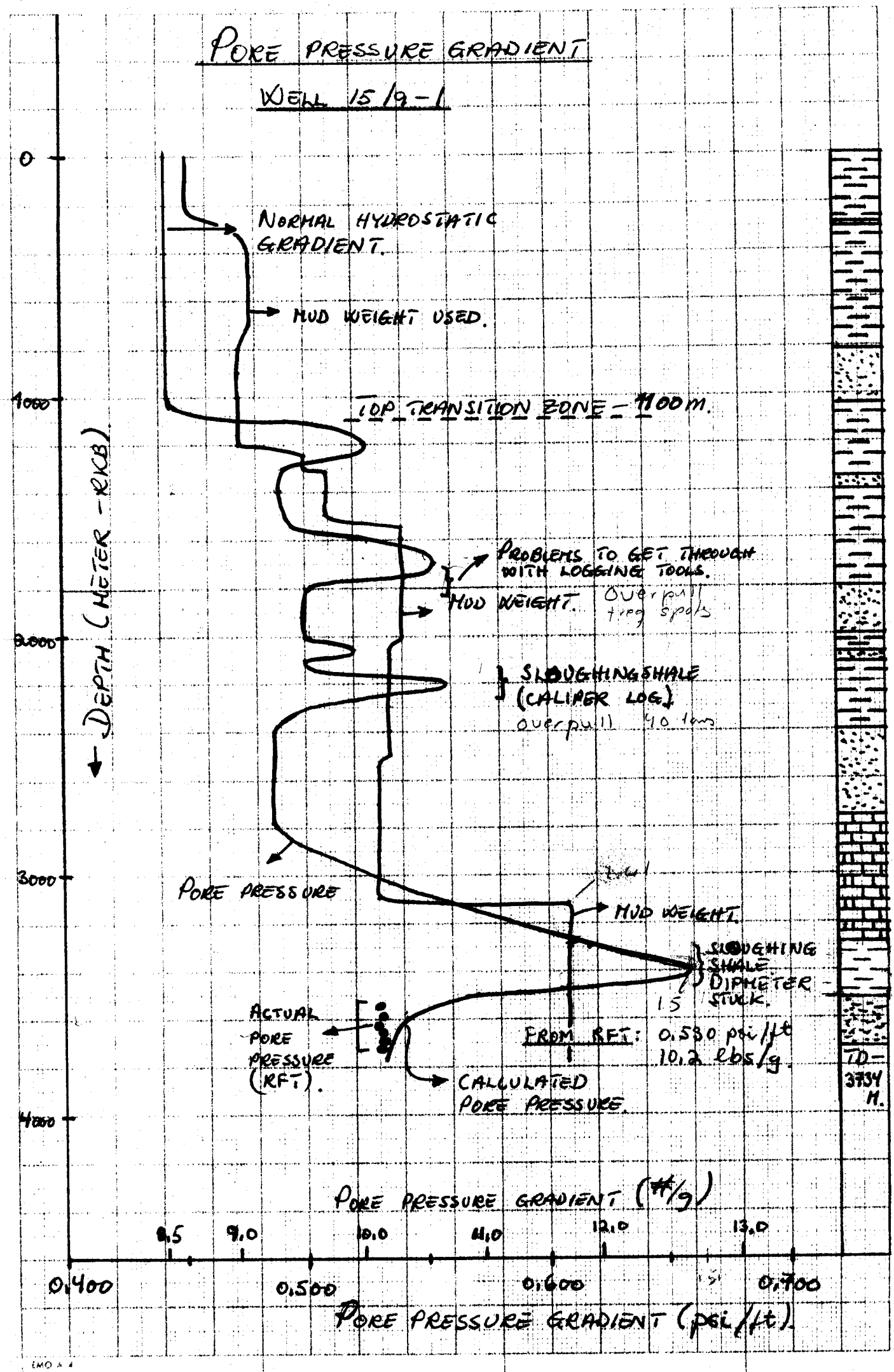
OVERBURDEN GRADIENT

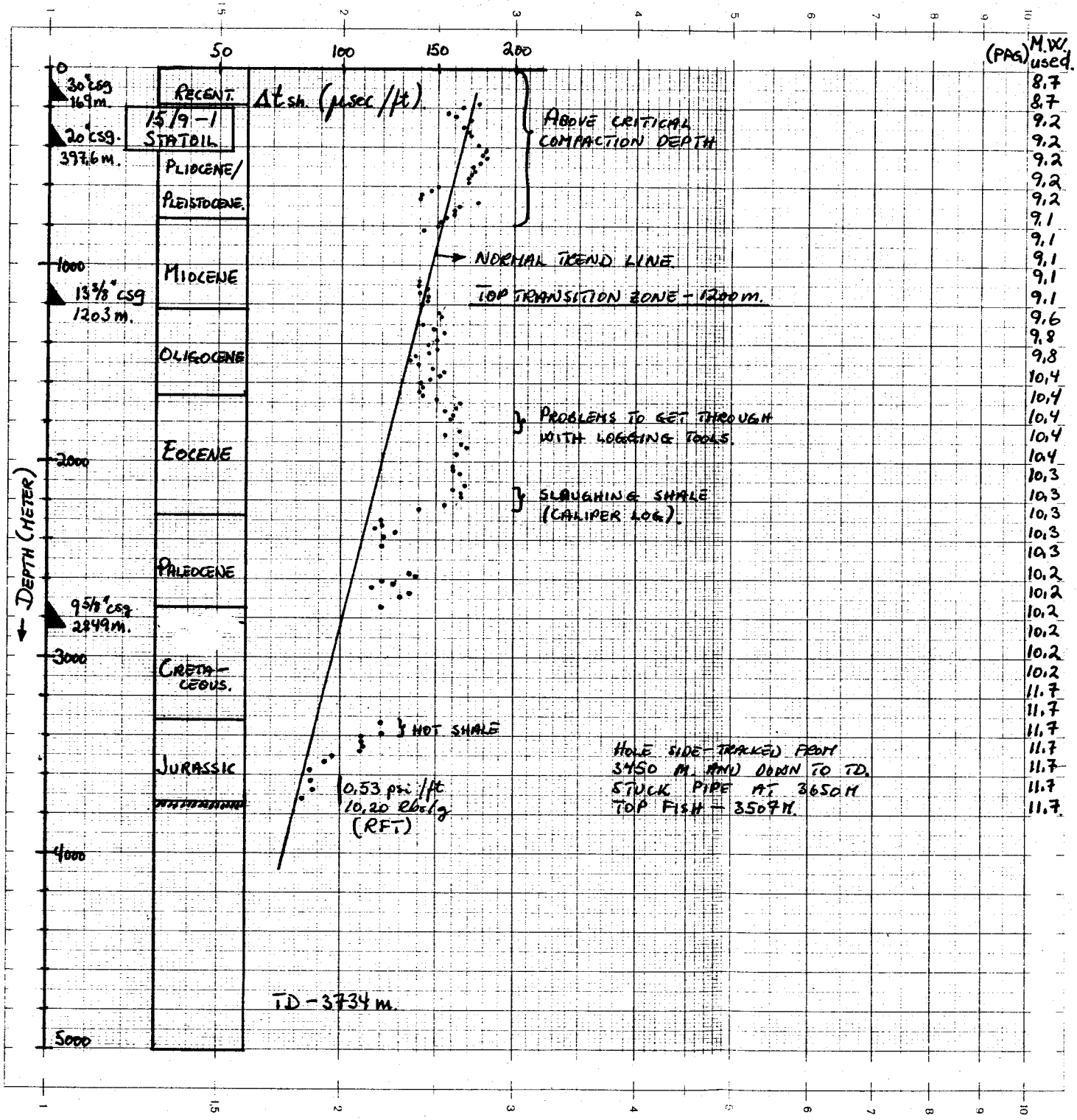
WELL 15/9-1



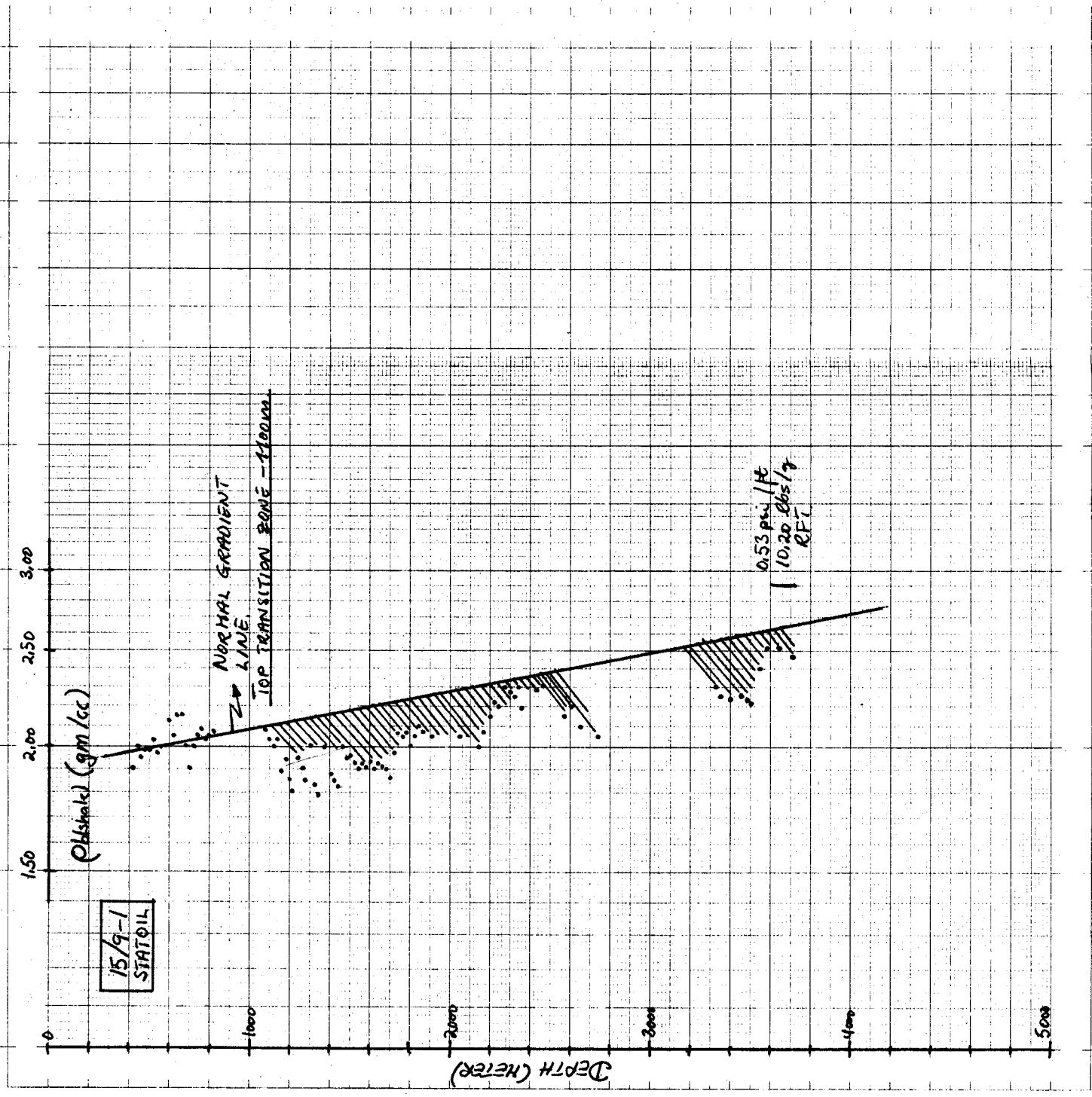
PORE PRESSURE GRADIENT

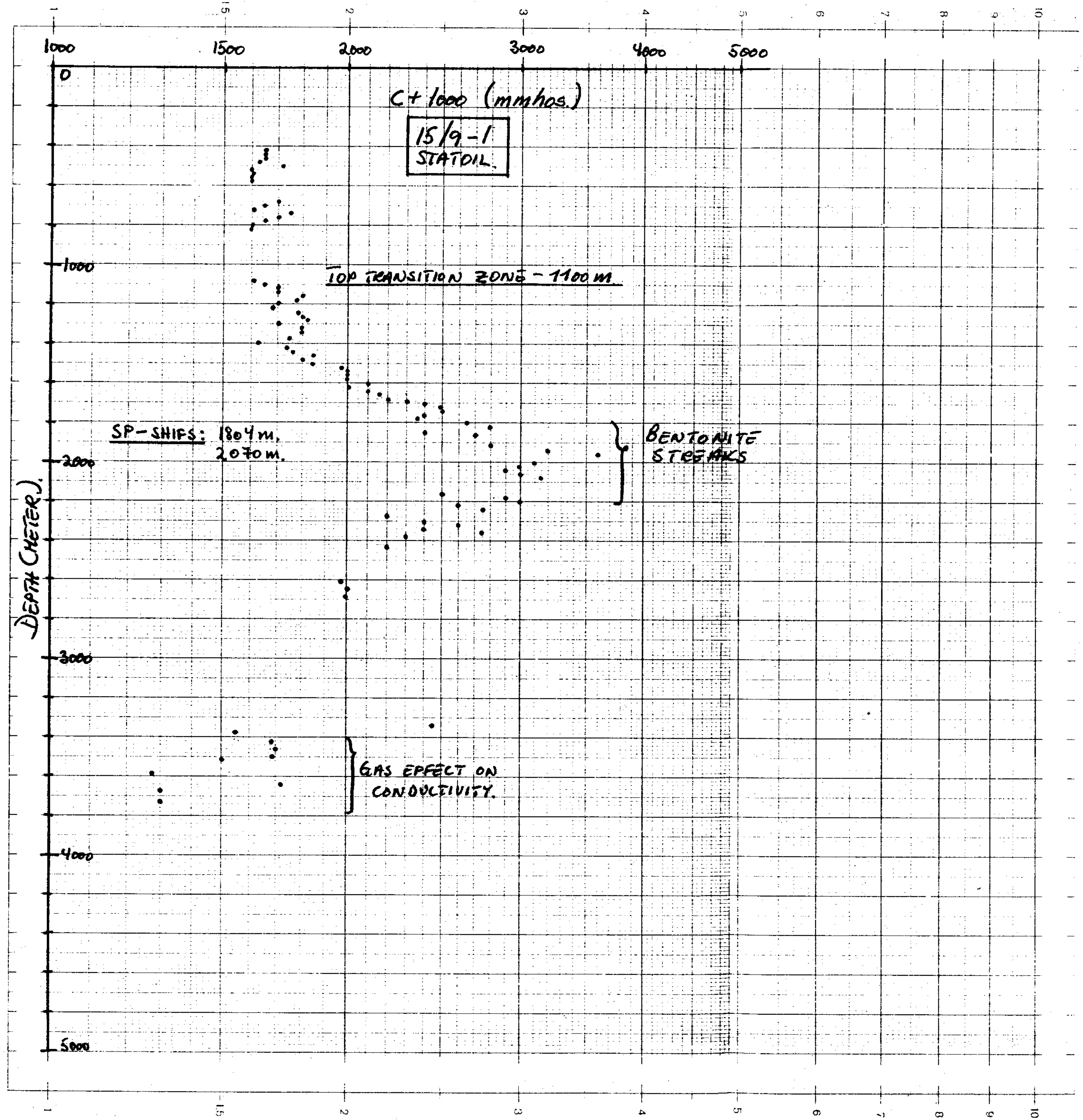
WELL 15/9-1

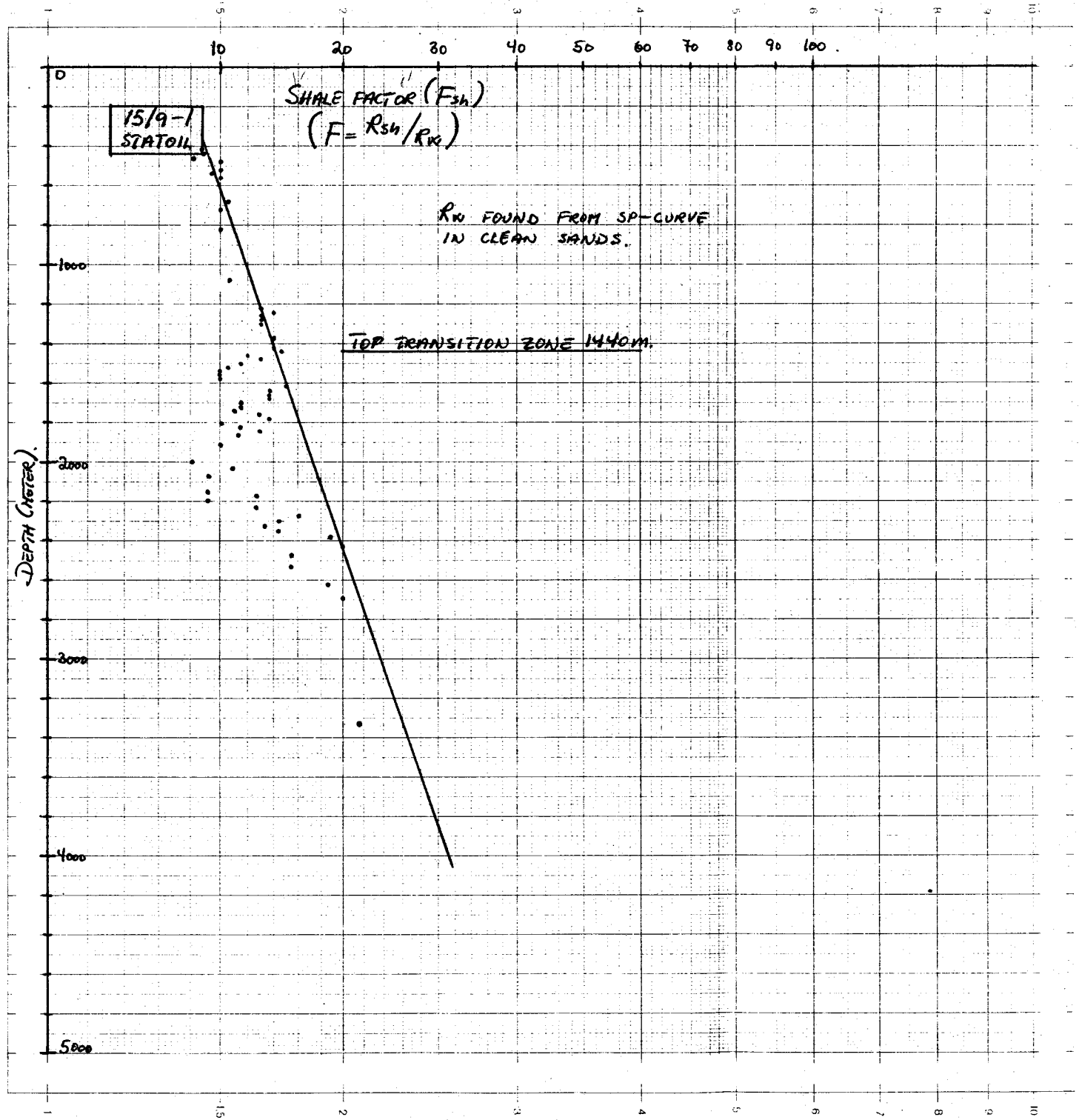




Eine Achse logar. geteilt, von 1 bis 10, Einheit 250 mm, die andere gleichm. in mm

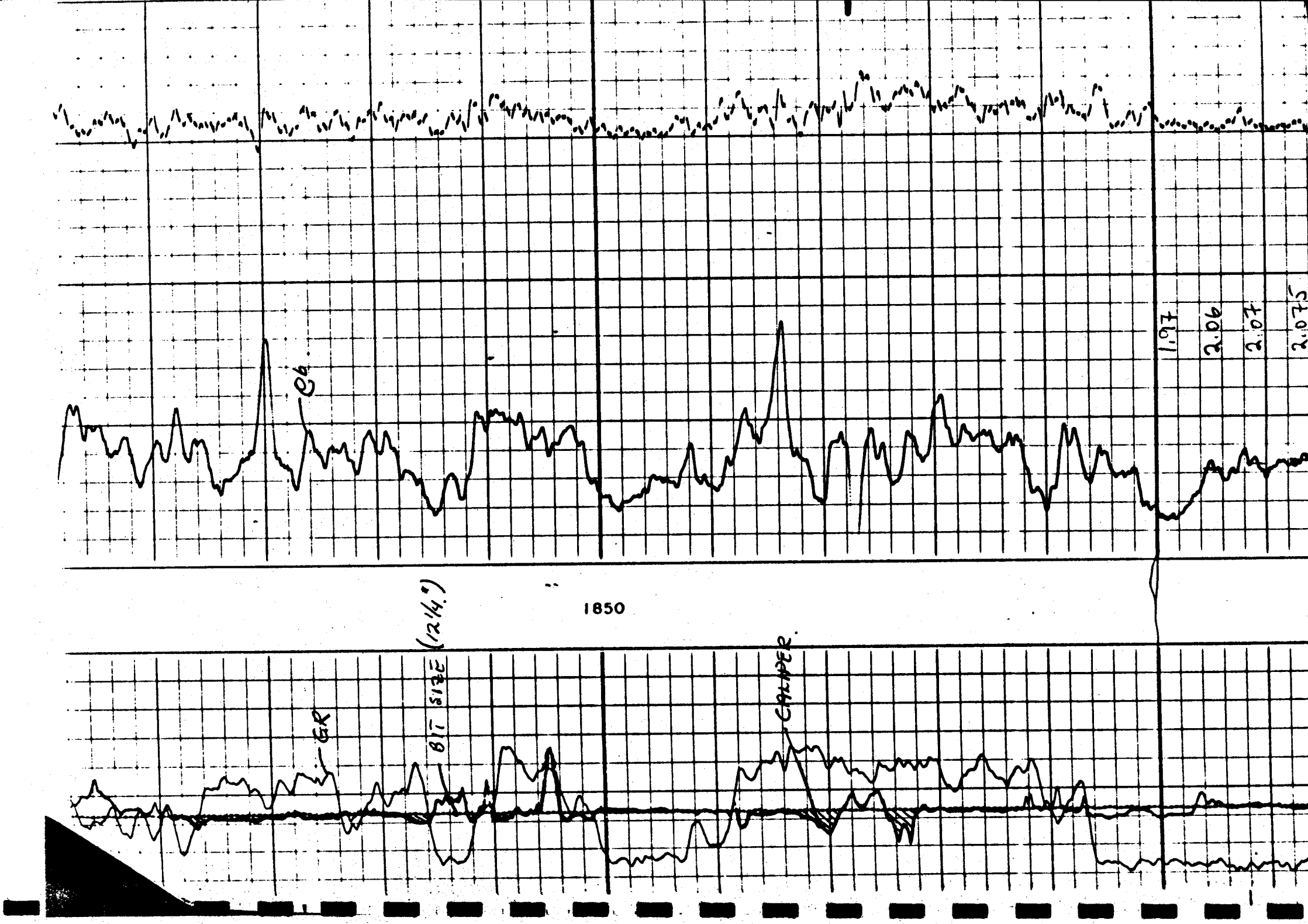






Eine Achse logar. geteilt, von 1 bis 10. Einheit 250 mm, die andere gleichm. in mm


1800


1850
GR
BIT SIZE (12 1/4")
CALIPER

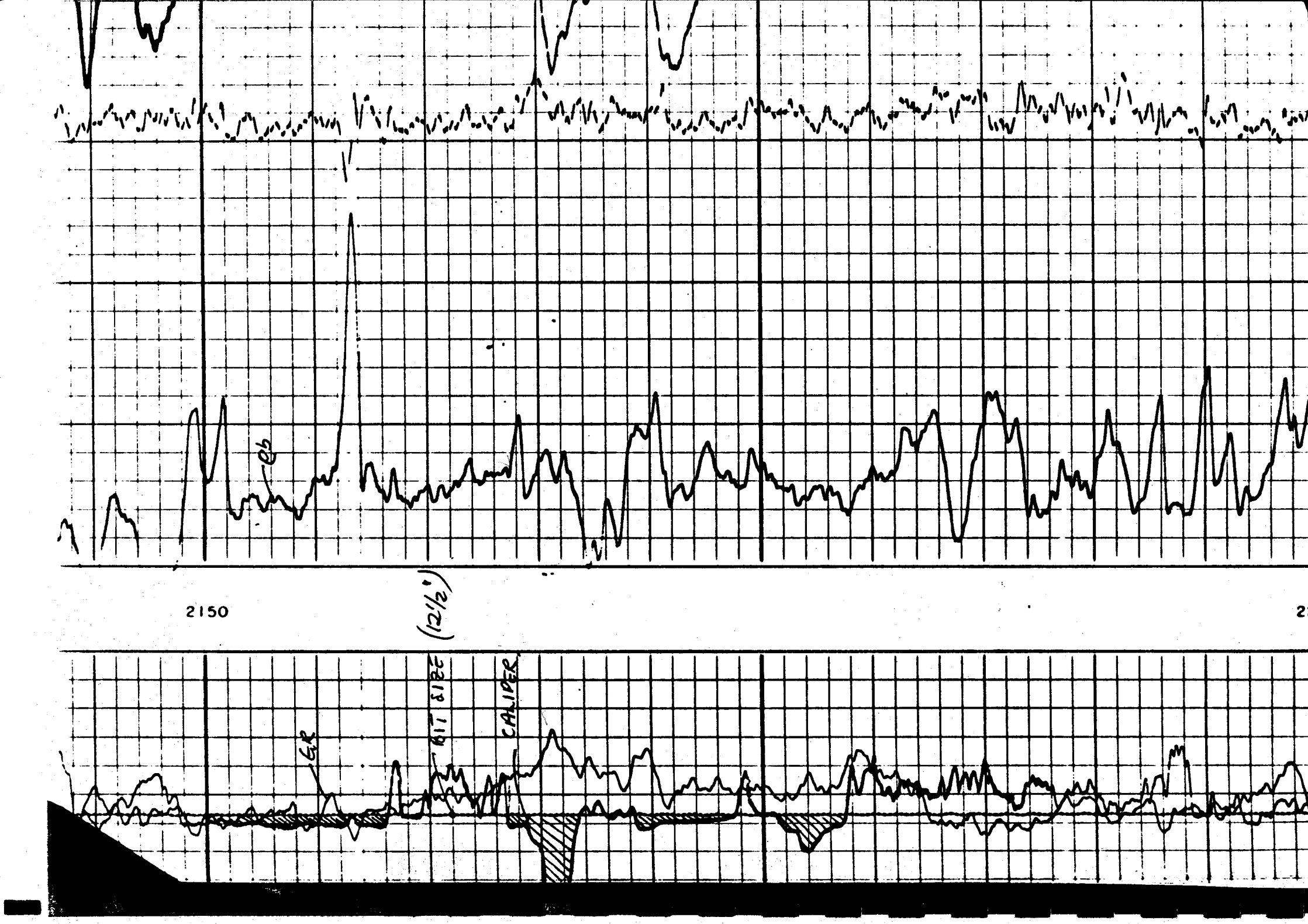

2150
(12½')
GR
BIT SIZE
CALIPER

FIGURE 4.

FRACTURE PRESSURE GRADIENT (WELL 15/9-1)