ESTIMATION OF CORRECTION FACTOR FOR BOTTOM HOLE TEMPERATURE IN PARTS OF THE NIGER DELTA BASIN

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ABSTRACT

The estimation of a correction factor for bottom hole temperature in parts of the Niger Delta Basin was done using temperature log data from 10 wells. The correction factor (¢) was estimated from data from 5 wells that has both the bottom hole temperature and continuous temperature and modeled as $¢ = C_T S_T / B_{HT} D$, *while the other 5 wells were used in extrapolating the bottom hole temperature using the estimated correction factor and the given continuous temperature log data. This estimated correction factor was found to depend on the depth and the stabilization days. It exhibits some physical properties like that of thermal conductivity, such as; decreases with an increasing depth. The correction factor is useful in extrapolating or interpolating true formation temperatures immediately after drilling.*

Key words: Extrapolating – Correction factor –Temperature – Niger Delta Basin – Stabilization days

1. INTRODUCTION

According to Michele et al., (2002), the Niger Delta is a coastal basin situated on the continental margin of the gulf of guinea in equatorial West Africa. It occupies an area located between longitude 4° – 9°E and latitude 4° – 6°N (Uko et al., 2002). From the Eocene to the present, the delta has prograded southwest ward, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km^2, a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in the basin depocenter (Kaplan et al., 1994).

In understanding the mechanism of the basin formation and geological processes, the knowledge of the subsurface temperature distribution cannot be overemphasized. Also, the knowledge of the subsurface temperature distribution is central to understanding the origin and evolution of sedimentary basin, oil and gas generation, deposition of ore bodies and the occurrence of geological processes such as earthquakes and volcanism (Nielsen, 1986). Temperature data from wells logged to total depth in the Niger delta could be used to derive estimates of the region temperatures and geothermal gradients in the area (Nwachukwu, 1976).

In borehole temperature measurement, every individual logging run should be accompanied by a reading of at least the maximum temperature in the borehole (Malcolm, 2002). The most abundant temperature information collected during normal logging operations of oil wells are the bottom hole temperature (B_{HT}). These logs are taken only few hours after drilling have stopped; hence the measured data are too low, besides they provide only two or three data points in a borehole (Akpabio et, al., 2003). This temperature measured is not the true temperature, it is the temperature of the mud in the borehole. Borehole mud is cooler than the formation being drilled, thus, the invasion of mud filtrate into a formation will cool it down (Malcolm, 2002). Ideally, temperature measurements are done after a sufficiently long shut time, when the influence of mud circulation has faded away and the equilibrium formation temperature has been reached. Due to economic reasons, this is often impossible in hydrocarbon boreholes,

hence, different methods for correction of perturbed temperature data exist (Andrei, 2003). In order to extrapolate to the actual temperature of formations, a multiple bottom hole temperature measurements at various times and depth is required, which yield to the temperature correction factor for the drilling mud circulation effect (Uko et al., 2002).

2. DATA

The data used in this study were obtained from 10 wells in the Niger delta basin supplied by the Shell Petroleum Development Company of Nigeria. These data specifies the depths, the continuous temperature (temperature after stabilization days), the bottom hole temperature (temperature before stabilization days) and the stabilization days (a period from well completion to logging in which the well has attained equilibrium or near equilibrium). Of the 10 wells, 5 wells (A1, A2, A3, B and C) had data on the depth, continuous temperature, bottom hole temperature and stabilization days, hence they were used in estimating the correction factor, while the remaining 5 wells (X1, X2, X3, Y, and Z) had data on depth, continuous temperature and stabilization days, so they were used in testing the estimated correction factor in obtaining the bottom hole temperature.

3. ESTIMATION OF THE CORRECTION FACTOR

The temperature of the earth usually increases with depth, and as a result, it is concluded that thermal energy flows from the earth's interior to the surface. A normal sedimentary basin, in which the Niger Delta Basin is not an exception, shows a more or less regular increase in temperature with depth. The increase is not linear as frequently depicted; it varies according to lithology depending principally on the lithology's thermal conductivity. However, despite the irregularities, there is an overall persistent increase in temperature with depth.

From the data collected, it shows that the continuous temperature (C_T) varies directly proportional to the depth (D) and the bottom hole temperature (B_{HT}) and inversely proportional to the stabilization days (S_T). Mathematically stated as;

$$C_T \propto D \times B_{HT} / S_T \qquad (1)$$

Introducing a constant of proportionality ¢, to have

$$C_T = ¢\, D \times B_{HT} / S_T \qquad (2)$$

$$¢ = C_T \times S_T / D \times B_{HT} \qquad (3)$$

where ¢ is the correction factor whose value depends on the stabilization days and the depth in question. Its unit is in hrs/ft.

4. ANALYSIS AND RESULTS

Tables 1.1 to 1.5 show data from 5 different wells (A1, A2, A3, B and C), which were used in estimating the correction factor (¢). The data from the wells specified the depths, continuous temperature, bottom hole temperature and stabilization days. The last column in each of the table is the value of the estimated correction factor which increases as the number of stabilization days increase and also decreases with an increase in depth. This decrease in the correction factor with an increase in depth is not linear but it is persistent.

Table 1.1: Well A1 with the values of their estimated correction factor

Depth (ft)	C_T (°C)	C_T (°F)	B_{HT}(°C)	B_{HT}(°F)	S_T(hours)	¢ (hrs/ft)
4574	83	181.4	67	152.6	720	0.187
5440	85	185.0	77	170.6	„	0.144
5857	87	188.6	78	172.4	„	0.134
6494	91	195.8	85	185.0	„	0.117
7002	98	208.4	93	199.4	„	0.107
8523	111	231.8	104	219.2	„	0.089
9414	124	255.2	110	230.0	„	0.085
10915	141	285.8	121	249.8	„	0.075

Table 1.2: Well A2with the values of their estimated correction factor

Depth (ft)	C_T (°C)	C_T (°F)	B_{HT}(°C)	B_{HT}(°F)	S_T(hours)	¢ (hrs/ft)
4000	59	138.2	49	120.2	720	0.207
5125	63	145.4	53	127.4	„	0.160
7856	87	188.6	71	159.8	„	0.108
8060	95	203.0	91	195.8	„	0.090

Table 1.3: Well A3 with the values of their estimated correction factor

Depth (ft)	C_T (°C)	C_T (°F)	B_{HT}(°C)	B_{HT}(°F)	S_T(hours)	¢ (hrs/ft)
2500	52	125.6	46	114.8	720	0.315
7800	101	213.8	95	203.0	„	0.097
8500	121	249.8	104	219.2	„	0.096

Table 1.4: Well B with the values of their estimated correction factor

Depth (ft)	C_T (°C)	C_T (°F)	B_{HT}(°C)	B_{HT}(°F)	S_T(hours)	¢ (hrs/ft)
8536	60	140.0	58	136.4	1440	0.173
9790	69	156.2	62	143.6	„	0.160

Table 1.5: Well C with the values of their estimated correction factor

Depth (ft)	C_T (°C)	C_T (°F)	B_{HT}(°C)	B_{HT}(°F)	S_T(hours)	¢ (hrs/ft)
7002	59	138.2	48	118.4	8760	1.460
8000	70	158.0	58	136.4	„	1.268
10000	92	197.6	73	163.4	„	1.059

In determining the bottom hole temperature using the estimated correction factor (¢), a different set of data were used. These data were obtained from 5 other wells (X1, X2, X3, Y and Z) also in the Niger delta basin as shown in tables 2.1 to 2.5. Parameters from these wells are; the depths, the continuous temperature and the stabilization days. From equation (3) above, the bottom hole temperatures were then calculated using the value of the estimated correction factor at a defined depth for a specified number of days of stabilization.

Amongst the 5 wells used in the determination of the B_{HT}, wells X1, X2, and X3 have stabilization days of 30 days (720 hours), hence the values of the estimated correction factor will correspond to that of wells A1, A2 and A3, by considering the depth. Well Y has stabilization days of 60 days (1440 hours); therefore their values of the estimated correction factor will rhyme with that of well B when the depth is equally considered. Similarly, the estimated correction factor of well Z will be the same with that of well C by considering their depths, because, they have the same stabilization days of 365 days (8760 hours).

Table 2.1: Result of calculated B_{HT} for well X1 using the depth corresponding ¢

Depth (ft)	C_T (°C)	C_T (°F)	Corresponding ¢ (hrs/ft)	S_T (hours)	Calculated B_{HT} (°F)
4600	63.9	147	0.184	720	125.05
5400	69.4	157	0.144	,,	145.37
6500	75.6	168	0.119	,,	156.38
7000	79.4	175	0.107	,,	168.22
8500	91.1	196	0.096	,,	172.94
9400	94.4	202	0.085	,,	182.03

Table 2.2: Result of calculated B_{HT} for well X2 using the depth corresponding ¢

Depth (ft)	C_T (°C)	C_T (°F)	Corresponding ¢ (hrs/ft)	S_T (hours)	Calculated B_{HT} (°F)
2500	44.4	112	0.315	720	102.40
4000	53.9	129	0.207	,,	112.17
5100	59.4	139	0.157	,,	124.99
6500	68.3	155	0.119	,,	144.28
7000	70.6	159	0.107	,,	152.84

Table 2.3: Result of calculated B_{HT} for well X3 using the depth corresponding ¢

Depth (ft)	C_T (°C)	C_T (°F)	Corresponding ¢ (hrs/ft)	S_T (hours)	Calculated B_{HT} (°F)
5100	44.4	112	0.157	720	100.71
5850	47.8	118	0.134	,,	108.38
6500	50.0	122	0.119	,,	113.56
7000	52.2	126	0.107	,,	121.12
8500	61.1	142	0.096	,,	125.29
9400	75.6	168	0.085	,,	151.39
10900	85.6	186	0.075	,,	163.82

Table 2.4: Result of calculated B_{HT} for well Y using the depth corresponding ¢

Depth (ft)	C_T (°C)	C_T (°F)	Corresponding ¢ (hrs/ft)	S_T (hours)	Calculated B_{HT} (°F)
8500	94.0	201	0.175	1440	194.58
9000	101.1	214	0.168	,,	203.81
9800	105.0	221	0.157	,,	206.84

Table 2.5: Result of calculated B_{HT} for well Z using the depth corresponding ¢

Depth (ft)	C_T (°C)	C_T (°F)	Corresponding ¢ (hrs/ft)	S_T (hours)	Calculated B_{HT} (°F)
7000	59.0	138	1.460	8760	118.29
8000	81.1	178	1.268	,,	153.71
9000	92.2	198	1.146	,,	168.17
10000	102.2	216	1.059	,,	178.67

A cursory look at tables 2.1, 2.2, and 2.3, reveals that they all have the same number of stabilization days, yet at the same depth their values of both continuous temperature and calculated bottom hole temperature are not the same. This observed difference might possibly be as a result of the variation in compositions of their respective wells, because at a given depth, the value of the estimated correction factor remains constant. For instance, at a depth of 7000ft in each of the three wells (X1, X2, and X3) as shown in tables 2.1, 2.2, and 2.3 respectively, the estimated correction factor was constant at 0.107 while their temperatures (both C_T and B_{HT}) vary.

According to Akpabio (1997), there are three geological formations of the Niger delta basin, namely; Benin, Agbada and Akata formations with depth range of 0 – 5600ft, 5600 – 8500ft and 8500 – 11000ft respectively.

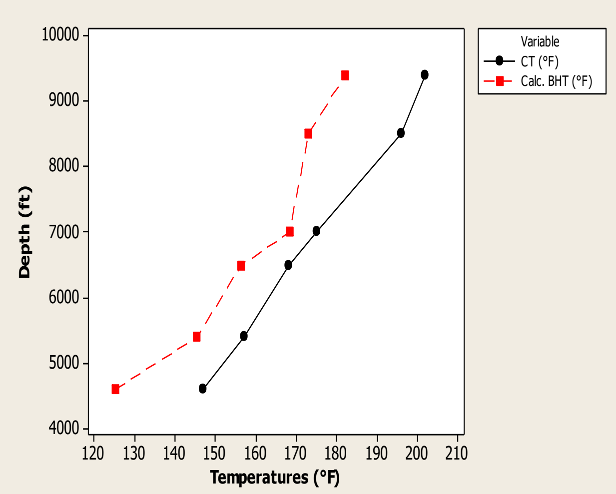

Fig. 1.1: Effect of ¢ on the calculated BHT for well X1

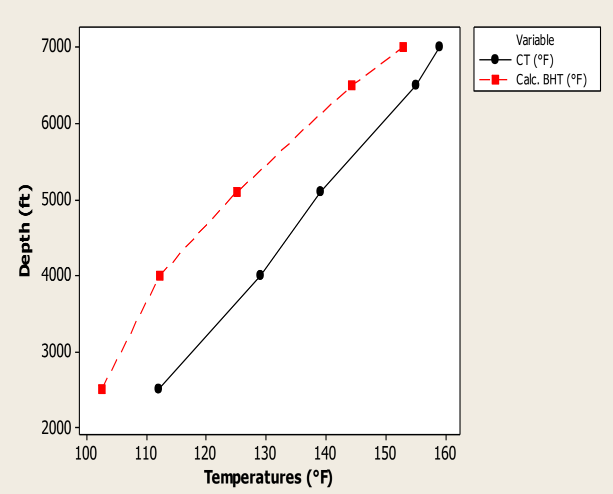

Fig. 1.2: Effect of ¢ on the calculated BHT for well X2

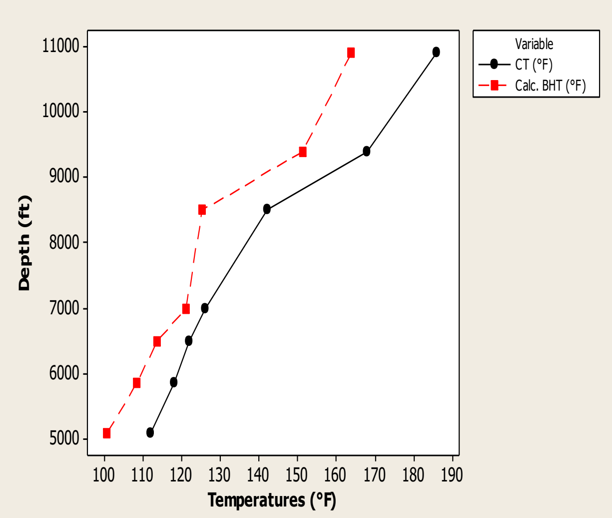

Fig. 1.3: Effect of ¢ on the calculated BHT for well X3

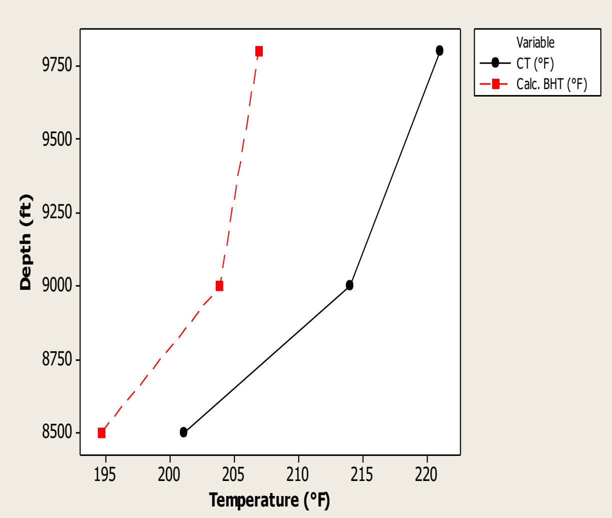

Fig. 1.4: Effect of ¢ on the calculated BHT for well Y

Owing to the depth range in wells X1, X2 and X3, they all show the three geological formations (Benin, Agbada and Akata formations) in the Niger delta basin as seen in figures 1.1, 1.2, and 1.3 respectively, while wells Y and Z represented in figures 1.4 and 1.5 only show two geological formations, that is, the Agbada and Akata formations. Generally, figures 1.1 to 1.5 outlined the impact of the estimated correction factor in extrapolating the bottom hole temperature from the continuous temperature.

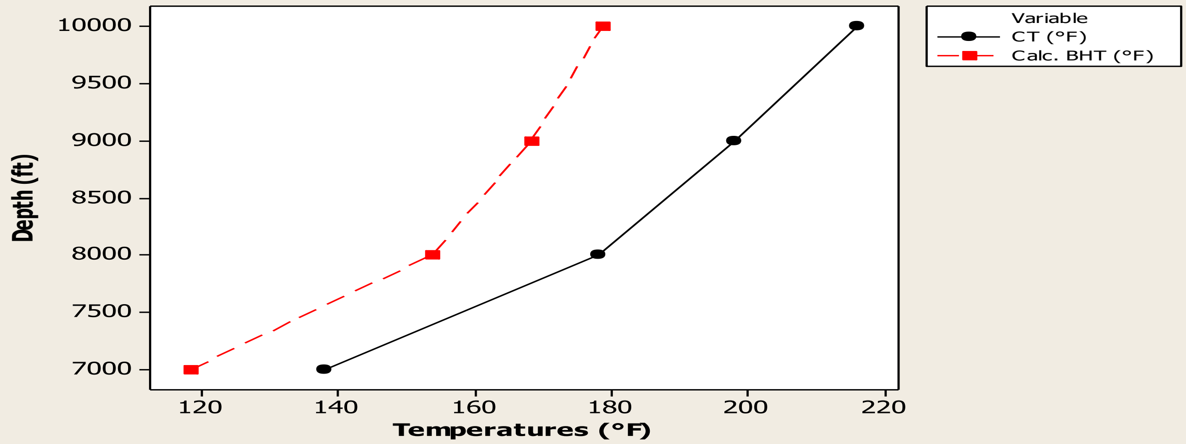

Fig. 1.5: Effect of ¢ on the calculated BHT for well Z

5. DISCUSSION AND CONCLUSION

The correction factor for bottom hole temperature in parts of the Niger delta basin has been estimated and equally used in extrapolating the bottom hole temperature from the continuous temperature. This was done without the knowledge of some factors like; the time of mud circulation and the diameter of the borehole. The estimated correction factor possesses similar characteristics to that of thermal conductivity. According to Warren (1992), thermal conductivity is an important property of a matter that accounts for the heat conduction ability of a substance and depends not only on the particular substance involved, but also on the state of that substance. This estimated correction factor exhibits this property as its value is higher on the Benin formation and much lower at the Akata formation, that is, both the correction factor and thermal conductivity of a formation decrease with depth. One would have termed this correction factor the thermal conductivity of the wells if not for the following reasons;

(i) The thermal conductivity can be interpreted as the rate of flow of heat per unit are of the well normal to the direction of heat flow, hence it depends on the heat flow in the well and also on the area of the well while the estimated correction factor have no relationship with the formations heat flow and the area of the well.

(ii) For the same number of stabilization days on different wells, the estimated correction factor remains the same at a definite depth whereas the thermal conductivity of a formation varies from well to well.

(iii) The unit of the estimated correction factor is given as hrs/ft while the unit of thermal conductivity is watts/m°C or watts/ft°F.

Above all, the estimated correction factor whose values depend solely on the depth in question and the stabilization days of a particular well can be used in extrapolating either the bottom hole temperature data from the continuous temperature data or vice versa. This estimated correction factor should be used with reasonable confidence in many or most other geological provinces, where temperature data are required for commercial applications, for example, in the scientific, engineering, exploration and research fields.

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