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Estimation of true formation temperature from well logs for basin modeling in Persian Gulf

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ABSTRACT

Static formation temperature should be determined as accurately as possible for a number of reasons; especially it is an essential parameter in petroleum system modeling. In this study, the commonly used empirical methods for log derived temperature correction are reviewed. After that, new correlation was developed by adapting previously presented methods to calibrate log recorded temperature by using true formation temperature from reservoir tests like DST and MDT in Persian Gulf basin. A correction factor formula was proposed by considering both depth and TSC directly. The adapted method provides an accurate calibration of log recorded temperature.

In addition, a sensitivity analysis was carried out to reveal the effect of log recorded temperature calibration on 1D petroleum system modeling.

1. Introduction

The Bottom-Hole Temperature (BHT) is an important parameter in different fields of study. These areas consist of Water resistivity (calculation of oil saturation from resistivity logs), detection of fluid movement, analysis of fluid pressures and in geochemical modeling of formations, reservoir-fluid formation volume factors, geothermal gradients and calibration of petroleum system models and maturity modeling (Waples and Ramly, 2001; Peters and Nelson, 2009). It was intended to study existing hydrocarbon layers and get valuable information on the flow and immigration of hydrocarbon resources as well as time of production through conducting three-dimensional modeling in the basin of the Persian Gulf and Oman Sea (6000 m of width) from Paleozoic Era until the present. One of the main parameters in petroleum system modeling is formation temperature. This parameter has a great impact on the maturity of source rock, hydrocarbon migration, type of accumulated hydrocarbon in the reservoir, etc.

Because of the importance of temperature, the effort has been made to extract these data from various resources. Actually, the main sources of formation temperature are Drill Stem Test (DST), Modular Dynamic Test (MDT) and log recorded temperature. Because during the MDT and DST, high flow volumes of oil or water are produced from the formation, therefore, these tests are generally the most reliable temperature data sources. In this study, all of these different sources have been used to extract BHT.

Because of the cooling effect of circulating drilling mud, the recorded BHT during well logging may be 20–80 °F lower than the actual formation temperature (Fertl, 1976). Prior to inserting the wire line tool the drilling mud is circulated. This drilling mud is colder than formation and cools the formation temperature down very efficiently via heat convection. When the circulation of the drilling mud stops (for example, in preparation for the insertion of a wire line tool), the borehole gradually regains the true formation temperature, because the large mass of formation around the borehole heats the drilling fluid up to its ambient temperature. This process is slow because it occurs via heat conduction, which is less efficient than heat convection. Equilibrium may only be attained after several months after stopping the circulation of the drilling fluid. Therefore, temperature which is recorded by wire line tools is usually lower than the true formation temperature.

Since as early as 1947, numerous attempts have been made to better understand and analytically describe the effects that several parameters have on the temperature distribution in wellbores (Bullard, 1947). Studied parameters include fluid temperature behavior in the borehole during well tripping, bottom-hole temperature during drilling, temperature profile over the entire borehole, and determination of static (true) formation temperature from geophysical wire line logging devices (Edwardson et al., 1962; Tragesser et al., 1967; Raymond, 1969; Kutasov and Eppelbaum, 2010; Fertl et al., 2007).

Fig. 1 shows the BHT from log header versus formation temperature from pressure test in Persian Gulf, Iran. This figure indicates that

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0920-4105/

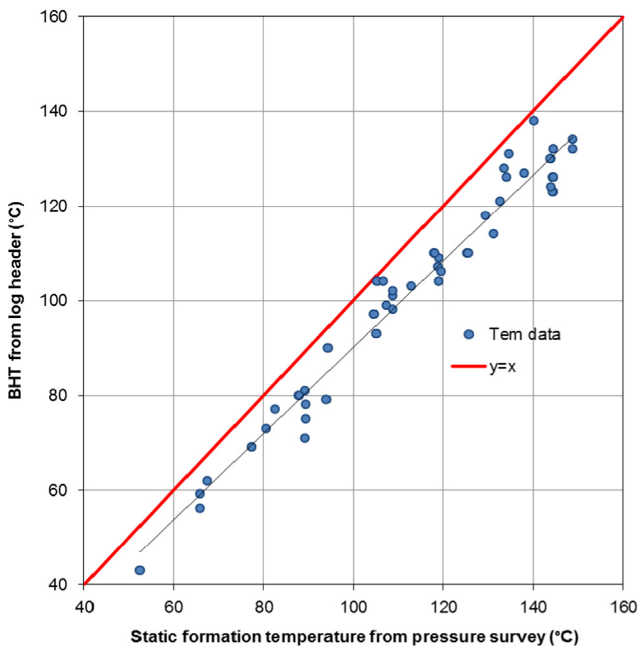

Fig. 1. Temperature recorded from log and pressure test in Persian Gulf.

the log derived temperatures are approximately 9.9% lower than formation temperatures recorded by pressure tests. Similar observation has been reported by Joyner (1975) in southwest Louisiana and Thomas (1979) in northern Perth basin, Australia.

As mentioned before, MDT and DST temperatures are generally the most reliable temperature data; unfortunately, there are a few test recorded temperature data whilst the log recorded temperatures are almost available in all the wells. Therefore, an upward calibration method for BHT correction is required.

2. Temperature correction methods

Various types of temperature corrections have been presented in the literature which can be applied to the BHT value to estimate formation temperature. This is usually done based on the time since circulation recorded with the BHT reading, or derived from an empirical correction based on the depth of the measurement.

2.1. Empirical correlations

Based on statistical data, Kehle et al. (1970) suggested a general depth dependent relationship to estimate equilibrium (static) formation temperature from the well depth (ft) and the measured

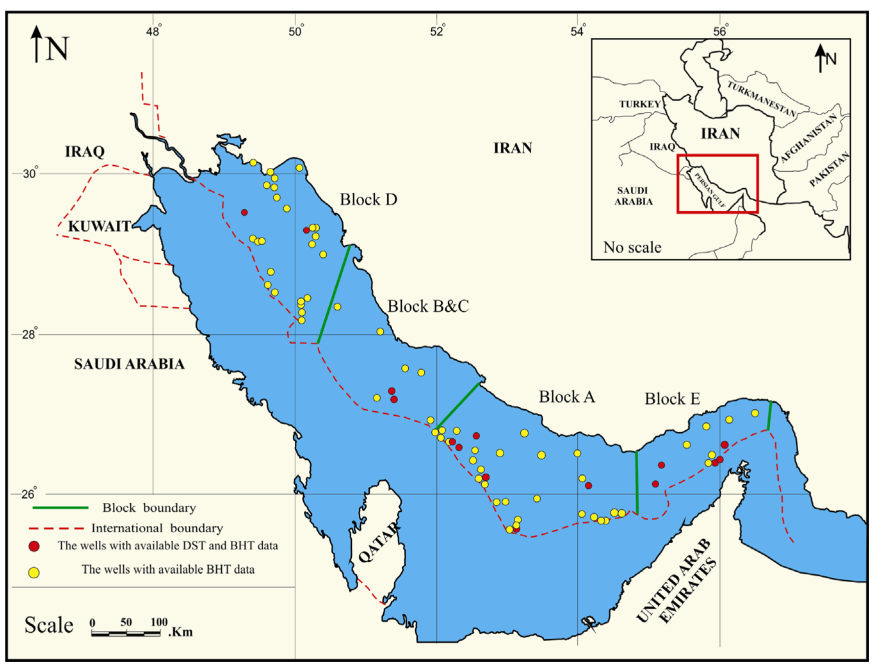

Fig. 2. Location of studied wells.

Table 1
Input parameters and calculated correction factors.

Well	Depth (m)	Real Temperature (°C)	BHT (°C)	TSC (h)	*f*
1	2028	89.29	71.00	15.5	1.40
	2572	93.95	79.00	14	1.28
2	3498	118.78	107.00	14	1.14
	3505	118.97	109.00	26.5	1.12
	3506	118.99	104.00	13.5	1.19
	4464	144.68	123.00	23	1.22
	4454	144.41	123.00	23	1.22
	4456	144.46	126.00	28	1.18
	4465	144.71	126.00	28	1.19
	4460	144.57	126.00	34	1.18