Investigation of Geothermal Gradient Variation Using Thermal Maturity Modeling in Rag-e-Safid Oilfield, SW Iran.

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Abstract

In this study vitrinite reflectance and Rock-Eval T_{max} data of Pabdeh, Gurpi and Kazhdumi Formations in well numbers 112, 2, 33, 99 and 18 of Rag-e-Safid oilfield, situated in southern Dezful Embayment, were used for thermal maturity modeling. Further the model was used to investigate the variations of geothermal gradient in the studied oilfield. Thermal maturity modeling in this oilfield reveals that well nos. 112, 2, 33, 99 and 18 have geothermal gradient as much as 31°C/km, 24°C/km, 22.3°C/km, 26°C/km and 23°C/km respectively. Iso geothermal gradient map of Rag-e-Safid oilfield was prepared using the thermal maturity model. The map indicates that, except for the well nos. 112 and 99, in rest of the oilfield, geothermal gradient is having the normal value (with mean of 23°C/km). The abnormalities in well number 112 is due to Izeh-Hendijan fault, and in well number 99 is due to the presence of paleo high (being as high as 31°C/km and 26°C/km for well numbers 112 and 99 respectively). This study demonstrates the capability of Vitrinite reflectance, T_{max} of Rock-Eval pyrolysis along with thermal models to elucidate the abnormalities in geothermal gradients.

Keywords: *Thermal Maturity Modeling, Geothermal Gradient, Vitrinite Reflectance, T_{max}, Rag-e-Safid oilfield.*

1. Introduction

Time and temperature are important factors in maturation (Waples, 1994). So maturity trend of organic matter is a suitable means to control geothermal gradient in a region. Recognition of geothermal gradient in an area is used to suggest a proper composition of drilling mud, drilling cement and drilling strings (Motiei, 1995). Tezheh and his co-workers used maturity modeling to determine oil window in Marun oilfield (Tezheh et al., 2004).

2. Geology of Studied Area

Rag-e-Safid oilfield, situated in southern Dezful Embayment, is a boomerang anticline with 49 km long and 4.5-7 km wide, located at 150 Km southeast of Ahwaz city (Fig. 1). Sub Hercynian orogeny resulted in missing of Gurpi (in center part of Rag-e-Safid oilfield), Ilam and lower part of Pabdeh Formations in this oilfield (Zohrabzadeh, 2004).

3. Methods

47 drilling cutting samples of Pabdeh, Gurpi and Kazhdumi Formations in well nos. 112, 2, 33, 99 and 18 of Rag-e-Safid oilfield (Fig. 1), after treatments are analyzed by Rock-Eval 6 instrument (Table 1). Then 33 TOC rich samples were selected for organic petrography studies. For that polish sections were prepared and optically studied using Zeiss Axioplan II microscope system equipped with J & M Photometer and a

spectrometer (200–1000 nm) (Table 1 and Fig. 2). PBM software (Pars Basin Modeler) version 1.7.0 is used to calculate maturity trend vs. depth. In order to model the oil field, stratigraphy data (included age, top of the formations, age of the unconformities), lithology of each formation, well data (including geographic coordination of the well, rotary table elevation), geochemical data (Rock Eval and vitrinite reflectance data) and Surface temperature (as much as 25°C) are fed to the software.

4. Discussion

Easy %Ro kinetic algorithm is used to calculate vitrinite reflectance by software. Slope of Vitrinite reflectance trend with depth is affected by geothermal gradient and sedimentation rate (Hunt, 1996). If observed %Ro and also T_{max} be in accordance with calculated %Ro and T_{max} trend then model can be accepted, and if not, model has to be corrected.

4-1. Estimation of Geothermal Gradient of Well no. 2: By using geothermal gradient as much as 24°C/km, observed %Ro and calculated %Ro are in accordance (Fig. 3a), but T_{max} data are lower than expected (Fig. 3b). Bangestan reservoir oil of Rag-e-Safid oilfield contains about 3.5% sulfur (Zohrabzadeh, 2004) demonstrating a source rock with high content of sulfur. Presence of sulfur in kerogen can reduce T_{max} (Snowdon, 1995) and so reduction of T_{max} in Fig. 3b can be due to presence of sulfur in Kazhdumi Formation.

4-2. Estimation of Geothermal Gradient of Well no. 33: By using geothermal gradient as much as 22.3°C/km, observed %Ro and calculated %Ro are in accordance (Fig. 4a). Calculated trend of T_{max} is also matched measured data (Fig. 4b).

4-3. Estimation of Geothermal Gradient of well no. 99: Optimization of model showed that by using geothermal gradient as much as 26°C/km, observed %Ro and calculated %Ro and also measured and calculated T_{max} will be in accordance. Well no. 99 is drilled on a paleo high (Fig. 1), so geothermal gradient in this well is higher than normal value in Rag-e-Safid oilfield.

4-4. Estimation of Geothermal Gradient of Well no. 112: By using geothermal gradient as much as 31°C/km observed and calculated maturity will be in agreement. Fig. 1 shows that well no. 112 is placed on Izeh-Hendijan basement fault. Barker mentioned that faults can cause thermal anomalies. This is because of fault planes movement against each other, producing frictional heating and cause an increase in vitrinite reflectance (Barker, 1996).

4-5. Estimation of Geothermal Gradient of Well no. 18: Optimization of model showed that by using geothermal gradient as much as 23°C/km, observed %Ro and calculated %Ro will be in agreement (Fig. 5a). On the other hand there is an interval in Pabdeh Formation (at depth between 2795-2845 m) that has a measured T_{max} as low much as 9°C lower than the calculated T_{max} (Fig. 5b). High value of TOC and HI in this interval (TOC= 3-5 Wt. % and HI> 550 mg HC/gr TOC) confirms presence of bitumen. Hence the main

reason for a decrease in T_{max} could be presence of bitumen as is also mentioned by Snowdon in 1995. Presence of bitumen also decreases the observed %Ro (suppressed vitrinite).

Iso-geothermal gradient map of Rag-e-Safid oilfield prepared by interpolation of the model's data (Fig. 6), demonstrates that the source rocks in and around the well nos. 112 and 99 have higher level of maturity in compare to other parts of the oilfield.

5. Conclusion

Maturity modeling by thermal indicator is a suitable way to elucidate the anomalies in geothermal gradients. Maturity modeling in Rag-e-safid Oilfield reveals that well nos. 112, 2, 33, 99 and 18 have geothermal gradient as much as 31°C/km, 24°C/km, 22.3°C/km, 26°C/km and 23°C/km respectively. Iso-geothermal gradient map of Rag-e-Safid oilfield indicates that, except for the well nos. 112 and 99, in rest of the oilfield, geothermal gradient have normal value (with mean of 23°C/km). The abnormality in well number 112 is due to Izeh-Hendijan fault and in well number 99 is due to the presence of paleo high (where basement is coming closer to the surface) causing an increase in geothermal gradient.

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Table 1: Selected Rock Eval and Vitrinite reflectance results from Pabdeh and Kazhdumi Formations of well no. 2 of Rag-e-Safid oilfield (in this table unit of depth is meter; S_1 and S_2 is mg HC/gr rock; S_3 is mg CO_2/gr rock; HI is mg HC/gr TOC; OI is mg HC/gr CO_2; TOC is Wt.%; T_{max} is °C and %Ro is percentage of reflectance in oil).

Well no.	Formation	Depth	S_1	S_2	S_3	T_{max}	HI	OI	TOC	%Ro
2	Pabdeh	2360.5	1.17	6.07	2.08	426	416	142	1.46	0.4972
		2389	1.76	15.96	2.53	420	494	78	3.23	No vitrinite
		2427	1.22	5.14	2.23	429	362	157	1.42	0.5339
		2446	1.44	10.75	2.13	424	486	96	2.21	0.5468
		2461	1.33	5.7	2.17	432	335	128	1.7	0.5589
		2482	1.54	4.88	2.34	431	378	181	1.29	0.5529
		2555	1.55	6.58	2.63	420	374	149	1.76	0.5216
	Kazhdumi	3372	0.78	3.46	1.35	431	370	145	0.94	0.6364
		3392	1.4	13.39	1.76	431	385	51	3.48	0.642
		3410	1.42	14.61	1.46	431	462	46	3.16	0.6459
		3429	1.4	9.08	1.79	429	375	74	2.42	0.6696
		3464	1.81	16.63	1.74	426	479	50	3.47	0.6807
		3502	0.47	3.52	1.49	428	205	87	1.72	0.7046
		3537	0.72	3.45	1.31	432	214	81	1.61	0.7123
		3573	0.47	2.48	0.97	434	184	72	1.35	0.7272
		3610	1.11	11.38	1.18	427	426	44	2.67	0.71
		3624	1.14	15.55	1.71	433	478	53	3.25	0.7429

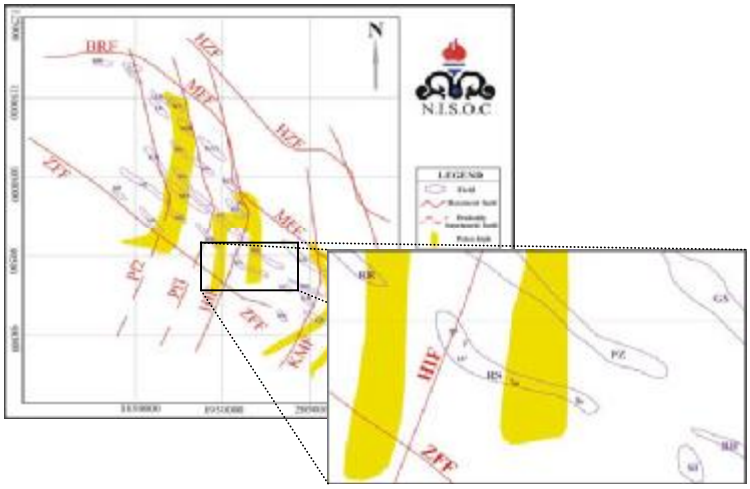

Figure1. Structural situation of Rag-e-Safid oilfield in Zagros, also studied wells is located on map. Yellow masses represent Paleo high (Heidarifard et al., 2007).

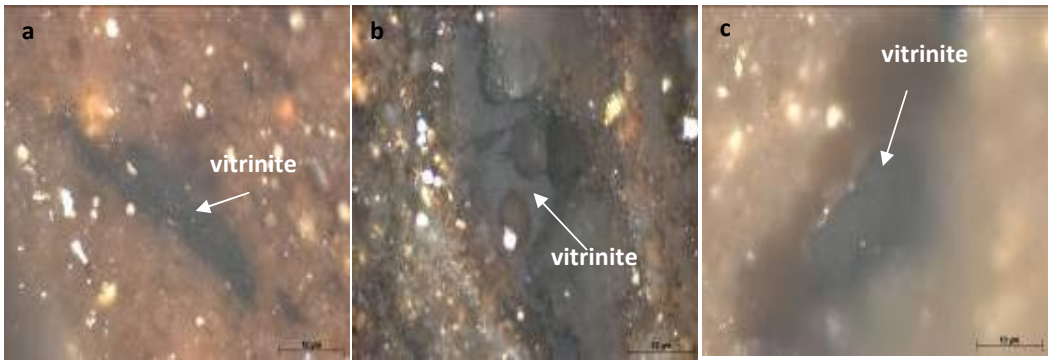

Figure 2. Digital image of some studied polish sections, a: well no. 18, Pd Fm, 2795 m; b: well no. 2, Kz Fm, 3392 m; d: well no. 33, Kz Fm, 2856 m.

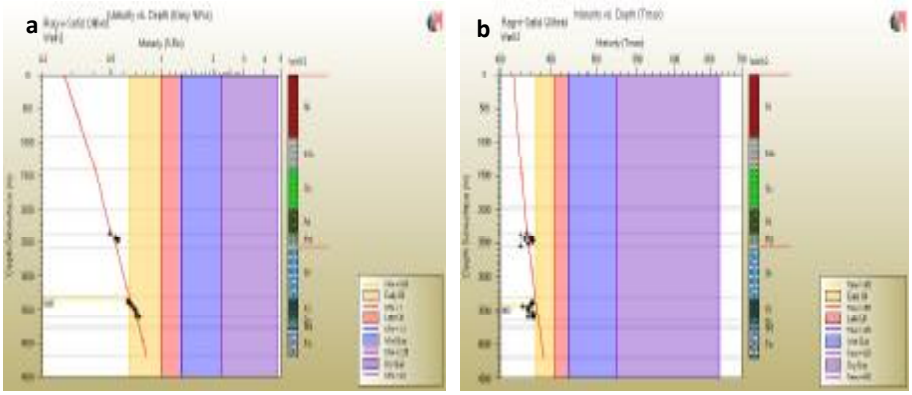

Figure 3. Maturity vs. depth plot in well no. 2, according to (a) Easy%Ro and (b) T_{max}

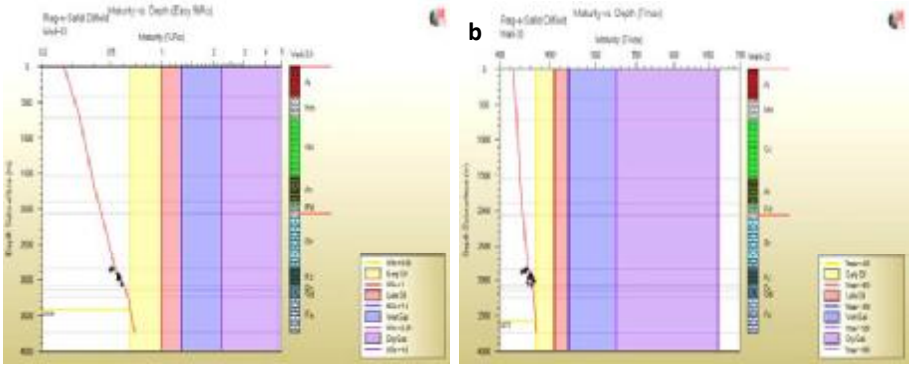

Figure 4. Maturity vs. depth plot in well no. 33, according to (a) Easy%Ro and (b) T_{max}

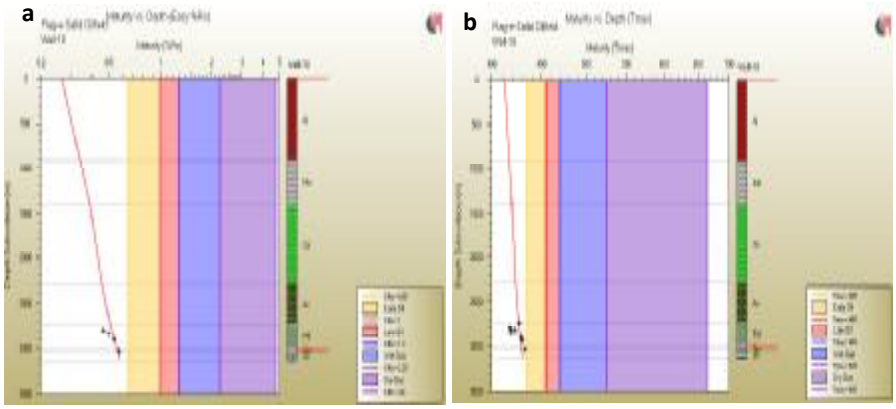

Figure 5. Maturity vs. depth plot in well no. 99, according to (a) Easy%Ro and (b) T_{max}.

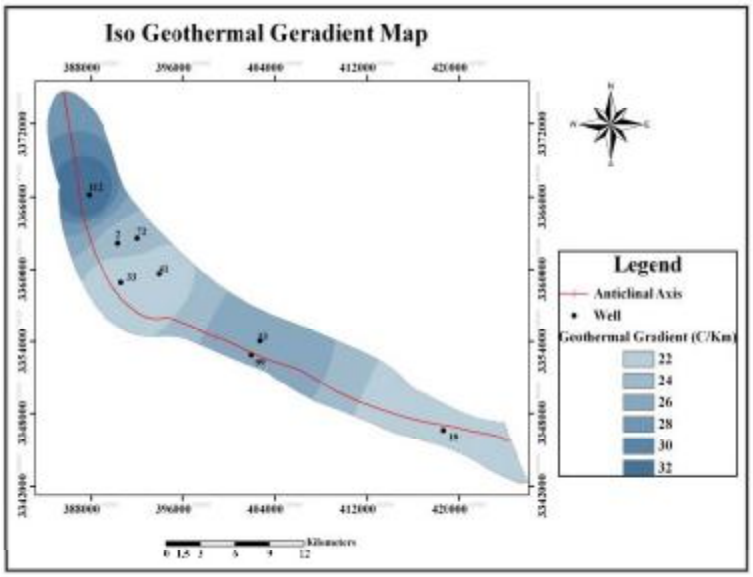

Figure 6. Iso geothermal gradient map of Rag-e-Safid oilfield (those wells that geothermal gradient of them is measured are also plotted).