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CORRECTION

Correction to: Probabilistic estimation of hydraulic fracture half-lengths: validating the Gaussian pressure-transient method with the traditional rate transient analysis-method (Wolfcamp case study)

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The original version of this article unfortunately contained serious typographical errors due to mishaps in the proof-printing process. This correction article aims to rectify these errors in order to do justice to our original work, which was executed with the greatest care for detail and accuracy.

The original article can be found online at https://doi.org/10.1007/s13202-023-01680-9.

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Point 1: Due to two distracting errors in the Abstract, the correct Abstract is given here in full below:

Abstract—Despite significant advancements in geomodelling technologies, accurately estimating hydraulic fracture half-length remains a challenging task. This paper introduces a detailed estimation approach using the Gaussian pressure transient (GPT) method, which is relatively new. The GPT method is iterative, ensuring fast convergence and providing reliable estimations of hydraulic fracture half-length based on a predetermined hydraulic diffusivity value obtained from Gaussian decline curve analysis (DCA). To validate the GPT results, production data from two case study wells in the Wolfcamp Shale Formation, located in the Midland Basin of West Texas, are utilized alongside the traditional rate transient analysis (RTA) method. Moreover, the GPT method offers the capability to probabilistically estimate hydraulic fracture half-lengths, presenting two innovative approaches to evaluate the robustness of this newly developed method for both deterministic and probabilistic estimations. The simulation results demonstrate a close correlation between the Gaussian method and micro-seismic fracture half-lengths, with separate confirmation from the classic RTA method. Through the case studies presented in this paper, the GPT method showcases its utility in estimating hydraulic fracture half-lengths for two Wolfcamp case study wells, effectively demonstrating the validity and practical applicability of this novel method.

Point 2: Some italicizations and typographical errors in the List of symbols were missing, so the correct List of symbols is given here in full below:

List of symbols

A Area around the fracture, ft^2

B_0 Oil formation volume factor at reservoir condition, bbl/STB

$C1$ Conversion factor for field units, 0.178108 bbls/ft^3

$C2$ Conversion factor for field units, 1.06235E-14 ft^2/mD

$C3$ Conversion factor for field units, 1.67868E-12 psi.day/cPoise

D_h Dimensionless reservoir diffusivity

h Reservoir thickness, ft

k Matrix permeability, Darcy

n Total number of fractures

P_0 Original reservoir pressure, psi

q_i Initial production rate, bbl/day

$q_r(t)$ Production rate at time t, bbl/day

t Dimensionless time

x Fixed distance to the fracture plane (set at 1 ft if using field units), ft

Y_f Fracture half-length, ft

μ Fluid viscosity, cP

P_{BH} Bottom hole pressure, psi

DCA Decline curve analysis

GPT Gaussian pressure transient

RTA Rate Transient Analysis

Point 3: Equation (1) on page 2 was published incorrectly, which should be centered and italicized. The correct Eq. (1) is given below.

$$q(t) = q_i \frac{1}{t} e^{\left(\frac{1}{4Dh}\right)\left(1-\frac{1}{t}\right)} \tag{1}$$

Point 4: The text "Formation volume factor (STB/ reservoir bbls)" in Table 1 on page 4 was published incorrectly, which should be aligned to the left. The correct Table 1 is given below.

Table 1 PVT mean values for Well 4H and 31H

PVT property	Well 4H	Well 31H
Formation volume factor (STB/ reservoir bbls)	1.316	1.324
Viscosity (cPoise)	0.775	0.731
Fluid type	Black oil	Black oil

Point 5: Equation (3) on page 6 was published incorrectly which should be centered and italicized, and use P_{BH} instead of BHP. The correct Eq. (3) is given below.

$$q_r(t) = \frac{2Ak\left(P_0 - P_{BH}\right)}{\mu D_h t} xe^{\left(\frac{-x^2}{4D_h t}\right)} \tag{3}$$

Point 6: In the sentence beginning with "BHP represents bottom…" on page 6, the symbol "BHP" was published incorrectly, which should be replaced with P_{BH}. The corrected part of the sentence is given below.

"P_{BH} represents bottom hole pressure"

Point 7: Equation (4) on page 6 was published incorrectly, which should be centered and italicized. The correct Eq. (4) is given below.

$$q_w(t) = \frac{q_r(t)}{B} \& Y_f = \frac{A}{2nh} \tag{4}$$

Point 8: The two symbols "Y_f" in Table 3 on page 7 were published incorrectly, which should be in italics. The correct Table 3 is given below.

Point 9: Equation (5) on page 7 was published incorrectly which should be centered and italicized, and replace BHP by P_{BH}. The correct Eq. (5) is given below.

$$q_w(t) = \frac{C1C2}{C3} \cdot \frac{2nhkY_f\left(P_0 - P_{BH}\right)}{\mu B_0 D_h t} xe^{\left(\frac{-x^2}{4D_h t}\right)} \tag{5}$$

Point 10: In the sentence beginning with "The conversion factors C1, C2, andC3 are needed…" on page 7, the three symbols "C1, C2, andC3" were published incorrectly, which should be in italicized. The correct symbols are given below.

"$C1$, $C2$, and$C3$"

Point 11: In the sentence beginning with "Rearranging Eq. (5) yields Eq. (6). Which was…" on page 7, the text. "Which" was published incorrectly. The dot should be removed, and the text "Which" should not be capitalized. The correct sentence is given below.

"Rearranging Eq. (5) yields Eq. (6), which was used in this study to stochastically model the fracture half-length:"

Table 3 Average fracture half-length Y_f from micro-seismic for Wells 4H, 44H, 45H, and 46H

Well	Avg Y_f (ft)	Cluster number	Total volume of fluid (gallons)	Total proppant (lb)
4H	570	99	219,000	200,000
31H	N/A	136	316,218	335,851
44H	638	> 75	300,000	333,000
45H	334.5	> 75	304,000	337,000
46H	295	143	303,000	336,000
Avg 45 and 46	314.75			

Table 4 Property values applied in history matching in approach A for both wells

Property	Well 4H	Well 31H
Permeability (nd)	100	100
Total cluster number	69	95
Reservoir height (ft)	100	100
Formation volume factor reservoir (bbls/STB)	1.428	1.371
Viscosity (cPoise)	0.6195	0.638
Hydraulic diffusivity (ft^2/day)	0.02267	0.02178

Point 12: The symbol "BHP" on page 7 was published incorrectly, which should be replaced with P_{BH}. The correct symbol is given below.

"P_{BH}"

Point 13: Equation (6) on page 7 was published incorrectly which should be in the center and italics and replace BHP by P_{BH}. The correct Eq. (6) is given below.

$$Y_f = \frac{C3}{C1C2} \cdot \frac{q_w(t).\mu B_0 D_h t}{2nhk\left(P_0 - P_{BH}\right)} xe^{\left(\frac{x^2}{4D_h t}\right)} \quad (6)$$

Point 14: The text "Formation volume factor (STB/reservoir bbls)" in Table 4 on page 7 was published incorrectly which should be aligned to the left. The correct Table 4 is given below.

Point 15: In the sentence beginning with "Two Approaches (A,B) were evaluated to…" on page 7, the text "Sections" was published incorrectly, which should not be capitalized. The correct sentence is given below.

"Two approaches (A,B) were evaluated to estimate the hydraulic fracture half-length, based on the GPT model explained in the previous sections."

Point 16: The two texts "Formation volume factor (STB/reservoir bbls)" in Table 5 on page 8 were published incorrectly, which should be aligned to the left. The correct Table 5 is given below.

Point 17: In the sentence beginning with "Fracture half-lengths were estimated with…" on page 8, the text "(Sect. 0)" should not be capitalized. The should be replaced by:.

"Fracture half-lengths were estimated with the GPT method using the proposed GPT approaches."

Point 18: The text "bottom-hole" in Table 6 on page 8 was published incorrectly, which should be replaced by P_{BH}. The correct Table 6 is given below.

Point 19: In the sentence beginning with "Firstly, PVT data were obtained from…" on page 8, the symbol "FVF" was published incorrectly, which should be replace by "formation volume factor (FVF)". The correct sentence is:

"Firstly, PVT data were obtained from available reports to address suitable formation volume factor (FVF) and viscosity values"

Table 5 Properties of PDF used in approach B for both wells

Parameter	Well 4H			Parameter	Well 31H		
	Sample size	PDF	Min–max		Sample size	PDF	Min–max
Total cluster number	99	Uniform	69–99	Total cluster number	136	Uniform	95–136
Viscosity (cPoise)	10	Pareto	0.45–0.71	Viscosity (cPoise)	10	Uniform	0.46–0.68
Flow rate (STB/day)	1454	Pearson type 5	20–2541	Flow rate (STB/day)	626	Lognormal	76.9–4256
Time (day)	1454	Uniform	1–1454	Time (day)	626	Uniform	1–626
Formation volume factor (bbl/STB)	10	Uniform	1.29–1.47	Formation volume factor (bbl/STB)	10	Min Ext value	1.29–1.43

Table 6 FVF and viscosity data obtained from PVT tests for Well 4H

Pressure, psi	Oil FVF, bbl/STB	Viscosity, cP
4680 (Reservoir)	**1.428**	**0.530**
4000	1.440	0.502
2886	1.462	0.459
2100	1.404	0.525
1600	1.355	0.586
1100	1.305	0.685
1000 (P_{BH})	**1.294**	**0.709**
600	1.250	0.828
150	1.171	1.077
15 (Surface)	1.053	1.846

Table 7 Deterministic fracture half-length Y_f-values estimated using Approach A for Well 4H

Well 4H	Bottom hole viscosity Y_f, ft	Reservoir viscosity Y_f, ft	Average Y_f, ft
Reservoir FVF	248	186	217

Point 20: In the sentence beginning with "Accordingly, two values of…" on page 8, The text "condition's FVF" was published incorrectly, which should be replaced by:

"Accordingly, two values of Y_f were estimated using the reservoir condition's FVF coupled with the viscosity at the reservoir and bottom hole conditions."

Point 21: The symbol "Y_f" in Table 7 on page 9 was published incorrectly, which should be in Italics. The correct Table 7 is given below.

Point 22: The symbol "BHP" in Table 8 on page 9 was published incorrectly, which should be replaced with P_{BH}. The correct Table 8 is given below.

Point 23: The symbol "Y_f" in Table 9 on page 9 was published incorrectly, which should be in italics. The correct Table 9 is given below.

Point 24: In the sentence beginning with "This section will summarize.." on page 9, the text "data shown in Sect. 0" on page 9 should be removed. The correct sentence is given below.

"This section will summarize the micro-seismic data to validate GPT approaches."

Table 8 FVF and viscosity data obtained from PVT tests for Well 31H

Pressure, psi	Oil FVF, bbl/STB	Viscosity, cP
5850 (Reservoir)	**1.371**	**0.598**
5000	1.383	0.553
4680	1.388	0.553
4000	1.398	0.527
3270	1.410	0.498
2335	1.428	0.457
1900	1.381	0.521
1500	1.339	0.585
1100	1.299	0.669
1000 (P_{BH})	**1.288**	**0.679**
700	1.259	0.792
300	1.211	0.965
15 (Surface)	1.061	2.107

Table 9 Facture half-length values using deterministic approach for Well 31H

Well 31H	Bottom hole viscosity Y_f, ft	Reservoir viscosity Y_f, ft	Average Y_f, ft
Reservoir FVF	188	166	177

Table 11 Probabilistic Y_f values from Approach B for Well 4H

Approach B—Well 4H	Y_f, ft
P10	37
P50	205
P90	1011
Mean	425

Point 25: The two symbols "Y_f" in Table 11 on page 10 were published incorrectly, which should be in italics. The correct Table 11 is given below.

Point 26: The term "$P - P_{wf}$" on page 10 was published incorrectly, which should be in italics. The correct term is given below.

"$P - P_{wf}$"

Point 27: The term "function,t $[\Delta(p)/q_o]$*′*" on page 10 was published incorrectly. A space needs to be inserted after the comma. The correct term is given below.

"function, t $[\Delta(p)/q_o]$*′*"

Table 12 Best fit distributions for input parameters of Eq. (6) for Well 31H

Parameter	Distribution	@Risk syntax
Total cluster number	Uniform	RiskUniform(95.2,136)
FVF	Minimum extreme value	RiskExtvalueMin(1.3887,0.033735,RiskTruncate(1.2878,1.4283))
Viscosity	Uniform	RiskUniform(0.43206,0.70355,RiskTruncate(0.457,0.679))
Flow rate	Lognormal	RiskLognorm(467.33,592.65,RiskShift(65.762),RiskTruncate2(78,4256.7),RiskCorrmat(RATE_TIME,1))
time	Uniform	RiskUniform(1.0,662,RiskCorrmat(RATE_TIME,2))

Table 13 Probabilistic Y_f values from Approach B for Well 31H

Approach B—Well 31H	Y_f, ft
P10	24
P50	139
P90	751
Mean	300

Table 14 Average fracture half-lengths reported from micro-seismic measurements

Well	Y_f, ft
4H	570
31H*	314

* For Well 31H, the micro-seismic Y_f was averaged from the offset wells (e.g., Wells 46H & 45H, see Figs. 6 and 7)

Table 15 Comparison of Y_f-estimations from GPT, RTA, and MS methods for Well 4H

Well 4H			
Method		Y_f, ft	Relative error to RTA
GPT Deterministic Approach A		217	9%
GPT Probabilistic Approach B	P10	37	82%
	P50	205	3%
	P90	1011	406%
	Mean	425	113%
RTA method		200	0%
Micro-seismic (MS)		570	185%
Well 31H			
Method		Y_f, ft	Relative error to RTA
GPT Deterministic Approach A		177	40%
GPT Probabilistic Approach B	P10	24	92%
	P50	139	53%
	P90	751	156%
	Mean	300	2%
RTA method		293	0%
Micro-seismic (MS)		314	7%

Point 28: The text "Minimum Extreme Value" in Table 12 on page 10 was published incorrectly, which should be aligned to the left. The correct Table 12 is given below.

Point 29: The two symbols "Y_f" in Table 13 on page 11 were published incorrectly, which should be in italics. The correct Table 13 is given below.

Point 30: The two symbols "Y_f" in Table 14 on page 11 were published incorrectly, which should be in italics. The correct Table 14 is given below.

Point 31: In the sentence beginning with "In the Cartesian plot, a straight…" on page 11 was published incorrectly. The correct sentence is given below.

"In the Cartesian plot, a straight line with a slope (m) can be estimated."

Point 32: Eq. (7) on page 11 should be centered. The correct Eq. (7) is given below.

$$\sqrt{k}A_c = \frac{79.65B\mu}{\sqrt{(\varphi\mu c_t)_i}}\left(\frac{1}{m}\right) \tag{7}$$

Point 33: The symbol "Nf" on page 11 was published incorrectly. The correct symbol is given below.

"N_f"

Point 34: The symbol "Hf" on page 11 was published incorrectly. The correct symbol is given below.

"H_f"

Point 35: Eq. (8) on page 11 was published incorrectly and should be in the Center. The correct Eq. (8) is given below.

$$A_c = 4N_f Y_f H_f \tag{8}$$

Point 36: In the sentence beginning with "For Well4H, GPT-Approach B successfully simulated…" on page 11, the term "Well4H" was published incorrectly. A space needs to be inserted after the word "Well". The correct term is given below.

"Well 4H"

Point 37: The three symbols "Y_f" in Table 15 on page 12 were published incorrectly, which should be in italics. The correct Table 15 is given below.

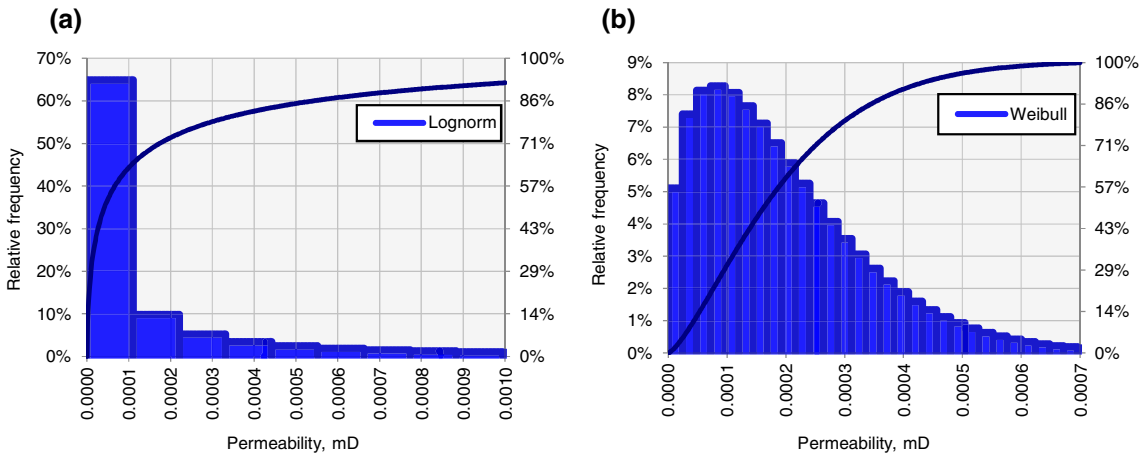

Fig. 2 Permeability probability density functions (**a**) 4H (118 sample size) and (**b**) 31H (95 sample size)

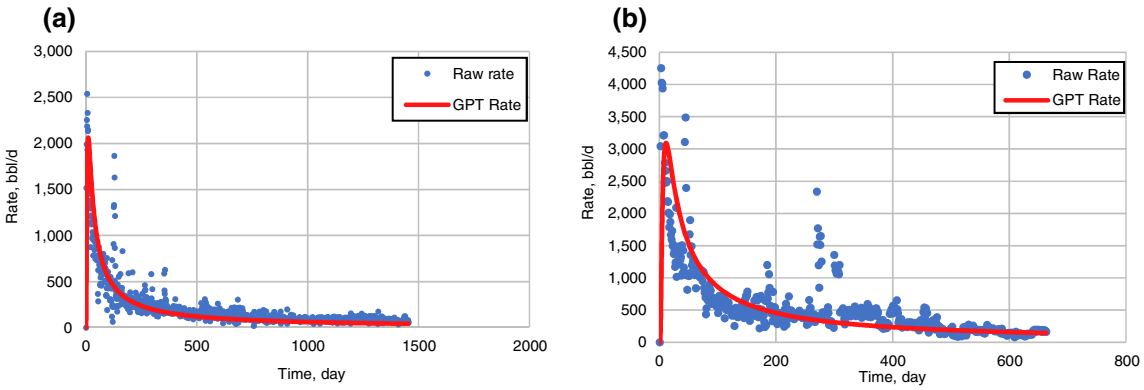

Fig. 3 History matching of production rates on Gaussian DCA model (**a**) Well 4H and (**b**) Well 31H

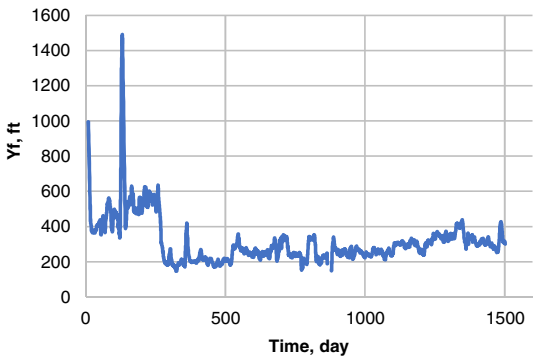

Fig. 13 Hydraulic fracture half-length with time for Well 4H

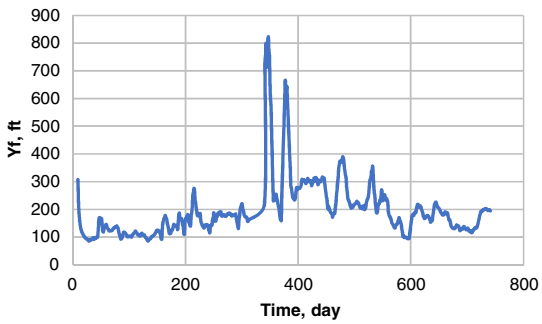

Fig. 14 Hydraulic fracture half-length with time for Well 31H

Point 38: The term "$[p_i - p_{wf}]/q_o$" in the caption of Fig. 12 on page 12 was published incorrectly, without italics. The correct term is "$[p_i - p_{wf}]/q_o$"

The below mentioned Figs. 2, 3, 13 and 14 are published incorrectly and the correct figures are given below.