

APPLICATION OF GEOSTATISTICAL SIMULATION FOR POROSITY AND
PERMEABILITY DETERMINATION FROM WELL LOGGING DATA

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Petroleum Engineering
Department of Mining and Petroleum Engineering
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จันทกานต์ ศรีสุริยนต์ : การประยุกต์ใช้แบบจำลองธรณีสถิติในการประเมินค่าความพรุน และค่าความซึมได้ของหินจากข้อมูลการหยังธรณีหลุมเจาะ (APPLICATION OF GEOSTATISTICAL SIMULATION FOR POROSITY AND PERMEABILITY DETERMINATION FROM WELL LOGGING DATA) อ.ที่ปรึกษา: ผศ. ดร. สุนทร พุ่มจันทร์, อ.ที่ปรึกษาร่วม: ดร. วิศรุต ตั้งสุนทรจันทร์, 120 หน้า.

การประเมินค่าความซึมได้ของหินมีความสำคัญมากต่อแหล่งกักเก็บ ถึงแม้ว่าความซึมได้ของหินสามารถวัดค่าได้โดยตรงจากห้องทดลองแต่ไม่สามารถวัดค่าได้ทุกความลึก เนื่องจากเป็นการยากที่จะได้แท่งตัวอย่างที่สมบูรณ์และการวัดค่าจากห้องทดลองนั้นมีราคาแพง ดังนั้นความซึมได้ของหินจึงถูกประมาณค่าผ่านคุณสมบัติของหินซึ่งได้จากการหยังธรณีหลุมเจาะ ความพรุนของหินเป็นข้อมูลตัวหนึ่งที่ได้จากการหยังธรณีหลุมเจาะซึ่งมีบทบาทต่อการประเมินค่าความซึมได้ของหิน ในงานวิจัยนี้มุ่งเน้นการประมาณค่าความพรุนของหินโดยอ้างอิงจากข้อมูลจริงของการหยังธรณีหลุมเจาะ โดยใช้แบบจำลองธรณีสถิติคือ Sequential Gaussian Simulation ค่าความพรุนของหินที่ประมาณค่าได้จะถูกนำไปใช้ประมาณค่าความซึมได้ของหิน

ข้อมูลต่างๆที่ใช้ในงานวิจัยนี้ได้มาจากหลุมเจาะจำนวนสิบสี่หลุมในแหล่งน้ำมัน ข้อมูลค่าความพรุนของหินถูกนำมาใช้เป็นข้อมูลสำหรับแบบจำลองธรณีสถิติ เพื่อใช้ในการประมาณค่าความพรุนของหินทั้งแหล่งน้ำมัน วิธี Hydraulic Flow Unit ถูกนำมาใช้ในการประเมินความสัมพันธ์หรือสมการระหว่างความซึมได้ของหินกับความพรุนของหิน ค่าความพรุนของหิน ณ ตำแหน่งที่มีการวัดค่าความซึมได้จะถูกเลือกเพื่อคำนวณและเปรียบเทียบค่าความซึมได้ของหินผ่านสามสมการที่แตกต่างกันได้แก่ สมการหาค่าความซึมได้ของหินโดยวิธี Hydraulic Flow Unit ความสัมพันธ์ระหว่างลอการิทึมของความซึมได้ของหินกับความพรุน และวิธีของ Jorgensen หลังจากนั้นความซึมได้ของหินที่ได้จากการคำนวณผ่านสมการและความพรุนของหินที่ประมาณได้ที่แตกต่างกันสองกรณีถูกป้อนเข้าไปในโปรแกรมการประมาณศักยภาพของแหล่งผลิตเพื่อเปรียบเทียบข้อมูลการผลิต งานวิจัยสามารถสรุปได้ว่า ข้อมูลการผลิตที่ได้จากทั้งสองกรณีไม่แตกต่างกันมากนัก และสมการหาค่าความซึมได้ของหินสามารถประยุกต์ใช้ในแหล่งกักเก็บนี้อย่างมีประสิทธิภาพ

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สาขาวิชาวิศวกรรมปิโตรเลียม

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ASST. PROF. SUNTHORN PUMJAN, Ph.D. THESIS CO-ADVISOR:
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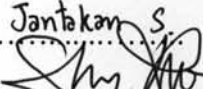
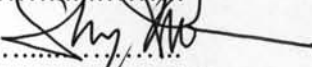

Permeability determination is very important in the oil field. Although permeability can be obtained directly in laboratory, it is unable to measure at every depth due to the difficulties in obtaining the complete core sample and it is uneconomic. Therefore, permeability is estimated indirectly using rock properties acquired through well log measurements. Porosity is one of well log measurement data that plays a role in determining permeability. This study focuses on the estimation of porosity based on well logging data. Using geostatistical simulation technique which is Sequential Gaussian Simulation (SGS), porosity values were generated and used to estimate permeability.

A set of field data obtained from locations along fourteen wells drilled in oil reservoir was selected for this study. SGS was used to simulate porosity across the field. The simulated porosity values at locations where permeability measurement made available were selected. The equation between porosity and permeability can then be determined based on hydraulic flow unit (HFU) method. Next, the permeability data are determined from three different approaches which are HFU, logarithm of permeability and porosity relationship, and the Jorgensen method. Two cases of simulated porosity and calculated permeability were input into reservoir simulation program for comparing production profiles. The study concludes that production profiles from both cases are not significant difference, and the obtained permeability equations based on HFU concept can effectively use in this field.

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LIST OF ABBREVIATIONS

| | |
|--------------|---|
| ANFIS | adaptive network-based fuzzy inference system |
| API | degree (American Petroleum Institute) |
| BHP | bottom hole pressure |
| Col | column |
| EREM | equivalent rock element model |
| FIS | fuzzy inference system |
| FGPR | field gas production rate |
| FGPT | field gas production total |
| FOE | field $(OIP_{(initial)} - OIP_{(now)}) / OIP_{(initial)}$ |
| FOPR | field oil production rate |
| FOPT | field oil production total |
| FPR | field pressure |
| FWPR | field water production rate |
| FWPT | field water production total |
| HFU | hydraulic flow unit |
| mD | millidarcy |
| OIP | oil in place |
| OOIP | original oil in place |
| ORAT | oil rate |
| OW | oil water |
| PVT | pressure-volume-temperature |
| PSIA or psia | pounds per square inch absolute |
| rb | reservoir barrel |
| RQI | reservoir quality index |
| SCAL | special core analysis |
| SGeMS | Stanford Geostatistical Modeling Software |
| STB or stb | stock-tank barrel |
| STB/D | stock-tank barrels per day |
| Visc | viscosity |
| WOC | water oil contact |

NOMENCLATURE

| | |
|--------------|------------------------------------|
| a | range distance |
| C_o | nugget value |
| C_l | function of sill value |
| e | estimation error |
| F_s | shape factor |
| F_{zi} | flow zone indicator |
| \vec{h} | distance |
| k | permeability |
| k_{rg} | relative gas permeability |
| k_{ro} | relative oil permeability |
| k_{rw} | relative water permeability |
| m | cementation exponent |
| n | number of data |
| $N(\vec{h})$ | number of data pair |
| P_c | capillary pressure |
| P_{bub} | bubble pressure |
| r | pore radius |
| R_s | solution gas-oil ratio |
| S_g | gas saturation |
| S_{gv} | surface area per unit grain volume |
| S_w | water saturation |
| Z^* | estimated value |
| Z_i | true value |
| $Z(x_i)$ | Realization |

GREEK LETTERS

| | |
|-------------------|---------------------|
| $\gamma(\vec{h})$ | variogram function |
| λ_i | kriging weight |
| μ | Lagrange multiplier |

| | |
|----------------------|--------------------------------------|
| ∇ | point to be estimated |
| v_α | sample at location x_α |
| $\sigma_{\hat{y}}^2$ | simple kriging variance |
| τ | tortuosity factor |
| Φ | effective porosity |
| Φ_z | ratio of pore volume to grain volume |
| ω_i | weight factor |