

REPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE
MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA
RECHERCHE SCIENTIFIQUE
ÉCOLE NATIONALE POLYTECHNIQUE



Département Génie Industriel

End Of Studies Project Thesis

For the attainment of the degree of State Engineer in Industrial Engineering

Specialization: Data Science & Artificial Intelligence

**An Interactive Data-Driven Assistant for Automated Petrophysical
Rock Typing**

Ali MOKRANI

Publicly Presented & Defended on (07/07/2025)

Jury Composition:

President:	Dr. Iskander ZOUAGHI	MCA	ENP
Examiner:	Dr. Oussama ARKI	MCA	ENP
Supervisors:	Dr. Imene BARECHE	MA	ENP
	Mr. Mohamed Yacine SAHAR	Senior Petrophysicist	SLB

REPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE
MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA
RECHERCHE SCIENTIFIQUE
ÉCOLE NATIONALE POLYTECHNIQUE



Département Génie Industriel

End Of Studies Project Thesis

For the attainment of the degree of State Engineer in Industrial Engineering

Specialization: Data Science & Artificial Intelligence

**An Interactive Data-Driven Assistant for Automated Petrophysical
Rock Typing**

Ali MOKRANI

Publicly Presented & Defended on (07/07/2025)

Jury Composition:

President:	Dr. Iskander ZOUAGHI	MCA	ENP
Examiner:	Dr. Oussama ARKI	MCA	ENP
Supervisors:	Dr. Imene BARECHE	MA	ENP
	Mr. Mohamed Yacine SAHAR	Senior Petrophysicist	SLB

REPUBLIQUE ALGÉRIENNE DÉMOCRATIQUE ET POPULAIRE
MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR ET DE LA
RECHERCHE SCIENTIFIQUE
ÉCOLE NATIONALE POLYTECHNIQUE



Département Génie Industriel

Mémoire de Projet de Fin d'Études

Pour l'obtention du diplôme d'Ingénieur d'État en Génie Industriel

Option : Data Science & Intelligence Artificielle

Développement d'un Assistant Interactif Pour La Classification
Automatisée Des Roches Pétrophysiques

Ali MOKRANI

Présenté et soutenu publiquement le (07/07/2025)

Composition du Jury:

Président:	Dr. Iskander ZOUAGHI	MCA	ENP
Examineur:	Dr. Oussama ARKI	MCA	ENP
Promoteurs:	Dr. Imene BARECHE	MA	ENP
	Mr. Mohamed Yacine SAHAR	Pétrophysicien	SLB

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

In The Name of Allah, The Most Gracious, The Most Merciful

الملخص:

يُعد التصنيف البتروفيزيائي للصخور (PRT) أمراً بالغ الأهمية لتحديد خصائص خزانات النفط، إلا أنه يعتمد تقليدياً على سير عمل يدوي وذاتي، مما يحد من قابليته للتوسع. وعلى الرغم من أن طريقة وحدة التدفق الهيدروليكي (HFU) تُوفّر إطاراً قوياً، فإن تطبيقها العملي ظل محدوداً. تُقدّم هذه الأطروحة مساعداً تفاعلياً يعمل على تطبيق آلي لمنهجية HFU من خلال استخدام خوارزمية (RDP) لتقسيم مخططات Lorenz، وتوظيف تقنيات التعلم الآلي لتصنيفها. ومن أبرز الميزات نظام محسّن يعتمد على وجود خبير في الحلقة، (expert-in-the-loop)، مما يُتيح إجراء تعديلات متكررة مدعومة بمقاييس كمية. كما تسهم هذه الأداة في ربط نتائج تصنيف HFU بالطرق التقليدية.

الكلمات المفتاحية: التصنيف البتروفيزيائي للصخور، الذكاء الاصطناعي، التعلم الآلي، خصائص خزانات النفط.

Résumé

La classification pétrophysique des roches (PRT) est cruciale pour la caractérisation des réservoirs, mais repose souvent sur des méthodes manuelles subjectives. Bien que robuste, la méthode des unités de flux hydrauliques (HFU) est peu adoptée en pratique, faute d'implémentation efficace. Cette thèse propose un assistant interactif automatisant la méthodologie HFU. L'algorithme de Ramer-Douglas-Peucker segmente les diagrammes de Lorenz modifiés (SMLP), tandis que l'apprentissage automatique classe les segments en types de roches. Un système d'affinage interactif permet aux experts d'ajuster les classifications à l'aide de mesures quantitatives. Les types de roches sont également reliés aux méthodes traditionnelles. Validé sur les datasets de Gulfaks et Poseidon, l'outil final est un module web combinant automatisation et personnalisation, offrant une solution évolutive et fiable pour la PRT.

Mots-clés : Classification pétrophysique des roches, Clustering, Apprentissage Automatique, Unité de Flux Hydraulique, Diagramme de Lorenz, Segmentation, Assistant interactif, Caractérisation du réservoir.

Abstract

Petrophysical Rock Typing (PRT) is vital for reservoir characterization, yet traditional methods rely on subjective interpretation or complex graphical workflows. The Hydraulic Flow Unit (HFU) method, though conceptually strong, lacks practical adoption due to implementation challenges. This thesis offers a fully automated, reproducible HFU workflow. It uses the Ramer-Douglas-Peucker algorithm to segment the Stratigraphic Modified Lorenz Plot (SMLP) and applies machine learning to classify segments into rock types. A key contribution is an expert-in-the-loop framework that enables iterative refinement using data-driven metrics. Rock types are further characterized with Pore Throat Radius Indicator boundaries to enhance interpretability. The approach was validated on the Gulfaks and Poseidon datasets and implemented as a web-based module combining automation with expert control. It supports both rapid default deployment and advanced customization, offering a scalable, consistent tool for reservoir studies.

Keywords: Petrophysical Rock Typing, Clustering, Machine Learning, Hydraulic Flow Unit, Super Lorenz Plot, segmentation, Interactive Assistant, Reservoir Characterization.

Acknowledgments

First and foremost, all praise is due to God The Almighty, for granting me the strength, patience, and guidance throughout this journey.

*I would like to express my profound gratitude to **Mr. Zouaghi**, whose support was instrumental in making this journey a reality. I truly owe this opportunity to him.*

*To **Mr. Sahar**, my supervisor within SLB, thank you for taking me under your wing and for the invaluable guidance and trust you extended throughout my time at the company. My sincere thanks also go to all the SLB employees who offered their support and expertise, especially **Ms. Chakkai** and **Ms. Hadjari**, whose kindness and assistance greatly enriched this experience.*

*A very special thank you to **Ms. Bareche**, my supervisor at ENP. Her unwavering dedication, meticulous attention to detail, and continuous encouragement have had a lasting impact on both this thesis and my personal growth. Her commitment to excellence and her genuine care made working with her a privilege.*

*I also wish to thank **Mr. Arki**, my examiner, who has accompanied and supported us over the past three years. His insights and presence throughout our academic journey have been deeply appreciated.*

To all the professors and teaching staff of ENP, especially to those in the Industrial Engineering Department, thank you for sharing your knowledge, experience, and for guiding us over the past five years.

Finally, I extend my sincere appreciation to everyone who contributed in any way to the realization of this thesis. Your support, whether big or small, has been appreciated.

Dedication

“To the cold showers on deep winter nights, preparing for colder realities... To the silent battles, where chaos shaped calm, and pain forged purpose... And to the journey itself, brutal, unseen, and unforgettable, for making the story worth telling.”

Contents

List of Tables

List of Figures

List of Algorithms

Acronyms

General Introduction	19
1 Context and Problem Statement	23
1.1 Introduction	23
1.2 Field Presentation	23
1.2.1 Hydrocarbon Industry	23
1.2.2 Global Oilfield Market	25
1.2.3 Oilfield Services Market	25
1.3 SLB Presentation	26
1.3.1 SLB Ltd	27
1.3.2 SLB Ltd. Activities	27
1.3.3 SLB Hierarchical Structure	28
1.3.4 SLB Values	29
1.3.5 SLB Operational Divisions	30
1.3.6 SLB Ltd. Organization	31

1.4	SLB NAF GeoUnit Organization	32
1.4.1	SLB Algeria	34
1.4.2	Digital & Integration Division	34
1.5	Exploration and Production Workflow and the Significance of Rock Typing	35
1.5.1	Exploration and Production Workflow	35
1.5.2	Subsurface Characterization: A Deeper Dive into Appraisal and Development	35
1.5.3	Petrophysical Evaluation: From Raw Measurements to Interpreted Rock Properties	37
1.5.4	Strategic Impact of Petrophysical Rock Typing	39
1.6	Problem Statement	40
1.6.1	Subjectivity in Traditional PRT methods	40
1.6.2	Complexity of Hydraulic Flow Unit Method	40
1.7	Objectives & Scope	41
1.8	Conclusion	41
2	Theoretical Background and Literature Review	43
2.1	Introduction	43
2.2	Fundamentals of Reservoir Petrophysics	43
2.2.1	Data Acquisition in Petrophysics	44
2.2.2	Bridging to Petrophysical Rock Typing (PRT)	45
2.2.3	Key Reservoir Rock and Fluid Properties	46
2.3	Traditional Petrophysical Rock Typing Methodologies	52
2.3.1	Foundational Concepts: From Pore Geometry to Rock Classification	52
2.3.2	Empirical Methods Based on Pore Throat Radius Indicators (PTRi)	54
2.3.3	Deterministic Methods Derived from Fluid Flow Principles	55

2.3.4	Rock Fabric Based Methods for Carbonates	56
2.3.5	Hydraulic Flow Unit	57
2.3.6	Challenges and Limitations of Traditional Methods . . .	58
2.4	Introduction to Artificial Intelligence and Machine Learning . .	59
2.4.1	Artificial Intelligence (AI): Overview and Geoscientific Relevance	60
2.4.2	Machine Learning (ML): Core Concepts	61
2.4.3	Machine Learning Project Workflow	62
2.4.4	Types of Machine Learning Algorithms	63
2.5	Challenges and Limitations of Machine Learning	66
2.6	Literature Review: Machine Learning Applications in Rock Typing	66
2.6.1	Early Statistical and Unsupervised Clustering	67
2.6.2	Integrated and Semi-Supervised Methodologies	67
2.6.3	Supervised Learning for Field-Scale Prediction	67
2.6.4	Rock Typing from Dynamic Data (Relative Permeability)	68
2.7	Comparative Analysis of Rock Typing Methodologies	70
2.8	Conclusion	70
3	Methodology	73
3.1	Introduction	73
3.2	Foundational Principles: The Hydraulic Flow Unit (HFU) Method	74
3.2.1	Core Concepts	74
3.2.2	Graphical HFU Workflow: A Step-by-Step Guide	75
3.2.3	Scaling the Methodology: The Multi-Well Approach . .	79
3.3	Automated Rock Typing Engine: Digital Implementation	82
3.3.1	Challenge of Automating the Point-Sorted Approximation	83
3.3.2	Conclusion of the Exploratory Phase: A Necessary Pivot	84
3.3.3	Automated Workflow: Step-by-Step Implementation . .	84

3.4	Framework for Guided Iterative Refinement and Validation . . .	93
3.4.1	Lack of Expert Control in Standard Clustering Challenge	93
3.4.2	Solution Part 1: Selecting Algorithms for Stable Refinement	94
3.4.3	Solution Part 2: A Quantitative Framework for Guided Subdivision	94
3.5	Bridging HFU and PTRi Methods: A Framework for Validation and Communication	96
3.6	Conclusion	98
4	Implementation, Evaluation & Deployment	99
4.1	Introduction	99
4.2	Experimental Setup	100
4.2.1	Gulfaks Single-Well Dataset	100
4.2.2	Poseidon Multi-Well Dataset	101
4.2.3	Technical Implementation Environment	101
4.3	Systematic Engine Development and Validation	102
4.3.1	Establishing the Benchmark and Segmenting the SMLP	103
4.3.2	Core Methodological Challenge: Automating Rock Type Classification	109
4.3.3	Question 1: Engineering Features for Robust Clustering	109
4.3.4	Question 2: Determining the Optimal Baseline Number of Rock Types (k)	117
4.3.5	Question 3: Selecting the Optimal Clustering Algorithm	119
4.4	Guided Iterative Refinement Framework in Action	123
4.5	Final Parameter Tuning: Automated Epsilon Selection	125
4.6	Assisted Rock Typing Module: Design and Integration	126
4.6.1	Objectives, Functionality, and System Architecture . . .	126
4.6.2	Modularity: A Key Design Principle	126

4.6.3	Interactive User Interface (UI): A Multi-Page Workflow .	127
4.6.4	Integration and Deployment Strategy	128
4.7	Conclusion	129
Conclusion		130
Bibliography		134
Appendix		140

Confidential