Global Scientific and Academic Research Journal of Economics, Business and Management
ISSN: 2583-5645 (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journals-gsarjebm-home/

A Knowledge-Based Decision Support Framework for the Optimisation of Determining Petroleum Exploration

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Article History

Received: 11/01/2023
Accepted: 15/01/2023
Published: 17/01/2023

Vol – 2 Issue – 1

PP: -22-27

Abstract

Risks and uncertainties affecting petroleum exploration are associated with petroleum geology, geophysics, geochemistry, and other methods that can cause high costs losses to the whole project. For this reason, the use of systematic decision-support methods for petroleum exploration is an essential tool for managerial decision-making. However, fewer scholars or experts have developed decision-making methods and support systems for petroleum exploration risk management. Most of the research only relies on the update of detection technology. This paper aims to present the innovation of works that mainly provide hybrid thinking to develop a decision-support framework based on knowledge-based for determining precise decision-making of petroleum exploration. The results of this study are introducing a cost-effective "geochemical method" to improve the accuracy of petroleum and source interpretation through oil source comparison technology. Also, it is combined with the 5M decision support methods (include Material, Method, Manipulation, Modeling, Mining decision) to improve the benefit of interpretation and establish a useful decision model for petroleum exploration in oil fields.

Keywords: *Petroleum Exploration; Geochemical Analysis; Knowledge-Based Decision Support System (KBDSS); Petroleum Exploration Decision Support Systems (PEDSS)*

1. Introduction

For the survival and development of a nation, petroleum is an important energy source and plays an indispensable role in realizing economic and social development. With the increasing complexity of the petroleum exploration environment and petroleum demanding, it is essential to obtain the drilling rates and success rates by lower economic costs. Risks and uncertainties affecting petroleum exploration are associated with petroleum geology, geophysics, geochemistry, and other methods resulting in enormous costs losses to the whole project. Thus, it is imperative to build strategic thinking for petroleum exploration by strengthening the management of petroleum exploration and integrating exploration and evaluation techniques into petroleum production management decisions.

In terms of petroleum exploration technology, oil-gas are fluid minerals that accumulate into a reservoir only after a certain distance of migration from the origin area (Tissot & Welte, 1984). Oil and source correlation is an important research technique in the petroleum exploration process because the distribution of oil is directly controlled by the oil source (Cheng et al., 1995). Usually, the petroleum reservoir and origin areas are not in the same place or the same stratum, or the same basin or sag. Sometimes, the petroleum in the same reservoir is from different oil-gas sources (Lu et al., 2008). Thus, to accurately understand the source of oil and gas, it is necessary to compare oil sources and determine the relationship between them to provide a scientific basis for guiding exploration and development decisions. Petroleum exploration usually encounters difficulties in making precise decisions about risk judgment with the explosive amount of vague information and technological knowledge (e.g., petroleum geology, geophysics, geochemistry, and other factors data) because it is challenging for them to transfer these data into practical knowledge. Thus, knowledge-based tools and processes like decision support systems (DSS) are needed to assist them in making evidence-based and precise decisions.

In this study, to overcome the above-mentioned related problems, including reducing costs and improving the accuracy of interpretation, we use an innovative approach to establish a research schema on decision-making models for petroleum exploration decision support systems (PEDSS). More specifically, we analyze the most influential decision-

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making models and support systems for PEDSS, evaluate the primary areas of current research (Fagundes et al., 2020), and offer a knowledge-based decision support systems (KBDSS) for implementing in the field. To this end, this project introduced a cost-effective "geochemical method" to improve the accuracy of petroleum and source interpretation through oil source comparison technology. Also.it is combined with the 5M decision method proposed by this research, to improve the benefit of interpretation and establish a useful decision model for petroleum exploration in oil fields. Overall, this study method uses a hybrid thinking combination of quantitative and qualitative evaluation techniques, which can reduce costs, increase the success rate, and have strong operability. It has important theoretical and practical significance for exploration decision management.

2. Literature mapping methodology

In terms of the functional theory and methodology of the Decision Support System (DSS) that provides sufficient autonomy to support complex decision-making and offer problem-solving (Anzaldi et al., 2014). Regarding the definition of a DSS, researchers have described this term from various perspectives (Zhai et al., 2020). Such as “decision support system is a computer-based support system for decision-makers who deal with semi-structured problems to improve the quality of decisions," “a human-computer system which can collect, process, and provide information based on computers," “a specific class of computerized information system, enabling to manage decision-making activities” (Jones 1980; Sheng and Zhang 2009; Yazdani et al. 2017; Zhai et al., 2020).

Over the last two decades, DSS research has referred to including several additional concepts and viewpoints and has developed many methods and models. To date, DSS has tended to support the analytical–deductive and inductive–consensual styles, which involve technical perspective and hybrid concepts. Most DSS relies on two main approaches: the Model-Driven DSS and the Knowledge-Driven DSS, based on theories and techniques from artificial intelligence and expert systems, provided smarter support for the decision-maker (Anzaldi et al., 2014; Courtney, 2001). The latter began evolving into the concept of organizational knowledge management. Now, it is evolving into a broader concept or idea of DSS serving as knowledge sources or connecting decision-makers with diverse information.

In general, the Model-Driven DSS approach is focused on analyzing data stored in databases by using algorithms functionalities, On-Line Analytical Processing (OLAP), or quantitative models that permit to extract patterns (Anzaldi et al., 2014; Sandeep and Rakesh, 2011). Significantly, The Model-Driven DSS is highly based on tacit domain knowledge and relies on a sequence of predefined instructions for responding to specific events. The Knowledge-Driven DSS approach is using a knowledge base for reasoning about a problem and to find a solution by using an inference engine. The inference engine is the algorithms or rules that use specific knowledge to draw proper conclusions. Usually, it applies data mining algorithms or Knowledge Discovery in Databases processes (KDD) (Anzaldi et al., 2014; Serrat-Capdevila et al., 2011).

Nowadays, Knowledge-Based Decision Support Systems (KBDSS) provide comprehensive mass applications, in which are systems or define processes designed to ensure more precise decision-making by effectively using timely and appropriate data, information, and knowledge management for the convergence industry (Wang et al., 2022). Besides, KBDSS integrates traditional DSS with the advances of the Expert System. Traditionally DSS constitutes data management and modeling as well as decision methodology and display of numerical data, while the advances of Expert System embrace symbolic reasoning and explanation capabilities (Klein and Methlie, 1995). Three critical approaches for developing on current KBDSS providing an interpretation of knowledge are Rule-based reasoning (RBR), Case-based reasoning (CBR), and hybrid reasoning (a combination of RBR and CBR).

In this study, considering the above conceptions and definitions, the petroleum exploration decision support systems (PEDSS) can be defined as a hybrid reasoning system that combines the Model-Driven DSS approach and the Knowledge-Driven DSS approach into KBDSS. KBDSS which extracts the experts’ analysis experience and process becomes CBR and RBR, aiming at providing petroleum exploration with a series of processes or procedure guides for supporting their analysis decision-making under different conditions and data sources. One of the most representative functions of PEDSS is that it does not give direct instructions or commands to the analyst of petroleum exploration but for referencing direction. Thus, PEDSS is not only able to provide a list of guiding options for ongoing analysis but also may help decision-makers to achieve better performances in processing tasks.

3. Method

3.1. Framework of PEKDSS

In this study, we present a hybrid reasoning approach that uses case-based reasoning and rule-based reasoning to target multiple disorder problems. The purpose is aiming at providing decisional tools that can enhance our issues by integrating all defined decisional flows and processes into different parts of the petroleum exploration analysis chain. Through the understanding of these transversal processes, petroleum exploration process management can be viewed as a correlation of different specific parts to reach the holistic decisional paradigm. For different stages and procedures, which could adopt appropriate analysis methods or models until the final resolution decision is obtained. To create this decisional model, these tools need to understand all kinds of operational information involved in the exploration decision process and technological knowledge process. The PEKDD is responsible for integrating all operational understanding and analysis knowledge, providing wisdom to advance towards gaining a precise exploration result.

To the end, this project applies the 5M decision process,

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which includes five procedures such as Material, Method, Manipulation, Modeling, Mining decision (show as Fig. 1). This framework of 5M-KBDSS for petroleum exploration is separated into two parts: including exploration decision process and technological knowledge process. The technological knowledge process extracts the knowledge of oil-gas analysis, which can build a case-based reasoning program, and it is from the perspective of geochemistry and geology through the systematic comparison and analysis of the source rock as well as oil-gas characteristics of the research area. Their purpose is aimed at finding commonalities, analyzing the differences between them, then establishing prediction models by the types of natural gas sources, and establishing primary controlling factors model for the oil-gas accumulation zone of exploration potential region. As for the exploration decision process, which is to classify and finalize the petroleum analysis process for establishing a judgment procedure on analysis and decision-making, and become a rule-based reasoning program for adopting different decision-making models and using different case experiences at different stages, and finally, obtain better exploration decision making.

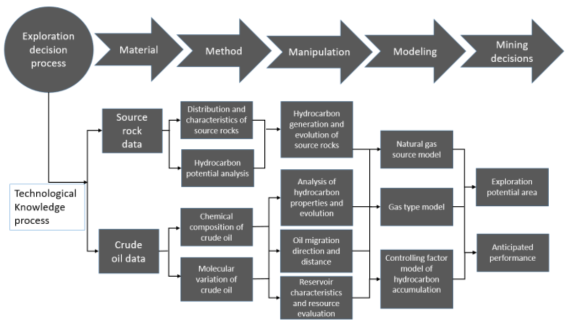

Fig. 1 A framework of 5M knowledge-based decision support systems for petroleum exploration

3.2. The knowledge process of PEKDSS

In the material stage, organic geochemical methods are used to qualitatively and quantitatively analyze the organic matter abundance of source rocks in the study area, then identify the types of organic matter, and evaluate the hydrocarbon generation potential of different lithologic source rocks. By comprehensively using organic petrology and biomarker geochemical parameters, the thermal evolution of organic matter will be reconstructed. The geochemical characteristics of significant source rocks and their possible distribution characteristics in the exploration areas will be analyzed.

The source rock in the study area is terrestrial originated (Liu et al., 2016; Shi et al., 2020). The indicators of source rock abundance evaluation include residual organic carbon (TOC, %), chloroform asphalt "A" (EOM, %), total hydrocarbon (HC, µg/g), and Hydrocarbon potential (S1+S2, mg/g) (Lu et al., 2008). The parent material types of specific source rock organic matter were evaluated by organic petrology and organic geochemistry methods of kerogen and soluble organic matter. The type of kerogen is determined by microscopic composition, elemental composition, and pyrolysis parameters. The composition of chloroform asphalt "A" group insoluble organic matter, chromatographic characteristics of saturated hydrocarbons, and biomarker compounds was used to determine their type characteristics. The maturity of the source rock is determined according to vitrinite reflectance (%) and biomarker compounds.

The hydrocarbon potential of source rocks was quantitatively evaluated. The hydrocarbon generation capacity of the source rock is an essential indicator for the quantitative evaluation of the hydrocarbon generation capacity of the source rock (Ayyildiz, 2013). It is the amount of hydrocarbon generation of the source rock per unit area. The main parameters, such as the thickness of the source rock, the organic carbon content, and the oil-gas yield of the organic matter are used to calculate the hydrocarbon generation capacity of the source rock per unit area.

$$Q = \rho \times H \times S \times C_{org} \times K \times D_{org}$$

In the formula:
Q—hydrocarbon generation amount of source rock;
H—the thickness of the source rock;
ρ—the rock density of the source rock;
S—distribution area of source rock;

Corg—remaining organic carbon content of source rock (%);
Dorg—hydrocarbon production rate of organic carbon (kg / t);
K—the recovery factor of organic matter;

For the method stage, the characteristics of the macroscopic chemical composition, microscopic molecular composition, and carbon isotope composition of oil-gas are systematically analyzed in the study area to determine the origin, source, and maturity distribution characteristics of different oil and gas. Based on the above data, we determined the distribution range and exploration potential of significant source rocks, then determine the comparability of crude oil and source rocks according to the characteristics of biomarker compounds and their evolution rules, and clarify the oil-gas source horizons and directions. The normal paraffin and biomarkers in crude oil are used to determine their biogenic and environmental significance are shown in the following table (as Table 1).

Table 1 biogenic and environmental significance of common n-alkanes and non-ring biomarkers

Compound	Biogenesis	Depositional environment
nC_{15},nC_{17},nC_{19}	algae	Marine/lacustrine facies
nC_{15},nC_{17},nC_{19}	Myxococcus	Marine facies (Ordovician)
nC_{27},nC_{29},nC_{31}	higher plant	Terrestrial facies
nC_{23}~nC_{31}	Non-marine algae	Marine facies

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2-methyl docosane	bacteria	Hypersaline environment
2,6,19,15,19-pentamethyl eicosane	Archaea	Hypersaline environment
2,6,10-trimethyl-7- (3-methyl-butyl) dodecane	Chlorella	Hypersaline environment
Phycosan	Synechocystis	Lacustrine / brackish water
16-dimethyl-plexin	Synechocystis	Lacustrine / brackish water
Medium-chain long monomethyl alkane	Cyanobacteria	Marine facies

In the stage of manipulation, the hydrocarbon generation properties and evolution of source rocks were analyzed. The evolution, migration direction, and distance of oil gas are analyzed to evaluate the characteristics and resources of oil-gas reservoirs. The molecular composition characteristics of nitrogenous compounds in crude oil were systematically analyzed, focusing on the change characteristics of the total concentration of carbazole-benzo, carbazole-compounds in various genetic types of crude oil, and the variation characteristics of isomers in reservoir space. Combined with the changing laws of crude oil maturity and other molecular composition parameters, the characteristics of oil-gas migration and accumulation are comprehensively studied.

In the modeling stage, it is to quantitative or semi-definite evaluation for oil-gas properties of source rocks. The distribution and composition of biomarkers were analyzed emphatically. Understanding the geochemical characteristics of oil-gas sources in the oil-generating system will lay a foundation for determining oil-gas sources. The source or types of natural gas and the main control factors of hydrocarbon accumulation were analyzed. Combined with the hydrocarbon source rock evaluation results, calculation of the amount of gas and evaluation of the number of resources was carried out.

Finally, the interpretation results of the above stages can provide the evaluation data for the determination of oil-gas exploration areas and the expected exploration benefits, and serve as the decision basis for exploration.

4. Evaluation and Results

4.1. Study area

Qaidam Basin (show as Fig.2) is China's highest and most evaporative inland basin situated in the border area of the provinces of Qinghai, Gansu, and the autonomous region of Xinjiang. The basin lies in a crescent valley surrounded by plateaus and the mountains of Altyn-Tagh, Qilian, and Kunlun. Stretching 800 kilometers from the east to the west and up to 350 kilometers from the north to the south, the basin covers 250,000 square kilometers. At an altitude of 2,600~3,000 meters, the basin slopes down from northwest to southeast, with annual evaporation up to 3,700mm. Qaidam Basin is divided into three blocks by its substrate, namely, Mangya depression, northern-margin fault block zone, and the new Sandhu (three lakes: Taijnar Lake, Suli Lake, and Dabsan Lake) depression.

The Qaidam Basin is one of the four major gas-producing regions in China. Abundant oil and gas resources are entrapped in strata ranging from the eldest Sinian Suberathem to the youngest quaternary system. After more than five decades of development, Qaidam's oil and gas development plays an irreplaceable role in promoting social and economic development on the Qinghai-Tibet Plateau.

It is also the main gas supply region for the West-East Natural Gas Transmission Project and Gansu, Qinghai, and Tibet regions. It is the primary source region of the national energy strategy. With the country's increasing demand for energy and the adjustment of energy structure, the demand for clean energy, such as natural gas also increases. The problem for today is the increased exploration costs, low accuracy of oil source assessment, and cost control issues because of the complicated geological exploration environment, increasing exploration cost and time-consuming exploration issues,

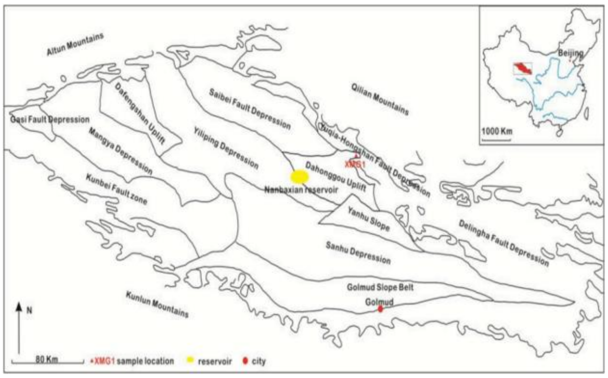

Fig.2 Sketch map of the target area - Qaidam Basin

4.2. Results

First of all, through the successful implementation of the knowledge process of PEKDSS, the resource potential was clarified, and the confidence of the bedrock exploration in the Altun Mountains was confirmed. In 2015, the DP 17 well was deployed. Through the gas test of the bedrock 4338-4351m section, the daily gas production was 51459m3. In the same year, the newly forecasted gas-bearing area was 8.9 km2, and the predicted geological reserves were 22.856 billion cubic meters. In 2016, wells DP 17-1 and DP 17-2 were deployed around the area, and they all achieved excellent results. At present, the cumulative gas production in the area is nearly 2 million cubic meters, showing a good prospect for exploration.

Secondly, N9 and N10 have been deployed in the Niudong area successively, and the effect is good. Well of N10 has obtained a daily output of 20,000 m3 high-yield industrial gas flow in Jurassic and E32 strata. On the one hand, it has expanded the Jurassic gas-bearing area; on the other hand, a breakthrough in the third series was achieved. The N9 well obtained industrial gas flow for the first time in the stratum

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under the ND fault, which expanded the exploration field and exploration stratum.

Finally, the Niuzhong slope is expected to achieve new breakthroughs. The gas-bearing characteristics of the NX1 well bedrock are similar to those of the DP1 well area. At present, conventional gas testing shows industrial-level gas flow production, and breakthroughs are expected to be achieved. Through the development of this project, the prospect of exploration of the gas-bearing scale of 100 billion cubic meters has been displayed in the eastern section of the Aljin Mountains, which is expected to become another significant breakthrough in the DP1 bedrock gas reservoir with enormous economic and social benefits.

5. Conclusion

This study aims to present the evolution of works mainly to solve the risk and uncertainties factors affecting petroleum exploration. Effectively avoiding planning decision risks, improving exploration decision-making efficiency, and finding low-cost and high-efficiency exploration targets are important issues for oil and gas companies should be solved. Oil and gas geochemical exploration is an important link in oil and gas exploration. It is currently a hot topic to use oil and gas geochemical technology to evaluate oil and gas resources through oil source comparisons and find favorable exploration areas. However, with the deepening of oil and gas exploration and the complexity of geology, it is necessary to combine technology with advanced management concepts to obtain a more successful drilling encounter rate.

In this study, we have provided hybrid thinking to develop a decision support framework based on a knowledge-based extract from experts' experiences and combined a rule-based process for determining precise decision-making of petroleum exploration. This framework of 5M-KBDSS for petroleum exploration (PEKDD) uses case-based reasoning and rule-based reasoning methods to target multiple disorder problems. Besides, we have presented the implementation of results on the study area of the Qaidam Basin and made several successful efforts.

From a technical point of view, we propose a new integrated geochemical interpretation method, which is the knowledge and technology discovery process. The project systematically evaluated the hydrocarbon generation potential of the source rocks in the study area by carrying out many source rock and oil-gas geochemical experiments and clarified its oil-gas generation characteristics. Through the comparative research method of crude oil geochemistry, a typical coal-derived oil reservoir in the Jurassic reservoir was discovered for the first time. Through natural gas geochemical research, it was clarified that the type of natural gas was high-to-mature coal-type gas, which clarified the source and storage relationship, and laid the foundation for the development of coal-based gas exploration ideas in the later period. Combined with comprehensive geological research such as reservoir oil-bearing characteristics, oil-gas migration, and experimental analysis of fluid inclusions, the accumulation period and main controlling elements were clarified. The oil-gas resources were evaluated at more than 1.7 billion tons indicating that the area has vast exploration potential.

From the aspect of decision-making management, this study also proposes new thinking of strategy management by the PEKDD framework, which will be structured and programmatic the analysis technology and interpretation procedure of petroleum exploration. Significantly, the PEKDD method has dramatically improved the benefit of decision-making on petroleum exploration. This method is not only conducive to scientific decision-making of oil-gas exploration, but also is reduced human, material, and economic costs. Due to the flexibility and diversity of decision-making, different index systems are used for oil source comparison and oil-gas exploration evaluation, so that exploration can obtain a higher encounter rate, thereby bringing considerable economic benefits.

Through the analysis of source rock and crude oil data, the relationship between oil sources is analyzed by using the geochemical method and PEKDD framework of the management method. By establishing the natural gas source, type, and primary control factor model of gas accumulation, it is pointed out that the study area has a large-scale exploration prospect, which is expected to be a significant breakthrough in the next oil gas and will bring good economic and social benefits. The combination of the technical methods into the EKDD framework is economical, flexible, and has a good application effect.

ACKNOWLEDGEMENT

This work was supported by the State Key Laboratory of Organic Geochemistry, GIGCAS (Grant No. SKLOG202014), Science and Technology Program of Maoming, China (No.2019396), and Ph.D. Programs Foundation of GUPT (No.519017). The author is also grateful for the research grants given to Ruei-Yuan Wang from GDUPT Talents Recruitment, Peoples R China under Grant No.2019rc098, and Academic Affairs in GDUPT for Goal Problem-Oriented Teaching Innovation and Practice Project Grant No.701-234660.

REFERENCES

1. Anzaldi, G., Rubion, E., Corchero, A., Sanfeliu, R., Domingo, X., Pijuan, J., and Tersa, F. P., (2014). Towards an Enhanced Knowledge-Based Decision Support System (DSS) for Integrated Water Resource Management (IWRM), Procedia Engineering, 89:1097-1104.
2. Ayyildiz, T., (2013). Source Rock Potential and Oil to Source Rock Correlation of the Upper Cretaceous (Campanian-Maastrichtian)-Lower Paleocene Units in the Malatya Basin, East Anatolia, Turkey. Liquid Fuels Technology, 31(13):1335-1345.
3. Cheng, K.M., Wang, T.G., and Zhong, N.N., (1995). Geochemistry of Source Rocks. Petroleum Industry Press, Beijing, pp. 17-40 (in Chinese).
4. Courtney, J. F., (2001). Decision making and knowledge management in inquiring organizations: toward a new decision-making paradigm for DSS,

*Corresponding Author: Ruei-Yuan Wang.

Decision Support Systems, 31: 17–38.

5. Fagundes, M.V.C, Teles, E.O., Melo, S. A.B., and Freires, F. G. M., (2020). Decision-making models and support systems for supply chain risk: literature mapping and future research agenda, European Research on Management and Business Economics, 26:63–70.
6. Jones, J.W., (1980). Decision support systems -An organizational perspective -KEEN, PG, MORTON. MSS. Adm. Sci. Q. 25 (2), 376–382. https://doi.org/10.2307/2392463.
7. Klein, M., and Methlie, L., (1995). Knowledge-Based Decision Support Systems. Annual reports in Organic Synthesis, Elsevier 1997, pp 458.
8. Liu, C., Li, H., and Zhang, X., (2016). Geochemical Characteristics of the Paleogene and Neogene Saline Lacustrine Source Rocks in the Western Qaidam Basin, Northwestern China. Energy & Fuels, 30 (6):4537-4549.
9. Lu, S.F., Zhang, M., and Zhong, N.N., (2008). Petroleum Geochemistry. Petroleum Industry Press, Beijing (in Chinese).
10. Sandeep, K, and Rakesh, K., (2011). CLIPS-based decision support system for water distribution networks. J. Sci. Drinking Water Engineering and Science, 4:37-50.
11. Serrat-Capdevila, A., Valdes, J.B., and Gupta, H.V., (2011). Decision Support Systems in Water Resources Planning and Management: Stakeholder Participation and the Sustainable Path to Science-Based Decision Making. In: Jao C, editors. Efficient Decision Support Systems- Practice and Challenges from Current to Future. INTECH, 423-440.
12. Sheng, Y.K., and Zhang, S., (2009). Analysis of problems and trends of decision support systems development. In: 2009 International Conference on E-Business and Information System Security, pp.1216-1218.
13. Shi, Y., Xu, L., and Xing, L. T., (2020). Geochemical characteristics of crude oil in the continental saline lake basin: a case study of the Upper Part of the Lower Ganchaigou Formation in Yingxi, Qaidam Basin, China. Petroleum Science and Technology, 38(3):232-239.
14. Tissot, B.P., and Welte, D.H., (1984). Petroleum Formation and Occurrence. Springer-Verlag, New York.
15. Wang, R. Y. Lin, P.A., Chu, J.Y., Tao, Y.H. and Ling, H.C. (2022): A decision support system for Taiwan's forest resource management using Remote Sensing Big Data, Enterprise Information Systems, 2022, 16(8–9), 1312–1333. https://doi.org/10.1080/17517575.2021.188312
16. Yazdani, M., Zarate, P., Coulibaly, A., and Zavadskas, E.K., (2017). A group decision-making support system in logistics and supply chain management. Expert Syst. Appl. 88, 376–392. https://doi.org/10.1016/j.eswa.2017.07.014.
17. Zhai, Z., Martinez, J.F., Beltran, V., and Martinez, N. L., (2020). Decision support systems for agriculture 4.0: Survey and challenges, Computers and Electronics in Agriculture, 170:pp.105256

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