Original Research Article

Analysis on innovation of geological exploration technology in petroleum development process

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***Abstract*:** In recent years, with the booming of the petroleum industry and the continual reserve urgency of fossil fuels, petroleum exploration technology in China is required to be at a higher level. At present, with the improvement and development of computing technology and other technology, China's fossil fuel exploration technology have greatly improved; the oil field work has a stage improvement, petroleum exploration technology has also improved. Shaanxi Changqing Oilfield has also made remarkable progress and it is worth mentioning that the three main techniques: well logging exploration technology; drilling technology; and exploration technology, have made great progress on innovation through new technologies. However, it does not mean that the petroleum exploration technology has met the requirements of petroleum development. Petroleum exploration technology is insufficient and needs to be unremittingly combined with other techniques for its improvement and innovation. Based on this, this paper studies and analyzes the innovation of geological exploration technology in petroleum development process.

***Keywords*:** petroleum development; geological exploration technology; innovation;

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Introduction

The main purpose of intensive studies on various technologies of petroleum geological exploration technology lies in applying the new technology into practical activities—reducing costs, optimizing petroleum geological exploration results, and automating logging drilling monitoring. The development of modern society also makes the application of new technology and new equipment in petroleum geological exploration and drilling become the inevitable direction of development. This paper makes a simple analysis on several petroleum geological exploration technologies and their innovation and development. It concludes that in practice, it is necessary for technical personnel to combine actual oilfield situations to continuously optimize the technology, enhancing the efficiency of oil extraction and achieve good economic and social benefits.

Necessity for Technological Innovation

Petroleum resources play an increasingly important part in China's economic development, thus relative personnel have paid more attention to the oil industry development in petroleum exploration—made a lot of effort to technological research and innovation, and invested some economic support. At present, China's oil exploration technology has made

great progress and achievements. Petroleum exploration work in various regions of China has been carried out smoothly. Shaanxi Changqing Oilfield geological exploration work is also smooth. However, compared to other developed countries, China's petroleum exploitation work is still not perfect and the geological exploration technology level still requires improvement[1].

In addition, petroleum resources are necessary for China's economic development. With the gradual development in economy, the amount of required fossil fuel is gradually increasing. According to estimates, in order to meet China's social development, fossil fuel demand will reach 3.80 tons by 2020. If it fails to meet this demand, this will bring adverse effects to societal and economic developments. At present, although China's petroleum exploitation work has made certain progress and the exploration technology level has improved, its oil reserves are not abundant and geological exploration work has not made practical progress. Therefore, it is urgent to strengthen China's current oil exploitation work, improve the exploration technology, and strive to achieve substantial breakthroughs via continuous innovation, so as to improve the status of China's petroleum geological exploration technology.

Key technical knowledge process of petroleum exploration enterprises

Technical knowledge process consists of knowledge accumulation, knowledge sharing, knowledge exchange, and a series of other flows, which are formed from core technology resources owned by enterprises (technological knowledge) among the enterprise's knowledge stagnation points, so as to ensure the enterprise generates value. Petroleum exploitation enterprise technology knowledge can be divided into two types: 1) explicit knowledge obtained from external enterprises and accumulated within internal enterprises, existing in the enterprise information flow, such as geological exploration steps, technical means of geophysical prospecting, drilling and other explicit knowledge; 2) implicit knowledge, which exists in the mind of organization members or experts and can't be expressed by text (such as experience in petroleum exploration projects, *etc*.). Petroleum exploration enterprises can master relevant explicit technical knowledge by constructing knowledge sharing platforms—sharing mechanisms, learning organizations, and other ways. Implicit technical knowledge can be changed into explicit ones by using codes through data mining, collating and summarizing, or changed into implicit knowledge easily grasped via social means, stored in the enterprise's knowledge base for members of the organization[2].

Oil flow and transformation mode of key petroleum exploration technical knowledge, knowledge obtained from the external and related technical knowledge of enterprises have also constantly increased the knowledge base of petroleum exploration technology. At the same time, personal technology knowledge of organization members and technology knowledge of enterprises, and the inter-converting of explicit technical knowledge and implicit technical knowledge into each other, have made petroleum exploration technology knowledge more perfect and systematic. Knowledge acquisition, integration, sharing, innovation, and application have made enterprises' knowledge on a rising trend, gradually increasing and helped form a knowledge process about the technological innovation of petroleum exploration for internal use of enterprise, serving enterprise petroleum exploration technology innovation. Key technology knowledge process of petroleum exploration enterprise is shown in *Figure 1*.

Petroleum geological exploration technology classifications

GIS technology

GIS technology in petroleum exploration is used in two aspects—the use of spatial data and the visualization of oil exploration results. During oil exploration, a lot of graphic data and basic data can be accumulated, by utilizing GIS technology to implement data management and storage, it can supply flexible and complete information management

environment to the staff. Oracle database is often used to implement management and organization of petroleum exploration. Application of server (B/S)/browser operation mode, allows users to combine intuitive HTML interface, and allows the user to develop a database for petroleum exploration data access. GIS has relatively strong ability for spatial data analysis which is crucial for data processing, thus GIS database can compare different data obtained during oil exploration, to obtain meaningful data. For the visualization of oil exploration results, the key is to implement a combination of computer data and graphics based on GIS visualization system and publish the data through network technology, allowing decision making more convenient[3].

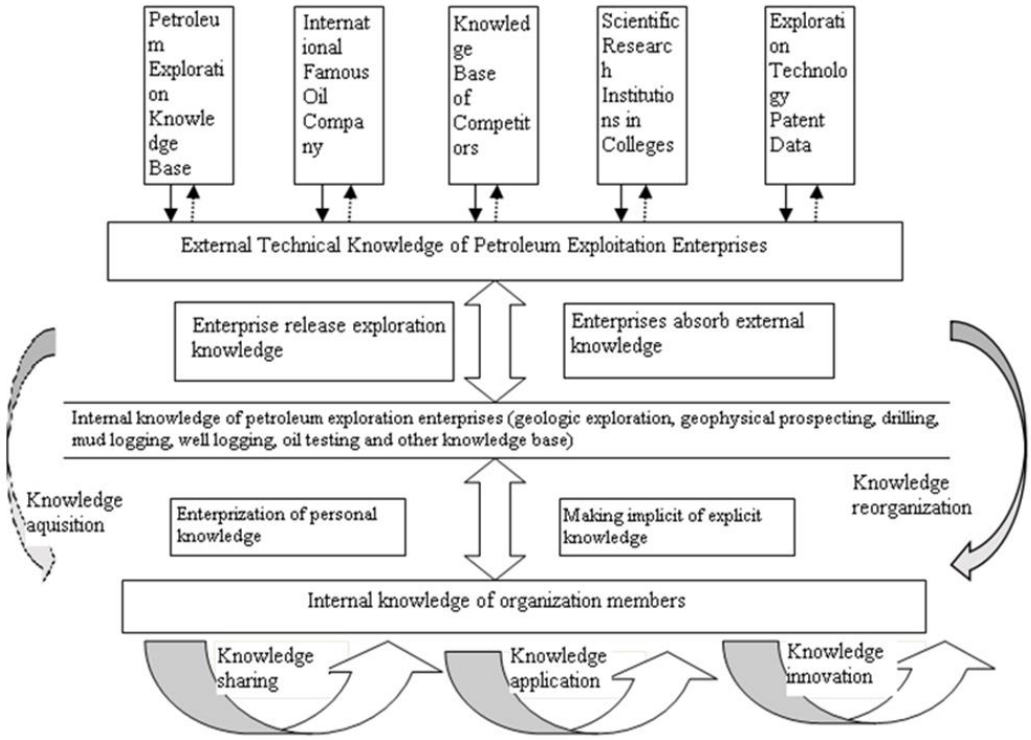

Figure 1. Flow chart of key technical knowledge of petroleum exploration enterprises

Well logging technology

For a long time, due to a technological disadvantage in the implementation of well logging, insufficient personnel and data limitations added with difficulty of the logging work also affected the quality of the assignments. With better technology, equipment quality has effectively improved; all logging instruments can intuitively visualize geological signals promoting data correctness and transmission ability. When the underground situation is complex, specific correct borehole information can be obtained from different performance devices.

In addition, because of the development of science and technology, logging equipment get better functions, such as nuclear magnetic resonance logging technology, casing well logging, logging while drilling technology and so on, which also saves time, providing more favorable conditions for logging works[4].

The application of virtual reality technology in petroleum exploration

Using virtual reality technology for petroleum geological exploration can improve the ability to identify exploration targets. This function can improve the efficiency and precision of exploration, and effectively reduce the chance of error in the exploration. Using the traditional method, plenty of practice for data collection and analysis is often needed;

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however, in the virtual reality technology system, only a few days is needed to analyze and visualize the data, making the data easily understood. This technique can also analyze the three layer model of reservoirs, allowing personnel to conveniently to apply these data, therefore, reducing work time thus improving work efficiency. By using virtual reality technology, data analysis can be done easily, reducing the chances for human error.

Petroleum geological exploration technology innovation strategies

The characteristic of petroleum exploration enterprise technological innovation

With the continuous extension of oil exploration, and the development of geographical related subject knowledge and information technology, the understanding of underground geological structures and its oil storage abilities have greatly increased. Oil exploration technology to a great extent, reduces the exploration cost, improves the efficiency of the exploration projects, and minimizes oil exploration industry's impact on the environment. The elements prompting oil exploration enterprise's technology innovation include: internal and external encouragement for innovation (incentives and innovation policy); internal and external technological innovation opportunity (external oil exploration technology development and internal exploration targets); and internal support system about technology innovation (technological innovation organization and enterprise innovation resources)[5]. Petroleum exploration enterprise's technological innovation drive elements structure is shown in *Figure 2*.

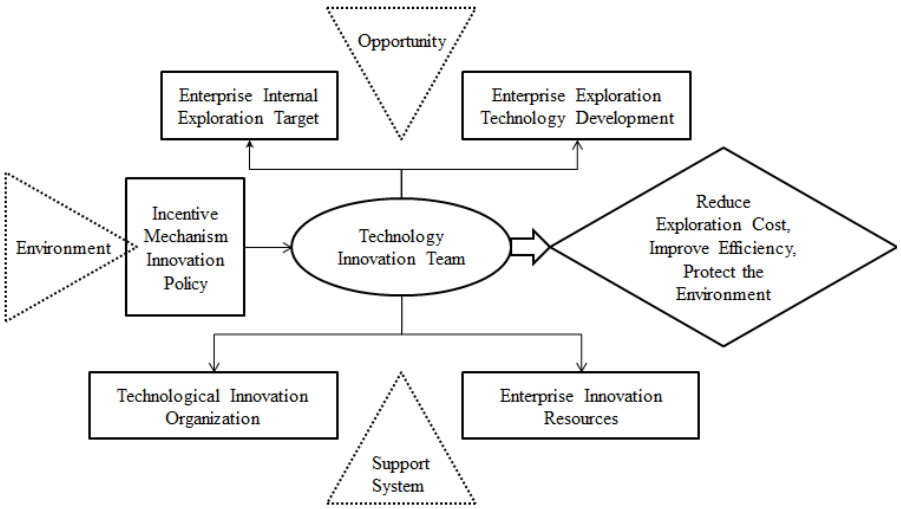

Figure 2. Technological innovation structure driving factors

Geophysical exploration technology innovation strategy

Geophysical exploration technology is one of the main technologies of petroleum geological exploration technology, which plays a key role in geological exploration[6]. Seismic reflection, digital seismic, and 3D seismic technology came along through constant innovation based off traditional geophysical exploration techniques.

The main application of geophysical exploration technology in petroleum exploration is to analyze and process data received by the equipment through creating a seismic wave in the exploration area, thus knowing the detail condition of petroleum in the target area. The development of 3D seismic technology, digital seismic technology, and reflection seismic technology greatly promoted the development of geophysical exploration. It enhances the accuracy of geophysical exploration, increases the stability of the technical performance, and made parameters accurate. Moreover, it effectively uses computer technology in geophysical exploration technology, providing higher resolution, accuracy,

and a more integrated technique. The progress of 3D seismic testing technology, reservoir seismic description technology, and 3D pre-stack depth migration technology effectively raised the accuracy of geophysical technology, while the application of high speed data and computer data processing technology greatly enhanced the effect of geophysical technology in practical use. The application cost is reduced, while prospecting technology gradually becoming more intelligent and automated. The developing trend of 3D visual explanation technology falls under the micro-computer group. This technology makes data collecting highly accurate and raises the ability of data processing. The specific analysis on seismic wave excitation and reception is shows in *Figure 3*.

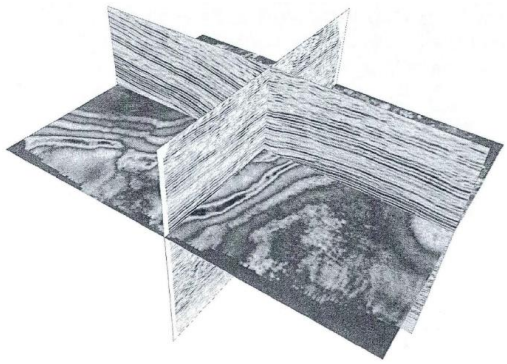

Figure 3. Comprehensive display of post-stack time migration data

The seismic wave excitation

A seismic wave is generated by artificial excitation during seismic exploration. There are different kinds of seismic sources in outdoor exploration work, adapting to various earth surface conditions. Some requirements are needed to ensure the distance of seismic wave propagation, including enough energy, lasting time period, repeatability, and minimizing wave interference as much as possible.

The explosion source, as it is detonated by a blasting cap, would create a spike pulse. This kind of excitation wave emits strong energy and a wide frequency band. Chemical-based explosives such as nitrate gas are commonly used. Seismic waves excited by nitrate gas have many advantages such as having nice pulse features and high energy. Therefore, it is an ideal seismic energy. The explosive seismic source is regarded to be the main seismic source since the very beginning of seismic prospecting.

In field construction, explosives are usually kept in a cylindrical plastic bag after being sealed under several to tens of meters of deep borehole and then detonated. In order to increase the concentrated downlink seismic wave energy, cumulative shell, autochthonal rocket, and detonation cords are developed which greatly improves the excitation effect of the seismic wave. The advantages of explosives in wells include reducing the strength of surface wave and the number of explosives.

Lithology characters are effective factors of explosion. Wave frequency spectrum depends on the lithology of buried explosives during the explosion. Rock layers that are neither too hard nor too soft is the best condition, and with good plasticity. The depth should be chosen below the water level. Using strong diving acoustic impedance makes the energy spread below. Experiments have shown that the relationship between explosive energy and medium will affect the wave energy. A relationship between geometric affinity and impedance affinity exists between the wave energy and the medium. A combination is achieved when the diameter of the explosive bag is as same as the explosive well. The ratio of explosive and medium characteristic impedance is called impedance coupling.

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Seismic wave receiving

Seismic wave receiving is carried out using specific equipment. It is mainly used to record the whole process of seismic wave spreading. It comprises of two parts, the detector and the seismograph. There are some requirements to equipment according to the characteristics of the seismic wave—the detector should be able to accurately detect good seismic waves as the ground displacement sensitivity is only measured in microns, and the recorder should have the function to selectively amplify the frequency. When spreading is observed in the time mark, this can be used to reflect interface depth.

Channel distances should be observed when measuring seismic waves, in order to avoid spatial aliasing. The detector should be placed in the ground or underwater to pick up the vibration of the seismic detector or receiver, which would then convert the mechanical vibrations to electrical signals. Commonly used seismometers are either composed of moving coil (for land work) or piezoelectric (for ocean and moor).

There are two main types of detectors classified by structure—non-rotating wire spring structures and rotating reed contact structures. The former has a simple structure, few pieces, and stable while the latter has many pieces, complicated, and has bad stability. Therefore none-rotating wire spring detector is suitable for high frequency detection. The main capability of the geophone includes sensitivity, frequency, damping, direct-current resistance, consistency, *etc*.

The innovation strategy of well logging technology

With China's developing economy, the demand for oil production is increasing and the requirement for logging technology is higher. The development of computer technology and electronic communication technology provides a powerful development condition for the development of logging technology, in particular enabling the transformation of data acquisition and processing from the direction of numerical control to imaging. Compared with numerical control instruments, imaging logging instruments are more advanced. Imaging logging instruments are of higher data transmission rates, and they could transfer more data in the same time period. Moreover, their higher resolution, sampling rate, and probing depth have been significantly improved. The imaging logging tool can not only carry a lot of detectors at the same time, but also can be used in any combination of instruments to effectively expand the search area of the borehole, leading to a more successful imaging measurement work.

Besides the imaging logging, logging technology in recent years include logging while drilling, nuclear magnetic resonance (NMR), and casing wells. With the development of research and improvement of logging technology innovation, each of the logging technologies has been widely and effectively used in geological prospecting.

The application of NMR technology significantly improves measurement accuracy and speed; this can effectively avoid failures during the logging process, significantly reducing logging time, lowers cost, and minimizes the time it takes to occupy the well site. The application of drilling technology significantly improves the reliability of the logging instrument; the size of the logging instrument becomes smaller and the cost lower. Based on radio wave penetration technology, the technical personnel can identify the drill blind ore bodies around it while computer technology and comprehensive logging system composed of logging instruments can greatly improve the success ratio of logging. The application of this advanced technology can effectively improve the efficiency of petroleum geology exploration and improve the competitiveness of the industry[10].

Innovation strategy of drilling technology

Drilling is the most expensive part in the exploration and development of petroleum geology, which can be accounted

for more than half of the total cost. Therefore, innovation becomes the key part for reducing the cost for many oil companies. There are two kinds of traditional drilling technology, i.e., under balanced drilling and large displacement drilling, and each has its own advantages and disadvantages. The advantages of under balanced drilling are that it can speed up the drilling speed and reduce the damage to the ground. On the other hand, it is more suitable for the development of depleted oil reservoirs. However, it is difficult to maintain and protect the reservoir. Large displacement drilling requires fewer platforms, therefore, it is mainly applied to the development of onshore oil and gas fields, as well as offshore oil.

Application of petroleum exploration technology knowledge

The application of petroleum exploration technology knowledge refers to the transformation from petroleum exploration technology knowledge to enterprise knowledge assets through knowledge sharing and transfer based on knowledge acquisition and integration. Only after the application of knowledge, the petroleum exploration technology can become the enterprise's own petroleum exploration technology. During the process of enterprise technological innovation, the application of knowledge integrates the petroleum exploration technology within the enterprise and technology knowledge obtained outside of the enterprise to realize the knowledge sharing, communication and learning, which will be finally applied to the practical exploration project. After practice, the achievement could be summarized, learned by the members of the organization as feedback. And through mastery of such feedback, the enterprise could get into the dynamic cycle process of the next knowledge application, providing better conditions for knowledge innovation. Moreover, the performance of petroleum exploration is improved and the enterprise technology innovation could be realized at the same time. During the process of knowledge application, more attention should be paid to the integration of knowledge, in particular the tacit knowledge in the minds of people which could not be learned intuitively but perceived through personal actions. Therefore, enterprises need to establish the transverse and longitudinal connection among systematic tools, instruction manuals, personnel communication, and organizational structure to transform the tacit knowledge to systematic knowledge to improve the efficiency of knowledge application. A flow chart of petroleum exploration technology knowledge is shown in *Figure 4*.

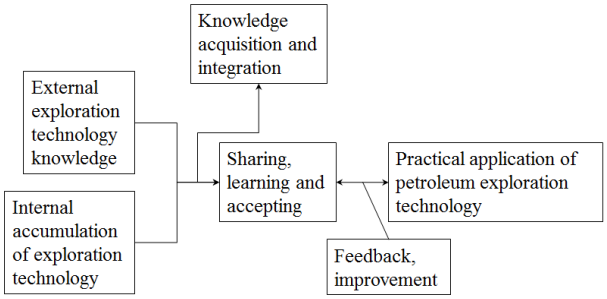

Figure 4. Flow chart of petroleum exploration technology knowledge

Conclusion

Petroleum has been one of the important resources that affect the development of a country, and it is also an important factor to promote social progress and development. In recent years, rapid economic development and increasing population promote its increasing demand. However, current petroleum production could no longer fully meet social needs, highly affecting the development of petroleum industry and challenging petroleum exploitation. To improve the amount of petroleum production and provide sufficient petroleum for society, it is important to increase the efficiency of oil production, in particular innovating petroleum exploration technology to ensure the future development of the petroleum industry.

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