“Deep-time Digital Basin” Based on Big Data and Artificial Intelligence

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1 Introduction

Information technology has been playing an ever-increasing role in geoscience. Sphicistcated database platforms are essential for geological data storage, analysis and exchange of Big Data (Febłowicz, 2013; Zhang et al., 2016; Teng et al., 2016; Tian and Li, 2018). The United States has built an information-sharing platform for state-owned scientific data as a national strategy. National core labs and related database have been established for the rapid exchange of fundamental data and technical knowledge, which greatly facilitated the success of shale gas revolution (Madden and Vossoughi, 2013; Mei et al., 2017, Haroon et al., 2018). However, for many countries, open data exchange is still at a very early stage (Yang et al., 2016; Wang, 2017). With the accumulation of data, artificial intelligence (AI) will lead the next industrial revolution, as unaided human brains are incapable of analyzing huge quantities and multi-dimensional data (Wang et al., 2014; Zhao et al., 2015; Chukwuna, 2018).

The Deep-time Digital Earth (DDE) program is a major international geoscience initiative recognized by the International Union of Geological Sciences (IUGS). DDE plans to compile global geological data and build a network of working database/computing platforms through international cooperation to facilitate earth-science research. These data and platforms will also improve geologists’ ability to predict the distribution and abundance of various fuel, mineral, material resources, and geological hazards, as well as contribute their expertise to debates concerning the future of the Earth (Gao et al., 2009; Sun et al., 2015; Zhang et al., 2015; Liang et al., 2018). Our participation in the DDE is focused on the development of a unified database and integrated platform for oil and gas exploration and development (E&P) and the construction of an interactive, real-time, multi-dimensional Deep-time Digital Basin (DDB) system which will enable large scale use of AI to enhance our understanding of geological objects. DDE big data, open platforms, advanced AI applications, highly integrated soft/hardware systems, as well as cloud computing, will facilitate the rapid development of new geological theories, and significantly improve the efficiency and quality of oil/gas E&P.

2 Major challenges in petroleum industry

The era of big data and artificial intelligence will change the way of our life. It will liberate productivity and trigger another “industrial revolution” in human history. However, due to national politics and commercial competitions, the current implementation of global data open exchange in the petroleum industry remains in its infancy, which seriously restricts innovation in related science and technology fields. This is reflected in the following ways. (1) Both raw data and outputs remain scattered in various companies and research institutions as “isolated information islands” where data utilization faces barriers; (2) A single, integrated and collaborative software platform has not been established because there are no unified standards both for data and software. Many research institutes and oil companies invest large amounts of money every year to develop software and purchase data, but are not able to establish their own software platform, let alone realize potential synergies of technology within the industry; (3) Most of the data reside in documents, and there is no electronic link connecting results with data; (4) Big data AI applications research, and the construction of knowledge bases remain at initial stages of development and have not been widely nor effectively applied.

3 The research framework of Deep-time Digital Basin (DDB)

DDB aims to establish an interactive, real-time, multi-dimensional, visual and digital basin platform. “Deep-time” refers to both the depth and time domains of the data, i.e., the depth and geological age of the given basin. Interactive and real-time means that original data and the results of interpretation and analysis of the data are linked organically by collaborative working platforms, in which results will be updated automatically whenever any changes in the original data are made. Most geological data and maps are 3D in their spatial distribution, whereas seismic data use double reflection time to represent depth. The depth difference between most geological and seismic data can be mutually transformed by a 3D velocity model. All data and maps (~ results) can be visualized interactively in 2D/3D, based on 3D girding technology. Figure 1 shows the research scheme and roadmap of the DDB.

4 Unified database

A unified database and collaborative working platform must be established as the foundation for comprehensive geological studies (Fig. 1). To accomplish this the following points need to be considered. (1) Consolidation of terms and standards as the premise for establishment of a unified database for the oil/gas industry globally, including the numerous data types related to a basin analysis as well as the terms and standards used by

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different companies or countries to describe the same geological phenomena. Genetic classifications are key for consolidating terms and standards. (2) Unification of the data flow with the work flow is the most efficient way to establish a comprehensive, accurate, and timely database since the working processes are the processes of data application and database construction. This will mean that data will be available where the work is done and workers will be able to add new data to the database. A data collection/database update process of this sort will be easier to realize for companies. (3) The DDE platform will not only provide fundamental data (e.g., outcrops, paleogeography, paleoclimates, paleontology, tectonics, and sedimentary) for the oil/gas database, but will also promote the consolidation of terms and standards, collaboration, and data sharing between companies and organizations globally.

5 Collaborative working platform

Understanding complex subsurface conditions and processes requires the combination of geology, geophysics, reservoir engineering other data, hence the need for comprehensive integration of software in a unified platform become to enable specialists to work collaboratively. At present, most professional software works independently, and data need to be converted between different formats. In this traditional mode, data conversion takes time and money, and when the data changes it is difficult to ensure the related data-analysis results will be updated synchronously.

The “Android” system for mobile phone is an excellent example for petroleum industry. A collaborative working platform for the oil/gas industry would comprehensively integrate geology, geophysics, reservoir engineering and other disciplines, organically link original data and results as mentioned above. This would greatly improve E&P efficiency and solve the problem of duplicated software development (Fig. 1). Our vision is that a unified platform should be characterized by standardize interfaces, unified database, and expandable functionality.

With the roll out of technologies in the area of 5G internet communication, super data storage and computing capability, to establish multiple “over-storage” and “over-computing” centers around the world are viable. In combinations with a collaborative working platform, companies can store and share (exchange) data, use and use world-class soft/hardware through the Internet. It would be advantageous to have “all applications are on the cloud, and all software developments and applications on a single platform”.

6 Artificial intelligence and knowledge base

DDB is an objective description of a sedimentary basin and its internal geo-bodies based on available data. With increases in data a 3D geological model of the Earth will become ever closer to being a reality. The knowledge base, on the contrary, is a subjective understanding about a geo-body or a geological phenomenon. With the deepening of E&P work, achievement of
the level of understanding will also move closer to being an objective reality.

Because there are certain patterns for the formation of basins or oil/gas reservoirs, inherent relationships should be able to be found between different types and sources of data. Most geologists have worked in one or a few basins for their entire working lives. Though some geologists have had the privilege of analyzing data from different basins globally, however, when faced with the massive and multi-dimensional data, the limited memory and imagination capability of human brains becomes an impediment which has hampered development of deep understanding of underground geological problems severely.

The DDB, along with AI technologies, will constitute a new approach to facilitate rapid correlation between various datasets and extraction of implicit relationships imbedded within those data. This allow us to establish patterns and models for different geological objects. Accuracy of the DDB will accelerate and ensure understanding of subsurface objects will be deepened through the repeated iterative inversions between data and models/patterns. With the support of big data and the integrated software platform, as well as the development of DDB and AI technology, the way we think and work will change, our vision will be extended, and our capacity to process and analyze data will be greatly improved. In turn, this will lead to an explosive development of new geological theories and the revolutionary change in the oil/gas E&P process.

7 Conclusions

DDE plans to build an open data platform globally and to conduct research on fundamental geological issues. Both data and research results will be open and free globally, to establish a secure foundation for individual applied studies. With the DDE platform and unified standard, oil companies, as well as countries, would be able to establish their own databases, working platforms with integrated software, and build their own super-storage and super-computing centers, to realize comprehensive sharing of data, soft/hardware and research results within a company or a country. The DDE program will be essential for the oil/gas industry, on the basis of which we intend to build an integrated database for oil/gas industry and an E & P collaborative working platform, to develop an interactive, real-time, multi-dimensional DDB and, with access to innovative AI technology, facilitate geological studies and oil/gas E&P.

Key words: deep-time digital earth (DDE), deep-time digital basin (DDB), big data, artificial intelligent, knowledge base

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