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Software Tools for the Automated Correlation of Geological Well Sections

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SUMMARY

The software has been developed to investigate the geological structure of underground gas storage (UGS), enhance the efficiency of geological and geophysical information analysis, and automate the correlation of well sections. Using the software in production improves the efficiency with which geophysical survey results are analysed, enables identification of possible complications in well and UGS operations, facilitates timely decision-making, and ensures prompt implementation of proper measures. The developed software provides comprehensive capabilities for users to accumulate, view, edit, and analyse geological and geophysical information. To automate the creation of graphical geological materials for individual wells and gas storage facilities, data from these databases should be used.

Keywords: Underground gas storage facilities; Geophysical well surveys; Database; Software; Geological and geophysical information processing.

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Introduction

Geological and technical problems arising during UGS facility operation are addressed using geophysical well surveys (GWS) (Volovetskyi, Romanyshyn, Altukhov et al., 2024). Modern geophysical survey methods enable the investigation of geological sections penetrated by wells, the identification of reservoir rocks, and the assessment of their saturation characteristics. The resulting geophysical data are therefore a key tool for characterizing the subsurface geological structure and evaluating its gas potential.

Method and Theory

Geophysical well logging investigations are currently applied to assess and monitor the condition and integrity of reservoir systems in oil, gas, gas condensate fields, and in UGS facilities. The study (Lai et al., 2024) reports that artificial intelligence is increasingly utilized to enhance the efficiency of geophysical well data processing. Previous studies (Amosu, Imsalem, and Sun, 2021; Lv et al., 2021; Zhang et al., 2024) have demonstrated that integration of artificial intelligence into the processing and geological interpretation of geophysical well data can substantially reduce personnel workload while improving operational accuracy and efficiency. The paper (Mishra, Sharma, and Patidar, 2022) provides a comprehensive analysis of machine learning techniques used for the automated creation of well log diagrams, enabling reliable lithology prediction and reservoir characteristics. The research (Guo et al., 2024) highlights the basic models, which are large-scale neural networks trained on extensive datasets, that exhibit exceptional adaptability and versatility, thereby performing effectively across diverse geoscientific tasks. Consequently, such models are considered highly suitable for analysing geoscientific data. The paper (Dell'Aversana, 2024) introduces a novel methodology for optimizing oil production by integrating fundamental artificial intelligence principles with geophysical data inversion and continuous monitoring techniques.

Results

Modern information technologies offer a number of advantages, among them the capacity to gather, process, analyse, and archive geophysical survey results in electronic format. In wells, geophysical surveys are conducted in cased and uncased barrels. The GWS system in an uncased well includes standard logging (SL), cavernometry, profilometry, lateral logging (LL), and other methods. Such investigations are essential for examining geological well sections and the structure of gas reservoirs, for determining the filtration-capacity parameters (FCP) of reservoir formations, and, more broadly, for monitoring UGS facility operation. The reliability of subsequent interpretation, including well section correlation and the construction of geological layers and structural maps, is closely related to the quality of the initial data (Volovetskyi, Romanyshyn, Bugai et al., 2024). During the interpretation of research results, the lithological characteristics of the well section and the nature of formation saturation are determined. Thus, during cavernometry and profilometry, the transverse dimension of the well is measured to evaluate its cross-sectional size, peculiarities of its shape, and changes along the wellbore. A high-quality interpretation of research results enables the correlation of sections and the identification of similar formations. It allows one to trace their occurrence and changes in thickness and detect tectonic disturbances. Well section correlation is generally divided into three types: general, regional, and detailed. General correlation compares well sections within the same area from top to bottom (Volovetskyi, Romanyshyn, Bugai et al., 2024). Regional correlation involves comparing sections exposed by wells in different areas. Detailed correlation involves comparing the productive (gas-saturated) intervals of well sections. It is the most important type of correlation because the results are used to study the geological structure of deposits in detail, carry out geological modelling, calculate hydrocarbon reserves, and resolve important operational problems related to gas storage facilities.

Geophysical surveys represent the primary source of information for characterizing the productive section. Therefore, a detailed correlation is performed based on logging materials, core data, and the results of well testing. The required amount of core selected for research depends on the well category. In reference wells, core sampling is carried out at every depth. In parametric wells, core samples help characterize the geology structure and gas-bearing strata of prospective new areas.

Exploration wells are sampled at intervals predicted to be gas-bearing, whereas prospecting wells target the productive formations themselves. The results of formation testing provide information on gas-bearing strata, as well as geological, process, and industrial data required to calculate gas reserves and develop production plans. Well testing is carried out during and after drilling, after the production string has been lowered. Formation testing is performed "top-down" during drilling as promising intervals of the section are exposed. Maximizing the preservation of the rock's natural filtration properties and ensuring hydraulic connection between the rock and the well are prerequisites for obtaining reliable data. This is achieved by regulating the physical and chemical properties of the flushing fluid, which prevents open well blowouts and keeps the formation from absorbing drilling fluid. Once the casing string has been lowered to the formation interval, perforation is performed. Perforator type and perforation density are selected based on the formation's structure, reservoir characteristics, well design, and other relevant factors. In a cased well, tests are carried out "from bottom to top". Cement bridges, set using various techniques, isolate the interval under test from those situated above it. The final stage of testing a formation, in the event of fluid or gas inflow, is its investigation, which, in uncased wells, is carried out using a string of testing tools on pipes or on a logging cable. It involves measuring gas or water flow rates under steady-state filtration conditions, together with the associated bottomhole and wellhead pressures and temperatures (Volovetskyi, Romanyshyn, Bugai et al., 2024). Observations are made on the restoration of formation pressure, the initial formation pressure is refined, and the amount of rock removed is determined, etc. Based on the refined data, the following are determined: productivity coefficients, gas factor, saturation pressure, piezoconductivity coefficient, and other indicators. Wellhead and deep fluid and gas samples are also collected, including at least three deep fluid and gas samples. The component composition and physicochemical properties of the liquid and gas are determined based on the analysis results of the selected samples. Figures 1-2 show screen forms used to collect well-testing information.

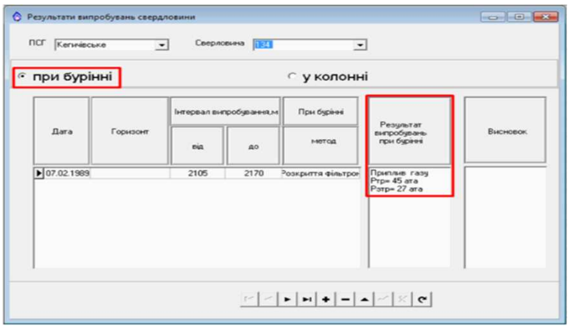

Figure 1. Example of a screen form for entering well test results obtained in drilling

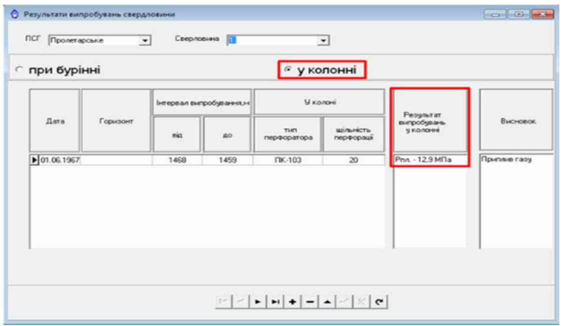

Figure 2. Example of a screen form for entering well test results in the column

Given the importance of each type of research conducted at wells, it is worth noting that, thanks to the accumulation of various geological and geophysical information, specialists can create a reliable model of the productive horizon and the gas reservoir as a whole, obtain geological sections, and create structural maps, among other results.

Accurately constructed geological well sections are essential for forming a trustworthy picture of a UGS facility's structure. These sections are compiled based on research results, particularly those from core, electrical, and radioactive logging studies. These sections use symbols to indicate the sequence of rock layers passed through by the well, their properties, and the results of geophysical measurements. Understanding the geological section enables specialists to make informed decisions during drilling and well operations. Based on the results of correlating well sections, geological maps, sections, etc., are constructed. Geological sections are built from geophysical survey data, most commonly seismic data, together with results from reference, parametric, exploration, appraisal, exploratory, and production drilling. Their construction follows a defined sequence of steps. First, an appropriate scale is determined according to the objectives of the work and the geological structure of the UGS facility (Volovetskyi, Romanyshyn, Bugai et al., 2024). Well data is then processed, and projections of the wellbore are drawn up. Then, the geological section is constructed. Specialists have developed software that enables generationg well sections to quickly solve operational tasks. The result is software for constructing a geological section of a UGS facility. It supports generating a section for a selected group of wells and provides options for its design, visualization, and printing. The program interface is presented in Figure 3.

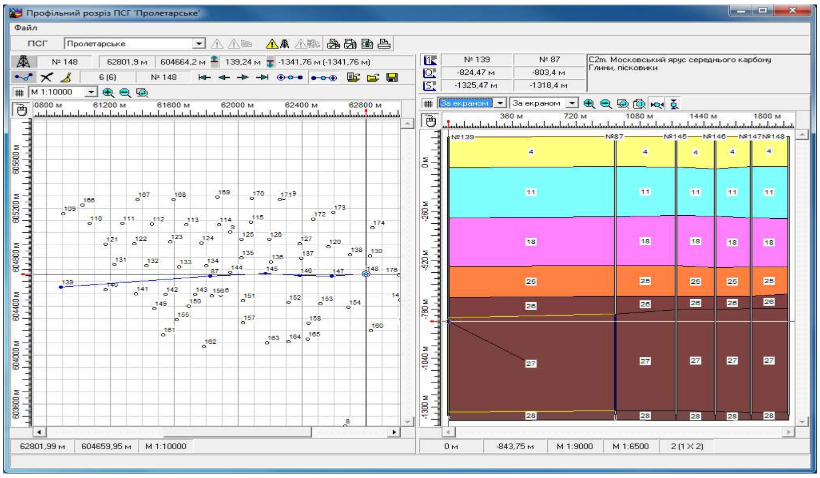

Figure 3. *Screen form of the program for constructing a geological section with a network of wells*

The program interface is divided into two functional areas. The left part shows the UGS wells, whereas the right part shows the geological section constructed along the selected well line. Both vertical and horizontal scales are displayed in meters, but their interpretation varies with the corresponding area of the interface. In the well display area (left part), the horizontal axis represents the X-coordinate, while the vertical axis indicates the Y-coordinate of the earth's surface. Within the geological section area (right part), the horizontal axis shows the distance measured along the section line, and the vertical axis represents depth (Volovetskyi, Romanyshyn, Bugai et al., 2024). A scaling bar for the well map is located above the horizontal scale (Figure 3). The upper part of the interface contains controls for navigation and section line management. These controls allow the user to identify the section panel, remove an individual well or all wells from the section line, determine the position of a selected well, and view the corresponding well number. The section line is formed by sequentially selecting the required wells with the left mouse button. Each subsequent selection creates a new segment connecting the previously selected point to the next. The resulting section line can be stored for later use. This is particularly useful when geological data for one or more wells included in the line are updated. The line can also be modified when required. Information about the selected well is displayed in the corresponding information panel, while the UGS selection panel is positioned above it. Selecting the appropriate control opens the layer selection window shown in Figure 4.

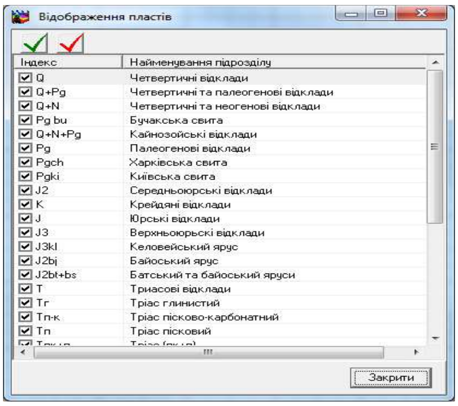

Figure 4. *Window for selecting the layers to be displayed*

To show the required layers in the section, the user selects them by left-clicking the small square graphic element positioned to the left of each layer's index. The modified settings are saved after the "Close" button is pressed.

Conclusions

GWS provides current information on the condition of both wells and productive horizons and can therefore serve as an important source of information for monitoring UGS facilities. Timely processing of these data requires appropriate software tools that can support the analysis of research results and facilitate the identification of operational issues. The study resulted in the development of software for automated correlation of UGS well sections. The developed functionality makes it possible to establish the sequence of rock layers identified in different wells, recognize contemporaneous layers, evaluate variations in layer thickness and lithological composition, analyse facies, and identify tectonic disturbances. The generalized and interpreted correlation results can subsequently be used to construct geological sections, structural maps, thickness maps, and heterogeneity maps. These graphical representations provide a basis for further investigation of the structure of productive formations.

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